OPERATION & MAINTENANCE MANUAL

MITSUBISHI DIESEL ENGINE

S12A2

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.

MITSUBISHI HEAVY INDUSTRIES, LTD.

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FOREWORD

This operation and maintenance manual contains detailed operation, inspection and maintenance information for Mitsubishi engines.

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

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

LIMITED WARRANTY

The manufacturer will repair or replace parts returned to the manufacturer when the manufacturer judges that the parts are defective in material and/or workmanship after conducting inspection.
The manufacturer's warranty is limited to the compensation work of repair or replacement of parts.
The warranty coverage is effective for the original purchaser only. Those to whom ownership is later transferred are not provided with the warranty.

- **The manufacturer makes no warranties, either expressed or implied, except as provided in this manual, including, but not limited to, warranties as to marketability, merchantability, fitness for a particular purpose or use, or against infringement of any patent.**
- **The manufacturer will not be liable for any damages or consequential damages, including, but not limited to, damages or other costs resulting from any abuse, misuse, misapplication of the engine and devices supplied 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 (LLC) that are not recommended by the manufacturer.**
- **The owner of the engine is responsible for the performance of the required maintenance listed in this operation manual.**
  The manufacturer may deny the warranty coverage if the engine or part has failed due to inadequate or improper maintenance.

Important information

- To avoid the potential hazard, accident prevention activities must be planned methodically and conducted continually by considering all aspect of engine operation, maintenance and inspection. All related personnel, including managers and supervisors, should actively participate, recognize their roles and organize themselves and their work to ensure a safe environment.
- The foremost safety objective is to prevent accidents which may result in injury or death, or equipment damage.
- Always observe laws or regulations of the local or federal/national government.
- The manufacturer cannot foresee all potential dangers of the engine, potential danger resulting from human error and other causes, or danger caused by a specific environment in which the engine is used. Since there are many actions that cannot be performed or must not be performed, it is impossible to indicate every caution in this manual or on warning labels. As such, it is extremely important to follow directions in this manual and also to take general safety measures when operating, maintaining and inspecting the engine.
- 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 dangers and who also have received risk avoidance training.
- To prevent an accident, do not attempt to carry out any operation other than those described in this manual, and do not use the engine for any unapproved purpose.
- When the ownership of the engine is transferred, be sure to provide this manual with the engine to the new owner. Also inform the manufacturer of the name and address of the new owner of the engine.
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- The contents in this manual are subject to change at any time without notice for improvement of the engine.
- Pictures or illustrations of the product in this manual may differ from those of product you have. Please note that, depending on specifications, items described in this manual may differ from those on your engine in shape, or may not be installed on your engine.
- Please contact your Mitsubishi dealer if you need more information or if you have any questions.
- If you lost or damaged this manual, obtain a new copy at your Mitsubishi dealer as soon as possible.
- Mitsubishi Heavy Industries recommends the engine owner to install an hour meter on the engine due to monitor correct service intervals and to perform the maintenance at the proper timing.

Warning indication

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

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

Warning statements

The warning statements in this manual describe potential danger in operating, inspecting or maintaining the engine, using the following five classifications to indicate the degree of potential hazard.
Failure to follow these directions could lead to serious accidents which could result in personal injury, or death in the worst case.

DANGER	Indicates a highly hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.
CAUTION	Indicates a potentially hazardous situation which, if not avoided, may result in property damage.
Note :	Indicates important information or information which is useful for engine operation.

Units of measurement

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

- Pressure :1 MPa = 10.197 kgf/cm^2
- Torque :1 N·m = 0.10197 kgf·m
- Force :1 N = 0.10197 kgf
- Horsepower :1 kW = 1.341 HP = 1.3596 PS
- Meter of mercury :1 kPa = 0.75 cmHg
- Meter of water :1 kPa = 10.197 cmH_2O(cmAq)
- Engine speed :1 min^{-1} = 1 rpm
- Kinetic viscosity: 1 mm^2/s = 1 cSt

Abbreviations, standards and others

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

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Chapter 1 BASIC SAFETY PRECAUTIONS

Fire and explosions

⚠ WARNING

Keep flames away

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

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

Store fuel and engine oil in a well ventilated designated area. Make sure that the caps of fuel and engine oil containers are tightly closed.

Keep engine surrounding area tidy and clean

Do not leave combustible or explosive materials, such as fuel, engine oil and LLC, near the engine. Such substances can cause fire or explosion.

Remove dust, dirt and other foreign materials accumulated on the engine and surrounding parts thoroughly. Such materials can cause fire or the engine to overheat. In particular, clean the top surface of the battery thoroughly. Dust can cause a short-circuit.

Ventilation of engine room

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

Do not open side cover until engine cools

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

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

Care for fuel, oil and exhaust gas leakage

If any fuel, oil or exhaust gas leakage is found, immediately take corrective measures to stop it.

Such leakages, if left uncorrected, can cause fuel or engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable materials, possibly leading to personal injury and/or damage to equipment.

Use explosion-proof lighting apparatus

When inspecting fuel, engine oil, coolant, battery electrolyte, etc., use a flameproof light. An ordinary lighting apparatus may ignite gas and cause it to explode.

Prevent electrical wires from short-circuiting

Avoid inspecting or servicing the electrical system with the ground cable connected to the battery. Otherwise, a fire could result from short-circuiting. Be sure to disconnect the battery cable from the negative (-) terminal before beginning with the work procedure.

Short-circuits, possibly resulting in fire, may be caused by a loose terminal or damaged cable/wire. Inspect the terminals, cables and wires, and repair or replace the faulty parts before beginning with the service procedure.

Keep fire extinguishers and a first-aid kit handy

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

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

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

Stay clear of all rotating and moving parts

⚠ WARNING

Install protective covers around rotating parts

Make sure the protective covers of the engine are correctly installed. Repair any damaged or loose covers. Never remove the covers such as damper cover, camshaft cover, or rocker cover that enclose the revolving parts during operation.

When the engine is coupled to driven equipment, be sure to provide protective covers over the parts such as the connecting belts and couplings that are exposed.

Never remove protective covers.

Check work area for safety

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

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

Stay clear of moving parts during engine running

Do not approach rotating or sliding parts of the engine when the engine is in operation. Keep objects likely to be caught by rotating parts away from such parts.

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

Lockout and Tagout

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

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

To accomplish the lockout/tagout, remove the starter switch key, set the battery switch to OFF and attach a "Do Not Run" or similar caution tag to the starter switch.

The starter switch key must be kept by the person who performs inspection and maintenance during the work.

Keep engine stopped during servicing

Be sure to stop the engine before proceeding to inspection and service procedure. Never attempt to make adjustments on the engine parts while the engine is running.

Rotating parts such as belt can entangle your body and cause serious injuries.

Always restore engine turning tools after use

Be sure to remove all turning tools used during maintenance and inspection work. Remember also that the turning gear must be returned to the operating condition before starting the engine.

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

Be careful of exhaust fume poisoning

⚠ WARNING

Operate the engine in a well-ventilated area

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

Be careful of falling

⚠ WARNING

Lift engine carefully

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

Attach the wire rope to the lifting hangers provided on the engine using a correct sling.

During lifting process, keep the engine in a well-balanced position by taking the center of gravity of the engine into consideration.

