



October 2003  OPERATION & MAINTENANCE MANUAL

OPERATION & MAINTENANCE MANUAL

S12U, S16U

MITSUBISHI DIESEL ENGINES S12U, S16U

NOTE

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 manual contains information for operation, inspection and maintenance of the Mitsubishi Engines.

Please read this manual carefully to understand the operation, inspection and maintenance procedures in order to use the engine properly.

Failure to follow directions in this manual can lead to serious accidents.

Limited Warranty

The manufacturer, at its option, will repair or replace any parts returned intact to the manufacturer only when the manufacturer, upon inspection, determines to be defective in material and/or workmanship.

The foregoing shall constitute the limited warranty provided by the manufacturer.

The manufacturer will provide the limited warranty only to the user with whom the manufacturer concludes the original contract, and shall not provide the limited warranty to a user to whom the ownership of the product may be transferred.

- The manufacturer makes no warranties, either express or implied, except as provided in this manual, including without limitation thereof, warranties as to marketability, merchantability, fitness for a particular purpose or use, or against infringement of any patent.
- The manufacturer will not be liable for any damages or consequential damages, including without limitation thereof, damages or other costs resulting from any abuse, misuse, misapplication of the engine and devices supplied by the manufacturer.
- The manufacturer will not be liable for any damages or personal injuries resulting from any modification, without the manufacturer's written permission, of the engine and devices supplied by the manufacturer.
- The manufacturer will not be liable for any damages or production losses caused by the use of fuel, engine oil and/or long life coolant that are not recommended by the manufacturer.

Important Information

- To avoid potential hazard, accident prevention activities must be planned methodically and conducted continually by considering all aspects of engine operation, maintenance and inspection. Everyone including managers and supervisors should actively participate, recognize one's role and organize oneself and one's work to ensure a safe environment.
- The foremost safety objective is to prevent accidents which could result in injury or death, or damage equipment.
- Observe all related federal/national and local codes and regulations to reduce the possibility of personal injury.
- The manufacturer cannot foresee all potential danger of the engine, potential danger resulting from human error and others, 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 not possible 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.
- This manual has been prepared for people whose native language is English. 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 danger and also received danger avoidance training.
- To prevent occurrence of an accident, do not attempt to carry out any operation other than those described in this manual, or to 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 the manufacturer of

the name and address of the new owner of the engine.

- This manual is copyrighted and all rights are reserved. The drawings and technical reference, including this manual, may not, in whole or in part, be duplicated, photocopied, translated, or reproduced in any electronic medium or machine readable form without prior written consent from the manufacturer.
- The contents in this manual are subject to change without notice for improvement of the engine.
- Your engine may differ from the photographs and figures in this manual.
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.
- If you need more detailed information or have questions, contact a Mitsubishi dealer.
- If this manual is misplaced, obtain a new copy from a Mitsubishi dealer as soon as possible.

Warnings

The following two methods are used to call the attention of the operators and maintenance personnel to the potential danger 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 by using the following five classifications to indicate the degree of potential hazard. Failure to follow these directions can lead to serious accidents which can result in personal injury, or death in the worst case.



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



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



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



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

Note

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

Explanation of Terms

Abbreviations, Standards and Others

- API = American Petroleum Institute
- ASTM = American Society for Testing and Materials
- JIS = Japanese Industrial Standards
- MIL = Military Specifications and Standards (U.S.)
- MSDS = Material Safety Data Sheet
- SAE = Society of Automotive Engineers (U.S.)
- LLC = Long Life Coolant

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 based on the following conversion rates.

- Pressure: 1 MPa = 10.197 kgf/cm²
- Torque: 1 N·m = 0.10197 kgf·m
- Force: 1 N = 0.10197 kgf
- Horsepower: 1 kW = 1.341 HP = 1.3596 PS
- Meter of mercury: 1 kPa = 0.7 cmHg
- Meter of water: 1 kPa = 10.197 cmH₂O (cmAq)
- Engine speed: 1 min⁻¹ = 1 rpm

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Chapter 1

BASIC SAFETY PRECAUTIONS

Warning Fire and Explosion

Keep flames away

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

Make sure that the caps of fuel and engine oil containers are tightly closed, and store them in the designated site.

Do not use flames or smoke where fuel or oil is handled or cleaning solvent is used for washing parts.

Spilled fuel, oil and LLC should be wiped immediately and thoroughly. Spilled fuel, oil and LLC can ignite and cause fire.



Keep engine and surrounding area clean

Do not store combustible (such as fuel, engine oil and LLC), explosive or dangerous materials near the engine. Those substances can cause a fire or explosion.

Keep the engine and the surrounding area free of dust, dirt and foreign materials, since they can cause fire or the engine to overheat.

Clean the top surface of the battery after performing maintenance work. Dust on the battery may cause a short-circuit.

The engine must be used at least 1 m [3.3 ft.] away from buildings and other equipment to prevent possible fire caused by engine heat.

Never open crankcase until engine cools

If the cover is opened while the engine is still hot, fresh air comes into crankcase and oil mist can be ignited by engine heat, then it may lead to the explosion of the engine.

Never open the engine crankcase cover before the engine becomes cool, wait at least 10 minutes after the engine stops.

Check for fuel, oil and exhaust gas leaks

Inspect fuel, oil and exhaust pipes regularly for damage and looseness. If a fuel, oil and exhaust gas leak is found, repair the leakage immediately. Fuel or oil spilled on a hot surface of the engine, and exhaust gas blown onto a combustible material may cause fire and result in personal injury and/or damage to equipment.

Use flameproof light

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

Do not short electrical wires

Before inspecting or servicing any electrical component, disconnect the ground cable from the negative (-) battery terminal to prevent short-circuit and fire.

Loose terminals or damaged cables/wires can cause a short-circuit that may result in fire. Before operating the engine, inspect the cables and wires, and repair or replace if necessary.

Keep fire extinguishers and first-aid kit nearby

Keep fire extinguishers nearby, and be familiarized with their usage.

Keep a first-aid kit at the designated place, and make sure it is easily accessible at anytime.

Establish response procedures to follow in the event of fire or accident, and post information concerning emergency contact locations and their contact methods.



Warning Stay Clear of All Rotating and Moving Parts

Install protective covers on rotating parts

Make sure the protective covers of the engine are correctly installed. Repair any damaged or loose covers. When the engine is coupled to other equipment or the radiator, install protective covers on the exposed connecting belt and coupling.



Never remove protective covers for rotating parts such as the damper cover, camshaft cover or rocker cover while the engine is operating.

Check surrounding area for safety

Before starting the engine, check to 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 all rotating and moving parts while engine is operating

Do not approach rotating and moving parts of the engine while the engine is in operation.

Rotating parts can entangle your body or tools and result in serious injury.

Keep items that can be easily entangled by rotating parts away from the engine.

If your body or tool contacts rotating and moving parts, serious injury may occur as a result.



Lock out and Tag out

Be sure to lock out and tag out before starting inspection and maintenance.

Lockout and tagout are effective methods of cutting off machines and equipment from energy sources. To lock out and tag out, pull out the key from the starter switch, turn off the battery switch, and post a tag on the starter switch indicating "Do Not Operate." The starter key switch should be kept by the person performing the inspection and maintenance. For the air starter system, close the main valve of the air tank, and post a tag indicating "Do Not Open the Valve."

Always stop engine before inspection and maintenance

Be sure to stop the engine before conducting inspection and maintenance. Never attempt to adjust the engine parts while the engine is running. Conducting inspection and maintenance on an operating engine can result in a serious accident of entanglement by rotating parts.

Always return turning tools to original position

Be sure to remove all turning tools used during maintenance and inspection.

Starting the engine with the turning tools inserted or turning gears engaged may not only cause engine damage but personal injury as well.

Warning Be Careful of Burns

Do not touch engine during operation or immediately after operation

Do not touch the main and exhaust parts of the engine during operation or immediately after operation to prevent burns.



To conduct maintenance and inspection, wait until the engine cools sufficiently as indicated with the temperature gage.

Open radiator filler cap carefully

Never open the radiator filler cap while the engine is operating or immediately after it is stopped.

The engine coolant is hot during engine operation and immediately after operation. If the radiator filler cap is opened when the coolant is at operating temperature, steam and hot coolant may blow out, causing skin burns as a result.

When opening the cap, stop the engine and allow the coolant temperature to drop sufficiently. Cover the cap with a cloth or use thick rubber glove, and then slowly open the cap.

When closing the cap, be sure to tighten securely.

Add coolant only after coolant temperature drops

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

Do not dismantle heat protection covers

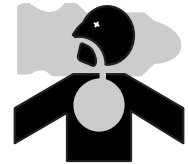
The high-temperature exhaust components are installed with heat protection covers. Do not dismantle these heat protection covers. If they must be removed during inspection and maintenance, be sure to reinstall them after completing the inspection and maintenance.

Warning Be Careful of Exhaust Fume Poisoning

Perform engine operation in a well-ventilated site

Exhaust gas from the engine contains carbon monoxide and other harmful substances.

Do not operate the engine in an enclosed area (inside a warehouse, tunnel, etc.) or in a site where all sides are blocked, since exhaust fumes can cause gas poisoning.



If the engine must be operated in an enclosed area, discharge the exhaust gas to the outside and provide adequate ventilation.

Connect an exhaust duct to the exhaust pipe to lead exhaust gas to the outside, and make sure exhaust gas does not leak from the duct joints.

Make sure the exhaust gas does not blow in the direction of plants or animals.

Warning Protect Ears from Noises

Wear earplugs

Be sure to wear earplugs when entering into the engine room.

The earplugs can be quite useful to protect ears from various engine noises.



Warning Be Careful When Lifting Engine

Lifting engine carefully

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

Attach appropriate slings to the hangers on the engine.

Keep the engine balanced during lifting by considering the center of gravity of the engine.

Keep the angle formed by slings attached to hangers within 60°. If the angle exceeds this limit, excessive load is applied on the hangers and may damage the hangers.

If wire ropes contact the engine, place a cloth or other soft padding to prevent damage to the engine and wire ropes.



Do not climb onto engine

Never climb onto the engine.

To work on parts located on the upper section, use a ladder, stand, etc.

Climbing on the engine can not only damage entire parts, but also cause parts to fall off and result in injury.

Always watch your footing

Use a stable work platform to stand on when working on the upper part of the engine and other hard-to-reach places.

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

Do not put obstacles on the stand.



Caution Be Careful of Handling Fuel, Engine Oil and LLC

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

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

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

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

Handle LLC carefully

Wear safety mask and rubber gloves when handling LLC. Avoid contact with skin and eyes to prevent personal injury.

Should LLC be accidentally swallowed, induce vomiting immediately and seek medical attention.

Should LLC enter eyes, flush immediately with plenty of water and seek medical attention. If LLC is spilled on skin or clothes, wash immediately with lot of water.

Keep flammable materials away from LLC to prevent fire. Never use flames or generate sparks near LLC since flames or sparks can cause fire.

Drained LLC is harmful. Do not dispose of into conventional sewage. Contact a Mitsubishi dealer for the disposal of drained LLC.

Properly dispose of drained oil and LLC

Do not dispose of engine oil, used cleaning oil or LLC into conventional sewage.

Prepare drip pan or other containers to receive oil and LLC drained from the engine. Do not drain them directly onto the ground.

For disposal of drained oil and LLC, consult a Mitsubishi dealer.

Caution Service Battery

Handle battery carefully

- Batteries release flammable hydrogen gas and oxygen. Never use flames or generate sparks near the battery since flames or sparks can cause an explosion.
- Do not use the battery when the fluid surface is lower than the minimum required level. Using a battery with a low electrolyte level can result in an explosion.
- Do not short the battery terminals with a tool or other metal object.
- When disconnecting battery cables, remove the cable from the negative (-) terminal first. When reconnecting cables, attach the cable to the positive (+) terminal first.
- Charge the battery in a well-ventilated area, with all filling hole plugs removed.
- Make sure the cable clamps are securely installed on the battery terminals. A loose cable clamp can cause sparks that may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [OFF] position or disconnect the cable from the negative (-) battery terminal to cut off the electrical current.
- Electrolyte contains dilute sulfuric acid. Careless handling of the battery can cause loss of sight and burns.
- Wear safety goggles and rubber gloves when working with the battery (replenishment of fluid, charging, etc.)
- If electrolyte is spilled on skin or clothes, wash immediately with lots of water. Then, use soap to clean thoroughly.
- If electrolyte enters eyes, flush immediately with lots of fresh water and see a physician as soon as possible.
- Should you accidentally swallow electrolyte, gargle with plenty of water, then drink lots of water. Consult a physician immediately.



Caution When Abnormality Occurs

If engine overheats, conduct cooling operation before stopping engine

If the engine overheats, do not stop the engine immediately. Abrupt stopping of an overheated engine may cause the coolant temperature to rise, resulting in seizing of the engine. If the engine overheats, operate the engine at low idling speed (cooling operation), and stop the engine after the coolant temperature lowers sufficiently.

Do not add coolant immediately after stopping the engine. Adding coolant to a hot engine may cause damage to the cylinder head from sudden change in temperature. Add coolant gradually after the engine cools to room temperature.

If engine stops due to abnormality, exercise caution when restarting

If the engine stops due to an abnormality, do not restart the engine immediately. If the engine stops with an alarm, check and correct the cause of the problem before restarting. Operating the engine without correcting the problem may result in serious engine problems.

If engine oil pressure drops, stop engine immediately

If the engine oil pressure decreases, stop the engine immediately, and inspect the lubricating system including the oil level and pump. Operating the engine with low oil pressure may cause seizing of bearings and other parts.

Caution Other Cautions

Never modify engine

Unauthorized modification of the engine will void the maker's warranty.

Modification of the engine may not only cause engine damage but may result in personal injury as well.

If there is a need to modify the engine, please contact a Mitsubishi dealer.

Never break seals

To ensure proper engine operation, the fuel control links are attached with seals that prevent accidental change of the injection volume and rotation speed settings. Operating the engine without these seals in place can result in the following problems, and also invalidates the warranty.

- Rapid wear of moving and rotating parts
- Engine damage such as seizing 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.

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 and damage to parts, as well as serious accidents.

Perform engine break-in

Break in a new engine by operating it with a light load and at a speed lower than normal during the first 50 hours of operation.

Operating a new engine under high load or severe conditions during the break-in period can shorten the service life of the engine.

Warm up engine before use

If the auxiliary devices for the starter (water heater, engine oil priming pump etc.) are not installed, let the engine idle for 5 to 10 minutes before using the engine for work.

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 an extended period of time. Prolonged warm-up operation causes carbon build-up in the cylinders that leads to incomplete combustion.

Never operate engine under overload condition

If the engine shows an overload condition such as the emission of exhaust smoke, decrease the load immediately so that the engine operates at appropriate output and load.

Overloading the engine causes not only high fuel consumption but also excessive carbon deposits inside the engine. Carbon deposits cause various problems and can shorten the service life of the engine.

Conduct cooling operation before stopping engine

Before stopping the engine, let it idle at low speed for 5 to 6 minutes to cool.

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

During cooling operation, check the engine for abnormalities.

Do not splash water on engine

Do not allow rainwater, etc., to enter the engine through the air inlet or exhaust openings.

Do not wash the engine while it is in operation, since the engine may suck in the cleaning fluid (water). If the engine is started with water inside the combustion chambers, water hammer action can damage the engine and result in serious accidents.

Conduct proper maintenance of air cleaner/pre-cleaner

The major cause of abnormal wear on engine parts is dust entering with intake air. Worn parts result in an increase of oil consumption, decrease of output, and starting difficulties. Conduct maintenance of the air cleaner/pre-cleaner according to the following directions to ensure optimum air filtering performance.

- Do not conduct maintenance of the air cleaner/pre-cleaner while the engine is operating. Without the air cleaner/pre-cleaner in place, the turbocharger can suck foreign particles into the engine, decrease the load immediately so that the engine operates at appropriate output and load.
- When removing the air cleaner, do not allow dust attached on the air cleaner/pre-cleaner to enter into the engine.
- If equipped with a dust indicator, conduct maintenance only when the clog warning sign appears. While servicing the air cleaner/pre-cleaner, do not let dust enter into the air cleaner/pre-cleaner, damage or deform the element.

Observe safety rules at workplace

Observe the safety rules established at your workplace when operating and maintaining the engine. Do not operate the engine if you are feeling ill. Operation of the engine with reduced awareness may cause accidental operations that may result in accidents. In such case, you should inform your supervisor of your condition.

When working in a team of two or more persons, use specified hand signals to communicate among the workers.

Wear proper work clothes and protective gear

Wear the work clothes specified by your workplace. Wear a hardhat, face shield, safety shoes, dust protective mask, gloves and other protective gear as needed.

When handling compressed air, wear safety goggles, hardhat, gloves and other necessary protective gear. Compressed air may cause personal injury when not wearing the proper protective gear.

Use appropriate tools for maintenance work

Use appropriate tools according to the type of maintenance work, and use them correctly.

If tools are damaged, replace with new tools.

Cautions concerning transportation

When transporting the engine using a truck, consider the engine weight, width and height to ensure safety. Abide by the pertinent laws and regulations.

Do not operate engine continuously under low load

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

Ventilate the engine room sufficiently

Be sure to provide sufficient ventilation in the engine room. Insufficient air in the room can cause the engine temperature to rise and the output power and performance to lower.

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

Do not touch high-pressure injection fuel

Should injected fuel leak from a fuel injection pipe, do not touch the spurting fuel.

Fuel in the fuel injection pipes is under high pressure. Touching high-pressure fuel can cause the fuel to penetrate the skin and result in gangrene.

Caution About Warning Labels

Maintain and inspect warning labels

Make sure all warning labels are legible.

If the description and/or illustration on a warning label cannot be seen clearly, clean or replace the label.

To clean warning labels, use a cloth, water and soap. Do not use solvents, gasoline or other chemicals to clean warning labels. Cleaning with chemicals may cause the labels to peel off.

If warning labels are damaged or missing, replace with new labels.

If a part of the engine with warning label is replaced with new part, also attach new warning label to the new part.

To obtain replacement warning labels, contact a Mitsubishi dealer.

Warning labels



fig.1-1 Warning for flywheel entanglement



fig.1-2 Warning for moving parts

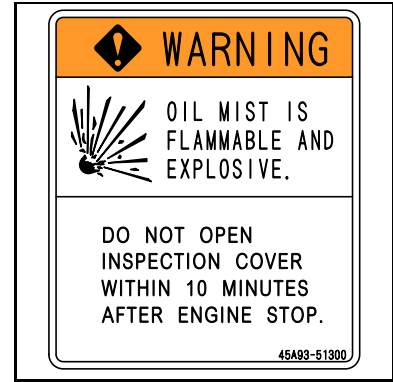


fig.1-3 Warning for oil mist



fig.1-4 Caution for footing

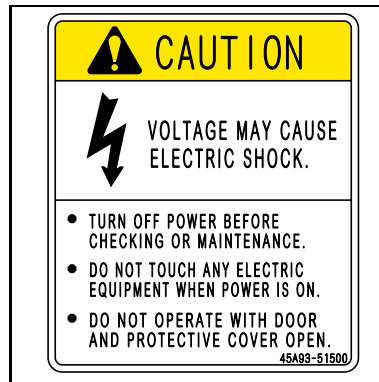


fig.1-5 Caution for electric shock

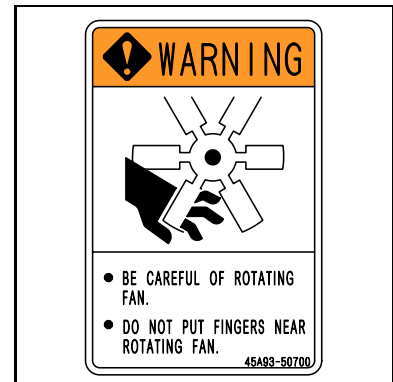


fig.1-6 Warning for rotating parts

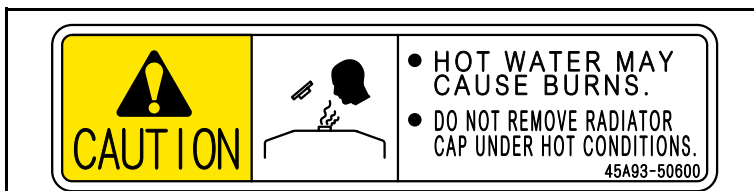


fig.1-7 Caution for burns

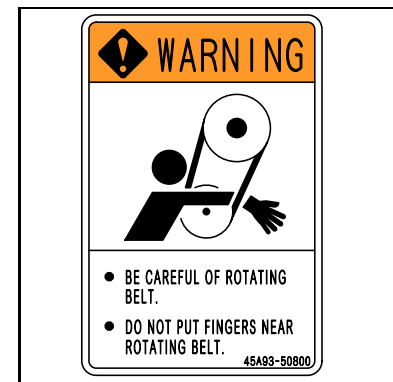


fig.1-8 Warning for rotating parts

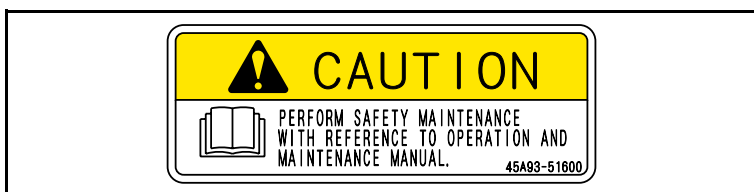


fig.1-9 Caution for referring to manual

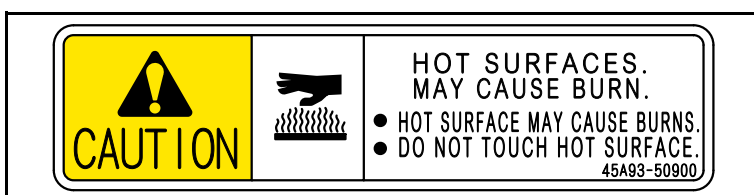


fig.1-10 Caution for burns

Chapter 2

NAME OF PARTS

Engine External Diagrams

The external diagram is for standard type of S12U/S16U engine.

The installed equipment and shapes differ on the engine type.