Keep the angle formed by slings attached to hangers within 60 °. If the angle exceeds this limit, excessive load could be imposed on the hangers and this could damage the hangers and result in a serious accident.

If the wire rope contacts the engine directly, place a cloth or other soft padding to avoid damage to the engine and wire rope.

Do not climb onto the engine

Do not climb onto the engine, nor step on any engine parts located on the lateral sides.

To work on parts located on the upper section of engine, use a ladder, stool, etc., that was firmly secured.

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

Always prepare stable scaffold

When working on the upper part of the engine and other hard-to-reach places, use a stable work platform. Standing on a decrepit stool or parts box may result in personal injury.

Do not place any unnecessary objects on a work platform.

Protect ears from noise

⚠ CAUTION

Wear ear plugs

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

Be careful of burn injuries

⚠ CAUTION

Do not touch the engine during or immediately after operation

To avoid burns, do not touch the engine during or immediately after operation.
A hot engine can cause burns.
To conduct maintenance and inspection work, wait until the engine has cooled sufficiently by checking the temperature gauge.

Add coolant only after the coolant temperature dropped

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

Never remove heat shields

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

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

Never open the radiator filler cap while the engine is running or immediately after the engine is stopped.
When opening the cap, stop the engine and allow the coolant temperature to lower sufficiently.
When opening the radiator filler cap, open slowly to discharge the pressure inside the tank. Also to avoid a risk of getting scalded by steam, wear thick rubber gloves or wrap a cloth around the cap.
When closing the cap, be sure to tighten securely.
The 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 and result in burns.

Do not touch high-pressure injection fuel

If fuel leaks or sprays out from the high pressure injection pipe, do not touch the fuel.
Fuel in the fuel injection pipes is under high pressure and if the fuel contact your skin, it goes into deep tissues and may result gangrene.

Be careful when handling fuel, engine oil or LLC

⚠ CAUTION

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

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

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

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

Handle LLC (long life coolant) carefully

When handling LLC, always wear rubber gloves and a protective face mask. If LLC or cooling water containing LLC comes into contact with your skin or eyes, or if it is swallowed, you would suffer from inflammation, irritation or poisoning.

Should LLC be accidentally swallowed, induce vomiting immediately and seek medical attention. Should LLC enter your eyes, flush them immediately with plenty of water and seek medical attention. If LLC splashes onto your skin or clothing, wash it away immediately with plenty of water.

Keep flames away from LLC. The LLC can catch flames, causing a fire. Coolant (containing LLC) drained from the engine is toxic. Never dispose of coolant into regular sewage. Abide by the applicable law and regulations when discarding drained coolant.

Proper disposal of waste oil, LLC and coolant

Do not discharge waste engine oil, LLC and coolant into sewerage, river, lake or other similar places. Such a way of disposal is strictly prohibited by laws and regulations.

Dispose of waste oil, LLC and coolant and other environmentally hazardous waste in accordance with the applicable law and regulations.

If any anomaly occurs

⚠ CAUTION

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

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

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

Avoid immediate restart after abnormal stop

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

Avoid continuous engine operation at low oil pressure

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

If V-belt breaks, stop engine immediately

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

Service battery

⚠ CAUTION

Handle the battery correctly

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

Other cautions

⚠ CAUTION

Never modify engine

Unauthorized modification of the engine will void the manufacturer's warranty.
Modification of the engine may not only cause engine damage but also produce personal injuries.
If there is a need to modify the engine, contact your Mitsubishi dealer.

Observe safety rules at work site

Observe the safety rules established at your workplace when operating and maintaining the engine.
Do not operate the engine if you are feeling ill, inform your supervisor of your condition.
Operation of the engine with reduced awareness may cause improper operation that could result in accidents.
When working in a team for two or more people, use specified hand signals to communicate among workers.

Work clothing and protective gear

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

Never break seals

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

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

Perform all specified pre-operation inspections and periodic inspections

Conduct the pre-operation inspections and periodic inspections as described in this manual.
Failure to conduct the specified inspections may cause various engine problems, damage to parts, and serious accidents.

Break-in the engine

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

Warm up the engine before use

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

Never operate the engine in an overloaded condition

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

Conduct cooling operation before stopping the engine

Before stopping the engine, let it idle at low speed for 5 to 6 minutes to cool down.
Stopping the engine immediately after high-load operation will cause engine parts to heat up and shorten the service life of the engine.
During cooling operation, check the engine for abnormalities.

Protection of the engine against water entry

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

Properly maintain the air cleaner and pre-cleaner

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

- Do not maintain the air cleaner or pre-cleaner while the engine is operating. Operating the engine without the air cleaner can suck particles of foreign matter into the engine and could result in serious accidents.
- Remove the air cleaner/pre-cleaner slowly to prevent dust accumulated on the element from falling off. After removing the air cleaner or pre-cleaner, immediately cover the opening (inlet port of air cleaner; port in body for pre-cleaner) with plastic sheet or similar means to prevent dust from entering the engine.
- If the engine is equipped with a dust indicator, conduct maintenance when the clog warning sign appears.

Use of tools optimum for each work

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

Avoidance of prolonged time of starter operation

Do not use the starter for more than 10 seconds at a time. If the engine does not start, wait for at least 1 minute before cranking again.
Continuous operation of the starter will drain the battery power and cause the starter to seize.