S12U Left View

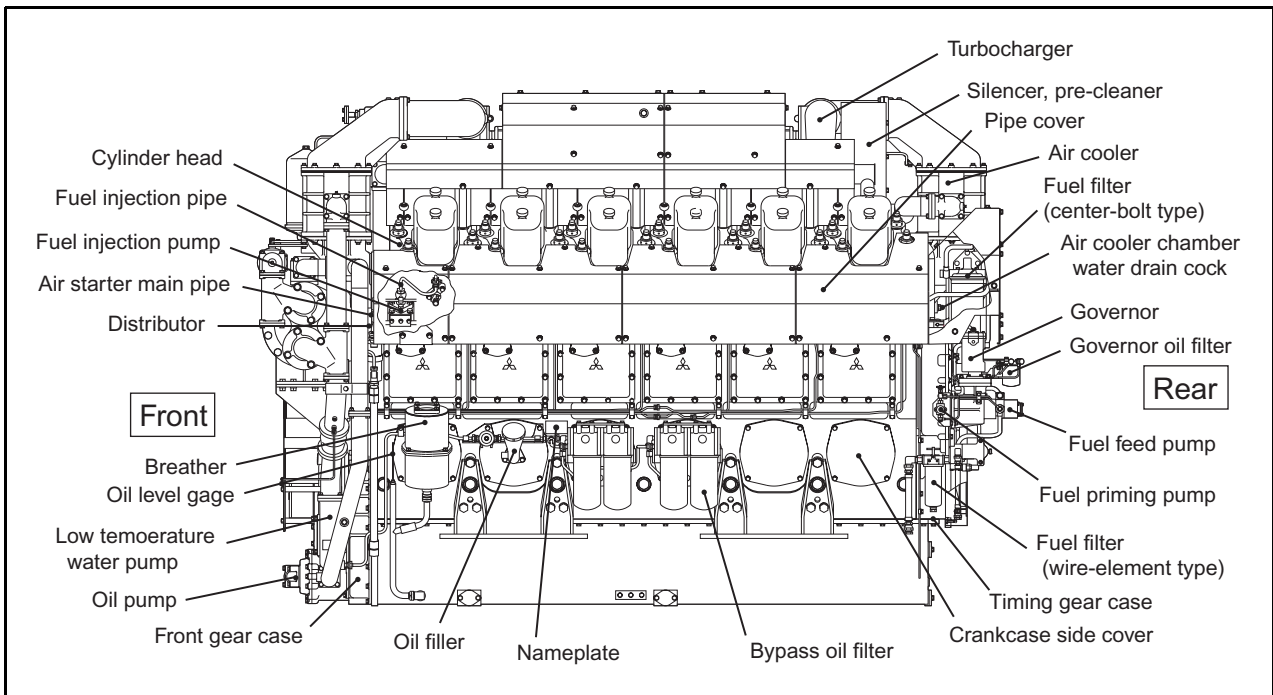


fig.2-1 S12U engine left view

S12U Right View

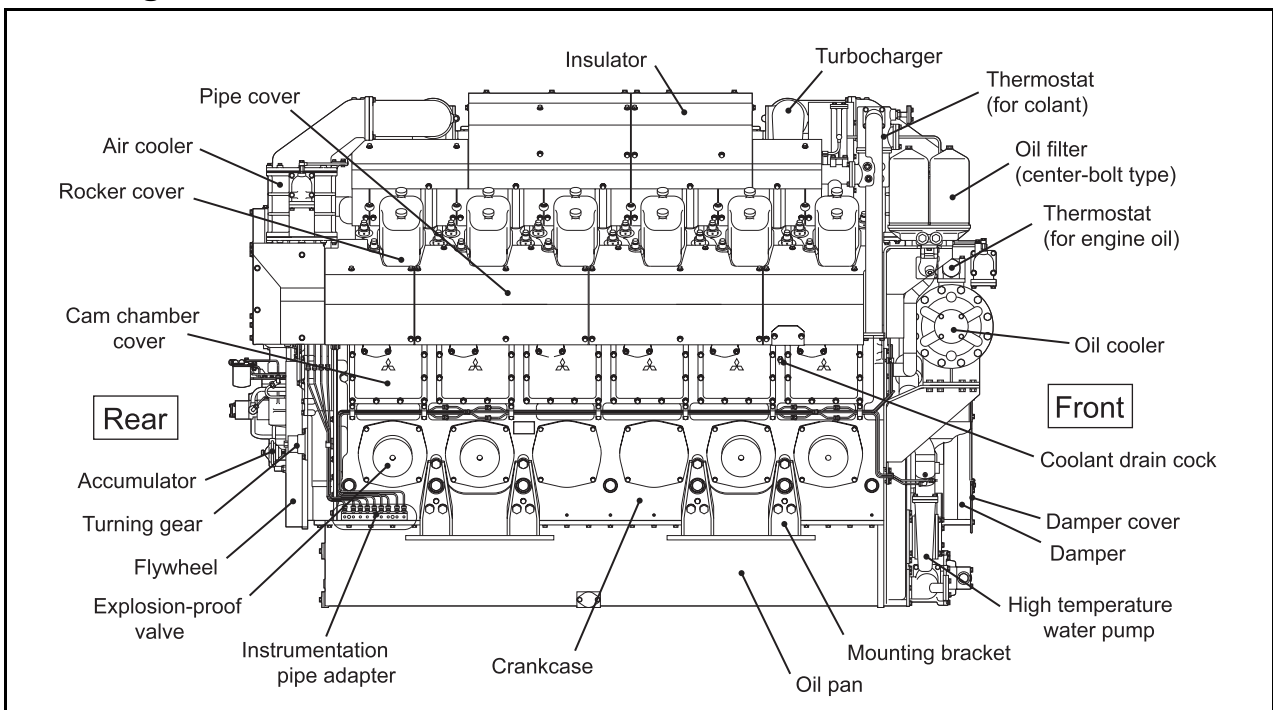


fig.2-2 S12U engine right view

S16U Left View

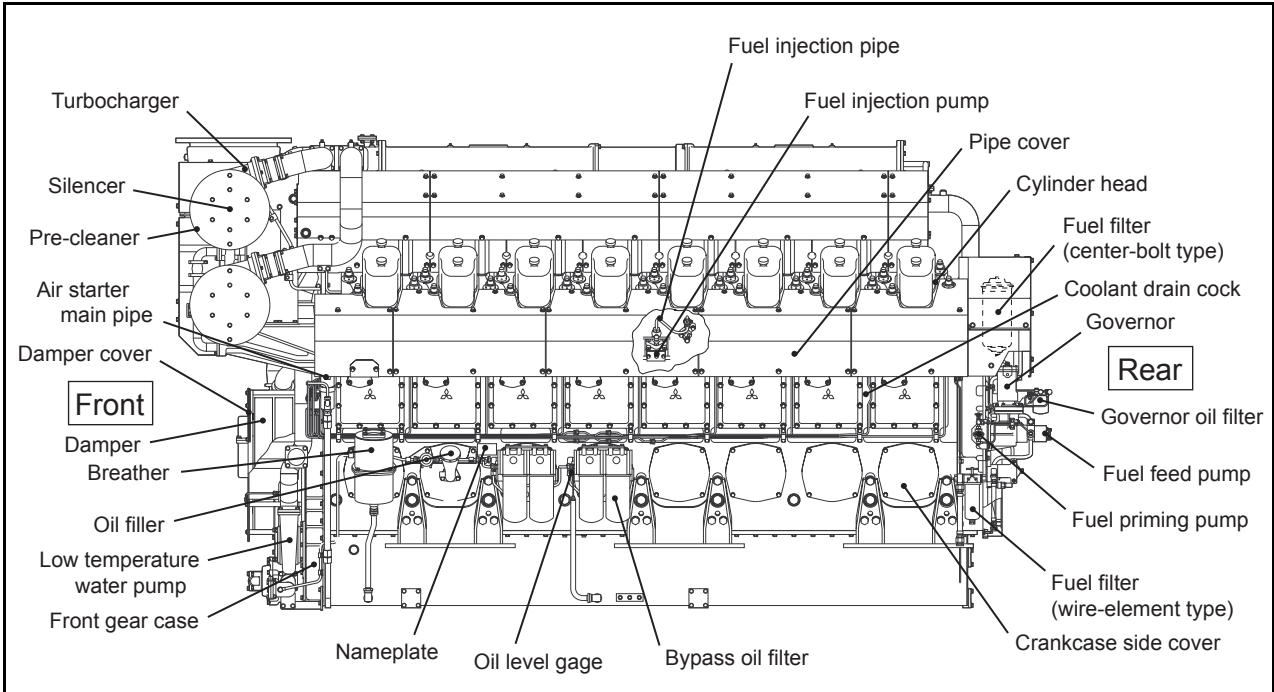


fig.2-3 S16U engine left view

S16U Right View

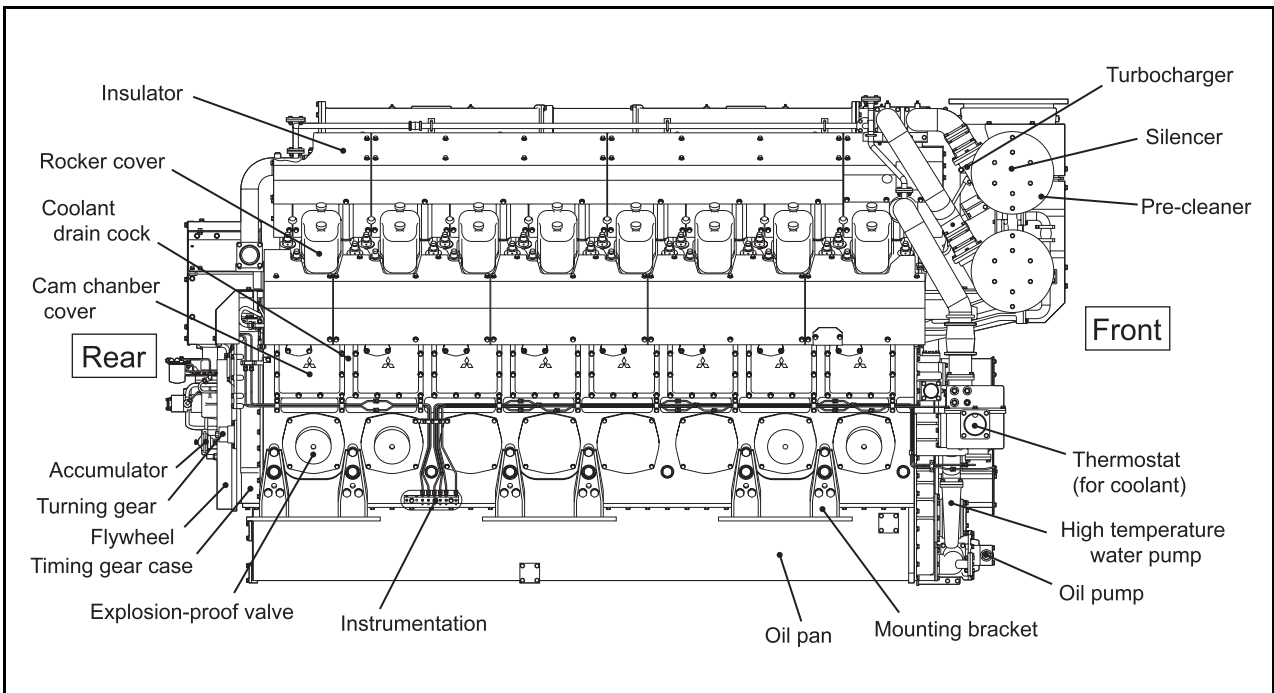


fig.2-4 S16U engine right view

Equipment and Instrument

Starting and Shutdown Devices

The shape and type of the starting and shutdown devices may vary from those described below depending on the engine specifications.

Start Switch

When the start switch on the operation panel is pressed, starting air is supplied to the air starter system and cranks the engine.

Stop Switch

When the stop switch on the operation panel is pressed, the shutdown cylinder operates and moves the control shaft of the fuel injection pump to the no-injection position to shut down the engine operation.

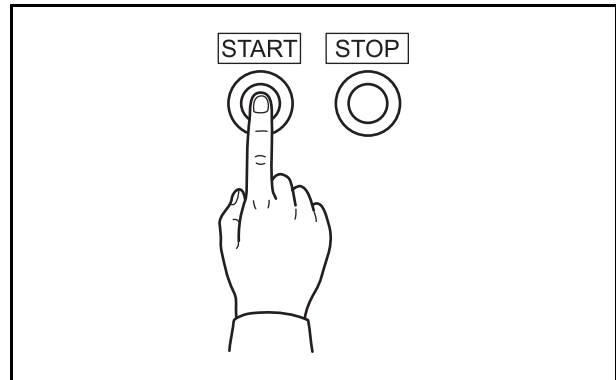


fig.2-5 Start switch and stop switch

Start Lever

The start lever is provided on the air starter pipe. When the lever is moved toward the OPEN position, air flows and cranks the engine. Once the engine starts, return the lever to the CLOSE position immediately.

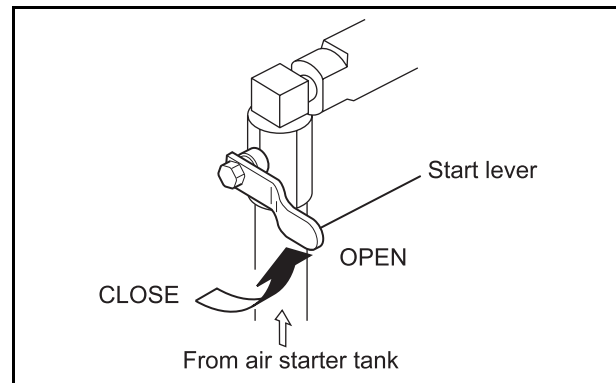


fig.2-6 Start lever

Manual Stop Lever

Use the manual stop lever to shut down the engine in the event of an emergency.

If the stop button is not working, use the manual stop lever. The lever is installed to the fuel control link and when the lever is moved in the STOP direction, the engine stops operation.

Should the engine continue operating even after the manual stop lever is operated, cut off the fuel supply to stop the engine.

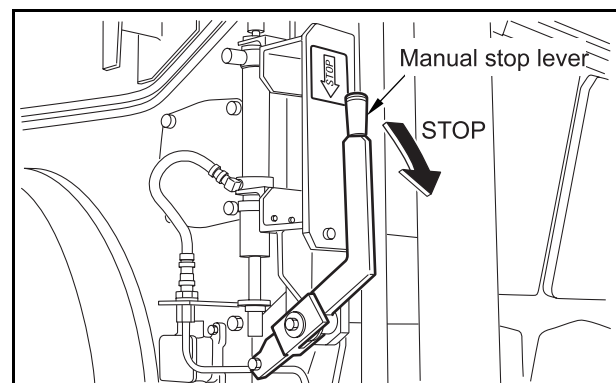


fig.2-7 Manual stop lever

Instruments

The instruments indicate the internal conditions of the engine in operation. In normal operation, record the numerical values indicated on the instruments at regular intervals. If the numerical value is far different from that in normal operation, the indications of the instruments allow prompt judgment of engine problems.

The instrument shape (round, square) and indication type (analog, digital) can vary depending on the engine specifications.

Tachometer

This indicates the engine revolutions per minute (rpm).

Note: The tachometer may have a built-in hour meter.

Hour Meter

This indicator shows cumulative engine operating hours.

Use the meter indication as a guideline for determining the need for regular inspection and servicing.

Oil Pressure Gage

This indicates the engine oil pressure.

Oil Temperature Gage

This indicates the engine oil temperature.

Jacket Coolant Temperature Gage

This indicates coolant temperature inside of the crankcase.

Oil Cooler Coolant Temperature Gage

This indicates coolant temperature in the oil cooler.

Air Cooler Coolant Temperature Gage

This indicates coolant temperature in the air cooler.

Jacket Coolant Pressure Gage

This indicates the pressure of coolant in the crankcase, cylinder heads and other parts.

Oil Cooler Coolant Pressure Gage

This indicates the coolant pressure in the oil cooler.

Air Cooler Coolant Pressure Gage

This indicates the coolant pressure in the air cooler.

Exhaust Temperature Gage

This indicates the temperature of exhaust gas at the cylinder outlets or turbocharger inlet or outlet.

Fuel Pressure Gage

This indicates the pressure of fuel supplied to the fuel injection pump by the fuel feed pump.

Inlet Pressure Gage

This indicates the pressure of inlet supplied to the air cooler.

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 Mitsubishi dealer.

Protection devices installed on the engine and their types (setting values) and shapes vary depending on the engine specifications. The following describes the typical protection devices installed in a Mitsubishi engine.

Low Oil Pressure Alarm

The oil pressure switch activates an alarm when the engine oil pressure drops to an abnormally low level.

High Coolant Temperature Alarm

The high coolant temperature alarm device generates a warning or stops the engine when the coolant temperature rises to an abnormally high level due to an engine malfunction or other reason.

Oil Filter Clog Alarm

The oil filter clog detector generates a warning when the oil filter becomes clogged and causes an abnormally large pressure difference between before and after the oil filter. When it generates an alarm, replace it with a new filter immediately and change engine oil, as well.

Overspeed Alarm

The overspeed alarm device generates a warning and stops the engine operation when the engine speed starts operating at abnormally high speed due to an engine malfunction or other reason.

Air Cleaner Clog Alarm (Air Cleaner Indicator)

A red signal appears as a warning when the air cleaner element becomes clogged and causes an abnormally large pressure difference between before and after the air cleaner. When a red signal appears, clean the air cleaner element immediately or replace it with a new element.

After the element is cleaned or replaced, press the reset button located at the upper part of the indicator to cancel the red signal.

While serving the air cleaner, do not enter dust into the air cleaner or damage the element.

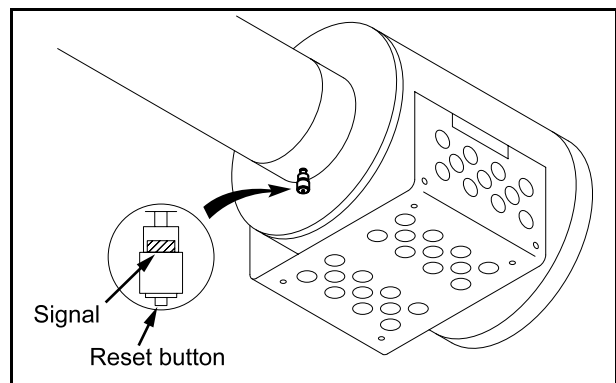


fig.2-8 Air cleaner indicator

Using Turning Gear

⚠ WARNING

Before starting the engine, return (pull out) the turning gear to 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 Untighten the retaining bolt.
- 2 Move the turning gear fully to engage the ring gear and tighten the bolt.

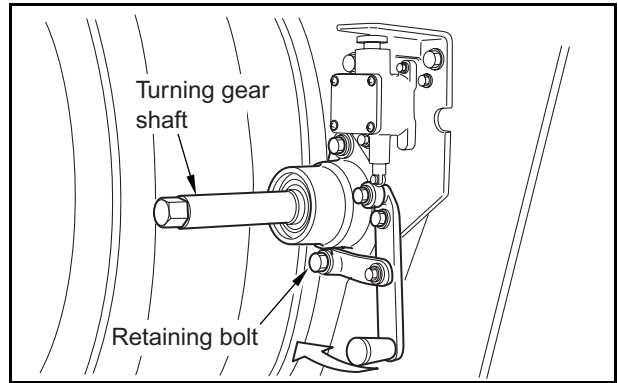


fig.2-9 Preparation for turning

- 3 Turn the shaft using the socket wrench and the ratchet handle.

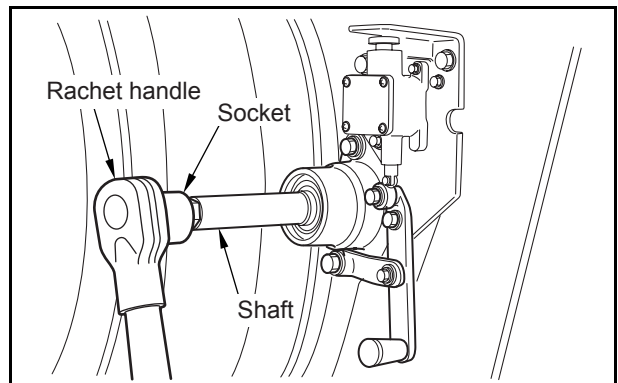


fig.2-10 Turning

- 4 After turning, move the turning gear, disengage the turning gear with the ring gear and tighten the retaining bolt.

⚠ CAUTION

Make sure the lock pin is securely inserted.

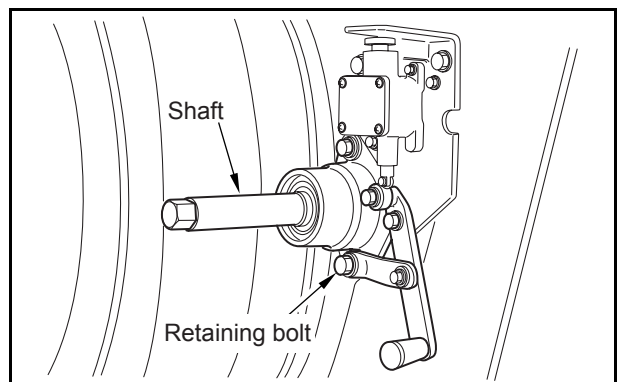


fig.2-11 Locking turning gear

Chapter 3

OPERATION

Preparation for Operation of New or Overhauled Engine

Before operating a new or overhauled engine, do the following inspection. For second operation onward, do the following normal operation outlined on page [3-8 "Normal Engine Operation"](#).

Fuel System

⚠ CAUTION

When handling fuel, make sure there are no flames near the engine.

Wipe any spilled fuel completely. Spilled fuel can ignite and cause fire.

CAUTION

Do not remove the strainer when filling the fuel tank.

Use fuel specified in "[Fuel](#)" (4-2).

Pouring fuel

- 1 Make sure the insides of the fuel tank and fuel pipes are clean.
- 2 Pour fuel into the fuel tank.
- 3 Remove the fuel feed pipe and drain plug from the fuel inlet of the engine, and check the discharged fuel for dust particles.
- 4 Reinstall the drain plug and fuel feed pipe.
- 5 Add fuel until the fuel level gage indicates "FULL."

Bleeding Fuel System

WARNING

When fuel overflows from the air vent plug, wipe thoroughly with a cloth. Spilled fuel is a fire hazard.

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

CAUTION

Closing all air vent plugs before locking the priming pump cap disallows the priming pump cap from returning to the original position due to internal pressure.

Bleed air from the location closest to the fuel tank that are the fuel filter (wire-element type), fuel filter (center-bolt type), then the fuel feed pipe.

Bleeding Air from Fuel Filters (Wire-Element Type)

CAUTION

Replace to a new part if there is a damage on the air vent plug, thread area of bracket or sealing washer.

- 1 Loosen the air vent plug on the fuel filter (wire-element type) by rotating about 1.5 turns.
- 2 Loosen the priming pump cap by turning counterclockwise and move it back and forth.
- 3 When there are no air bubbles in the fuel flowing from the air vent plug, tighten the air vent plug to the specified torque.

Bleeding Air from Fuel Filters (Center-Bolt Type)

CAUTION

Replace to a new part if there is a damage on the air vent plug, thread area of bracket or sealing washer.

- 1 Loosen the air vent plug on the fuel filter (center-bolt type) by rotating about 1.5 turns.
- 2 Move its priming pump cap back and forth.
- 3 When there are no air bubbles in the fuel flowing from the air vent plug, tighten the air vent plug to the specified torque.

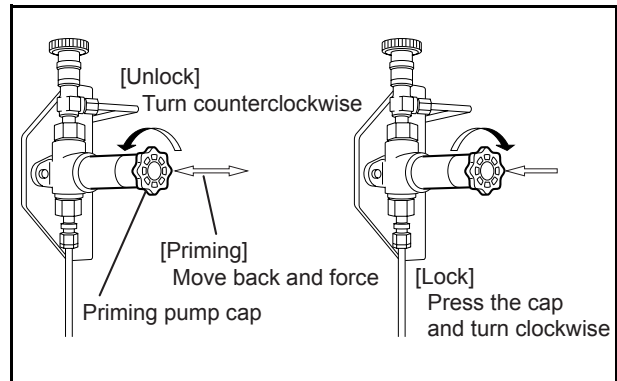


fig.3-1 Priming pump operating method

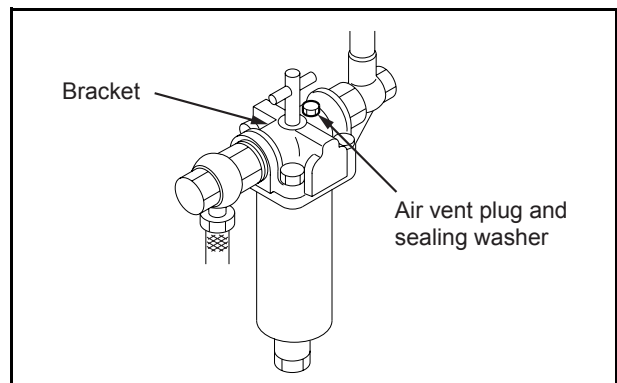


fig.3-2 Bleeding air from fuel filters (wire-element type)

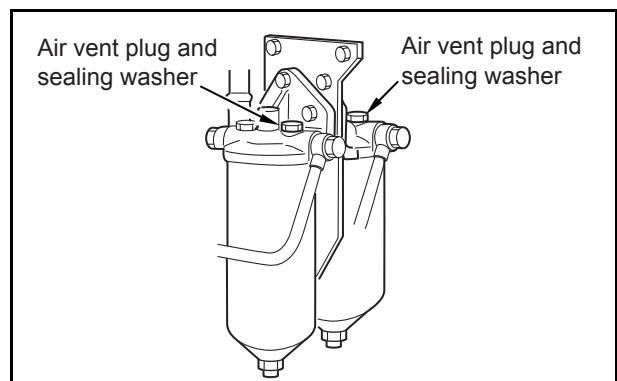


fig.3-3 Bleeding air from fuel filters (center-bolt type)

Bleeding Air from Fuel Filters (Cartridge-Type)

- 1 Set the handle of the fuel filters (cartridge-type) to the "Left - Open, Right - Bleed" position, and loosen the right-side air vent plug by rotating it about 1.5 turns.
- 2 Move the priming pump cap back and forth. When the fuel flowing from the right-side air vent plug no longer contains air bubbles, tighten the air vent plug.
- 3 Set the handle to the "Right - Open, Left - Bleed" position, and open the left-side air vent plug.
- 4 Move the priming pump cap back and forth. When the fuel flowing from the left side air vent plug no longer contains air bubbles, tighten the air vent plug.
- 5 Return the handle to the normal position.

CAUTION

Replace to a new part if there is a damage on the air vent plug, thread area of bracket or sealing washer.

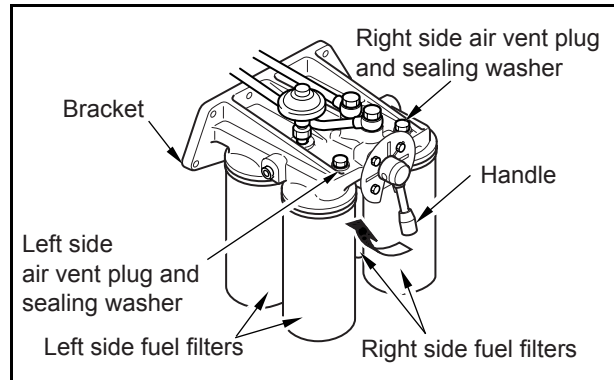


fig.3-4 Bleeding air from fuel filters (cartridge-type)

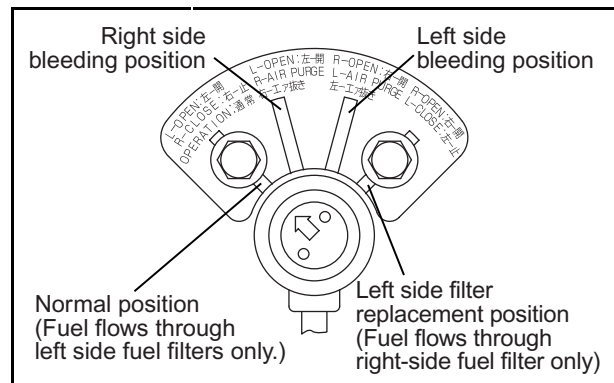


fig.3-5 Fuel filter switchover cock

Bleeding Air from Fuel Feed Pipe

- 1 Loosen the air vent cock on the fuel feed pipe by rotating about 1.5 turns.
- 2 Move the priming pump cap back and forth repeatedly. When there are no air bubbles in the fuel flowing from the air vent cock, press the priming pump cap and turn the cap clockwise to lock.
- 3 Tighten the air vent cock on the fuel feed pipe.

CAUTION

Tighten the priming cap before closing the air vent plug.

Closing all air vent plugs before the priming pump cap disallows the priming pump cap from returning to the original position due to internal pressure.

When fuel overflows from the air vent plug, wipe thoroughly with a cloth. Spilled fuel causes fire hazard.

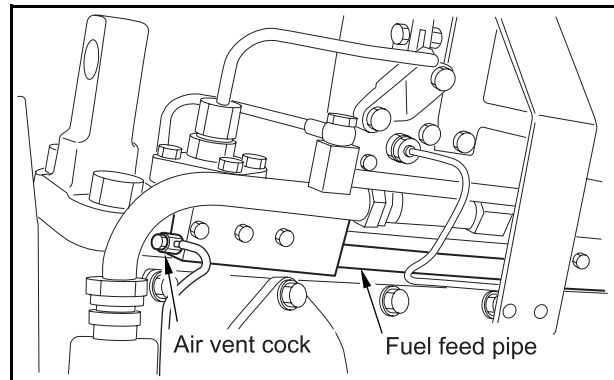


fig.3-6 Bleeding air from fuel feed pipe (1)

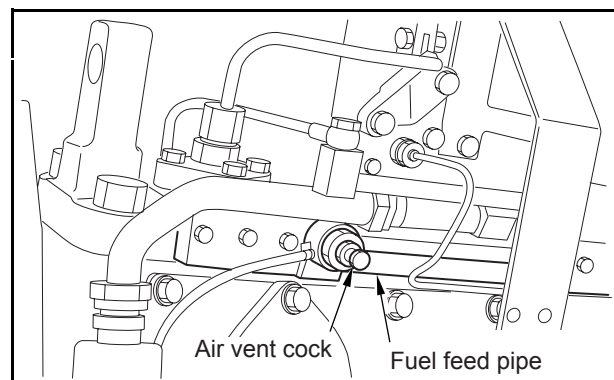


fig.3-7 Bleeding air from fuel feed pipe (2)

Lubricating System

Pouring engine oil

- 1 Remove the cap from the oil filler.
- 2 Pour engine oil of the specified type.

Specified engine oil: Class CD or CF
(API Service Classification)

Engine oil capacity (oil pan)

S12U: approx. 450 L [118.88 U. S. gal.]

S16U: approx. 600 L [158.50 U. S. gal.]

Note: Regarding engine oil, refer to "Engine Oil" (4-4).

- 3 Check the oil level with the oil level gage.
If the automatic oil feeder is installed, check if it works normally.
The oil level should be between the MAXIMUM and MINIMUM marks on the oil level gage.
If the oil level is low, add specified type of engine oil.
- 4 Check the oil pan and other parts for oil leaks.
Repair any oil leakage found.
- 5 Operate the engine oil priming pump to circulate oil in the engine.
- 6 Remove the rocker cover, and make sure that oil is supplied to the valve mechanisms.
- 7 Stop the priming pump. After about 30 minutes, add engine oil until the oil level reaches the Maximum line on the oil level gage.
- 8 Reinstall the cap on the oil filler.

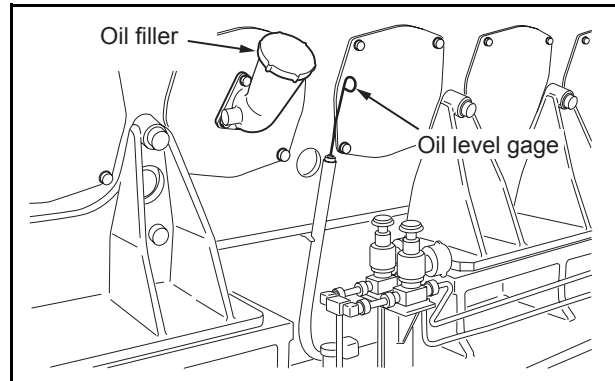


fig.3-8 Oil filler and oil level gage

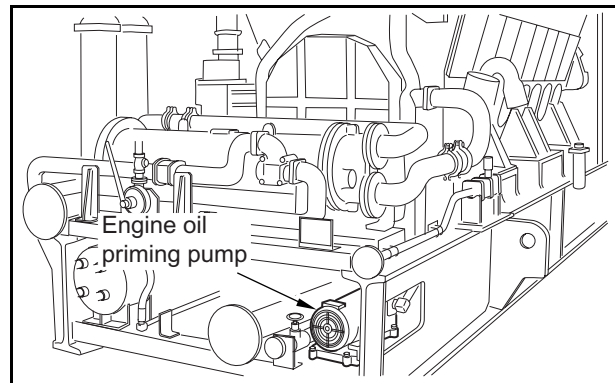


fig.3-9 Engine oil priming pump

Cooling System

Pouring coolant

- 1 Make sure the drain cocks on the engine and water pump are closed firmly.
- 2 Remove the cap from the water supply inlet of the coolant tank, and pour undiluted LLC.

Note:(a) Determine the amounts of LLC and water to be poured by using the LLC concentration chart.

(b) Regarding coolant, refer to "Coolant" (4-6).

Coolant capacity (engine only)

S12U: approx. 520 L [137.37 U. S. gal]

S16U: approx. 700 L [184.92 U. S. gal]

- 3 Pour soft water with minimal impurities slowly to the full level.
- 4 When coolant reaches the full level securely, close the water supply inlet cap of the coolant tank.
- 5 To release air from the water pump and coolant pipes, pull the manual stop lever fully to the STOP position and hold it in that position to keep the fuel injection pump in no-injection condition, then supply starting air and crank the engine for about 10 seconds.
- 6 Wait for about 1 minute, then repeat the above cranking operation twice to remove air from the water pump.
- 7 Check the level gage on the coolant tank to make sure there is sufficient coolant (surface level at about the center of the level gage). If the coolant level is low, add coolant.
- 8 Start the engine, and operate it under light load until the thermostat opens the valve to allow soft water and LLC to mix thoroughly.
- 9 Stop the engine, check the level gage on the coolant tank again. If the coolant level is low, add coolant (so that the surface level rises to about the center of the level gage).

Note: Always add coolant having the same LLC concentration.

- 10 Check the pipe joint and other parts for coolant leaks.

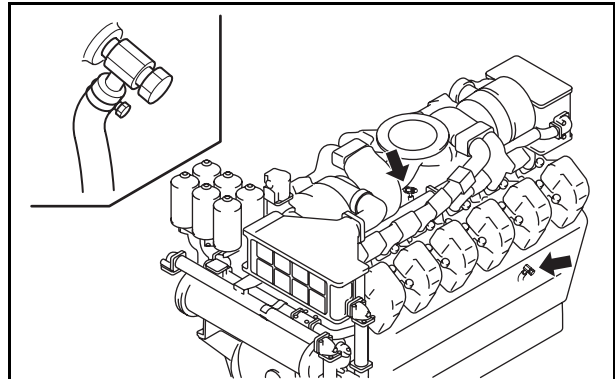


fig.3-10 Coolant drain cock on the engine

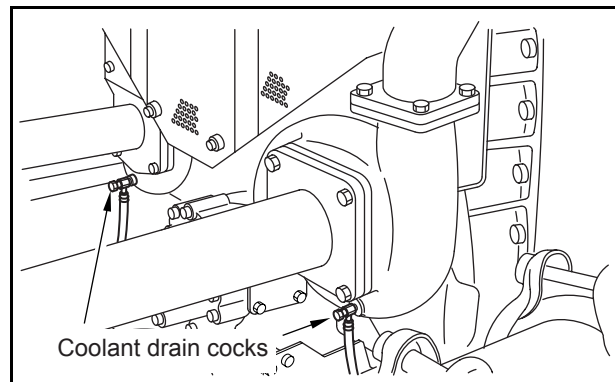


fig.3-11 Coolant drain cock on the water pump

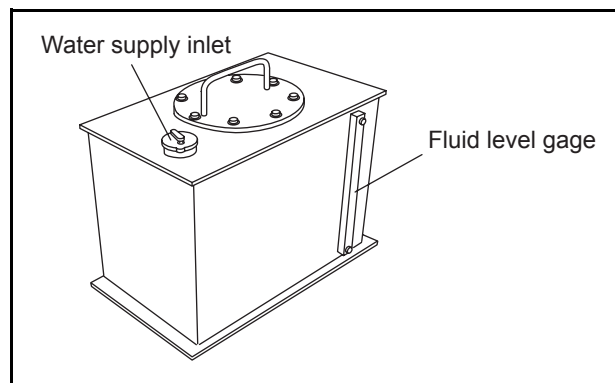


fig.3-12 Water tank coolant level

Electrical Systems Checking Battery

⚠ WARNING

If electrolyte is spilled on the eyes, skin or clothes, wash immediately with plenty of water. If electrolyte enters the eyes, flush immediately with lots of fresh water and see a physician.

Do not use flames near the battery. When handling the battery, be careful of sparks generated by accidental shorting.

Regarding other cautions in handling the battery, refer to "Caution Service Battery" (1-5).

Electrolyte level

Electrolyte evaporates during use and the fluid level gradually decreases. The fluid surface should be between the LOWER LEVEL and UPPER LEVEL lines. If there are no level lines on the battery, make sure that the fluid surface is about 10 to 15 mm [0.394 to 0.591 in.] above the top edges of the plate. If the fluid level is lower, remove the caps and add distilled water to the proper level.

Note: When pouring fresh electrolyte, pour the fluid carefully.

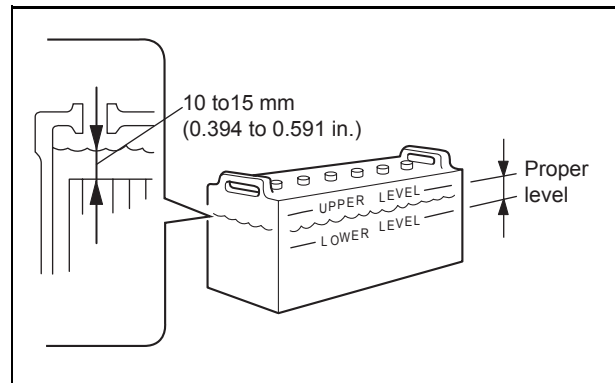


fig.3-13 Inspecting electrolyte level

Checking specific gravity of electrolyte

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

Table 3-1 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

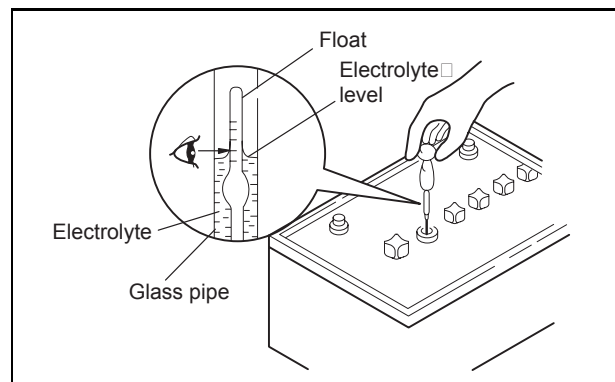


fig.3-14 Inspecting specific gravity of electrolyte

Checking loosened wire

Check the faulty wire connection for other parts of the electrical system and the battery terminal.

Checking Valves for Open/Closed Position

Make sure the following valves, plugs and cocks are open or closed properly.

- Fuel feed valve: Open
- Coolant drain cock (coolant tank): Closed
- Coolant drain cock (engine): Closed
- Coolant drain cock (water pump): Closed
- Oil drain valve: Closed
- Air supply valve (air tank): Open

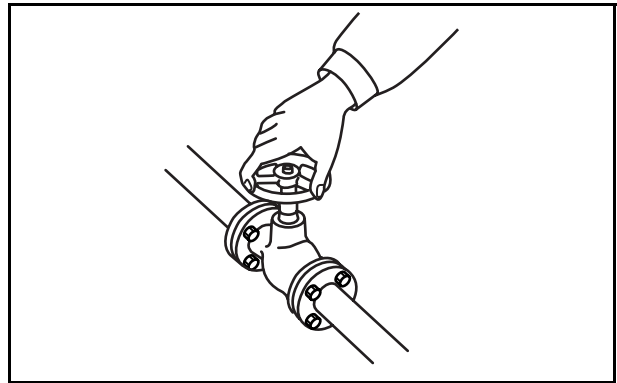


fig.3-15 Checking valves for open/closed position

Test Operation

To conduct a test operation, follow the procedures below.

Note: Refer to "[Normal Engine Operation](#)" (3-8) to operate the engine.

- 1 To circulate engine oil throughout the engine, pull the manual stop lever fully to the STOP position and hold it in that position to keep the fuel injection pump in no-injection condition, then supply starting air and crank the engine for about 10 seconds.
Then, wait for about one minute, and repeat the above process twice to fully circulate engine oil.
- 2 Start the engine.
- 3 Operate the engine under no load and at low idling speed for 10 minutes.
- 4 Stop the engine.
Leave the engine for about 30 minutes. While waiting, check the engine exterior for leakage of fuel, engine oil, coolant and exhaust gas.
After 30 minutes, check the engine oil level and coolant level. If they are low, add engine oil or coolant to the specified level.
- 5 Operate the engine under no load and at low idling speed for 5 minutes.
- 6 Operate the engine under no load and at rated speed for 5 minutes.
- 7 Operate the engine under 25% rated load and at rated speed for 30 minutes. (In the case of a main marine engine, apply load according to a cube curve.)
- 8 Operate the engine under 50% rated load and at rated speed for 30 minutes. (In the case of a main marine engine, apply load according to a cube curve.)
- 9 Operate the engine under 70% rated load and at rated speed for 30 minutes. (In the case of a main marine engine, apply load according to a cube curve.)
- 10 Operate the engine under 100% rated load and at rated speed for 60 minutes. (In the case of a main marine engine, apply load according to a cube curve.)
- 11 Stop the engine.

Normal Engine Operation

The following describes the procedures for operating the engine in normal operating condition.

⚠ CAUTION

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

Preparations for Operation (Pre-Start Inspection)

Always conduct the following inspection before starting the engine.

External Inspection

⚠ CAUTION

A fire can be caused by combustible materials placed near hot engine parts (exhaust manifolds and other exhaust gas passages) or battery, fuel leaks, and oil leaks. Check the engine exterior carefully. If an abnormality is found, be sure to repair or contact a Mitsubishi dealer.

Before starting the engine, clean the top surface of the battery with wet cloth.

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 the engine and battery are clean.
If combustible materials or waste are found near the engine or battery, remove them.
- 2 Check the entire engine for leakage of fuel, engine oil coolant. If leaks are found, repair leakage or contact a Mitsubishi dealer.
- 3 Visually check for loose bolts and nuts.
- 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

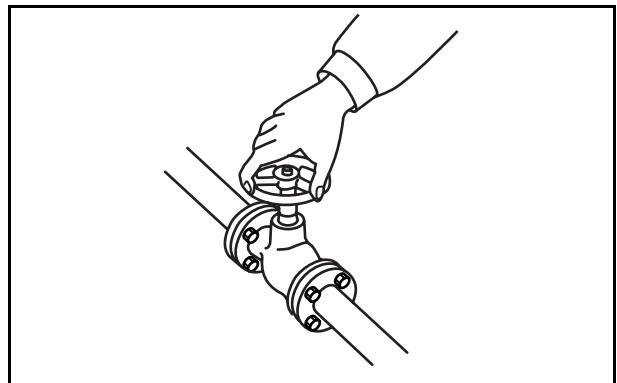


fig.3-16 Checking valves for open/closed position

Cleaning Fuel Filters (Wire-Element Type)

Rotate the handle of the fuel filter (wire-element) 1 or 2 turns in the direction of the arrow (clockwise) to clean the element inside the filter.

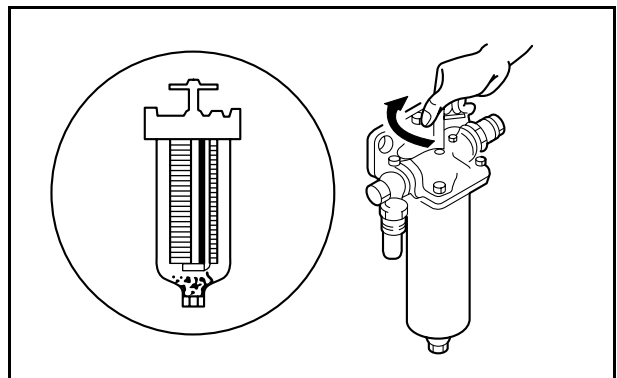


fig.3-17 Cleaning fuel filter (wire-element type)

Checking Fuel Level in Tank

⚠ DANGER

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

CAUTION

Do not remove the strainer when filling the fuel tank.
Use fuel specified in "Fuel" (4-2).

Check the fuel level if it is full.
If the fuel level is low, add fuel to FULL level in the level gage.

Draining Water from Fuel Tank

⚠ WARNING

When handling fuel, make sure there are no flames or heat source in the area.
Wipe any spilled fuel completely. Spilled fuel can ignite and cause fire.

CAUTION

Do not remove the strainer when filling the fuel tank.
Use fuel specified in "Fuel" (4-2).

Fuel mixed with water and/or dust not only reduces the output but can also cause malfunctions of the fuel system. Drain water from the fuel tank by following procedures below.

- 1 Place a fuel receiving tray (capacity: 2 L [0.53 U. S. gal] or more) under the drain cock on the fuel tank.
- 2 Open the drain cock on the fuel tank, and drain at least 1 to 2 L [0.26 to 0.53 U. S. gal] of fuel.
- 3 Make sure water and dust particles were drained together with fuel, then close the drain cock.

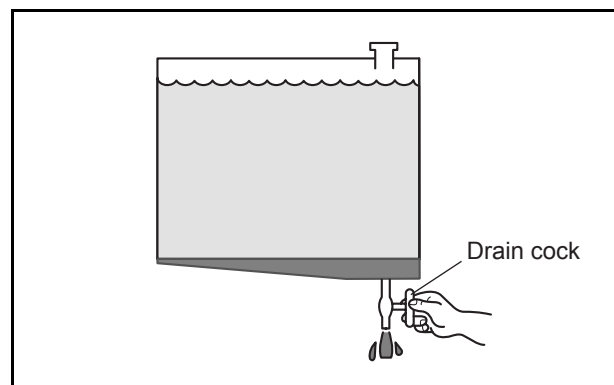


fig.3-18 Draining water from fuel tank

Checking Engine Oil Level

- 1 Pull out the oil level gage and wipe it with a cloth.
- 2 Insert the oil level gage fully into the oil level gage guide, then pull out the gage again.
- 3 The oil level should be between the MAXIMUM and MINIMUM marks on the oil level gage.
- 4 If the oil level is low, remove the oil filter cap and add engine oil of the specified type to the MAXIMUM level.
- 5 Securely tighten the oil filler cap after adding the engine oil.
- 6 Check the oil pan and other parts for oil leakage.

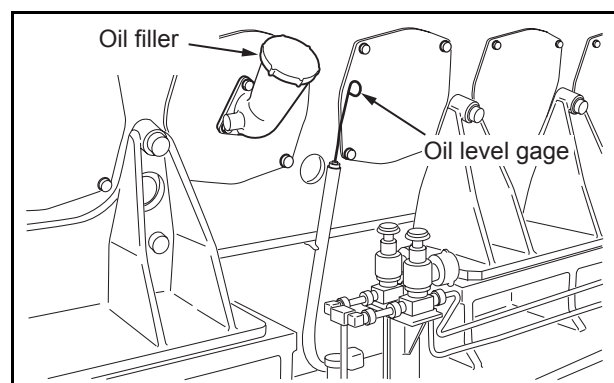


fig.3-19 Oil filler and oil level gage

Checking Coolant Level

⚠ WARNING

Never check the coolant level while the engine is in operation or immediately after it is stopped but wait until the coolant temperature drops sufficiently. If not, hot water blow out, causing skin burns as a result.

Check if the coolant level is appropriate in the coolant tank (at around center of the level gage). If the coolant level is low, add coolant to the specified level.

CAUTION

Always add coolant having the same LLC concentration. Never add plain water.

- Note:(a) Determine the amounts of LLC and water to be poured by using the LLC concentration chart.
- (b) Regarding coolant, refer to "Coolant" (4-6).

Inspection of Air Cleaner Indicator

- 1 Check the air cleaner indicator for the element clog.
- 2 If the element clogs, the red signal mark is visible.
- 3 Immediately clean or replace the air cleaner element when the signal turns red.

Note: Regarding cleaning of the air cleaner element, refer to "Cleaning, Inspecting and Changing Air Cleaner Element" (6-18).

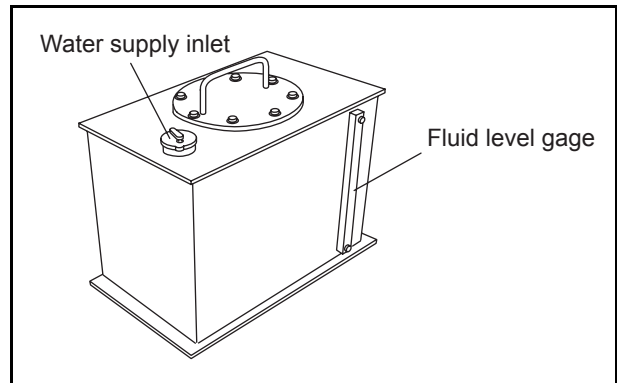


fig.3-20 Checking coolant level

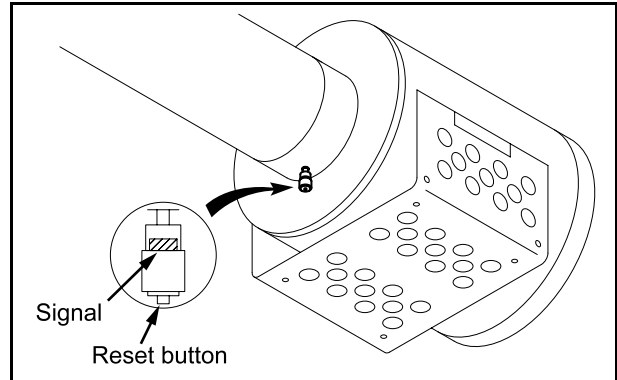


fig.3-21 Air cleaner indicator

Draining Water from Air Starter Tank

WARNING

Slowly open the starting air handle of the air tank. If the handle is opened quickly, the engine can start abruptly and cause an unexpected accident.

- 1 Close the starting air handle of the air tank.
- 2 Open the drain valve handle located under the drain valve on the front side of the tank to drain accumulated water from the tank.

Note: The amount of drained water can vary depending on the relative humidity and air consumption.

- 3 Close the drain valve handle after draining water.
- 4 Open the starting air handles slowly.

Inspection of Air Tank Air Pressure

Check the air pressure gage to see if the air pressure in the air tank conforms to the standard.

Air tank internal pressure standard:

2.94 MPa (30 kgf/cm²) [426 psi]

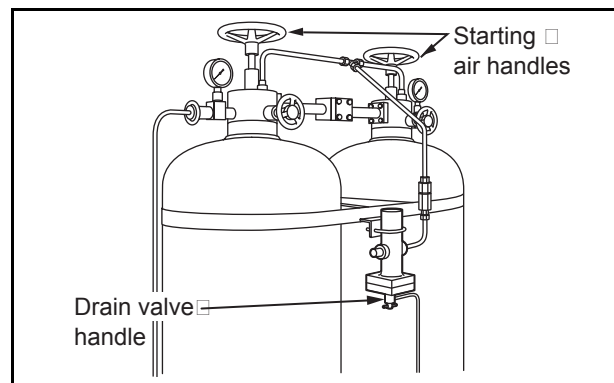


fig.3-22 Draining water from air starter tank

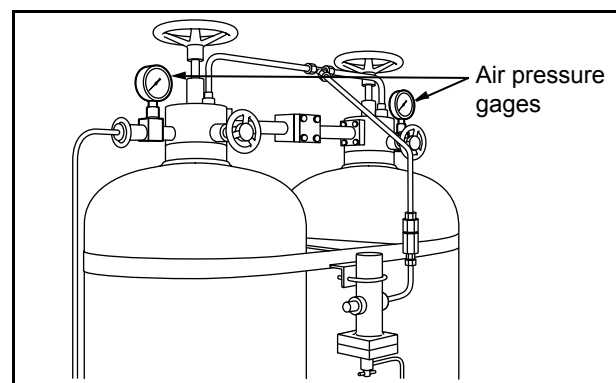


fig.3-23 Inspection of air tank air pressure

Starting

The starting method varies depending 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 tools are not left on or near the engine. In loud voice, notify people in the area when starting the engine.

CAUTION

Never load the engine at starting time. (Disengage the clutch if it is installed.)

- 1 Check to make sure the air tank internal pressure is 2.94 MPa (30 kgf/cm²) [426 psi].
- 2 Open the air tank main valve.
- 3 Set the start lever to OPEN or press the Start button to start the engine.
After confirming the engine startup, set the start lever to CLOSE and close the air tank main valve.
In the case of automatic startup, keep the air tank main valve open.
If the engine does not start, wait for 2 minutes, then set the air tank pressure to the specified level and start the engine again.

Note: If the engine fails to start after three attempts, contact a Mitsubishi dealer.

Warming-up Operation

WARNING

Do not approach rotating parts while in operation.

Entanglement by rotating parts can cause serious injury.

CAUTION

Do not conduct warm-up operation for an extended period of time.

Prolonged warm-up operation causes carbon buildup in the cylinders that leads to incomplete combustion.

Emergency engines do not require a warm-up operation since they start up for immediate operation. However, be sure to check all items on the inspection and maintenance chart.

Do not operate the engine under excessive load (indicated by discharge of black smoke) during a warm-up operation. Operating the engine under excessive load not only consumes fuel unnecessarily, but also causes incomplete combustion, which can result in carbon deposits and shorten the engine service life.

Conduct a warm-up operation according to the ambient temperature.

When the air temperature is lower than 5 °C [41 °F], operate the engine under no load and at low idling speed for 5 to 10 minutes.

When the air temperature is higher than 5 °C [41 °F], operate the engine under no load and at low idling speed for at least 20 seconds.