Do not turn off the battery switch during operation

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

Cautionary instructions for transporting the engine

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

Do not operate engine continuously under low load

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

Engine external diagrams

Left view

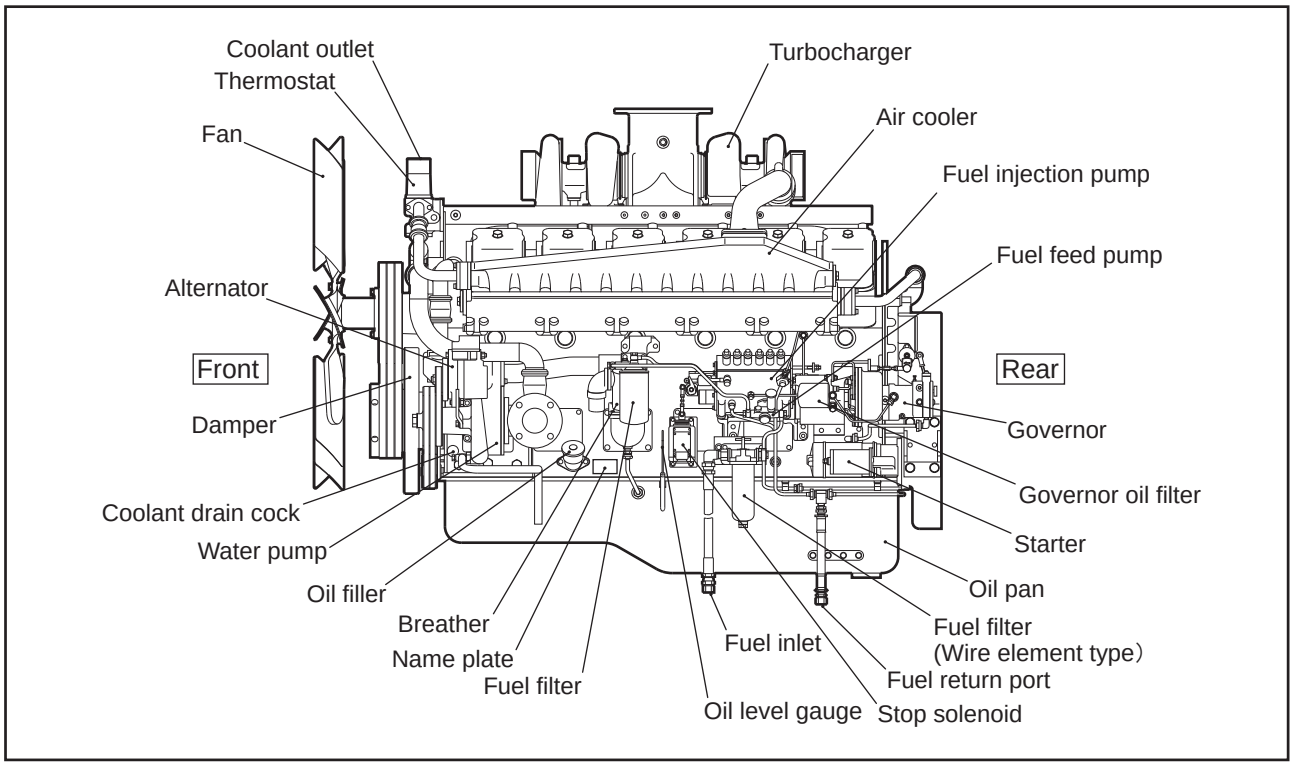

Fig. 2-1 Engine left view

Right view

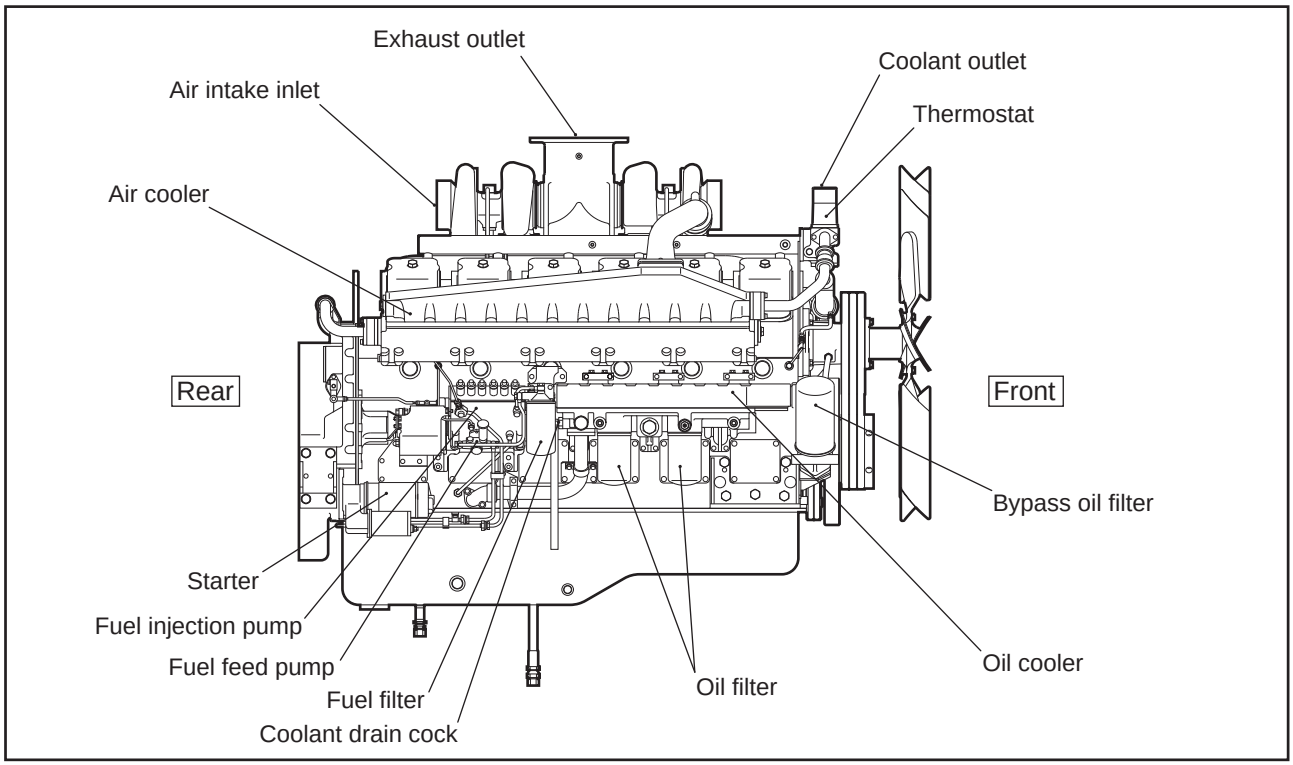

Fig. 2-2 Engine right view

Equipment and instrument

The installed equipment and shapes differ on the engine type.

Start and stop instrument

Start switch

When the start switch on the operation panel is pressed, starting system is operated and cranks the engine.

Stop switch

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

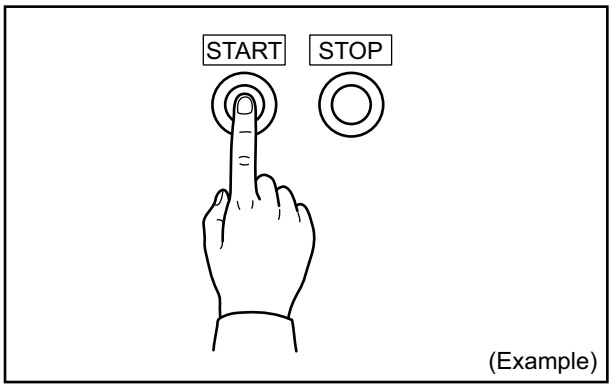

Fig. 2-3 Start switch and stop switch

Manual stop lever

Use the manual stop lever to shut down the engine in the event of an emergency. If the stop switch fails to stop engine operation, use the manual stop lever. When the manual stop lever, which is located in the fuel control link, is moved in the [STOP] direction, the engine stops.

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

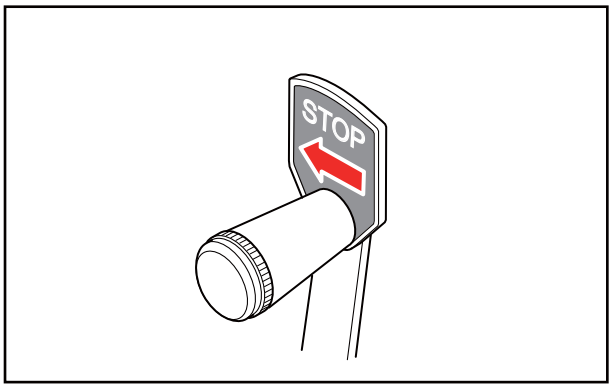

Fig. 2-4 Manual stop lever

Stop solenoid

The stop solenoid operates for normal shutdown of engine operation. The stop solenoid moves the rack of fuel injection pump to cut the fuel, and consequently stops the engine. Two types of stop solenoids are available.

♦RUN OFF type

Not energized while the engine is running. Energized by a stop signal to stop the engine.