The above guidelines for warm-up operation do not apply when the engine is equipped with an auxiliary starting device (water heater, engine oil priming pump, etc.).

Inspection of Oil Pressure

During warming-up operation, check if the oil pressure is in the range of standard value.

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

Oil pressure standard value during warming-up: 0.20 to 0.39 MPa (2.0 to 4.0 kgf/cm²) [29 to 56.56 psi] (at low idling)

Note: The oil pressure gage indicates higher pressure than normal immediately after the engine starts since the oil temperature is low. This does not denote an abnormality. The pressure gradually lowers to the normal level as the oil temperature rises.

External Inspection during Warming-up

Check the external view of the engine to make sure there is no fuel, oil, cooling water or exhaust gas leakage from joints.

Operation

⚠ WARNING

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

⚠ CAUTION

Do not touch any part of the engine while it is operating or immediately after it is shut down. A hot engine can cause burns.

CAUTION

Provide adequate ventilation in the engine room. If air supplied to the engine room is restricted, the room temperature increases and can affect engine output and performance.

During the first 50 hours of operation, break-in the engine by operating it with light load and at lower speed than normal.

Operating the engine under high load or severe conditions during the break-in period can shorten the service life of the engine.

After the warm-up operation, start operating the engine with load.

Inspection During Operation

Check for leakages.

Inspect the exterior of the engine to make sure there is no leakage from joints.

Check to make sure the engine does not produce abnormal noise or vibrations.

Inspect the engine for abnormal operating sound and vibrations such as knocking.

Check to make sure the exhaust gas is normal color.

Check the color of the exhaust gas discharged from the exhaust pipe.

Note: Regarding abnormal exhaust gas conditions, refer to ["Engine Produces Large Amount of Smoke While in Operation"](#) (9-8).

Check to make sure that the mist discharged from the breather is not abnormal in the amount or color.

Check to make sure the instruments and gages indicate normal values.

Table 3-2 Data for rated speed

Item		Standard value
Engine oil pressure	No load, low idling speed	0.20 to 0.39 MPa (2.0 to 4.0 kgf/cm ²) [29 to 56.56 psi]
	Rated speed	0.39 to 0.69 MPa (4.0 to 7.0 kgf/cm ²) [56.56 to 100.08 psi]
Engine oil temperature		70 to 100 °C [158 to 212 °F]
Jacket coolant pressure		0.05 to 0.34 MPa (0.5 to 3.5 kgf/cm ²) [7.25 to 49.31 psi]
Jacket coolant temperature		65 to 85 °C [149 to 185 °F]
Oil cooler/air cooler coolant pressure		0.05 to 0.34 MPa (0.5 to 3.5 kgf/cm ²) [7.25 to 49.31 psi]
Oil cooler/air cooler coolant temperature		30 to 85 °C [86 to 185 °F]
Exhaust temperature	Cylinder outlets	250 to 650 °C [482 to 1202 °F]
	Turbo-charger outlet	250 to 600 °C [482 to 1112 °F]

Note:(a) When the oil pressure drops below 0.29 MPa (3 kgf/cm²) [42.7 psi] in normal operation, or below 0.10 MPa (1 kgf/cm²) [14.2 psi] at minimum speed with no load, stop the engine immediately. Before restarting the engine, check and correct the cause of the problem.

(b) When the high temperature alarm switch is activated in normal operation, change the engine operation immediately to no-load idling condition until the engine temperature decreases to normal operating level. Then, operate the engine for another 5 or 6 minutes for cooling before stopping the engine.

Before restarting the engine, check and correct the cause of the problem.

If the above inspection finds an abnormality, stop the engine immediately, correct all problems, and restart the engine. If the engine cannot be repaired, contact a Mitsubishi dealer.

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 service life of the engine. Before stopping the engine, let it operate at low idle speed for 5 to 6 minutes to cool down operation. Stopping the engine immediately after high-speed operation can cause engine parts to be heated up and result in bad effects.

During cooling operation, check the engine for abnormalities.

Do not accelerate the engine prior to shutting it down.

Do not restart the engine immediately after it shuts down due to an abnormality. If an alarm is generated when the engine stops, locate the cause of the problem and correct the problem before restarting the engine.

Continuing engine operation without correcting the problem can result in a serious accident.

For stopping the engine, follow the instructions since stopping procedure varies depending upon the models and its installed equipment.

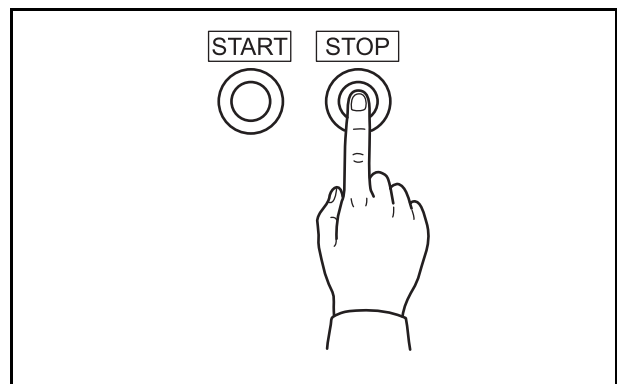


fig.3-24 Stop button

Emergency Stop

CAUTION

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

To stop the engine with emergency lever, pull the manual lever to the arrow direction and continue pulling the lever until the engine stops completely.

Note: If the operation of the manual stop lever fails to shut down the engine, cut off the fuel supply.

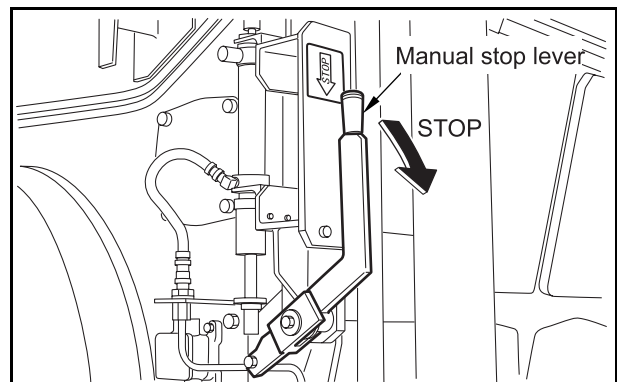


fig.3-25 Manual stop lever

Inspection After Stopping

Inspect the engine parts to make sure there is no fuel, oil or coolant leakage. If a fuel or oil leak is found, repair the leakage or contact a Mitsubishi dealer.

Chapter 4

MAINTENANCE

Cautions Concerning Maintenance

Stop the engine before checking or adding fuel, oil or coolant.

⚠ WARNING

Be sure to stop the engine before checking and adding fuel, engine oil or coolant.

Make sure the coolant temperature is sufficiently low before checking coolant. Do not check coolant immediately after the engine stops.

Do not attempt to adjust the parts while the engine is operating.

Failure to follow the above directions may cause fire, skins burns or entanglement by rotating parts.

Handle electrolyte carefully.

⚠ CAUTION

Should electrolyte enter eyes or contact the skin or clothes, flush immediately with plenty of water.

Should electrolyte enter eyes, wash immediately with water and seek medical attention.

Handle LLC carefully.

⚠ CAUTION

Should LLC be accidentally swallowed, induce vomiting immediately and seek medical attention.

Should LLC enter eyes, flush immediately with plenty of water and seek medical attention.

LLC is a potent alkaline solution. Do not drink or allow it to enter your eyes.

Always wear protective gear.

⚠ CAUTION

Wear protective gear such as a hardhat, face shield, work clothes, safety shoes, dust protective mask, etc.

Be sure to wear protective goggles and other protective devices when handling compressed air.

Compressed air can cause personal injury if handled carelessly.

Use recommended fuel, engine oil and coolant.

CAUTION

Use fuel, engine oil and coolant specified in this manual, and handle them with utmost caution.

When adding engine oil, use oil of the same brand.

Do not mix oils of different brands.

Perform all specified pre-start inspections and periodic inspections.

CAUTION

Conduct the pre-start inspection and periodic inspection as specified in this manual.

Failure to conduct pre-start inspections and periodic inspections may cause various engine problems and damage to parts as well as serious accidents.

Use only genuine Mitsubishi parts.

CAUTION

When replacing new parts, use only genuine Mitsubishi parts.

To obtain new parts, contact a Mitsubishi dealer.

Fuel

Recommended Fuel

Use commercially available diesel fuel (JIS K2204).

Note: Some Class-A heavy oils are unsuitable for use in the Mitsubishi diesel engine. Use fuel that meets the Use Limit Property Guideline for Diesel Fuel. If the engine is continuously used for many hours, refer to the recommended use limit.

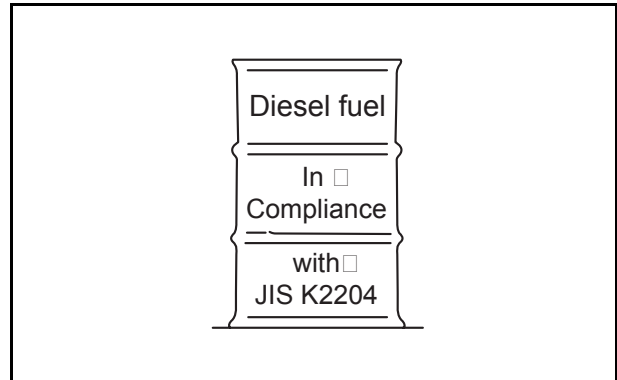


fig.4-1 Recommended fuel

It is necessary to use fuel that has a pour point suitable for the ambient temperature. Choose the fuel type from the chart on the right.

Table 4-1 Recommended Fuel

Standard	Classification
JIS K2204	TYPE 1, TYPE 2, TYPE 3
ASTM D975	No. 1-D, No. 2-D
BS 2869	CLASS-A1, CLASS A-2
DIN 51601	DIESEL-FUEL
ISO 8217	DMX-CLASS

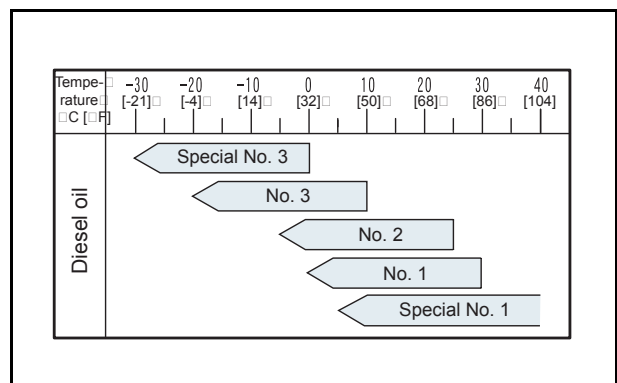


fig.4-2 Recommended fuel according to air temperature

Handling Fuel

When using fuel kept in a storage tank, allow it to sit for more than 24 hours so dust and water can settle at the bottom. Then, use clean fuel from the upper layer. Fill the fuel tank or service tank after each work day. This prevents water from mixing with fuel in the tank and gives time for dust and water to separate and settle at the bottom of the tank.

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

Be sure to pour fuel through a strainer. Use of a clean, lint-free cheesecloth is recommended.

Table 4-2 Fuel Use Limit Property Guideline

Property		Recommend use limit	Current use limit	Remarks
Flash point		As stipulated by regulation		JIS K2204, 2205 Diesel fuel: 50°C or higher Class-A heavy oil: 60 °C [140 °F] or higher
Distillation	First distillation point	170 °C [338 °F] or higher	170 °C [338 °F] or higher	JIS K2254
	90% distillation point	330 to 380 °C [626 to 716 °F]	330 to 380 °C [626 to 716 °F]	
Pour point		More than 6°C [10.8 °F] below ambient temperature		JIS K2269
Cloud point		Below ambient temperature		
Carbon residue (10% residual oil)		0.4 weight % or lower	1.0 weight % or lower	JIS K2270
Cetane number		45 or higher		
Cetane index (new)		45 or higher		JIS K2280-1996
Kinetic viscosity		2.0 mm ² /s [0.0031 in ²] or higher (30 °C [86 °F]) 8.0 mm ² /s [0.0124 in ²] or lower (50 °C [122 °F]) 10.5 mm ² /s [0.0163 in ²] or lower (40 °C [104 °F]) 16.0 mm ² /s [0.0248 in ²] or lower (30 °C [86 °F])		
Sulfur content		0.2 weight % or lower	1.0 weight % or lower	JISK25410.05 weight % (same as diesel fuel) is recommended.
Water and sediment		0.1 volume % or lower		JIS K2275
Ash		0.03 weight % or lower		JIS K2272
Copper plate corrosion (100°C [212°F], 3 hrs.)		No.3 or lower	No.3 or lower	ASTM - No.3 JIS K2513 - Discoloration No.3
Specific gravity (15°C [59°F])		0.83 to 0.87		0.80 to 0.87
Coking test	Should not be carbonized more than 75% at 250 °C [482 °F]		Should not be carbonized 100% at 250 °C [482 °F]	Fed791B (U.S.) 250 °C [482 °F] X 24Hr 230 °C [446 °F] X 24Hr 180 °C [356 °F] X 48Hr
	Should not be evaporated more than 55% at 230 °C [446 °F]			
	Should not be turn to tar at 180 °C [356 °F]			
Aromatics content (HPLC method)		38 weight % or lower	38 weight % or lower	JIS K 2536 Total of aromatic content
Asphaltene		0.1 weight % or lower	0.1 weight % or lower	ICP analysis (U.K.)
Particulate contaminant		5.0 mg/l or lower	5.0 mg/l or lower	JIS B9931 Including foreign substance in the fuel pipe lines

Engine Oil

Recommended Engine Oil

Use class CD (recommended) and CF engine oils. Class CE and CF-4 engine oils are designed for diesel fuel with a sulfur content of less than 0.5% and less than 0.2%, respectively. Since the sulfur content of most Class-A heavy oil exceeds 0.5%, do not use Class CE or CF-4 engine oil when using Class-A heavy oil as fuel.

Use of improper or inferior oil can cause excessive wear of bearings and moving parts, thus shortening the engine life. It can also result in the sticking of piston rings and seizing of pistons in the cylinders, thus causing major damage.

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 results in inadequate lubrication and leakage of combustion gas that cause increased wear and reduced output.

Recommended oil viscosity is SAE 15W-40 for all seasons.

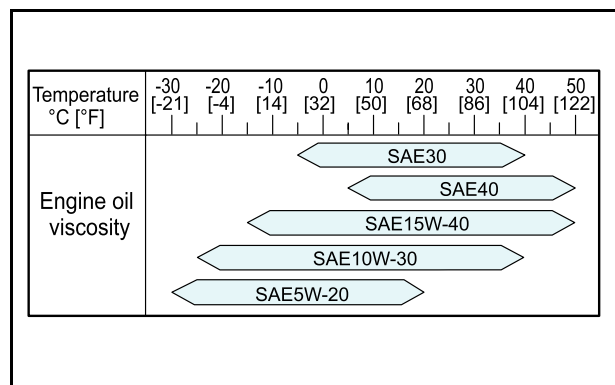


fig.4-3 Recommended oil viscosity according to air temperature

Handling Engine Oil

WARNING

Before pouring engine oil into the engine, stop the engine and make sure there are no flames near the engine. Oil leaked or spilled onto hot surfaces or electrical components can cause a fire. Wipe any spilled oil immediately and thoroughly.

After pouring engine oil, close filler cap surely.

CAUTION

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

If oil of more than the legally specified amount must be handled, be sure to have the work performed by a service station in compliance with the legal regulations.

Use an oil pump to remove oil from the engine or oil can. Do not use a hose to siphon with the mouth.

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 (material safety data sheet) of the engine oil used and follow the instructions.

Coolant

Recommended Coolant

Water used in the engine cooling system must be soft water. The water quality must meet the following requirements.

Water quality should meet with recommended limit, however, within limit is acceptable.

Table 4-3 Water quality standards

Item	Chemical symbol	Unit	Recommended	Limit	Main adverse effect	
					Corrosion and rust	Scale formation
pH (25°C [77°F])	-	-	6.5 to 8.5	6.5 to 8.5	O	O
Electrical conductivity (25°C [77°F])	-	μ S/cm	<250	<400	O	O
Total hardness	CaCO ₃	ppm	< 95	< 100	-	O
M alkalinity	CaCO ₃	ppm	< 70	< 150	-	O
Chlorine ion	Cl ⁻	ppm	< 100	< 100	O	-
Sulfuric acid ion	SO ₄ ⁴⁻	ppm	< 50	< 100	O	-
Total iron	Fe	ppm	< 1.0	< 1.0	-	O
Silica	SiO ₂	ppm	-	< 50	-	O
Residue from evaporation	-	ppm	< 250	< 400	-	O

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 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 long life coolant (LLC) as coolant, because it prevents not only freezing of coolant but also rusting of the cooling system.

Use an all-season, non-amine type LLC.

Recommended LLC

Recommended brands of LLC are shown in the chart below.

Table 4-4 Recommended brands of LLC

Manufacturer	Brand
Nippon Oil Corporation	Super Coolant X
Mitsubishi Fuso Truck & Bus Corporation	Fuso Diesel Long Life Coolant
TEXACO	Code 7998

Note: When using an LLC other than the above, frequent inspections are required since the service life may be shorter.

Features and Performance of Recommended LLC

- Use LLC with no amine content.
- Use LLC with no silicate or borate.
- Use LLC that is close to neutral on the pH scale and slightly alkaline.
- Use LLC that contains balanced chemical additives as substitutes for amines.
- Use LLC that offers long life (with 30% LLC concentration and service life of more than 1 year).

Maintenance of LLC

CAUTION

Coolant (containing LLC) drained from an engine is toxic, and must not be disposed of into regular sewage.

For disposal of used coolant, consult a Mitsubishi dealer.

Replacement timing of LLC

When a coolant mixed with the LLC recommended by our company is used, replace coolant every 12000 hours or 2 years, whichever comes first, in a regular-use or general-purpose engine. In an emergency engine, replace coolant every 2 years.

LLC concentration

When determining the LLC concentration, provide a margin of 5°C [41°F] below the expected lowest temperature in your region. Maintain the LLC concentration between 30 and 60% throughout the year.

LLC of less than 30% concentration does not provide sufficient corrosion protection. If the LLC concentration is as low as several percent, it may promote corrosion.

LLC of more than 60% concentration can adversely affect its freeze protection characteristic and cause the engine to overheat easily.

When adding coolant without changing all coolant, do not add plain water. Always use coolant having the same LLC concentration.

Table 4-5 Recommended LLC concentration (for reference only)

Lowest ambient temperature (°C [°F])	up to -15 [5]	up to -24 [-11]	up to -36 [-32]	up to -43 [-45]
LLC concentration (%)	30	40	50	55

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

Importance of LLC

Today's trend is toward smaller and more light-weight engines offering greater output, lower fuel consumption and lower exhaust emission level. Conditions to which engine coolant is subjected 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. These materials differ in ionizing tendency, and this difference promotes corrosion through the medium of engine coolant. To prevent the above problem, it is necessary to use LLC (long life coolant).

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 after many months of use. Moreover, if the chemicals are not well proportioned to match the metals used in the cooling system, certain chemicals in the LLC become rapidly used up and result in dissolving of metals. Moreover, other corrosion preventing chemicals react with dissolving metals and further accelerate corrosion. This condition can result in more corrosion than when plain soft water is used. This problem is often caused by the use of inappropriate LLC.

Examples of Abnormalities Caused by LLC

Pitting on 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 copper deposits produce galvanic or local-cell action, thus corroding and pitting iron that has a higher ionizing tendency.

Corrosion of aluminum parts

Silicate is highly effective in protecting aluminum against rusting. However, it is unstable in a solution in which 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.

(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 radiator

As LLC's general performance deteriorates or when its concentration in the coolant is too low, its anti-corrosion performance 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

Filters

Filters remove impurities such as dust particles from fuel, engine oil and air starter system. While it is important to use clean fuel, engine oil and air supply, filters must be changed regularly to ensure maximum engine performance and extend the service life of the engine.

Refer to ["PERIODIC MAINTENANCE CHART" \(5-1\)](#) for the procedure for changing filters. The interval of changing filters can be shortened depending on the usage and operating conditions as well as quality of fuel and oil in use.

When replacing filters, use genuine Mitsubishi parts.

Do not wash and reuse cartridge-type filters.

Always use new filters.

When filters are changed, inspect the removed filters for metal particles. If metal particles are found, consult a Mitsubishi dealer.

Electrical Parts

Do not splash water on electrical parts. Water can cause electrical leakage and short-circuiting, resulting in equipment damage. Wet electrical parts can also cause electric shock.

When cleaning the engine, keep water away from electrical parts.

If malfunctioning of electrical parts is suspected, consult a Mitsubishi dealer.

Also, do not use disassembled or reassembled electrical parts.

Cautions in Operating Engine in Cold Weather Season

When the ambient temperature is low, fuel and engine oil become thick and coolant can freeze, thus making it difficult to start the engine or causing damage to the cylinder heads. To prevent these problems, observe the following directions.

Fuel

WARNING

When handling fuel, make sure there are no flames near engine.

Wipe any spilled fuel completely. Spilled fuel can ignite and cause fire.

Use appropriate fuel according to the ambient temperature.

Note: Regarding fuel, refer to ["Fuel" \(4-2\)](#).

Engine Oil

Replace engine oil suitable to the ambient temperature.

Note: Regarding engine oil, refer to ["Engine Oil" \(4-4\)](#).

Coolant

CAUTION

Remove the radiator cap only after the engine cools to room temperature. Place a cloth over the cap, and turn the cap about a half turn to release pressure. Opening the radiator cap while the engine is hot causes steam and hot coolant to blow out, resulting in skin burns.

Freezing of coolant due to cold temperatures can damage the crankcase. Be sure to use all-season long life coolant that prevent freezing of cooling water and rusting of the engine cooling system.

Note: Regarding coolant, refer to ["Coolant" \(4-6\)](#).

Battery

WARNING

Never use flames near the battery, and be careful to handle battery since flames can cause an explosion.

CAUTION

If electrolyte is spilled on skin or clothes, wash immediately with lots of water. If electrolyte gets into your eyes, flush immediately with lots of fresh water and consult a physician as soon as possible. For other cautions to handle battery, refer to ["Caution Service Battery" \(1-5\)](#)

When the ambient temperature drops to a very low level, the charging rate becomes low even if the specific gravity of electrolyte remains the same. Therefore, in a cold area the battery may not provide sufficient power to start the engine immediately. Furthermore, electrolyte becomes easier to freeze when its specific gravity is low. Therefore, it is recommended to additionally charge the battery to increase the specific gravity of electrolyte and the charging rate.

Note: For the inspection of specific gravity of electrolyte, refer to ["Checking specific gravity of electrolyte" \(3-6\)](#).

Maintenance After Cold Season

After a cold season ends, change fuel, engine oil and coolant to those suitable for the outside temperature in accordance with the specifications described in this manual.

Chapter 5

PERIODIC MAINTENANCE CHART

How to Use Periodic Maintenance Chart

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 periodic maintenance chart. The maintenance chart shows the standard service intervals. Whenever you notice the abnormalities mentioned below, make sure the service must be performed to the defective part of the engine, regardless recommended service intervals in the "Periodic Maintenance Chart"; abnormal noise, black exhaust smoke, white exhaust smoke, abnormally high temperature of exhaust gas, abnormal vibration in engine, fuel, oil or exhaust gas leakage.

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 Mitsubishi dealer regarding service intervals.)

Perform service items listed under the service interval. Service items with shorter intervals should also be included in the longer interval service.

Items marked with * in the maintenance chart require special tools or large equipment. For the servicing of these items, consult a Mitsubishi dealer.

Periodic Maintenance Chart

Appropriate service intervals vary depending on the engine specifications. Perform all daily inspection and maintenance items in an 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 emergency engine 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 1/2 load).

If the engine cannot be operated under load every month, operate the engine under load (more than 1/2 load) for more than 2 hours.

During the engine maintenance operation, check the ease of startup, oil pressure, and exhaust color and vibration.

Periodic maintenance chart for general-purpose engine

If the engine is used for different purposes other than the above usage, do maintenance according to the "[Periodic Maintenance Chart for General-Purpose Power Supply Engine](#)".

General Definition of Regular-Use Engine, Emergency Engine and General-Purpose 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.

General definition of general-purpose engine

An engine used for a purpose other than power generation - for example, to drive a pump, as the main engine for a ship, and for an industrial vehicle - and operated under constant or cyclically varying load and speed.