♦RUN ON type

Energized while the engine is running, and de-energized to stop the engine.

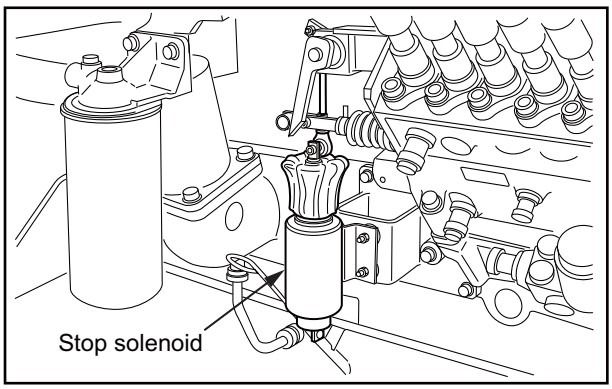

Fig. 2-5 Stop solenoid

Instruments

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

Oil pressure unit

Always detect the oil pressure.

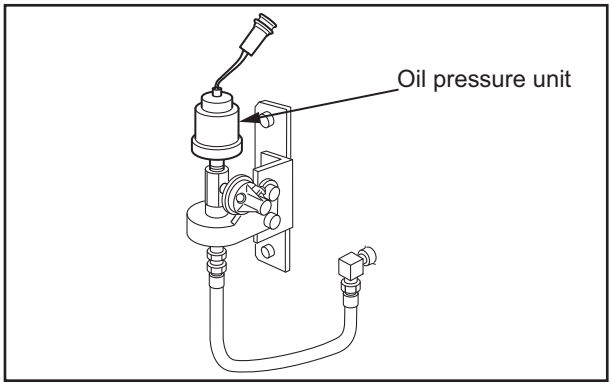

Fig. 2-6 Oil pressure unit

Thermo unit

Always detect the coolant temperature of engine.

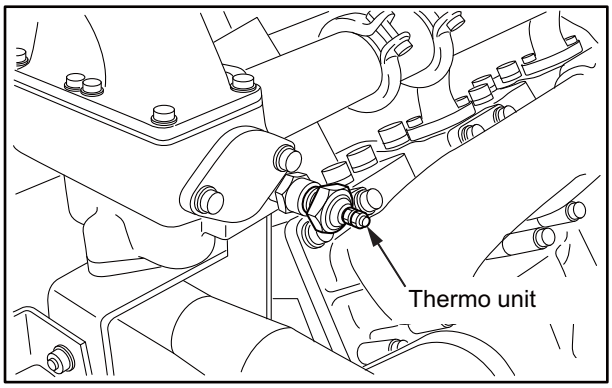

Fig. 2-7 Thermo unit

Revolution detection pickup

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

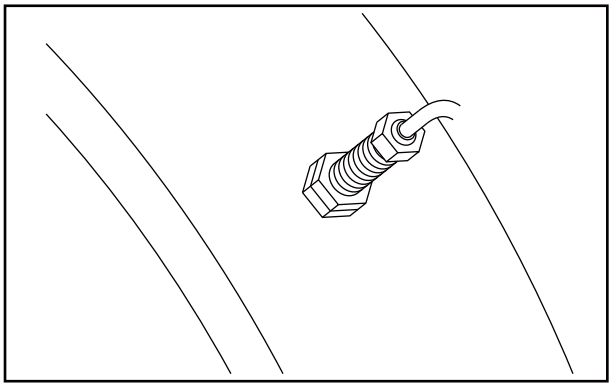

Fig. 2-8 Revolution detection pickup

Engine protection devices

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

Oil pressure switch

The oil pressure switch generates an alarm when the engine oil pressure becomes low and reaches the specified pressure.

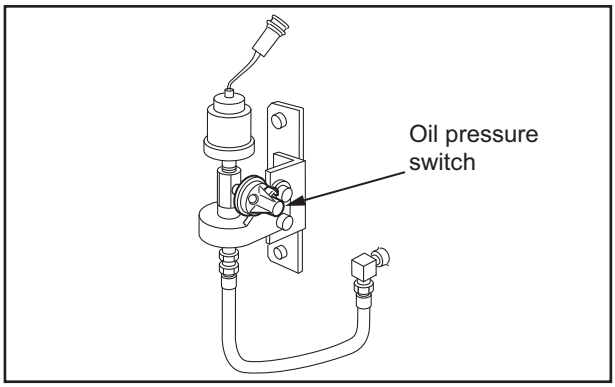

Fig. 2-9 Oil pressure switch

Thermo switch

The thermo switch activates the alarm system when the coolant temperature reaches the specified value.

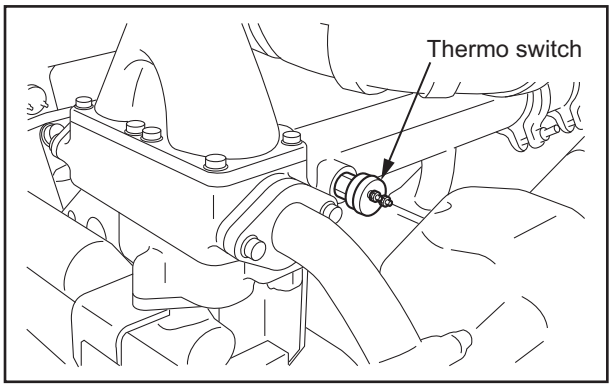

Fig. 2-10 Thermo switch

Oil filter alarm switch

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

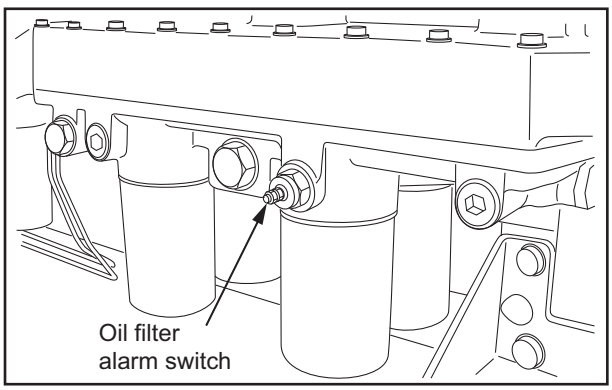

Fig. 2-11 Oil filter alarm switch

Overrun detection pickup

The overrun detection pickup generates an alarm when the engine speed becomes high and reaches the specified engine speed.

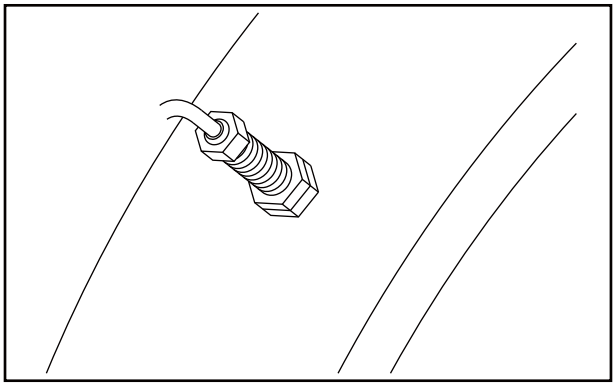

Fig. 2-12 Overrun detection pickup

Air cleaner indicator

The air cleaner indicator alarms with its red signal when air cleaner elements become clogged, the difference in pressure between inlet and outlet of air cleaner reaches the specified value. The signal indicates only, and does not generate an alarm. Therefore, the periodic visually inspection is needed.
Press the reset button on the top of air cleaner indicator and restore the signal after cleaned the air cleaner indicator or replaced with a new one.