Periodic Maintenance Chart for Engine in Regular Use

Table 5-1 Periodic maintenance chart for engine in regular use (1 / 5)

Service interval	Service item	Service contents	Page
Every day	External	Inspect leakage and looseness of bolts and nuts. Retighten bolts and nuts.	3-8
	Fuel tank	Inspect fuel level and drain water.	3-9
	Fuel filters (wire-element)	Clean inside of the filter by using handle.	3-8
	Engine oil	Inspect oil level and add oil by using oil level gage. Inspect level regulator operation.	3-9
	Coolant	Inspect coolant level and add coolant by using fluid level gage.	3-10
	Air cleaner	Inspect air cleaner indicator for element clog.	3-10
	Air starter tank	Inspect air pressure and drain water.	3-11
	Operating condition	Check operating period, performance record, sound, vibration and gage function.	3-13
Every 500 service hours	Air cooler	Inspect water leakage from air cooler chamber and drain water.	6-16
	Fuel filters	Drain water.	6-1
	Fuel control linkage	Inspect ball joints, bolts and nuts for looseness and smooth movement.	6-6
	Engine oil	Inspect engine oil for mixing of fuel and water.	6-11
		Analyze engine oil properties (according to engine oil analysis service)	6-12
		Change.	6-7
	Oil filter and bypass oil filter	Change.	6-7
	Exhaust pipes and exhaust muffler	Inspect and drain water.	6-16
Air starter compressor	Drain water.	6-18	
Zinc rod	Inspect and change.	6-13	
First 1500 service hours	Valve clearance	Inspect and adjust (also inspect inside of rocker chamber).	*
	Camshafts and tappets	Inspect.	*
	Air cooler cover	Retighten air cooler cover mounting bolt (Also after first 1500 service hours from gasket replacement).	*
Every 1500 service hours	Fuel filters	Change.	6-3
	Coolant	Inspect LLC concentration.	6-14
	Pre-cleaner	Clean.	6-16
	Air cleaner element	Clean and inspect.	6-17
	Air starter strainer	Drain water and clean.	6-18

Table 5-1 Periodic maintenance chart for engine in regular use (2 / 5)

Service interval	Service item	Service contents	Page
Every 3000 service hours	Valve clearance	Inspect and adjust (also inspect inside of rocker chamber).	*
	Fuel injection nozzles	Change nozzle tips and adjust pressure.	*
	Fuel filters (wire-element)	Disassemble and clean inside.	6-1
	Breather	Inspect and clean mist separator, and change expendable parts.	*
	Governor oil filter	Change.	*
	Pre-cleaner	Change.	6-17
	Air cleaner element	Change.	6-18
	Magnetic pickup	Inspect clearance with the flywheel, attachment of foreign items on the tip, mounting nut tightness, an open-circuit and connector disconnection.	*
After 3000 services hours or 2 years, whichever comes first	Fuel system accumulator	Refill with nitrogen gas.	*
Every 6000 service hours	Camshafts and tappets	Inspect.	*
	Crankcase	Inspect inside (remove the side cover for inspection).	
	Water pump	Change oil seals, unit seals and other expendable parts.	
	Damper	Check temperature with thermo label and check for silicon oil leakage.	
	Turbocharger	Inspection of shaft and wheel smooth rotation and thrust for looseness.	
	Inspection of pipe clamps of fuel lines, oil lines, instrument pipes and starting air pipes	Inspection of interference and wear, and repair rubber tape.	
After 12000 service hours or 2 years, whichever comes first	Coolant	Change.	6-13

Table 5-1 Periodic maintenance chart for engine in regular use (3 / 5)

Service interval	Service item	Service contents	Page	
Every 12000 service hours	Overhaul of top end of engine (remove the cylinder heads for inspection and maintenance.)		*	
	Cylinder heads and valve mechanisms	Disassemble and maintain, clean and change expendable parts.		
		Valve seat		Inspect, regrind and lap.
		Cylinder head gasket		Change.
		Copper tubes		Change copper tubes and O-rings.
		Inlet and exhaust valves		Inspect, regrind and lap.
		Valve guides, valve rotator, valve cotter, pushrods, rocker arm bushings, valve springs, tappet rollers, tappet roller bushing, tappet shafts, tappet guides, tappet guide set screws.		Inspect.
		Stem seal		Change.
		Safety valve		Inspect and change expendable parts.
	Cylinder liners	Inspect and clean.		
	Pistons	Inspect including overhaul and clean.		
	Piston rings	Change.		
	Connecting rods	Inspect bolts, inspect Magnaflux serrations, change big-end bearing shells and inspect small-end bushings.		
	Crankshaft	Inspect and adjust deflection.		
Damper	Analyze silicon oil properties and change thermo label.			
Front gear and timing gear	Inspect gear teeth.			

Table 5-1 Periodic maintenance chart for engine in regular use (4 / 5)

Service interval	Service item		Service contents	Page
Every 12000 service hours	Fuel system	Fuel control linkage	Change ball joints and ball bearings.	*
		Fuel injection pump	Disassemble and maintain, and change deflectors and O-rings.	
		Fuel feed pump	Change oil seals and O-rings.	
		Fuel injection pipes	Change.	
		Fuel injection timing	Inspect and adjust.	
		Fuel pressure regulator valve	Inspect.	
		Fuel system accumulator	Change.	
		Fuel pipes	Change O-rings and sealing washers.	
	Lubricating system	Oil pump	Change bushings.	
		Oil cooler	Inspect and clean element.	
		Regulator valve	Disassemble and maintain.	
		Oil pipes	Change O-rings and gaskets.	
	Cooling system	Water pump	Change bearings.	
		Coolant pipes	Change O-rings.	
	Inlet and exhaust systems	Turbocharger	Remove carbon deposits and change seal rings, bearings and expendable parts.	
		Air cooler	Clean element.	
		Air cooler cover	Change gaskets.	
		Air inlet pipes	Change O-rings.	
		Exhaust pipes	Change gaskets, bolts and nuts.	
		Exhaust duct	Change V-clamps.	
	Air starter system	Starting valve	Inspect, lap and change O-rings and gaskets.	
		Air pipes	Change gaskets.	
		Air tank	Inspect safety valve operation.	
		Distributor	Change valve, shaft, bushings, pins and gaskets.	
	Protection device	Increasing coolant temperature, decreasing oil pressure, over-speed and emergency stop device	Inspect operation.	
	Flexible hoses		Change.	

Table 5-1 Periodic maintenance chart for engine in regular use (5 / 5)

Service interval	Service item	Service contents	Page	
Every 24000 service hours	Major overhaul (complete disassembly and inspection) Change all O-rings, gaskets and seals.		*	
	Cylinder heads and valve mechanisms	Change inlet and exhaust valves, valve seats, valve guides, valve rotators and valve cotters.		
		Inspect and change pushrods, rocker arm bushings, valve springs, tappet rollers, tappet roller bushings, tappet shafts, tappet guides and tappet guide set screws.		
	Cylinder liners			Change.
	Main bearings			Inspect caps and bolts, and change main bearings.
	Cam bushings			Inspect and change (in 2nd 24000-service-hour-interval inspection and maintenance).
	Pistons			Disassemble and inspect piston crown, and change O-rings.
	Connecting rods			Change bolts and small-end bushings.
	Crankshaft			Inspect journals and pins, and change slingers.
	Damper			Change (in 2nd 24000-service-hour-interval inspection and maintenance).
	Spring coupling			Disassemble and maintain (by spring coupling manufacturer).
	Timing gear and front gear	All shafts		Inspect.
		Rear idler gear		Inspect and change assemblies (including bushings).
		Change front idler bearing, camshaft roller bearing, front seal, rear seal, front gear case gasket and rear gear case gasket.		
	Fuel system	Fuel injection nozzles		Change nozzle holder assemblies.
		Fuel injection pump		Change plunger assembly and delivery valve.
		Fuel feed pump (trochoid type)		Change pump assembly.
		Regulator valve		Change.
	Lubricating system	Oil pump		Change safety valve and spring.
		Oil thermostat		Change.
		Oil pan		Clean and change gasket.
		Engine oil regulator valve		Inspect and change.
	Cooling system	Water pump		Change shaft and impeller.
		Coolant thermostat		Change.
	Inlet and exhaust systems	Air cooler		Change element (in 2nd 24000-hour-interval inspection and maintenance).
		Exhaust pipes		Inspect and change bellows.
		Exhaust duct		Change seal rings.
	Governor	Actuator		Disassemble and maintain (by governor manufacturer).
		Governor case		Change bearings, O-rings and gaskets.
Control shaft		Change oil seals.		

Periodic Maintenance Chart for Emergency Engine

Table 5-2 Periodic maintenance chart for emergency engine (1 / 5)

Service interval	Service item	Service contents	Page
Every week	Conducting maintenance operation	Operate the engine under no load for 3 to 5 minutes. Inspect starting property, exhaust color, abnormal vibrations, abnormal sounds and abnormal odors. Inspect displayed value of each gage (such as oil pressure gage, water temperature gage, oil temperature gage, exhaust temperature and rotating speed gage).	3-13
	External	Inspect leakage and looseness of bolts and nuts. Retighten bolts and nuts.	3-8
	Fuel tank	Inspect fuel level.	3-9
	Engine oil	Inspect oil level and add oil by using oil level gage. Inspect level regulator operation.	3-9
	Coolant	Inspect coolant level and coolant oil by using fluid level gage.	3-10
	Air cooler	Inspect water leakage from air cooler chamber and drain water.	6-16
	Air starter tank	Inspect air pressure.	3-11
Every month	Conducting maintenance operation	Operate the engine under load (at 50 % or more) for 15 to 30 minutes. Inspect starting property, exhaust color, abnormal vibrations, abnormal sounds, abnormal odors. Inspect displayed value of each gage (such as oil pressure gage, water temperature gage, oil temperature gage, exhaust temperature, rotating speed gage).	3-13
	Fuel filter (wire-element)	Clean inside of the filter by using handle.	6-2
	Fuel control linkage	Inspect ball joints, bolts and nuts for looseness and smooth movement.	6-6
	Engine oil	Inspect engine oil for mixing of fuel and water.	6-11
	Air cleaner	Inspect air cleaner indicator for element clog.	3-10
	Pre-cleaner	Inspect for clog.	-
	Air starter compressor	Drain water.	6-18
	Air starter tank	Drain water.	3-11
Every 6 months	Fuel filter (wire-element and center-bolt)	Drain water.	6-1
After 6 months or 500 service hours, whichever comes first	Zinc rod	Inspect and change.	6-13

Table 5-2 Periodic maintenance chart for emergency engine (2 / 5)

Service interval	Service item	Service contents	Page
After 1 year or 500 service hours, whichever comes first	Engine oil	Analyze engine oil properties. (according to engine oil analysis service)	6-12
Every year	Conducting maintenance operation	Operate the engine under no load for 2 hours (more than 1/2 load). Inspect starting property, exhaust color, abnormal vibrations, abnormal sounds and abnormal odors. Inspect displayed value of each gage (such as oil pressure gage, water temperature gage, oil temperature gage, exhaust temperature and rotating speed gage).	3-13
	Valve clearance	Inspect and adjust (also inspect inside of rocker chamber).	*
	Camshaft and tappets	Inspect.	*
	Damper	Check temperature with thermo label and check for silicon oil leakage.	*
	Magnetic pickup	Inspect clearance with the flywheel, attachment of foreign items on the tip, mounting nut tightness, an open-circuit and connector disconnection.	*
	Fuel tank	Drain water.	6-2
	Fuel injection nozzles	Change nozzle tips and adjust pressure.	*
	Fuel injection timing	Inspect and adjust.	*
	Coolant	Inspect LLC concentration.	6-13
	Exhaust pipes and exhaust muffler	Inspect and drain water.	6-16
	Pre-cleaner	Clean.	6-16
	Air cleaner element	Clean and inspect.	6-17
	Protection device	Increasing coolant temperature, decreasing oil pressure, overspeed and emergency stop device	Inspect operation.
After 2 years or 500 service hours, whichever comes first	Engine oil	Change.	6-7
	Oil filter and bypass oil filter	Change.	6-7
After 2 years or 1500 service hours, whichever comes first	Fuel filters (center-bolt and cartridge)	Change.	6-3
	Fuel filter (wire-element)	Clean inside.	6-2

Table 5-2 Periodic maintenance chart for emergency engine (3 / 5)

Service interval	Service item	Service contents	Page
Every 2 years	Turbocharger	Inspection of shaft for smooth rotation and wheel thrust for looseness.	*
	Fuel system accumulator	Refill with nitrogen gas.	*
	Coolant	Change.	6-14
	Coolant thermostat	Inspect.	*
	Starting valve	Inspect, lap and change O-rings and gaskets.	*
	Distributor	Inspect valve, shafts, bushings and pins, and change gaskets.	*
	Air starter strainer	Drain water and clean.	6-18
Every 4 years	Overhaul of top end of engine Disassemble one cylinder, and inspect cylinder head, piston and connecting rod. If abnormalities are found, disassemble all cylinders for inspection.		*
	Cylinder heads and valve mechanisms	Disassemble and maintain, clean and change expendable parts.	
		Valve seat	Inspect, regrind and lap.
		Inlet and exhaust valves	Inspect, regrind and lap.
		Cylinder head gasket	Change cylinder head gaskets.
		Valve guides, valve rotator, valve cotter, pushrods, rocker arm bushings, valve springs, tappet rollers, tappet brush, tappet shafts, tappet guides, tappet guide set screws	Inspect.
		Stem seal	Change.
	Safety valve	Inspect and change expendable parts.	
	Cylinder liners	Inspect and clean.	
	Crankcase	Inspect inside(remove the side cover for inspection).	
	Pistons	Inspect including overhaul and clean.	
	Piston rings	Inspect.	
	Connecting rods	Inspect bolts, inspect Magnaflux serrations, change big-end bearing shells and inspect small-end bushings.	
	Crankshaft	Inspect and adjust deflection, and inspect journals and pins.	
	Damper	Analyze silicon oil properties and change thermo label.	
Inspection of pipe clamps of fuel lines, oil lines, instrument pipes and starting air pipes	Inspection of interference and wear, and repair rubber tape.		
Flexible hoses	Change.		

Table 5-2 Periodic maintenance chart for emergency engine (4 / 5)

Service interval	Service item	Service contents	Page	
Every 4 years	Fuel system	Fuel injection nozzles	Change nozzle tips and adjust pressure.	*
		Fuel injection pump	Disassemble, maintain, adjust and change O-rings.	
		Fuel tank	Clean inside.	
	Lubricating system	Oil pump	Inspect discoloration and external.	
		Oil cooler	Inspect and clean element.	
		Breather	Clean mist separator and change expendable parts.	
		Governor oil filter	Change.	
	Cooling system	Coolant thermostat	Change.	
	Inlet and exhaust systems	Turbocharger	Remove carbons, change seal rings and change expendable parts.	
		Air cooler	Disassemble and clean element.	
Pre-cleaner		Change.	6-16	
Air cleaner element		Change.	6-17	
Every 8 years	Major overhaul (complete disassembly and inspection) Change all O-rings, gaskets and seals.		*	
	Cylinder heads and valve mechanisms	Disassemble and maintain, clean and change expendable parts.		
		Inlet and exhaust valves and valve seats		Inspect, regrind and lap.
		Valve guides, valve rotators, valve cutters, pushrods, rocker arm bushings, valve springs, tappet rollers, tappet roller bushings, tappet shafts, tappet guides and tappet guide set screws		Inspect.
		Stem seal		Change.
		Copper tubes and copper tube O-rings		Change.
	Safety valves	Inspect and change expendable parts.		
	Cylinder liners	Inspect, clean and change O-rings.		
	Main bearings	Inspect main bearing caps, bolts and main bearings, and inspect thrust plate.		
	Cam bushings	Inspect.		
	Pistons	Inspect including overhaul and clean.		
	Piston rings	Change.		
	Connecting rods	Inspect bolts, inspect Magnaflux serrations, change big-end bearing shells and inspect small-end bushings.		
	Front gear and timing gear	Inspect gear teeth, bearings and shafts. Change front seal, rear seal, front gear case gasket and rear gear case gasket.		

Table 5-2 Periodic maintenance chart for emergency engine (5 / 5)

Service interval	Service item	Service contents	Page	
Every 8 years	Fuel system	Fuel regulator valve	Inspect.	*
		Fuel pipes	Change O-rings and sealing washers.	
		Fuel control linkage	Change ball joints and ball bearings.	
		Fuel system accumulator	Change.	
		Fuel feed pump	Change oil seals and O-rings.	
		Fuel injection pipes	Inspect.	
	Lubricating system	Oil pump	Disassemble and maintain.	
		Oil thermostat	Inspect.	
		Engine oil regulator valve	Disassemble and maintain.	
		Oil pipes	Change O-rings and gaskets.	
	Cooling System	Water pump	Change oil seals, unit seals, expendable parts and bearings.	
		Coolant pipes	Change O-rings.	
	Inlet and exhaust systems	Air cooler cover	Change gaskets.	
		Air inlet pipes	Change O-rings.	
		Exhaust pipes	Change gaskets, bolts and nuts.	
		Exhaust duct	Change seal rings, gaskets and V-clamps.	
	Air starter system	Air pipes	Change gaskets.	
		Air tank	Inspect safety valve operation.	
	Governor	Actuator	Disassemble and maintain (by governor manufacturer).	
		Governor case	Change bearings, O-rings and gaskets.	
		Control shaft	Change oil seals.	

Periodic Maintenance Chart for General-Purpose Power Supply Engine

Table 5-3 Periodic maintenance chart for general-purpose power supply engine (1 / 5)

Service interval	Service item	Service contents	Page
Every day	External	Inspect leakage and looseness of bolts and nuts. Retighten bolts and nuts.	3-8
	Fuel tank	Inspect fuel level and drain water.	3-9
	Fuel filters (wire-element)	Clean inside of the filter by using handle.	3-8
	Engine oil	Inspect oil level and add oil by using oil level gage. Inspect level regulator operation.	3-9
	Coolant	Inspect coolant level and add coolant by using fluid level gage.	3-10
	Air cleaner	Inspect air cleaner indicator for element clog.	3-10
	Air starter tank	Inspect air pressure and drain water.	3-11
	Operating condition	Check operating period, performance record, sound, vibration and gage function.	3-13
After 500 services hours or 1 month, whichever comes first	Air cooler	Inspect water leakage from air cooler chamber and drain water.	6-18
	Fuel filters	Drain water.	6-1
	Fuel control linkage	Inspect ball joints, bolts and nuts for looseness and smooth movement.	6-6
	Engine oil	Inspect engine oil for mixing of fuel and water.	6-11
	Exhaust pipes and exhaust muffler	Inspect and drain water.	6-16
After 500 services hours or 6 months, whichever comes first	Air starter compressor	Drain water.	6-19
	Zinc rod	Inspect and change.	6-13
After 500 services hours or 1 year, whichever comes first	Engine oil	Change.	6-7
	Engine oil	Analyze engine oil properties (according to engine oil analysis service).	6-12
	Oil filter and bypass oil filter	Change.	6-7
After first 1500 services hours or 1 year, whichever comes first	Valve clearance	Inspect and adjust (also inspect inside of rocker chamber).	*
	Camshaft and tappets	Inspect.	*
	Air cooler cover	Retighten air cooler cover mounting bolt (Also after first 1500 service hours or first 1 year, whichever comes first from gasket replacement).	*
After 1500 services hours or 1 year, whichever comes first	Fuel filters	Change.	6-4
	Coolant	Inspect LLC concentration.	6-13
	Pre-cleaner	Clean.	6-17
	Air cleaner element	Clean and inspect.	6-18
	Air starter strainer	Drain water and clean.	6-19

Table 5-3 Periodic maintenance chart for general-purpose power supply engine (2 / 5)

Service interval	Service item	Service contents	Page
Every 3000 service hours	Valve clearance	Inspect and adjust (also inspect inside of rocker chamber).	*
	Fuel injection nozzles	Inspect and change nozzle tips and adjust pressure.	*
After 3000 services hours or 2 years, whichever comes first	Fuel filter (wire-element)	Clean inside.	6-3
	Breather	Inspect and clean mist separator, and change expendable parts.	*
	Governor oil filter	Change.	*
	Air cleaner element	Change.	6-17
	Pre-cleaner	Change.	6-18
	Magnetic pickup	Inspect clearance with the flywheel, attachment of foreign items on the tip, mounting nut tightness, an open-circuit and connector disconnection.	*
	Fuel system accumulator	Refill with nitrogen gas.	*
After 6000 services hours or 4 years, whichever comes first	Camshafts and tappets	Inspect.	*
	Crankcase	Inspect inside (remove the side cover for inspection).	
	Water pump	Change oil seals, unit seals and other expendable parts.	
	Damper	Check temperature with thermo label and check for silicon oil leakage.	
	Turbocharger	Inspection of shaft and wheel for smooth rotation and thrust for looseness.	
	Inspection of pipe clamps of fuel lines, oil lines, instrument pipes and starting air pipes	Inspection of interference and wear, and repair rubber tape.	
	Flexible hoses	Change.	
	Protection device	Increasing coolant temperature, decreasing oil pressure, over-speed and emergency stop device Inspect operation.	
After 12000 service hours or 4 years, whichever comes first	Flexible hoses	Change.	*
	Fuel system accumulator	Change.	
After 12000 service hours or 2 years, whichever comes first	Coolant	Change.	6-13

Table 5-3 Periodic maintenance chart for general-purpose power supply engine (3 / 5)

Service interval	Service item	Service contents	Page	
After 12000 service hours or 8 years, whichever comes first	Overhaul of top end of engine (remove the cylinder heads for inspection and maintenance.)		*	
	Cylinder heads and valve mechanisms	Disassemble and maintain, clean and change expendable parts.		
		Valve seat		Inspect, regrind and lap.
		Inlet and exhaust valves		Inspect, regrind and lap.
		Cylinder head gasket		Change.
		Copper tubes		Change copper tubes and O-rings.
		Valve guides, valve rotator, valve cotter, pushrods, rocker arm bushings, valve springs, tappet rollers, tappet roller bushings, tappet shafts, tappet guides, tappet guide set screws.		Inspect.
		Stem seal		Change.
		Safety valve		Inspect and change expendable parts.
	Cylinder liners	Inspect and clean.		
	Pistons	Inspect including overhaul and clean.		
	Piston rings	Change.		
	Connecting rods	Inspect bolts, inspect Magnaflux serrations, change big-end bearing shells and inspect small-end bushings.		
	Crankshaft	Inspect and adjust deflection.		
Damper	Analyze silicon oil properties and change thermo label.			
Front gear and timing gear	Inspect gear teeth.			

Table 5-3 Periodic maintenance chart for general-purpose power supply engine (4 / 5)

Service interval	Service item	Service contents	Page	
After 12000 service hours or 8 years, whichever comes first	Fuel system	Fuel control linkage	Change ball joints and ball bearings.	*
		Fuel injection pump	Disassemble and maintain, and change deflectors and O-rings.	
		Fuel feed pump	Change oil seals and O-rings.	
		Fuel injection pipes	Change.	
		Fuel injection timing	Inspect and adjust.	
		Fuel pressure regulator valve	Inspect.	
		Fuel system accumulator	Change.	
		Fuel pipes	Change O-rings and sealing washers.	
	Lubricating system	Oil pump	Change bushings.	
		Oil cooler	Inspect and clean element.	
		Regulator valve	Disassemble and maintain.	
		Oil pipes	Change O-rings and gaskets.	
	Cooling system	Oil pipes	Change bearings.	
		Coolant pipes	Change O-rings.	
	Inlet and exhaust systems	Turbocharger	Remove carbon deposits and change seal rings, expendable parts and bearings.	
		Air cooler	Clean element.	
		Air cooler cover	Change gasket.	
		Air inlet pipes	Change O-rings.	
		Exhaust pipes	Change gaskets, bolts and nuts.	
		Exhaust duct	Change V-clamps.	
	Air starter system	Starting valve	Inspect, lap and change O-rings and gaskets.	
		Air pipes	Change gaskets.	
		Air tank	Inspect safety valve operation.	
		Distributor	Change valve, shaft, bushings, pins and gaskets.	

Table 5-3 Periodic maintenance chart for general-purpose power supply engine (5 / 5)

Service interval	Service item	Service contents	Page	
Every 24000 service hours	Major overhaul (complete disassembly and inspection) Change all O-rings, gaskets and seals.		*	
	Cylinder Heads and Valve Mechanisms	Change inlet and exhaust valves, valve seats, valve guides, valve rotators and valve cotters.		
		Inspect and change pushrods, rocker arm bushings, valve springs, tappet rollers, tappet roller bushings, tappet shafts, tappet guides and tappet guide set screws.		
	Cylinder liners			Change.
	Main bearing			Inspect main bearing caps and bolts, and change main bearings.
	Cam bushings			Inspect and change (in 2nd 24000-service-hour-interval inspection and maintenance).
	Pistons			Disassemble and inspect piston crown, and change O-rings.
	Connecting rods			Change connecting rod bolts and small-end bushings.
	Crankshaft			Inspect journals and pins, and change slingers.
	Damper			Change (in 2nd 24000-service-hour-interval inspection and maintenance).
	Spring coupling			Disassemble and maintain (by spring coupling manufacturer).
	Timing gear and front gear	All shafts		Inspect.
		Rear idler gear		Inspect and change rear idler gear assemblies (including bushings).
		Change front idler bearing, camshaft roller bearing, front seal, rear seal, front gear case gasket and rear gear case gasket.		
	Fuel system	Fuel injection nozzles		Change nozzle holder assemblies.
		Fuel injection pump		Change plunger assembly and delivery valve.
		Fuel feed pump		Change pump assembly.
		Regulator valve		Change.
	Lubricating system	Oil pump		Change safety valve and spring.
		Oil thermostat		Change.
		Oil pan		Clean and change gasket.
		Engine oil regulator valve		Inspect and change.
	Cooling system	Water pump		Change shaft and impeller.
		Coolant thermostat		Change.
	Inlet and exhaust systems	Air cooler		Change element (in 2nd 24000-service-hour-interval inspection and maintenance).
		Exhaust pipes		Inspect and change bellows.
		Exhaust duct		Change seal rings.
Governor	Actuator	Disassemble and maintain (by governor manufacturer).		
	Governor case	Change bearings, O-rings and gaskets.		
	Control shaft	Change oil seals.		

Chapter 6

PERIODIC INSPECTION AND MAINTENANCE PROCEDURES

Fuel System

Draining Water from Fuel Filters (Wire-Element Type)

⚠ WARNING

Before handling fuel, make sure there is no flame or heat source in the area.

Wipe spilled fuel thoroughly. Spilled fuel can cause a fire.

⚠ CAUTION

Check for damage of threaded section of the filter case, the drain plug and the sealing washer, if any damage are found, replace with the new one.