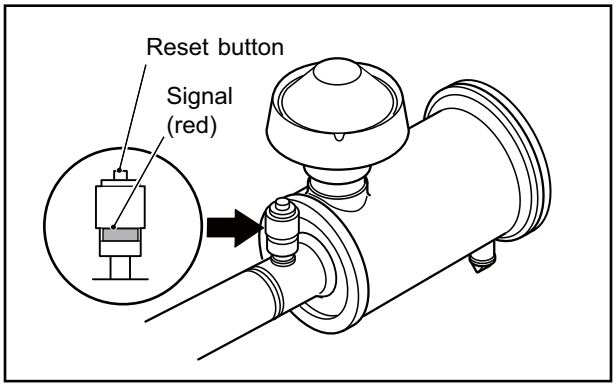

Fig. 2-13 Air cleaner indicator

Operational environment

CAUTION

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

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

Preparation for operating new or overhauled engine

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

Preparation of fuel system

⚠ CAUTION

When handling fuel, make sure there are no open flames or other fire hazards near the engine.

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

CAUTION

Do not remove the strainer when filling the fuel tank.

For fuel to be used, refer to "FUEL" (4-1).

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

Fuel system - Bleed air

WARNING

When fuel overflow from the air vent plug, wipe thoroughly. Spilled fuel causes fire hazard.
After bleeding, lock the priming pump cap securely. If the cap is not locked tightly, the priming pump can be damaged, causing a fuel leak that could lead to a fire.

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

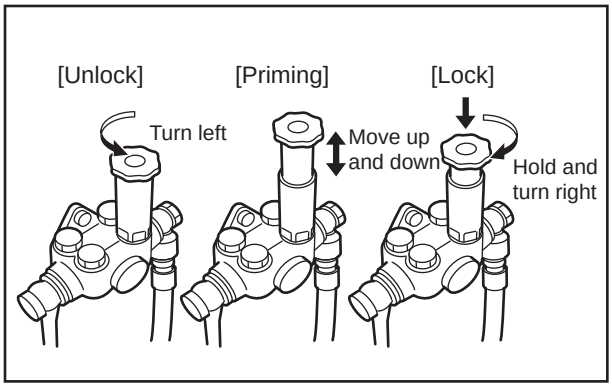

Fig. 3-1 Priming pump - Handle

Fuel filters (wire-element type) - Bleed air

CAUTION

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

1. Loosen the air vent plug on the fuel filter (wire-element type) about 1.5 turns.
2. Turn the priming pump cap counterclockwise to unlock, and move the fuel filter up and down.
3. When the fuel from the air vent plug becomes free from air bubbles, stop priming and tighten the air vent plug to the specified torque.

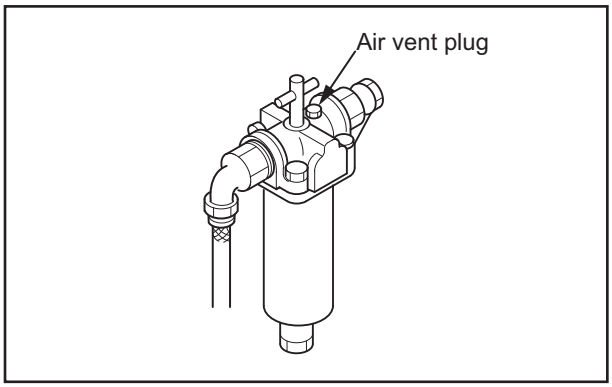

Fig. 3-2 Fuel filters (wire-element type) - Bleed air

Fuel filter - Bleed air

CAUTION

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

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

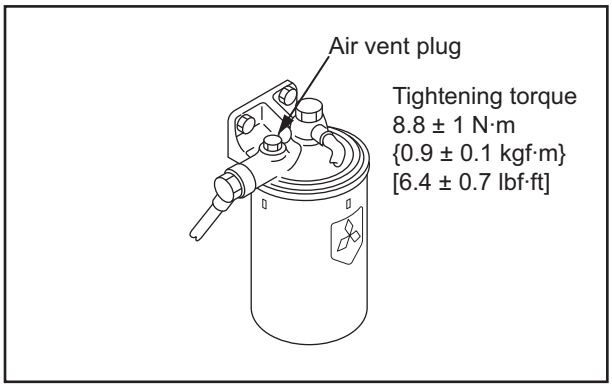

Fig. 3-3 Fuel filter - Bleed air

Fuel injection pump - Bleed air

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

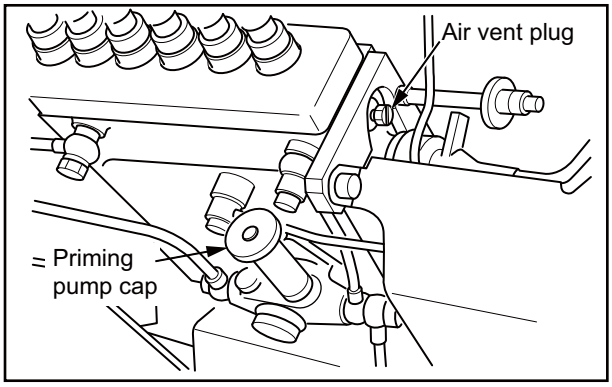

Fig. 3-4 Fuel injection pump - Bleed air

Priming pump cap tightening method

⚠ CAUTION

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

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

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

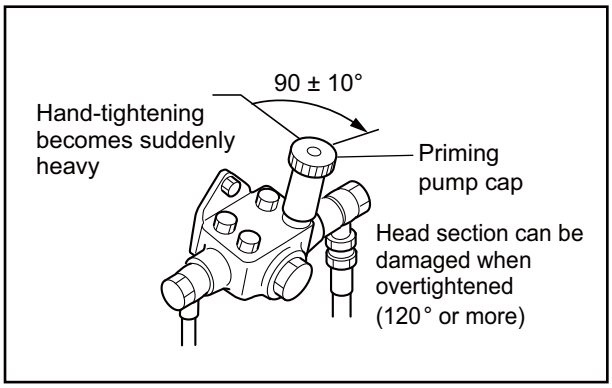

Fig. 3-5 Priming pump cap tightening method

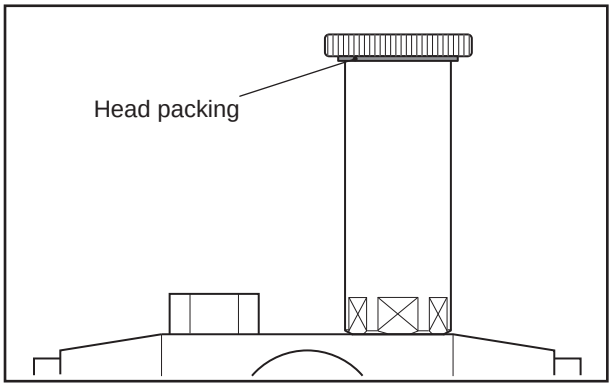

Fig. 3-6 Priming pump head packing

Preparation of lubrication system

Engine oil - Refill

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

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

3. Remove the rocker cover, and pour engine oil to the valve mechanism and camshaft oil bath. Pour engine oil to camshaft oil bath from cylinder head side.
   Oil capacity per cylinder: 0.8 L [0.21 U.S. gal.]
4. Reinstall the rocker covers.
5. Check the oil level in the oil pan as follows:
6. Pull out the oil level gauge and wipe it clean with a waste cloth.
7. Insert the oil level gauge fully into the oil level gauge guide, then pull out the gauge again.
8. The correct oil level is between the MAXIMUM and MINIMUM marks on the oil level gauge.
   If the oil level is low, add engine oil of the specified type.
9. Check the oil pan and other area for oil leaks. Repair the oil leakage if any.
10. Crank the engine with the starter for 10 seconds to circulate oil throughout the engine. After 1 minute of rest period, perform the above cranking operation again to circulate oil in the engine.