- 1 Close the fuel feed valve to cut off the fuel supply to the engine.
- 2 Place a container under the fuel filter to receive drained fuel.
- 3 Turn the handle at the top of the fuel filter to remove dust and other particles from the element.
- 4 Remove the drain plug and the sealing washer to discharge sediment from the filter.
- 5 Reinstall the drain plug and the sealing washer.
- 6 Bleed air from the fuel system.

Note: Refer to "[Bleeding Fuel System](#)" (3-2) for the procedure for releasing air from the fuel system.

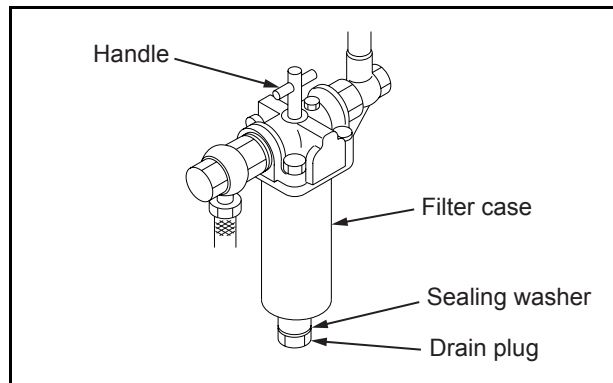


fig.6-1 Draining water from fuel filter (wire-element type)

Draining Water from Fuel Filters (Center-Bolt Type)

⚠ WARNING

Before handling fuel, make sure there is no flame or heat source in the area.

Wipe spilled fuel thoroughly. Spilled fuel can cause a fire.

⚠ CAUTION

Check for damage of the center bolt, drain plug threaded section and the sealing washer. If any damage are found, replace with the new one.

- 1 Close the fuel feed valve to cut off the fuel supply to the engine.
- 2 Place a container under the fuel filter to receive drained fuel.
- 3 Remove the drain plug and the sealing washer to discharge sediment from the filter.
- 4 Reinstall the drain plug and the sealing washer.
- 5 Bleed air from the fuel system.

Note: Refer to "[Bleeding Fuel System](#)" (3-2) for the procedure for releasing air from the fuel system.

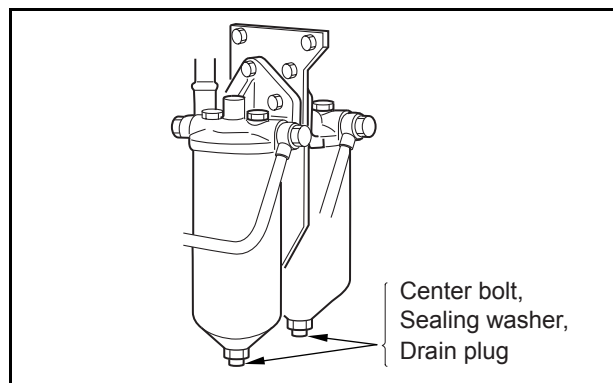


fig.6-2 Draining water from fuel filter (center-bolt type)

Draining Water from Fuel Tank

⚠ WARNING

When handling fuel, make sure there are no flames or heat source in the area.
Wipe any spilled fuel completely. Spilled fuel can ignite and cause fire.

⚠ CAUTION

Do not remove the strainer when filling the fuel tank.
Use fuel specified in "Fuel" (4-2).

Fuel mixed with water and/or dust not only reduces the output but can also cause malfunctions of the fuel system. Drain water from the fuel tank by following procedures below.

- 1 Place a fuel receiving tray (capacity: 2 L [0.53 U. S. gal] or more) under the drain cock on the fuel tank.
- 2 Open the drain cock on the fuel tank, and drain at least 1 to 2 L [0.26 to 0.53 U. S. gal] of fuel.
- 3 Make sure water and dust particles were drained together with fuel, then close the drain cock.

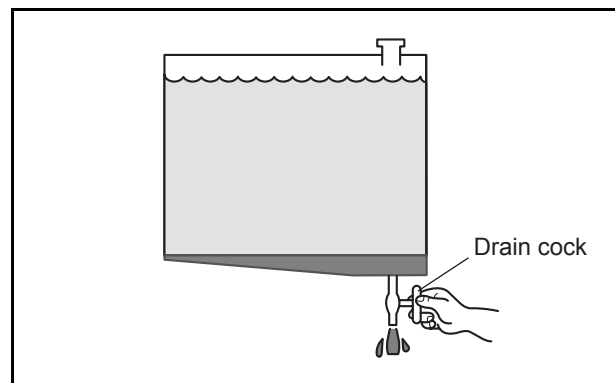


fig.6-3 Draining water from fuel tank

Cleaning inside of Fuel Filters (Wire-Element Type)

⚠ WARNING

Before handling fuel, make sure there is no flame or heat source in the area.
Wipe spilled fuel thoroughly. Spilled fuel can cause a fire.

⚠ CAUTION

Check for damage of the filter case, the drain plug threaded section and the sealing washer, if any damage are found, replace with the new one.

- 1 Close the fuel feed valve to cut off the fuel supply to the engine.
- 2 Place a container under the fuel filter to receive drained fuel.
- 3 Drain fuel by removing the drain plug and the sealing washer.
- 4 Remove the filter case by loosening the mounting bolt at the top of the filter.
- 5 Remove dust and other particles from the element using the soft brush with diesel fuel.
- 6 Also clean inside of the case.
- 7 Reinstall the drain plug, the sealing washer and the filter case to the original position.
- 8 Bleed air from the fuel system.

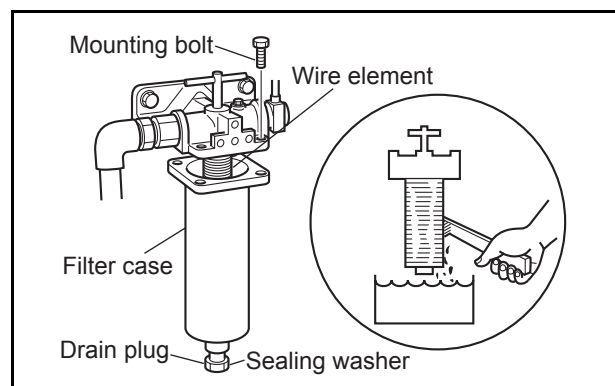


fig.6-4 Cleaning inside of fuel filter (wire-element)

Note: Refer to "Bleeding Fuel System" (3-2) for the procedure for releasing air from the fuel system.

Changing Fuel Filters (Center-Bolt Type)

⚠ WARNING

When handling fuel, make sure there are no flames or heat source in the area.

Wipe any spilled fuel completely. Spilled fuel can ignite and cause fire.

⚠ CAUTION

The fuel filter (center-bolt type) uses a paper element. It cannot be cleaned for reuse.

When installing a new element, be careful not to damage the element.

Check the threaded sections of the air vent plugs, the bracket, the drain plugs, the center bolts and the sealing washers. If the threads are damaged, replace the damaged part.

- 1 Close the fuel supply valve to the engine.
 - 2 Clean the area around the fuel filters.
 - 3 Place a fuel receiving tray under the fuel filters.
 - 4 Remove the drain plug and the sealing washers to discharge fuel from the filter.
 - 5 After fuel is drained, reinstall the drain plug and the sealing washers.
 - 6 Remove the center bolt, and disassemble the fuel filter unit.
 - 7 Clean the inside surface of the case and O-ring groove.
 - 8 Wipe off fuel from element mounting surface of the bracket and external O-ring seal surface with a cloth.
 - 9 Use the O-rings provided in a new filter element kit to replace old parts.
 - 10 Reassemble the fuel filter unit.
 - 11 Tighten the center bolt to 63.7 ± 4.9 N·m (6.5 ± 0.5 kgf·m) [46.98 ± 3.61 lbf·ft].
 - 12 After replacing the fuel filter, open the fuel supply valve to the engine, then bleed air from the fuel system.
- Note: Regarding bleeding of the fuel system, refer to ["Bleeding Fuel System" \(3-2\)](#).
- 13 Start the engine and let it idle for several minutes.
 - 14 Check the fuel filter mounting sections for fuel leakage. If fuel leakage is found, disassemble the fuel filter and check the O-rings for damage. If there is no gasket damage, reassemble the fuel filter.

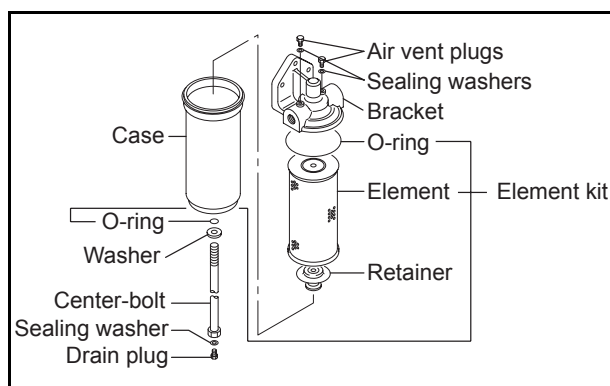


fig.6-5 Changing fuel filters (center-bolt type)

Changing Fuel Filters (Cartridge Type)

⚠ WARNING

When handling fuel, make sure there are no flames or heat source in the area.
Wipe any spilled fuel completely. Spilled fuel can ignite and cause fire.

⚠ CAUTION

This fuel filter (cartridge type) uses a paper element. It cannot be cleaned for reuse.
The fuel filter cartridges must be installed by hand, and caution should be exercised to prevent denting or scratching the cartridge surfaces. Do not use a filter wrench for installation.
Check the threaded sections of the air vent plugs, bracket and sealing washers. If the threads are damaged, replace the damaged part.

Changing Fuel Filters with Engine Stop

- 1 Close the fuel supply valve to the engine.
- 2 Clean the area around the fuel filters.
- 3 Place a fuel receiving tray under the fuel filters.
- 4 Set the filter handle to the “Left-Close, Right-Open”.
- 5 Using the filter wrench, remove 2 fuel filters from left side.
- 6 Apply clean fuel to the gasket on the new fuel filters.
- 7 Install the fuel filters. When the gasket contacts the mounting surface on filter bracket, further rotate 3/4 to a full turn.
- 8 Set the fuel filter handle to the “Left-Close, Right-Open”, then take same measures stated in 5 to 7 and replace 2 fuel filters from right side.
- 9 After replacing the filters, open the fuel feed valve to the engine, then bleed air from the fuel system.

Note: Regarding bleeding of the fuel system, refer to ["Bleeding Fuel System" \(3-2\)](#).

- 10 Start the engine and let it idle for several minutes.
- 11 Check each fuel filter for fuel leaks. If fuel leaks from a filter, remove the filter and check the gasket for scratches or other abnormalities, then reinstall the filter.

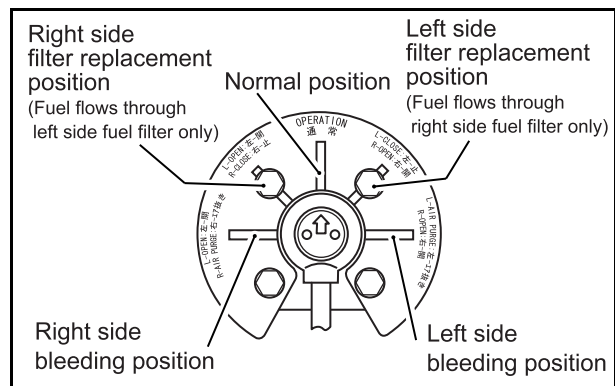


fig.6-6 Fuel filter switchover handle

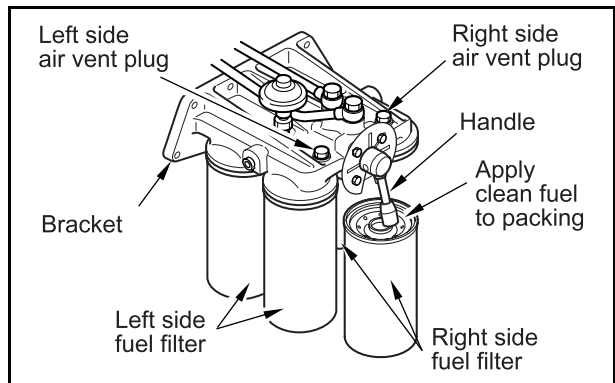


fig.6-7 Changing fuel filters (cartridge type)

Changing Fuel Filters while Engine in Operation

CAUTION

To replace the fuel filters while the engine is in operation, be sure to run the engine under no load low idling and at rated speed.

If the fuel filter is replaced during the engine is in high-speed operation, fuel can leak from the switchover lever.

- 1 Clean the area around the fuel filters.
- 2 Place a fuel receiving tray under the fuel filters.
- 3 Set the fuel filter handle to the "Left-CLOSE, Right-OPEN".
- 4 Using a filter wrench, remove 2 fuel filters either from left side or right side.
- 5 Coat the gaskets of new fuel filters with clean fuel.
- 6 Mount the new fuel filters to the bracket. Tighten each filter until it contacts the bracket, the further tighten 3/4 to 1 turn by hand.
- 7 Set the handle to the "Left-AIR PURGE, Right-OPEN".
- 8 Loosen the air vent plug of the left side fuel filter.
- 9 When the fuel flows from the air vent plug no longer contains air bubbles, tighten the air vent plug.
- 10 Return the handle to the "Left-OPEN, Right-CLOSE".
- 11 Using the filter wrench, remove 2 right fuel filters.
- 12 Apply clean fuel to the gasket on the new fuel filters.
- 13 Install the fuel filters. When the gasket contacts the mounting surface on filter bracket, further rotate 3/4 to full turn.
- 14 Set the fuel filter handle to the "Right-AIR PURGE, Left-OPEN" position.
- 15 Loosen the air vent plug of the right side fuel filter.
- 16 When the fuel flows from the air vent plug no longer contains air bubbles, tighten the air vent plug.
- 17 Return the handle to the NORMAL position.
- 18 Start the engine, and let it under no load low idling for several minutes.
- 19 Check each fuel filter for fuel leaks. If fuel leaks from a filter, loosen the filter and check the gasket for scratches or other abnormalities.

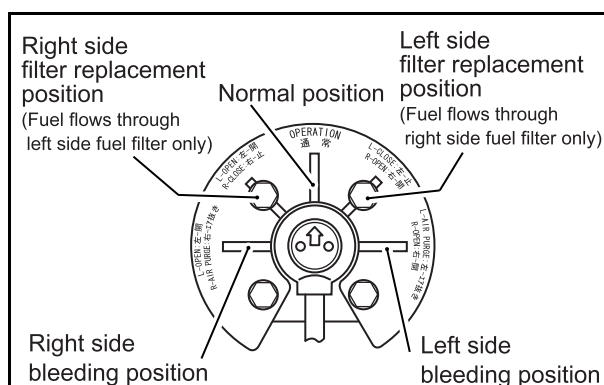


fig.6-8 Fuel filter switchover handle

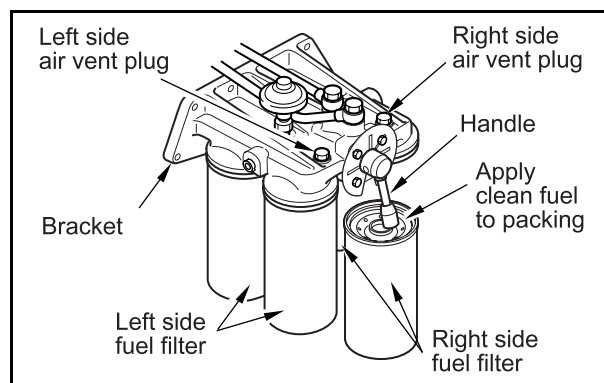


fig.6-9 Changing fuel filters (cartridge type)

Inspection of Fuel Control Linkage Ball Joints

Check the ball joints in the fuel control linkage for looseness.

If the amount of looseness is more than 0.1 mm [0.004 in.], consult a Mitsubishi dealer to replace the ball joints.

CAUTION

Never break a seal of fuel control link to replace the ball joints.

If the seal on the ball joint is broken, the warranty may be invalidated.

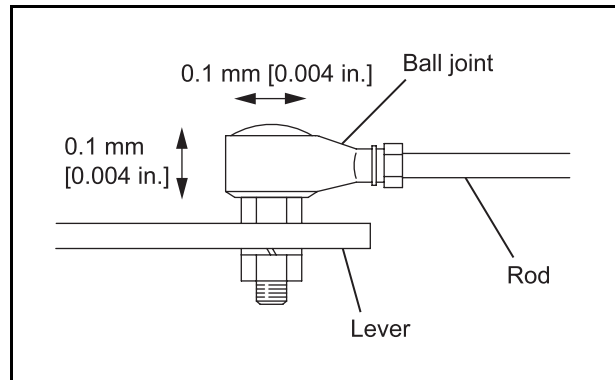


fig.6-10 Inspection of the ball joints for looseness

Lubricating System

Changing Engine Oil, Oil Filters and Bypass Oil Filter

⚠ CAUTION

To drain oil or change oil filters, wear gloves. Hot engine oil and parts may cause burns.

CAUTION

When changing engine oil, change the oil filters and bypass oil filter at the same time.

It is recommended to analyze engine oil properties at the same time.

Also change the oil filters whenever the filter alarm turns on.

The oil filters use paper elements. Never clean and reuse them. When replacing the filters, be sure to install new packings.

Draining Engine Oil

To ensure thorough drainage, drain engine oil from the oil pan while it is still warm at 30 to 40 °C [86 to 104 °F] after engine operation.

Be sure to suck out the engine oil when draining.

Engine oil capacity (oil pan)

S12U: approx. 450 L [118.88 U. S. gal.]

S16U: approx. 600 L [158.50 U. S. gal.]

Changing Oil Filters (S12U)

⚠ CAUTION

Inspect the damage of the drain plug and filter bracket threaded sections, the center bolt and the gasket, if any damage are found, replace it with the new one.

- 1 Clean the area around the oil filters.
 - 2 Remove the center bolts and the gaskets, and remove the cases and elements.
 - 3 Remove the packing from the bracket.
- Note: Disassemble the removed elements to see if they have collected metal particles. If there are metal particles on the elements, consult your Mitsubishi dealer.
- 4 By using a clean cloth, wipe off oil from the filter bracket surface and inside the groove of packing that contacts the oil filter mounting sections.
 - 5 Mount a packing provided in a new element kit into each groove on the bracket.
 - 6 Install the element, and set the spring retainer and set spring on top of each element.
 - 7 Install each case and the gaskets of the center bolts, then tighten the center bolt to 83.4 ± 4.9 N·m (8.5 ± 0.5 kgf·m) [61.51 ± 3.61 lbf·ft].

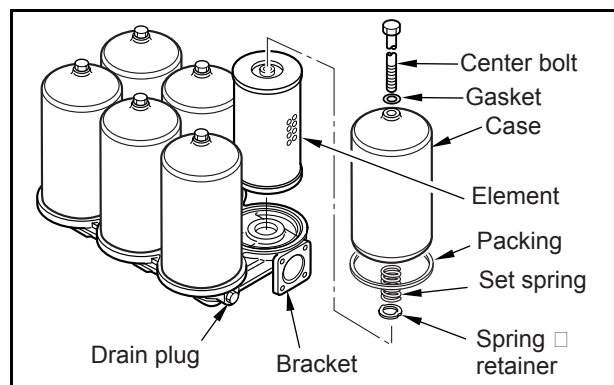


fig.6-11 Changing oil filter element (S12U)

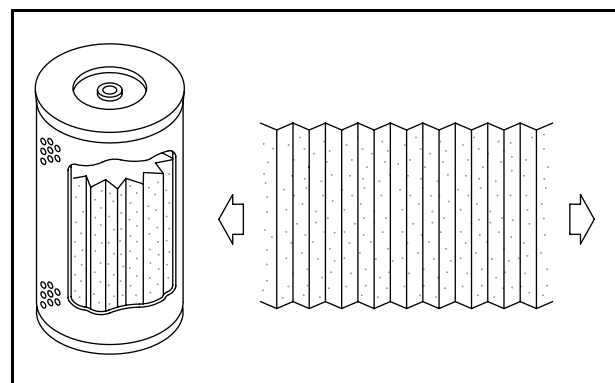


fig.6-12 Inspection of oil filter

Changing Oil Filters (Switchover Type) (S12U)

CAUTION

Inspect the damage of the drain plug and filter bracket threaded sections, the center bolt and the gasket, if any damage are found, replace it with the new one.

Changing Oil Filters with Engine Stop

Refer to "Changing Fuel Filters (Center-Bolt Type)" (6-3) for the procedure for changing oil filter element.

Changing Oil Filters While Engine in Operation

CAUTION

To replace the oil filters while the engine is in operation, be sure to run the engine under no load low idling and rated speed. If the oil filter is replaced during the engine is in high-speed operation, oil can leak from switchover lever.

- 1 Clean the surrounding area of the oil filters.
- 2 Place a container under the oil filters to receive drained oil.
- 3 Remove the cover from the oil filter switchover cock.
- 4 Turn the switchover cock to have pin position "Left-Close, Right-Open".
- 5 Refer to "Changing Oil Filters (S12U)" (6-7) for the procedure for changing 3 new sets of left oil filter elements.
- 6 Turn the switchover cock to have pin position "Right-Close, Left-Open".
- 7 Refer to "Changing Oil Filters (S12U)" (6-7) for the procedure for changing 3 new sets of right oil filter elements.
- 8 Return the switchover cock pin to the NORMAL position and reinstall the cover to the switchover cock.

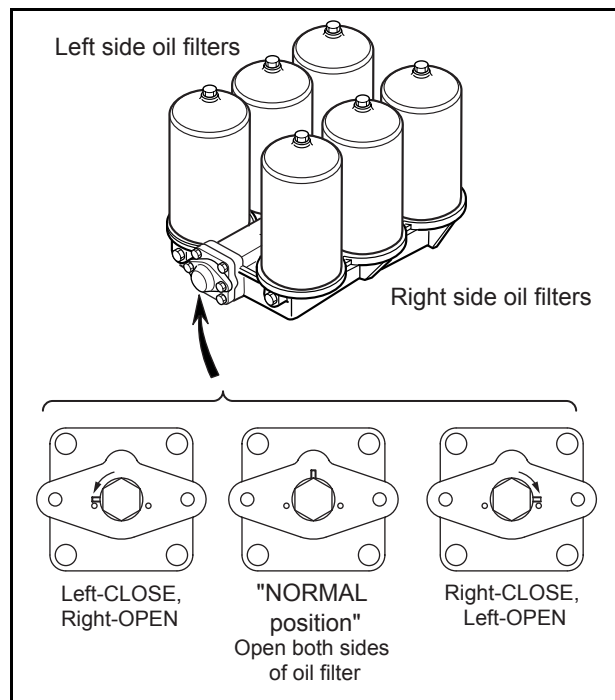


fig.6-13 Changing oil filters (switchover type)

Changing Oil Filters (Swithover Type) (S16U)

Changing Oil Filters with Engine Stop

- 1 Clean the surrounding area of the oil filters.
- 2 Open the air vent valves on the filter covers to release the internal pressure of the oil filters.
- 3 Open the drain valve located below the filter body to discharge engine oil from the oil filters.
- 4 Remove the bolts and nuts, and dismount the filter covers.
- 5 Remove the filter bodies, wing nuts and washers, and dismount the oil filter elements.

Note: Open the removed elements to see if they have collected metal particles. If metal particles are found on the elements, consult your Mitsubishi dealer.

- 6 By using a clean cloth, wipe off oil from the oil filter mounting surfaces and O-ring mounting surfaces of the filter bodies.
- 7 Install the packings provided in a new element kit securely into the grooves on the filter bodies.
- 8 Install the elements, packings and washers, and secure them in place by tightening the wing nuts.
- 9 Install the filter covers to the filter bodies with the bolts and nuts.
- 10 Close the air vent valves and drain plug.

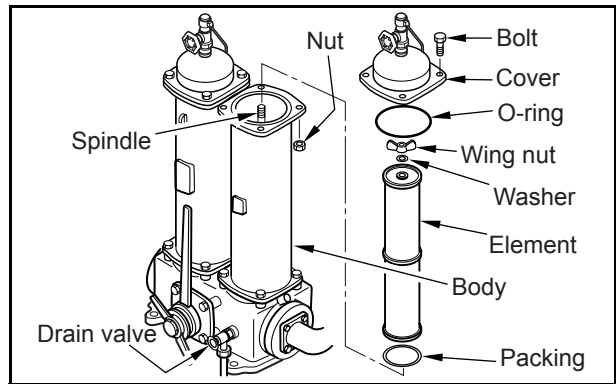


fig.6-14 Changing oil filter elements

Changing Oil Filters While Engine in Operation

CAUTION

To replace the oil filters while the engine is in operation, be sure to run the engine under no load low idling and rated speed. If the oil filter is replaced during the engine is in high-speed operation, oil can leak from swithover lever.

- 1 Clean the surrounding area of the oil filters.
- 2 Turn the oil filter tightening handle for an angle of 90 to 180 degrees in the counterclockwise direction. Remove the cover from the oil filter swithover cock.
- 3 Move the swithover handle to the "Left-STOP" or "Right-STOP" position.

Note: When the swithover handle is operated, the stopper located on the back side of the handle enters the stopper hole on the flange to secure the handle in place.

- 4 Change the element and packing in the oil filter on the side selected by the swithover handle.
- 5 Change the element and packing in the other oil filter by following the same procedure.

- 6 Return the swithover handle to the "Both Right and Left Filters in Use" position (center position), and turn the oil filter tightening handle to the right to tighten.