CAUTION

To crank the engine, shut off the fuel supply to the engine and operate the starters.
When conducting the above cranking operation, also check the items to be inspected for the cooling system by cranking.

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

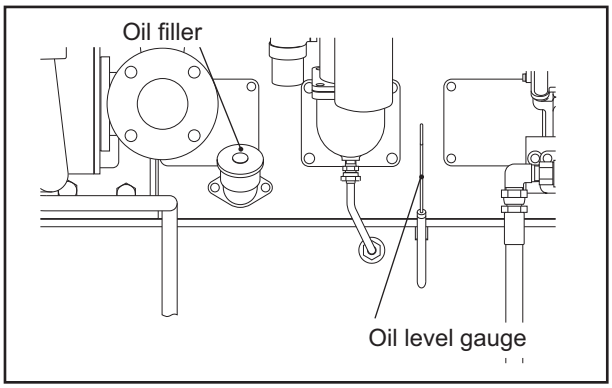

Fig. 3-7 Oil filler and oil level gauge

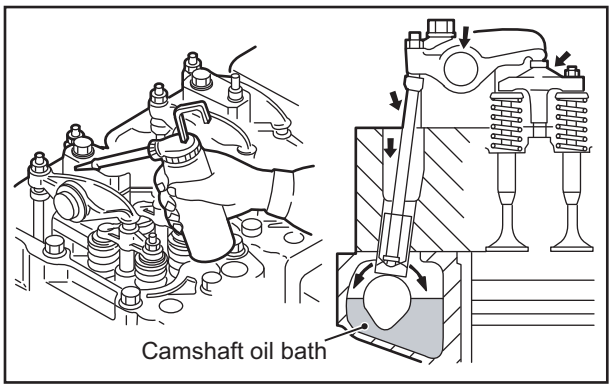

Fig. 3-8 Pouring engine oil on valve mechanisms and chamber

Preparation of cooling system

Coolant - Refill

1. Make sure the drain cocks on the engine and water pump are closed securely.
2. Remove the radiator cap, and pour in undiluted LLC.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.
For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

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

Note: For absolute air bleeding, loosen the air vent cock on the upper section of thermostat when adding water.

4. Check the radiator and other parts for coolant leaks. Repair leakage if found.
5. When coolant reaches the full level, close the radiator cap securely.
6. Crank the engine for about 10 seconds using a starters.
7. Wait for about 1 minute, then repeat the above cranking operation to remove air from the water pump.

CAUTION

To crank the engine, shut off the fuel supply to the engine and operate the starters.
When conducting the above cranking operation, also check the items to be inspected for the lubricating system by cranking.

8. Check the coolant level in the radiator.
9. If the engine is equipped with a reserve tank, fill the reserve tank with coolant to the full level as well.

Note: Always use the coolant with the same LLC concentration.

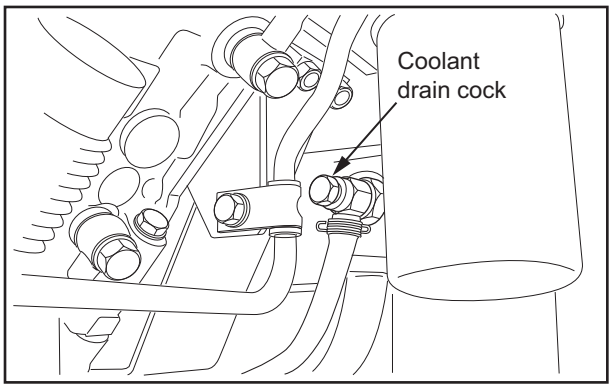

Fig. 3-9 Coolant drain cock (engine)

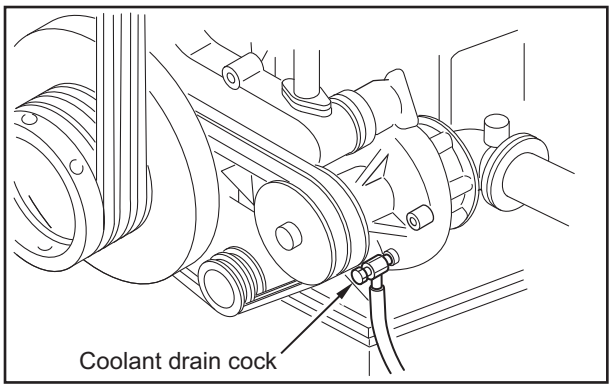

Fig. 3-10 Coolant drain cock (water pump)

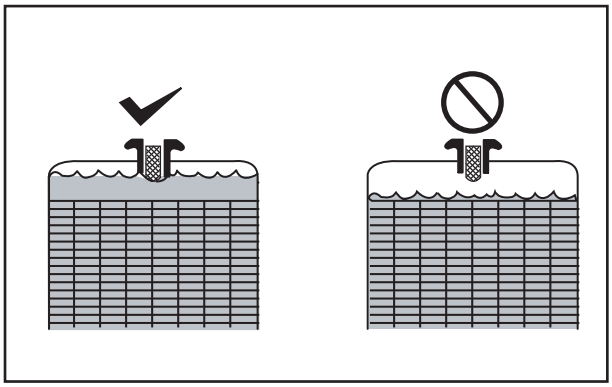

Fig. 3-11 Radiator coolant level

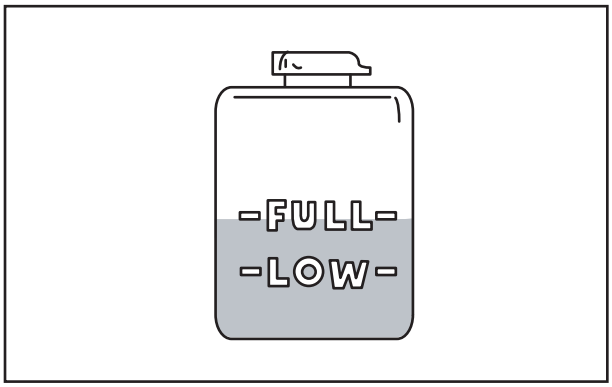

Fig. 3-12 Reserve tank coolant level

Preparation of electrical system

Battery - Inspect

WARNING

If battery electrolyte is spilled on your skin, flush immediately with plenty of water. If battery electrolyte enters the eyes, flush them immediately with lots of fresh water and seek medical attention at once.

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

Battery electrolyte level - Inspect

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

For the battery without level lines, the correct fluid surface level is about 10 to 15 mm [0.394 to 0.591 in.] above the top of the plates.

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

Note: When adding distilled water, pour in carefully.

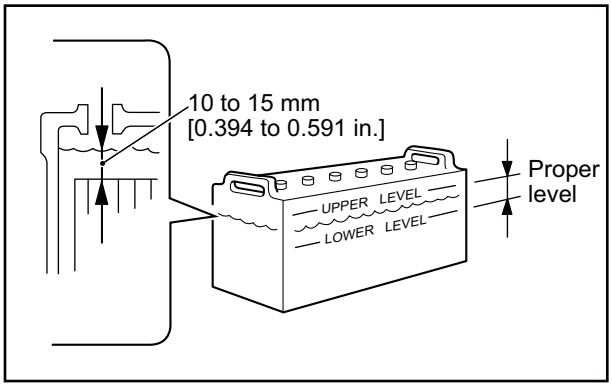

Fig. 3-13 Battery electrolyte level - Inspect

Specific gravity of battery electrolyte - Check

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

Table 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

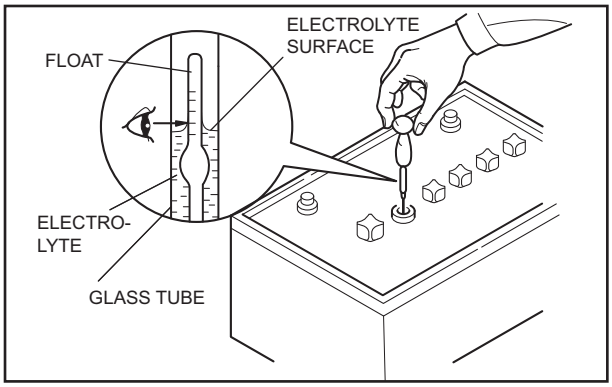

Fig. 3-14 Specific gravity of battery electrolyte - Check

Test operation

To conduct a test operation, follow the procedures below.

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

Starting and stopping

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

Inspection

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

⚠ CAUTION

Remove the radiator cap only after the engine has cooled to room temperature. Place a waste cloth over the cap, and loosen the cap about a half-turn or stand the lever to the upright position to release internal pressure. Opening the radiator cap while the engine is hot causes steam and hot coolant to spray out and may result in skin burns.

6. If the coolant level is low, add coolant to the specified level.
   If the engine is equipped with a reserve tank, fill the reserve tank with coolant to the full level as well.

CAUTION

Always use the coolant with the same LLC concentration.

Normal engine operation

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

CAUTION

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

Preparations for operation

Always conduct the following inspection before starting the engine.

Engine external - Inspect

⚠ CAUTION

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

Inspect the engine exterior as described below.

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Check the entire engine for leaks of fuel, engine oil or coolant. If leaks are found, repair the leak, or contact your local 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

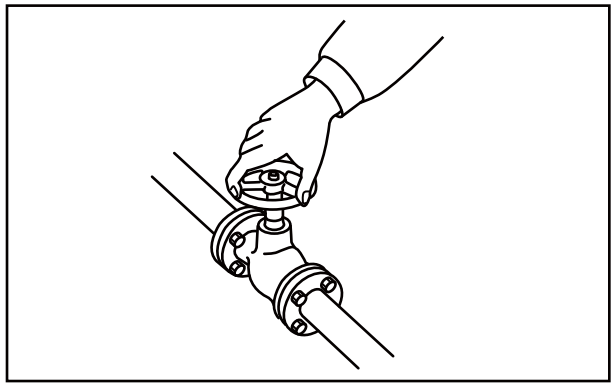

Fig. 3-15 Valves for open/closed position - Check

Fuel tank oil level - Check

⚠ WARNING

When working around fuel, make sure there are no open flames, heaters or other fire hazards.

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

CAUTION

Do not remove the strainer when filling the fuel tank.

For fuel to be used, refer to "FUEL" (4-1).

Make sure the fuel tank is full.

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

Engine oil level - Check

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

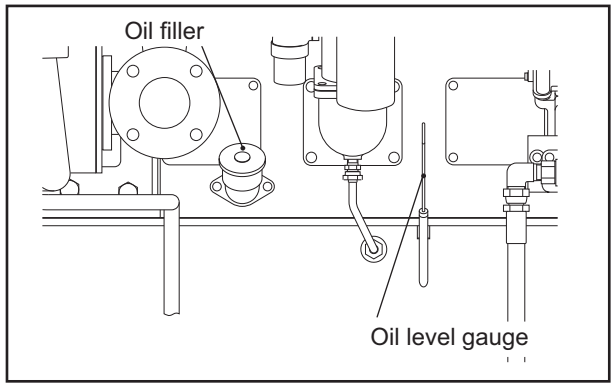

Fig. 3-16 Oil filler and oil level gauge

Coolant level - Check

⚠ WARNING

Remove the radiator cap only after the engine has cooled to room temperature. Place a waste cloth over the cap, and loosen the cap about a half-turn or stand the lever to the upright position to release internal pressure. Opening the radiator cap while the engine is hot causes steam and hot coolant to spray out and may result in skin burns.

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

CAUTION

Always use the coolant with the same LLC concentration.

Note: Determine the quantities of LLC based on the coolant capacity and the LLC concentration chart.
For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

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

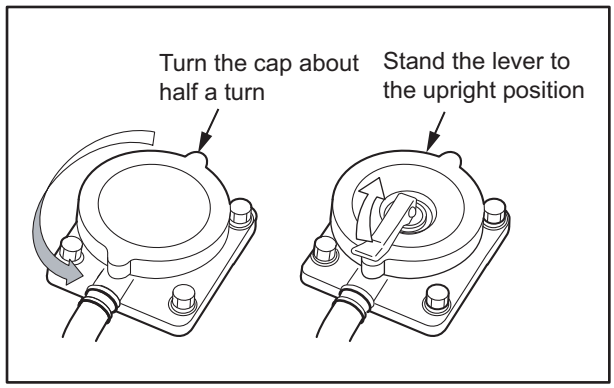

Fig. 3-17 Radiator cap

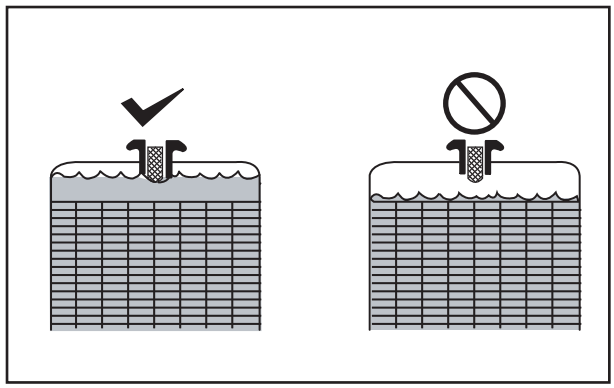

Fig. 3-18 Radiator coolant level

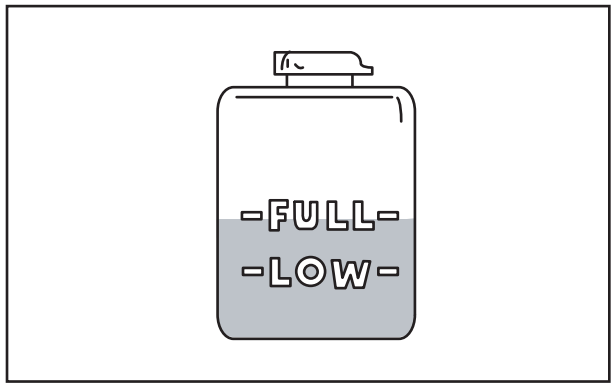

Fig. 3-19 Reserve tank coolant level

Fuel control link - Check

Check fuel control link for smooth movement.
When the manual stop lever is pulled to the direction of arrow, check that the lever can be pulled 2 mm [0.08 in.] more from the stop position.
Also check ball joint for looseness and play.