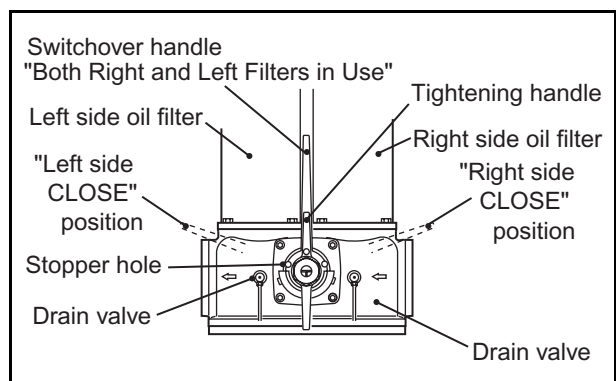


fig.6-15 Oil filter swithover handle

Changing Bypass Oil Filter

- 1 Clean the area around the oil filters.
- 2 Place an oil-receiving tray under the bypass oil filter.
- 3 Using the provided filter wrench, remove each bypass oil filter.

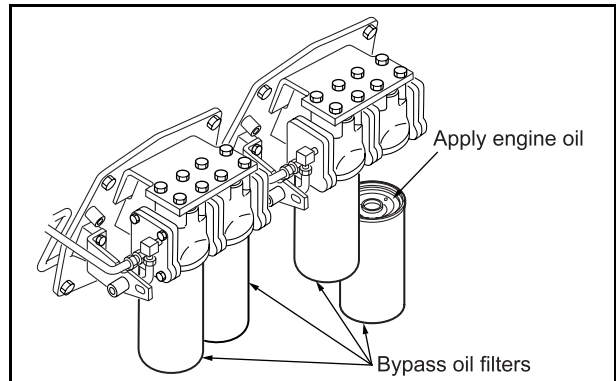


fig.6-16 Changing bypass oil filters

Note: Check the filter elements in the removed oil filter for metal particles. If metal particles are found, consult a Mitsubishi dealer.

- 4 Wipe oil from the oil filter mounting surface on the filter bracket with a cloth.
- 5 Check the new bypass oil filter for proper seating of the packing.
- 6 Apply clean engine oil to the packing.
- 7 Install the bypass oil filter to the filter bracket. When the packing contacts the mounting surface on the filter bracket, further rotate 3/4 to a full turn.

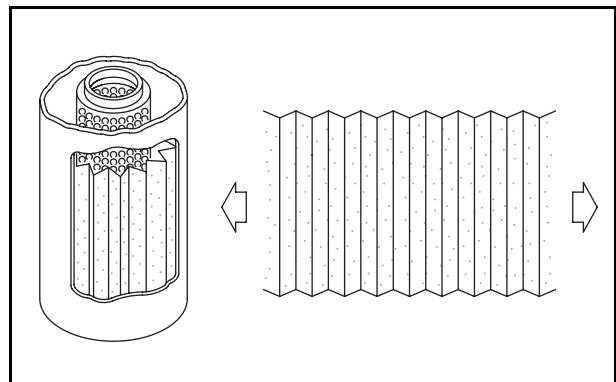


fig.6-17 Inspection of bypass oil filter

CAUTION
Do not use the filter wrench for the installation of filters to prevent filters from deformation.

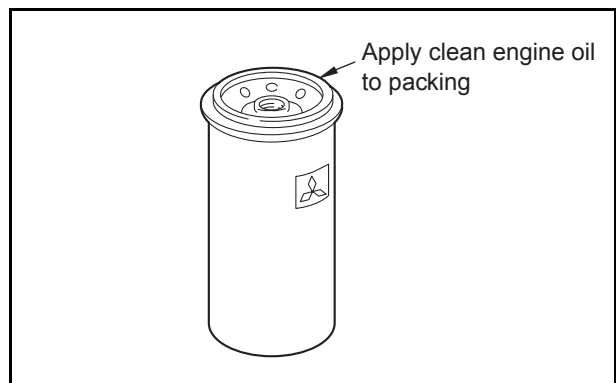


fig.6-18 Bypass oil filter

Pouring Engine Oil

- 1 Remove the cap from the oil filler.
- 2 Pour designated engine oil to the specified level.

Specified engine oil Class CD or CF
(API Service Classification)

Specified engine oil capacity (oil pan)
S12U: approx. 450 L [118.88 U. S. gal]
S16U: approx. 600 L [158.50 U. S. gal]

Note: Regarding engine oil, refer to "Engine Oil" (4-4).

- 3 Check the oil level with the oil level gage.
 - If the automatic oil feeder is installed, check if it works normally.
 - The oil level should be between the MAXIMUM and MINIMUM marks on the oil level gage.
 - If the oil level is low, add specified type of engine oil.
- 4 Check the oil pan and other parts for engine oil leaks. Repair any oil leakage found.
- 5 Operate the engine oil priming pump to circulate oil in the engine.
- 6 Remove the rocker cover, and make sure that oil is supplied to the valve mechanisms, and install the rocker cover.
- 7 Stop the priming pump. After about 30 minutes, add engine oil until the oil level reaches the MAXIMUM line on the oil level gage.
- 8 Reinstall the cap on the oil filler.

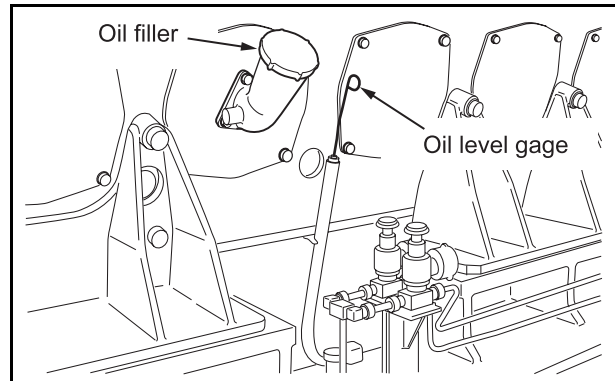


fig.6-19 Oil filler and level gage

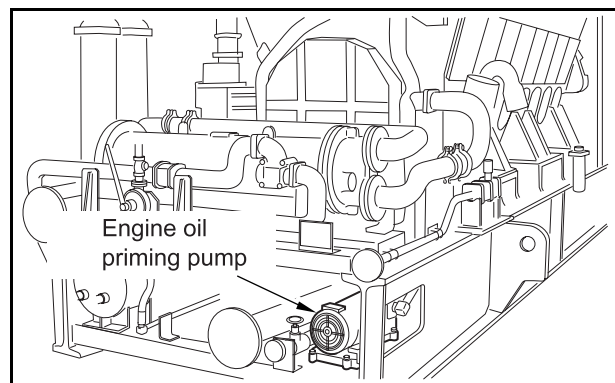


fig.6-20 Engine oil priming pump

Inspection of Engine Oil Leakage After Replacing Oil Filter

- 1 Start the engine, and let it idle for several minutes.
- 2 Check the oil filter for engine oil leakage. If any leakage are found, remove and reassemble, making sure that there are no scratches on the packing, then reinstall or reassemble the filter.

Inspection of Engine Oil for Mixing of Fuel and Water

⚠ 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 Mitsubishi dealer.

Analysis of Engine Oil Properties

For many years of trouble-free engine operation, Mitsubishi offers engine oil analysis service. This service provides detailed information of your engine condition by analyzing a sample of engine oil collected from your engine with special oil sampling tools.

The engine oil analysis service can provide the following information:

- It can detect the amount of extremely fine metal powder in engine oil which could result from friction. This information helps you to locate abnormally worn internal engine parts.
- It can detect water, LLC or salt in the engine oil, which should not be contained in the engine oil.
- It can provide the information of engine oil degradation. This information helps you to arrange proper operating conditions and maintenance and to plan the most appropriate oil change intervals.

The engine oil analysis service is designed to diagnose the internal condition of an engine, which previously required engine disassembly. It is highly recommended to take advantage of our engine oil analysis service so you can understand your engine condition before the engine manifests abnormalities or malfunctions.

Engine Oil Sampling Tool Sets and Ordering Procedure

Table 6-1 Engine oil sampling tool sets

Product name	Part no.	Remarks
Engine oil sampling set	36291-19100	Contains oil sampling pump, pipes and bottles
Oil sample bottle set	36291-00098	1 carton: 6 bottles Includes suction pipes and oil sample data labels.

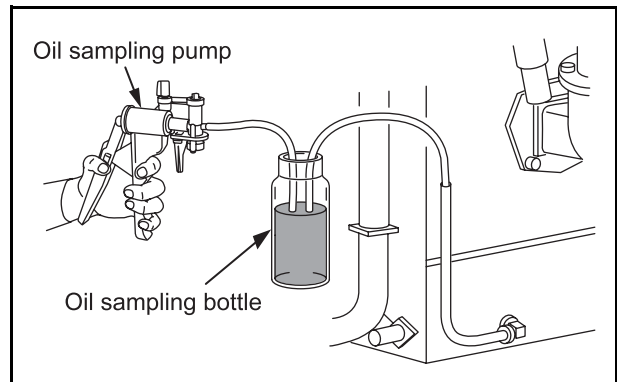


fig.6-21 Engine oil sampling tool sets

The oil sampling pump is reusable, but a new oil sample bottle and new suction pipe must be used each time.

Order an engine oil sampling tool set through the regular parts ordering channel. The analysis fee is included in the price of the sample oil bottle. Note that an oil sample will not be analyzed unless it is contained in the specified oil sample bottle.

There will be an additional charge for the analysis of optional items.

Cooling System

Checking LLC Concentration

Check the LLC concentration in the coolant by using an optical hydrometer for battery fluid and antifreeze. Regarding LLC concentration, refer to "Coolant" (4-6).

Inspection and Replacement of Zinc Rods

Zinc rods (zinc electrodes) are installed at various sections of the sea water passage to prevent corrosion caused by sea water.

- 1 Remove each zinc rod and remove deposits (scale) from the surface.
- 2 If the zinc rod has worn to half the original size, replace it with a new zinc rod. If the zinc rod is larger than half the original size, reinstall it.

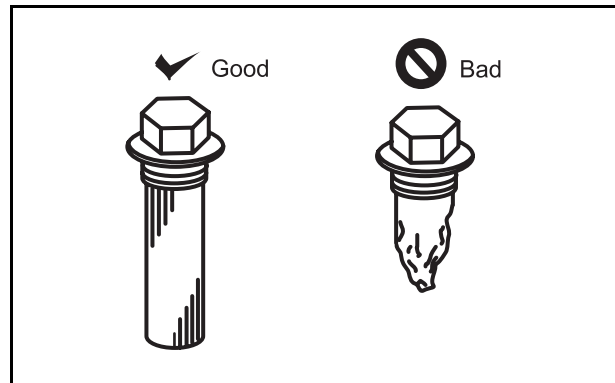


fig.6-22 Zinc rod good/bad

Changing Coolant

⚠ WARNING

Coolant (containing LLC) drained from an engine is toxic, and must not be disposed of into regular sewage. For disposal of used coolant, consult a Mitsubishi dealer.

CAUTION

When a coolant mixed with the LLC recommended by our company is used, replace coolant every 12000 hours or 2 years, whichever comes first, in a regular-use or general-purpose engine. In an emergency engine, replace coolant every 2 years.

Draining Coolant

- 1 Allow the coolant temperature to lower to 30 to 40 °C [86 to 104 °F].
- 2 Prepare a container to receive drained coolant.
- 3 Open the drain cocks on the engine, low-temperature water pump, high-temperature water pump, coolant pipe and expansion tank to drain coolant.

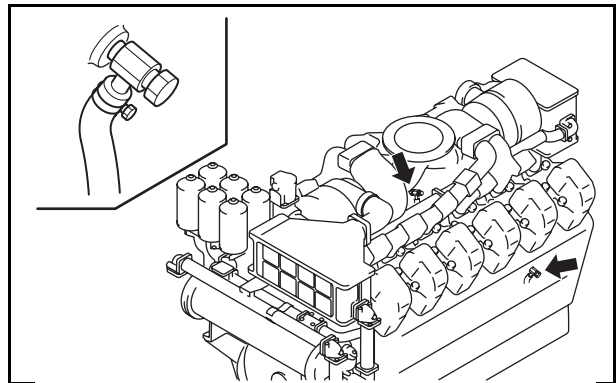


fig.6-23 Coolant drain cock (on engine)

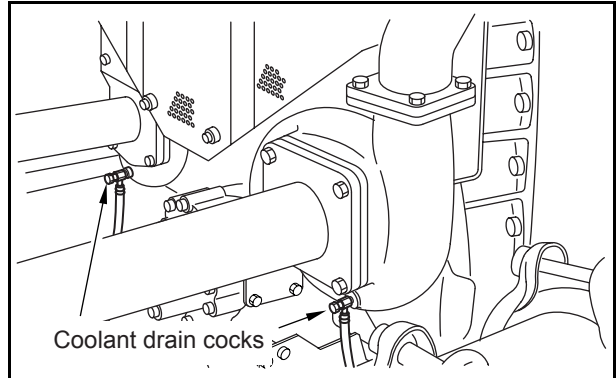


fig.6-24 Coolant drain cock (on water pump)

Cleaning the Cooling System

- 1 Close the drain cocks or plug.
- 2 Pour a cleaning solution (non-corrosive solution to rubber and metals) in the cooling system, and operate the engine with low idling for about 10 minutes, stop the engine, then drain the cleaning solution.
- 3 Close the drain cocks or plugs.
- 4 Pour fresh water, and operate the engine with low idling for about 10 minutes.
Continue flushing the cooling system in the above manner until the draining water is clear.

Pouring coolant

- 1 Make sure the drain cocks on the engine and water pump are closed firmly.
- 2 Remove the cap from the water supply inlet of the coolant tank, and pour undiluted LLC.

Note:(a) Determine the amounts of LLC and water to be poured by using the LLC concentration chart.

(b) Regarding coolant, refer to "Coolant" (4-6).

Coolant capacity (engine only)

S12U: approx. 520 L [137.37 U. S. gal]

S16U: approx. 700 L [184.92 U. S. gal]

- 3 Pour soft water with minimal impurities slowly to the full level.
- 4 When coolant reaches the full level securely, close the water supply inlet cap of the coolant tank.
- 5 To release air from the water pump and coolant pipes, pull the manual stop lever fully to the STOP position and hold it in that position to keep the fuel injection pump in no-injection condition, then supply starting air and crank the engine for about 10 seconds.
- 6 Wait for about 1 minute, then repeat the above cranking operation twice to remove air from the water pump.
- 7 Check the level gage on the coolant tank to make sure there is sufficient coolant (surface level at about the center of the level gage). If the coolant level is low, add coolant.
- 8 Start the engine, and operate it under light load until the thermostat opens the valve to allow soft water and LLC to mix thoroughly.
- 9 Stop the engine, check the level gage on the coolant tank. If the coolant level is low, add coolant to the center of the fluid level gage.

Note: Always add coolant having the same LLC concentration.

- 10 Check the pipe joint and other parts for coolant leaks.

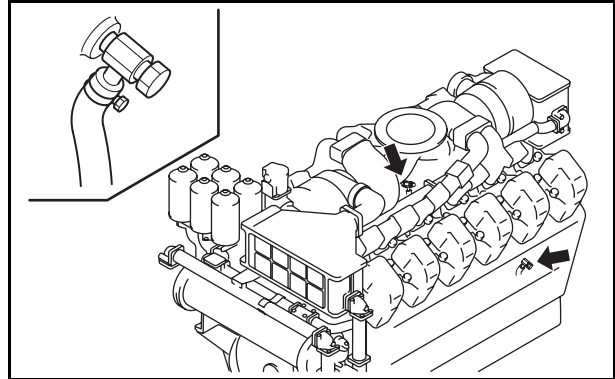


fig.6-25 Coolant drain cock on the engine

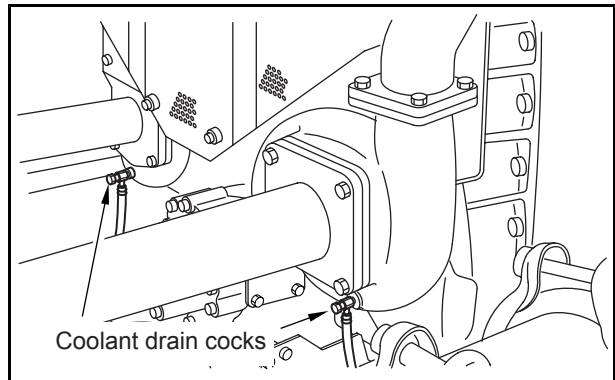


fig.6-26 Coolant drain cock on the water pump

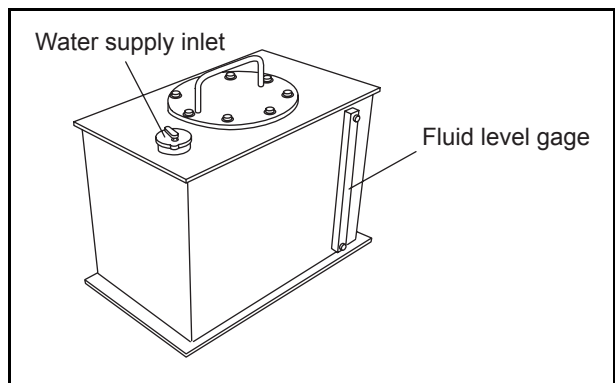


fig.6-27 Water tank coolant level

Inlet and Exhaust Systems Inspection and Draining Water of Exhaust Pipes and Exhaust Muffler

Check the exhaust pipes and muffler for damage and cracks. If they are damaged or cracked, contact a Mitsubishi dealer.

Remove the drain plug and allow water to drain from the exhaust muffler. Be sure to reinstall the drain plug after draining water.

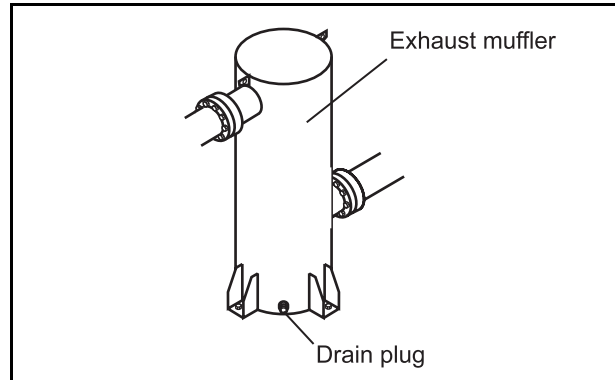


fig.6-28 Inspection and raining water of exhaust pipes and exhaust muffler

Draining Water From Air Cooler Chamber and Inspection for Water Leakage

Loosen the water drain cock on the air cooler chamber to drain condensed water from the air cooler chamber, and also check the air cooler for air leaks.

Be sure to close the drain cock after draining condensed water or checking water leakage.

If a large amount of water is discharged from the water drain cock, there may be water leaks in the air cooler or water pipes. If this happens, contact a Mitsubishi dealer.

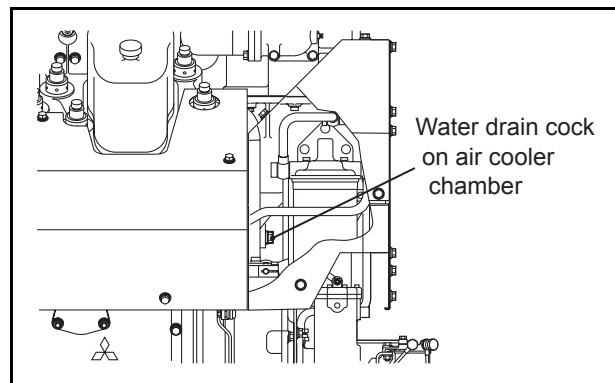


fig.6-29 Water drain cock on air cooler chamber (S12U)

Cleaning, Inspection and Changing Pre-Cleaner

CAUTION

Do not service the air cleaner while the engine is running. Maintenance of the air cleaner while the engine is in operation can cause dust to enter the engine and result in rapid wear of parts, leading to a shorter service life.

Remove dust from the inlet side of the pre-cleaner installed to the silencer of the turbocharger. Be sure to keep the pre-cleaner clean to ensure optimum engine performance.

- 1 Remove the pre-cleaner from the silencer, and hand-wash the pre-cleaner with a mild detergent.
- 2 Rinse the pre-cleaner with clean water.
- 3 After drying thoroughly, inspect the pre-cleaner for cracks and damage.
If the pre-cleaner is cracked or damaged, replace it with a new part.
- 4 After cleaning, inspecting or changing the pre-cleaner, reinstall it to the silencer.

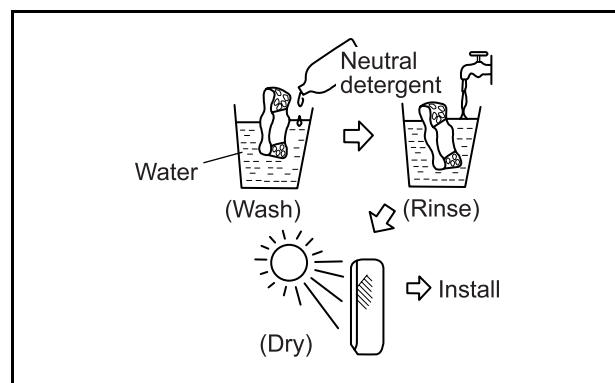


fig.6-30 Cleaning pre-cleaner

Cleaning, Inspecting and Changing Air Cleaner Element

CAUTION

When handling compressed air, wear safety goggles, hardhat, gloves and other necessary protective gear. Compressed air may cause personal injury when not wearing the proper protective gear. Do not service the air cleaner while the engine is running. Maintenance of the air cleaner while the engine is in operation can cause dust to enter the engine and result in rapid wear of parts, leading to a shorter service life.

Never knock or hit the element.

- 1 Remove the air cleaner cap or the wing nut.
- 2 Pull out the air cleaner element from the body.
- 3 Blow compressed air (0.69 MPa (7 kgf/cm²) [100 psi] or lower) onto the inside surface of the element to remove dust and other contaminants.
- 4 To remove dust stuck on the element, blow dry compressed air onto the outside surface from a distance.

Blow compressed air on the inside surface toward outside along the net pattern.
Then, blow compressed air on the outside and inside surface again.
- 5 After cleaning, place a light bulb in the element to check for damage, pinholes and worn sections.
- 6 If any breakage are found, replace the air cleaner element with the new one.
- 7 Reinstall the air cleaner element after cleaning, inspecting or replacing the air cleaner element.

CAUTION

If abnormalities such as damage, pinholes and thin sections are found in the element or if the air cleaner indicator shows red sign soon after the cleaned element is installed, install a new filter element in the air cleaner.

If the indicator shows a red sign, after the clean element is installed, reset the indicator by pressing the reset button.

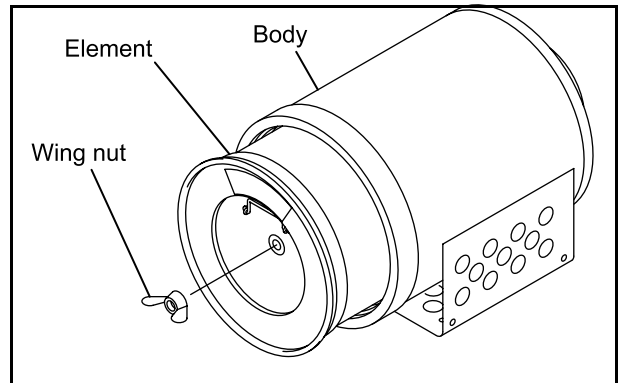


fig.6-31 Removal of air cleaner element

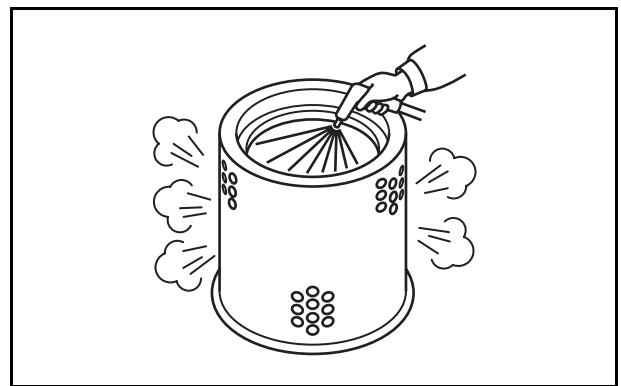


fig.6-32 Cleaning air cleaner element

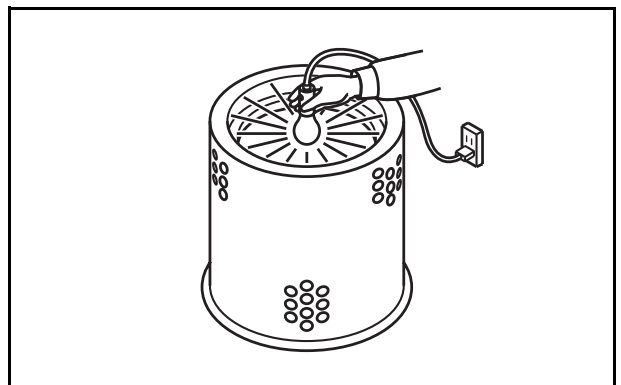


fig.6-33 Inspecting air cleaner element

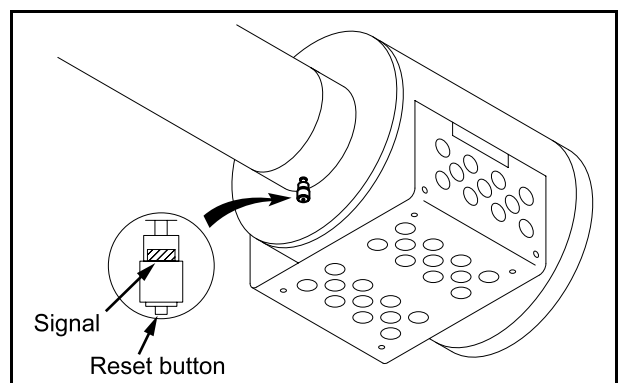


fig.6-34 Air cleaner indicator

Air Starter System

Draining Water and Cleaning Air Starter Strainer

- 1 Close the starter valve handle of the air starter tank.
- 2 Remove the drain plug of air starter strainer and drain water from the air strainer.
- 3 Remove the cap and remove the filter from the cap.
- 4 Clean the filter with diesel fuel, then blow compressed air to dry.
- 5 Reinstall the air strainer as it is.
- 6 Open the air starter handle slowly.

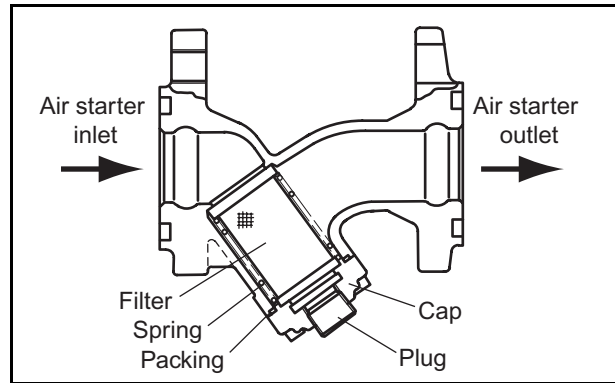


fig.6-35 Air starter strainer

Draining Water from Air Starter Compressor

- 1 Check the starter valve handle of the air strainer tank.
- 2 Remove the drain plug and drain water from the air strainer compressor.
- 3 Install the drain plug after draining water.
- 4 Open the starter valve handle of the air starter tank slowly.

Note: The air compressor model and shape differ on the type of the engine.

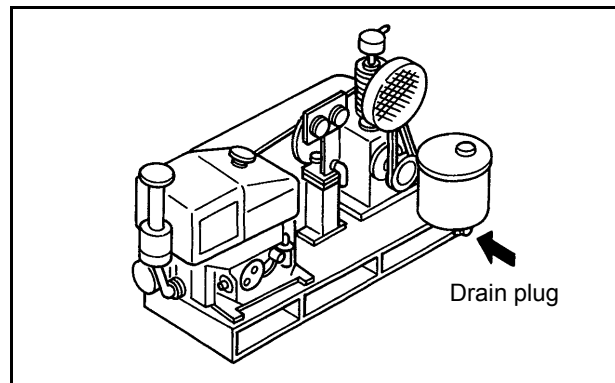


fig.6-36 Air starter compressor

Chapter 7

LONG-TERM STORAGE

The following describes the method to store the engine in a non-operable condition for more than three months and the method for storing the engine in an operable condition for more than three months.

If the engine is not properly prepared for a long-term storage of more than three months, internal engine parts can rust and become damaged. Be sure to follow the directions below when storing the engine for an extended period of time.

Storing Engine in Non-Operable Condition for More Than 3 Months Preparation for Storage

- 1 Drain engine oil, and pour rust-preventive oil (NP-10-2) into the engine.
- 2 Prepare a fuel mixture containing 50% rust-preventive oil (NP-9), and pour it into the fuel tank.
- 3 Operate the engine at a speed of 500 to 600 min⁻¹ (idling) for 5 to 10 minutes under no load.
- 4 Immediately before stopping the engine, spray volatile corrosion inhibitor (V.C.I.) through the inlet side to prevent rust on the air intake system.
- 5 With the engine not in operation, drain the fuel mixture from the fuel tank.
- 6 Apply rust-preventive oil (NP-3) liberally on the exposed sections of the machine.
- 7 Seal air inlet, exhaust outlet, breather and other openings with adhesive cloth tape.
- 8 Cover the entire engine.

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

(b) Coolant does not need to be drained since it contains long life coolant. (Add long life coolant to increase the concentration between 30 and 60%.)

(c) Post a sign at an easily noticeable location to warn that the rust-preventive oil in the engine must be replaced with engine oil and the fuel tank must be filled with fuel before operating the engine.

(d) New engine oil may be used in place of rust-preventive oil (NP-10-2).

Table 7-1 Recommended rust-preventive oil and corrosion inhibitor

JIS No.	Recommended product	Application
K2246	NP-3 Nippon Oil Corporation Anti Rust P-1400	Prevention of rust on exposed machine surfaces
	NP-9 Nippon Oil Corporation Anti Rust P-2100	Prevention of rust on fuel system
	NP-10-2 Nippon Oil Corporation Anti Rust P-230	Prevention of rust on lubricating system
Z1519	- Ryokou Kagaku V.C.I.Diana volatile corrosion inhibitor	Prevention of rust on air intake system

Maintenance during Storage

Charge the battery once a month.

After checking proper electrolyte level in the battery, charge the battery.

Using Engine after Storage

- 1 Remove the cover from the engine.
- 2 Remove sealing tapes from the openings of the engine.
- 3 Drain rust-preventive oil, and pour appropriate engine oil.

Note: Regarding engine oil, refer to ["Engine Oil" \(4-4\)](#).

- 4 Prepare the engine for operation by following the directions in ["Preparation for Operation of New or Overhauled Engine" \(3-1\)](#).
- 5 Start the engine.

Note: With regards to starting the engine, refer to ["Normal Engine Operation" \(3-8\)](#).

- 6 Conduct a warm-up operation to circulate oil throughout the engine.
- 7 Apply load and increase the engine speed to the rated speed.

Storing Engine in Operable Condition for More Than 3 Months

When the engine is not operated during storage of more than three months, internal engine parts can rust and lose oil film. As a result, the engine can seize when it is started after storage. To prevent this, the engine must be operated periodically for maintenance purposes during storage.

Operating Engine for Maintenance Purposes

Operate the engine for maintenance purposes at least once a month by following the directions below.

- 1 With no fuel supplied to the engine (press the engine stop button to shut off fuel injection), operate the air starters three times for 10 seconds at intervals of about 1 minute and check the engine oil pressure gage to make sure the oil pressure increases.
- 2 After the engine starts, operate under no load for 5 to 10 minutes.

Note: Regarding operation of the engine, refer to ["Preparations for Operation \(Pre-Start Inspection\)" \(3-8\)](#).

Chapter 8

TRANSPORTATION

Lifting Engine Carefully

⚠ WARNING

To lift the engine, use wire ropes, shackles and slings capable of supporting the weight of the engine.

Attach slings to the hangers provided on the engine to lift the engine.

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 is applied on the hangers and may damage the hangers.

Attach wire ropes to the hanger after removing the pipe cover and the insulator near the hanger for lifting.

To prevent wire ropes from contacting the engine, place a cloth or other soft padding to prevent damage to the engine and wire ropes.

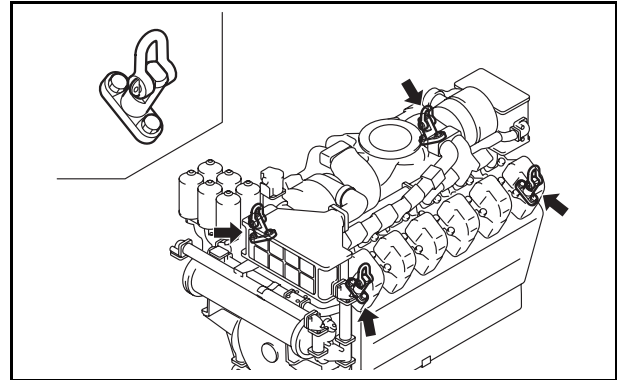


fig.8-1 Hangers for lifting

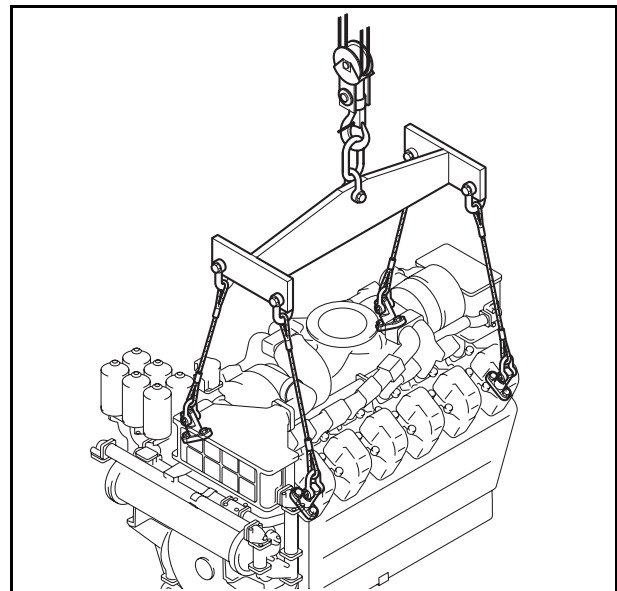


fig.8-2 Lifting the engine

Chapter 9

TROUBLESHOOTING

General Precautions

Contact a Mitsubishi Dealer for Repair Service

Repairing a malfunctioning engine may require special equipment or 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 generates a malfunction, contact a Mitsubishi dealer.

Examination before Work

Before troubleshooting, examine possible causes of the problem and try to see 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 efficiently.

Notes Regarding Contamination

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

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

Notes Regarding Parts Handling

Handle parts carefully.

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

Work Safety

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

Use correct tools and perform work with utmost caution.

Be sure to estimate the weight of the part being dismounted. If the removed part is too heavy, it may fall during lifting, causing damage to the part as well as personal injury.

Conditions Required for Proper Engine Operation

The following table shows the conditions required for proper engine operation, and the locations that affect those conditions.

Table 9-1 Conditions required for proper engine operation

Required condition	Affecting locations
Complete compression of air	Affected by cylinder liners, pistons, piston rings, exhaust valves, inlet valves, and their related parts
Appropriate quantity of fuel injected in proper spray pattern and at correct timing	Affected by fuel injection pump, fuel injection nozzles, governor, and their related parts
Appropriate air volume	Affected by air cleaner, turbocharger, air cooler, and their related parts
All bearings in good condition	Affected by bearing adjustment and engine lubricating system
Proper circulation of engine oil and coolant and proper temperature control	Affected by engine oil circulated inside and outside engine, coolant circulating parts, oil pump, water pump, etc

If any of the above conditions is not met, the engine can manifest problems such as output decrease, lack of smoothness in operation, inability to run at low speed, excessive vibrations, and other general engine problems.

Troubleshooting

Engine Turns, But It Does Not Start

Table 9-2 Engine turns, but it does not start (1 / 2)

Problem	Cause	Remedy
A Engine emits hardly any exhaust smoke.	(1) No fuel supplied to fuel injection pump	
	a Air trapped in fuel supply system	Bleed air from fuel filter and fuel feed pipes, and inspect each part for damage and air leaks. Disassemble and repair, if necessary.
	b Empty daily fuel tank	Add fuel.
	c Clogged fuel filter	Disassemble and clean, or replace element.
	d Clogged fuel feed pipe	Clean inside of pipe.
	e Fuel not supplied due to malfunction of fuel feed pump or drive unit	Disassemble and inspect, or replace fuel feed pump or drive unit.
	(2) Fuel supplied to fuel injection pumps	
	a Loose fuel injection pipe	If loosened, tighten.
	b Seized or damaged parts in fuel injection pump Malfunction of fuel lever Control rack does not move	Inspect control link. If there is a fuel lever linkage problem, disassemble and repair. Remove cam chamber cover, and operate by hand. If parts are defective, disassemble and repair, or replace.
	c Seized plunger	Replace, if defective.
	d Clogged two-way delivery valve	Inspect two-way delivery valve, and disassemble and clean.
e Broken plunger spring	Disassemble and repair, or replace if defective.	
B Engine emits small amount of exhaust smoke. (Check the cause of insufficient injected fuel. Check all items in A-(1) and (2)-b, and also check items at right.)	a Fuel lever does not open fully	Check relation of movement with fuel lever, and disassemble and repair if defective.
	b Seized tappet in fuel injection pump	Check for uneven movement, and disassemble and repair, or replace.
	c Worn tappet roller or camshaft in fuel injection pump (reduced amount of injected fuel)	Replace, if worn.
	d Seized or worn plunger in fuel injection pump, worn broken plunger spring (reduced amount of injected fuel)	Check for uneven movement, and disassemble and repair, or replace.
	e Loose tightening screw of control rack of fuel injection pump	Tighten screw.
	f Defective oil sealing performance of two-way delivery valve, or broken two-way delivery valve spring	Disassemble and repair, or replace.
	g Fuel viscosity too high to allow smooth flow	Use fuel with viscosity suitable for ambient temperature. If fuel quality is improper, change fuel.
	h Large amount of fuel leaks from fuel injection nozzles, and insufficient injected fuel	Check leak-off pipe for amount of fuel leaks, check with nozzle tester, and replace defective parts if necessary.

Table 9-2 Engine turns, but it does not start (2 / 2)

Problem	Cause	Remedy
C Engine emits large amount of exhaust smoke. (Check the cause of ignition failure despite sufficient amount of injected fuel.)	(1) Improper fuel injection timing	
	a Malfunction of camshaft drive	Inspect camshaft drive section, and adjust fuel injection timing correctly.
	b Deviation of fuel ignition timing due to worn fuel injection pump tappet roller or camshaft cam	Replace if worn.
	(2) Poor spray condition of fuel injection nozzles	
	a Sticking of needle valve in fuel injection nozzle, or improper valve seat sealing	Check with nozzle tester, and disassemble and repair, or replace.
	b Fuel injection nozzle valve opening pressure is low	Using nozzle tester, adjust adjustment screw so that fuel is injected at specified valve opening pressure.
	c Damaged or broken nozzle spring	Replace if damaged.
	d Large amount of fuel leaks from nozzle	Clean mounting surfaces of nozzle and holder. Replace if necessary.
	(3) Insufficient compression pressure (cylinder internal temperature does not reach ignition temperature)	
	a Inadequate rotation speed	If starting air pressure is low, increase pressure. If engine oil viscosity is high, heat oil or change oil to one with appropriate viscosity. Repair if there are other abnormalities.
	b Inlet/exhaust valve not contacting valve seat properly	Disassemble and repair by lapping valve in valve seat, or replace if necessary.
	c Valve remaining open	Check for sticking of valve and valve guide, incorrect tappet assembly, and valve clearance, and correct abnormalities if necessary.
	d Leaking of compression pressure due to worn cylinder liners or sticking of piston rings	Disassemble and repair, or replace if necessary.
	e Leaking of compression pressure from cylinder cover	Check for gas leaks, and tighten cylinder cover properly. Repair gas seal surface or replace gas seal ring, if necessary.
	(4) Inappropriate fuel	
	a Inappropriate fuel or water in fuel	Drain fuel and check. Change to higher-quality fuel, if necessary.

Engine Does Not Turn

Table 9-3 Engine does not turn

Problem	Cause	Remedy
A Malfunction of starting air system.	a Malfunction of starting valve	Inspect starting valve, and repair or replace.
	b Starting air pressure lower than specified	Check air tank pressure, and increase pressure if low.
B Malfunction of mechanical engine parts	a Seizing of moving parts in engine	Disassemble and inspect pistons, connecting rods, crankshaft, camshaft, bushings of timing gear and others, inlet and exhaust valves, etc., and repair.
	b Deviation of timing due to incorrect engine assembly Pistons are hitting valves	Disassemble and repair.
	c Viscosity of engine oil too high, or clotted oil	Change oil to one with lower viscosity.

Engine Output is Low

Table 9-4 Engine output is low

Problem	Cause	Remedy
A Engine emits small amount of exhaust. (Engine output and speed are inadequate due to insufficient injected fuel.)	(1) Tendency of engine moving parts toward seizing	
	a Tendency toward seizing due to insufficient clearances of engine parts	Check abnormal heating of parts listed in B-a in Table 9-3, and repair defective parts.
	b Inadequate lubrication	Check oil level, oil pressure and oil viscosity, and add, adjust or replace oil, and also clean lubricating system if there is oil clogging.
	(2) Insufficient amount of fuel supply	
	a Clogged fuel system or loose pipe	Clean or replace. (Refer to A in Table 9-2.)
	b Malfunction of fuel supply or injection system	Clean or replace. (Refer to B in Table 9-2.)
B Engine emits excessive white exhaust smoke.	(1) Engine knocking and excessive white smoke when engine is cold	
	Injection timing too advanced	Correct. (Refer to C-(1) in Table 9-2.)
	(2) Poor combustion due to low compression pressure	
	a Valve remaining open.	Check for valve, valve guide sticking and valve clearances, and repair.
	b Inlet/exhaust valve not contacting valve seat properly	Disassemble and correct by lapping valve in valve seat, or replace if necessary.
	c Broken inlet/exhaust valve spring	Disassemble and repair, or replace if necessary.
	d Leaking of compression pressure due to worn cylinders or sticking of piston rings.	Disassemble and repair, or replace if necessary.
(3) Poor fuel condition (water in fuel)	Open drain cock and check fuel. Drain water or change fuel.	
C Engine emits excessive black exhaust smoke.	(1) Fuel injection timing too retarded	Correct. (Refer to C-(1) in Table 9-2.)
	(2) Uneven fuel injection among cylinders (Poor combustion condition, unstable rotation with knocking)	
	a One or more worn tappet rollers or cams on camshaft in fuel injection pumps causing deviation of fuel injection timing	Replace if worn.
	b One or more plunger springs seized, worn or broken	Disassemble, repair or replace.
	(3) Poor spray condition of some fuel injection nozzles (Exhaust temperature of cylinders with poor fuel spray condition may become high.)	Refer to C-(2) in Table 9-2.
	(4) Poor combustion due to insufficient inlet	
	a Malfunction of turbocharger (damage of vanes, seizing of bearing, etc.)	Disassemble and repair, or replace if necessary.
	b Malfunction of inlet/exhaust valve	Refer to B-(2) in Table 9-4.
c Air cleaner clogged with dust	Disassemble and clean, or replace if necessary.	

Engine Knocks

Table 9-5 Engine knocks

Problem	Cause	Remedy
A Engine knocks slightly and emits black exhaust smoke.	Fuel injection timing too retarded	Refer to C-(1) in Table 9-2.
B Knocking is severe, and exhaust smoke is white.	Fuel injection timing is too advanced	Refer to C-(1) in Table 9-2.
C Knocking is severe in certain cylinders.	Uneven fuel injection among cylinders	
	a Excessive fuel injection in some cylinders	Refer to C-(2)-a in Table 9-2.
	b Fuel injection timing too advanced in some cylinders	Refer to C-(2)-b in Table 9-2.
D Ignition retardation occurs and results in simultaneous ignition to cause severe knocking.	Improper spray of fuel by fuel injection nozzles	
	Fuel is not sprayed in proper condition in some cylinders.	Refer to C-(2) in Table 9-2.
E Ignition retardation occurs frequently and results in simultaneous ignition to cause severe knocking.	Low engine compression	
	Amount of intake air is low in some cylinders.	Refer to C-(3) in Table 9-2.
F Injection of fuel generates knocking, and engine emits large amount of black or gray exhaust smoke. When oil does not rise, engine does not knock severely and emits bluish white exhaust smoke.	Engine oil rising above pistons	
	a Oil level too high in crankcase	Discharge oil to appropriate level.
	b Worn piston rings or sticking of piston rings, resulting in inadequate scraping of oil	Check crankcase breather pipe for gas leak, and replace if there are defective parts.
	c Excessive clearance between cylinder and piston	Check crankcase breather pipe for gas leak, and replace if necessary.
	d Engine oil viscosity too low	Change to high-quality oil with higher viscosity.
G Abnormal noise produced when injection is stopped suddenly and engine is allowed to rotate by inertia (engine mechanical failure)	a Excessive connecting rod bearing clearance, or bearing metal flaking.	Disassemble and inspect, and repair or replace if necessary.
	b Loose connecting rod cap tightening bolts	Disassemble and inspect, and repair or replace if necessary.
	c Excessive clearance between cylinder and piston	Check crankcase breather pipe for gas leak, and replace if necessary.
	d Piston hitting foreign item fallen inside cylinder	Disassemble and inspect.
H Low compression temperature and retarded ignition cause severe knocking, especially after engine starts in cold weather.	Engine too cold	Operate engine until it warms up before increasing engine speed.

Engine Produces Large Amount of Smoke While in Operation

Table 9-6 Engine produces large amount of smoke while in operation

Problem	Cause	Remedy
A Engine emits excessive white exhaust smoke.	(1) Severe knocking	
	Fuel injection timing too advanced	Refer to C-(1) in Table 9-2.
	(2) Knocking produced only in cylinders with insufficient compression	
	Low engine compression	Refer to C-(3) in Table 9-2.
	(3) Improper fuel	
	a Water contained in fuel	Open drain cock and check. Remove water or change fuel.
	(4) Other	
	a Large amount engine oil rising above pistons	Inspect and repair or replace as described in F in Table 9-5.
	b Engine too cold, resulting in poor combustion	Inspect temperature regulator, and adjust it properly to prevent overcooling.
	c Engine operating too long with no load	Unburned oil is trapped in exhaust pipe. White smoke stops after engine is operated under load.
B Engine emits excessive black exhaust smoke.	(1) Minor knocking	
	a Injection timing too retarded	Refer to C-(1) in Table 9-2.
	(2) Other	
	a Excessive amount of injected fuel	Check if fuel injection pump rack set screw or bolt is loose, and repair.
	b Fuel injection not uniform	Inspect, and repair or replace as described in C-(2) in Table 9-4.
	c Improper spray of fuel by fuel injection nozzles	Inspect, and repair or replace as described in C-(2) in Table 9-4.
	d Low engine compression	Inspect, and repair or replace as described in C-(2) in Table 9-4.
	e Large amount engine oil rising above pistons	Inspect and repair or replace as described in F in Table 9-5.

Engine Operates at High Speed and Does Not Stop

Table 9-7 Engine operates at high speed and does not stop

Problem	Cause	Remedy
Fuel injection pump does not set to no-injection condition.	Link between fuel increase/decrease lever and governor failing to return smoothly to original position	Check if link returns without catching, and repair if necessary.
	a Loose control link lever	Repair if rack does not move in connection with governor lever.
	b Sticking of rack disallowing its return to original position	Check rack for smoothness, and disassemble and repair.

Malfunction of Lubricating System

Table 9-8 Malfunction of lubrication system

Problem	Cause	Remedy
A Oil pressure does not rise immediately after startup.	a Engine oil level too low	Check oil level gage, and add oil if level is low.
	b Engine oil viscosity too high for smooth pumping of oil (Especially when temperature is low)	Change oil to one with appropriate viscosity.
	c Clogged oil pump suction side or strainer screen	Remove pipe from pump discharge side, and check oil discharge. If no oil is discharged, disassemble, clean and repair, or replace.
	d Malfunction of regulator valve	Repair or replace defective parts, such as broken valve spring and seized valve.
	e Clogged oil filter element	Disassemble, clean, replace.
	f Defective oil pressure gage	Disconnect oil pressure gage pipe. If oil pours out, replace oil pressure gage.
B Oil pressure drops gradually during operation.	a Clogged oil filter element	Disassemble, clean, replace.
	b Engine oil viscosity too low	Oil temperature rises and causes oil pressure to drop. Change oil to one with higher viscosity.
	c Abnormally high oil temperature	Engine is overheated. Do not operate engine until oil temperature is low.
	d Tendency toward bearing seizing	Disassemble, repair.
C Oil pressure abruptly drops during operation and remains there.	a Damage bearing causing increased oil leaks	Disassemble and repair.
	b Cracking in engine oil passage, or oil leakage from joint	Check for leaks, and repair or replace defective parts.
D Oil pressure fluctuates suddenly during operation.	Engine oil level too low, causing air to mix into oil	Check oil level gage, and add oil if level is low.

Chapter 10

MAIN SPECIFICATIONS

Main Specifications

Table 10-1 Main specifications table

Engine model	S12U	S16U
Type	Water-cooled, 4-stroke cycle, turbocharged diesel, air cooler	
Number of cylinders, arrangement	12-V	16-V
Bore×stroke (mm [in.])	240×260 [9.45×10.2]	
Total displacement (L [U. S. gal])	141.1 [37.27]	188.2 [49.72]
Combustion type	Direct injection	
Compression ratio	13.5:1	
Firing order	1-12-5-8-3-10-6-7-2-11-4-9	1-9-6-14-2-10-4-12 -8-16-3-11-7-15-5-13
Rotating direction	Counterclockwise as viewed from flywheel or clockwise (reverse rotation by option)	
Dimensions (L×W×H (mm) [in.])	3520×1842×2374 [139×72.5×93.5]	4586×1710×2490 [181×67.3×98]
Dry weight (kg [lb.])	Approx. 15500 [34172]	Approx. 20500 [45195]
Fuel	Diesel fuel (refer to 4-3 "Fuel Use Limit Property Guideline")	
Fuel injection pump	Bosh unit pump	
Governor	WOODWARD UG8L, UG8D hydraulic governor, WOODWARD EG10P electrohydraulic governor or TOHO SEISAKUSHO SG4080C electric governor	
Fuel filter	Wire-element type (primary) and paper-element type (secondary)	
Fuel injection nozzle	Hole type	
Lubricating system	Forced circulation type (pressure feed by oil pump)	
Lubrication oil (oil pan)	Class CD or CF oil (API service classification)	
Engine oil capacity (oil pan) (L [U. S. gal])	Approx. 450 [118.88]	Approx. 600 [158.50]
Oil filter	Paper-element type	
Oil cooler	Water cooled multi-plate	
Cooling system	Force water cooling by centrifugal pump	
Cooling water capacity (L [U. S. gal])	Approx. 520 [137.37]	Approx. 700 [184.92]
Water pump	Centrifugal volute type	
Starting system	Air-compression direct entry type	
Turbocharger	Mitsubishi TD24×2	Mitsubishi TD18×4