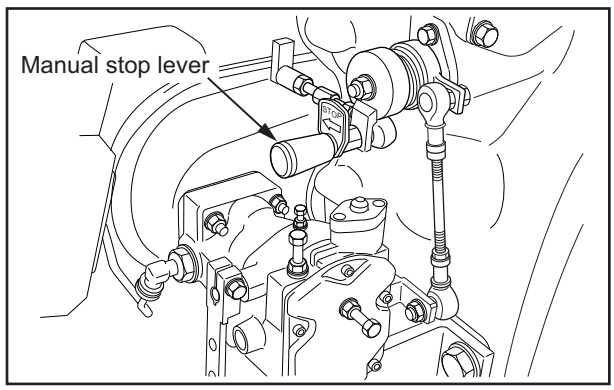

Fig. 3-20 Fuel control link - Check

Air tank - Drain water

CAUTION

There are 2 places for draining water in the air tank: drain valve on the top of air tank, and drain handle on the bottom of drain separator.

1. Open the drain valve slowly, and check that water in the tank is drained from drain pipe.
2. After water is drained and the air is discharged in the tank, tighten the drain valve firmly.
3. Loosen the drain handle on the bottom of drain separator. Check that water in the drain separator is discharged from the drain pipe.
4. Close the drain handle after draining water firmly.

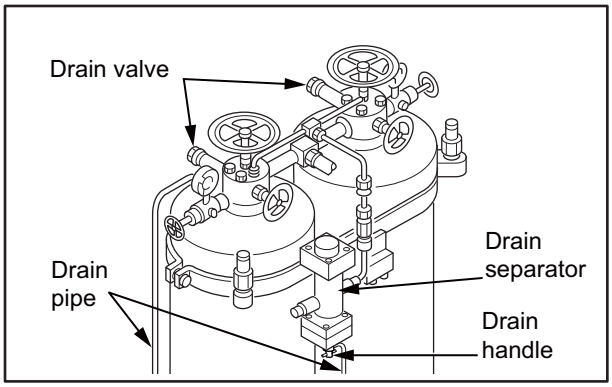

Fig. 3-21 Air tank - Drain water

Air tank air pressure - Check

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

1. Open the air pressure gauge valve.
2. Check air pressure in the air tank with air pressure gauge.
   Specified value: 2.94 MPa {30 kgf/cm^2} [427 psi]
3. Close the air pressure gauge valve.

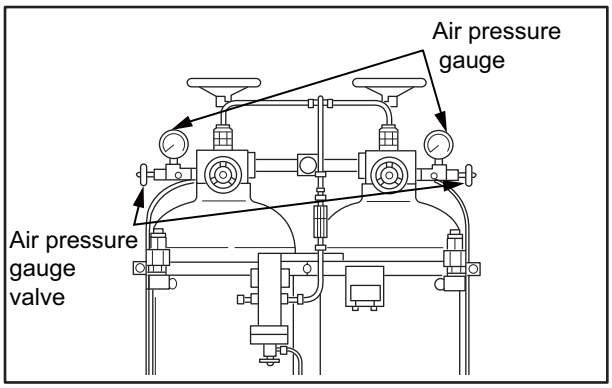

Fig. 3-22 Air tank air pressure - Check

Air cleaner - Check

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

Note: For cleaning of the air cleaner element, refer to "Air cleaner element - Clean, Check and Replace" (8-18).

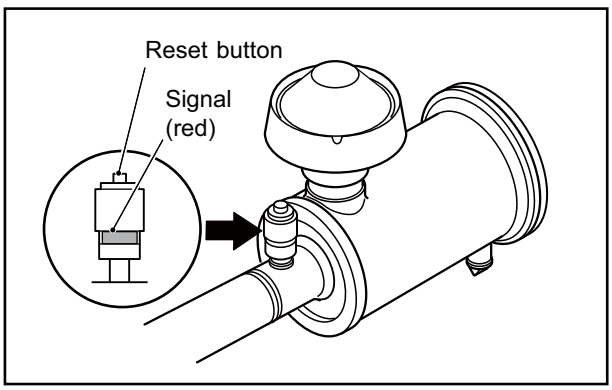

Fig. 3-23 Air cleaner - Check

Temperature of damper - Check

Damper temperature management by thermo label

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

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

CAUTION

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

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

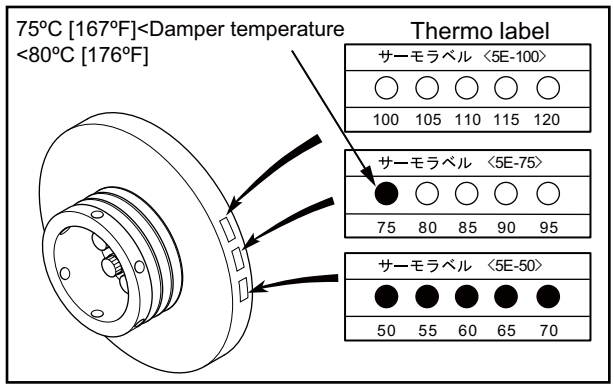

Fig. 3-24 Thermo label of damper

Starting

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

⚠ WARNING

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

CAUTION

Do not apply a load to the engine at starting. (Disengage the clutch if installed.)

Continuous operation of the starter will drain the battery power and cause the starter to seize. Do not use the starter for more than 10 seconds at a time. When the engine does not start, wait for more than one minute before cranking again.

Warming-up operation

⚠ WARNING

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

CAUTION

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

Do not turn the battery switch to OFF. Turning off the battery switch while the engine is in warm-up operation not only stops the instrument operations but also may deteriorate the alternator diode and regulator.

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

During warming-up operation, do not operate the engine in an overloaded condition (if overloaded, black smoke is exhausted). Overloading causes not only high fuel consumption but also excessive carbon deposits inside the engine. Carbon deposits cause various problems and will shorten the service life of the engine.

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

Checking engine oil pressure

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

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

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

External inspection during warm-up

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

Operation

Cautions when operating

⚠ WARNING

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

⚠ CAUTION

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

CAUTION

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

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

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

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

Inspection during operation

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

Check for abnormal engine noises or vibrations such as knocking.

Check the color of exhaust gas from the exhaust muffler.

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

Table 3-2 Standard values at rated speed

Item	Reference value
Engine oil pressure	0.39 MPa {4 kgf/cm^2} [57 psi] or more
Coolant temperature	70 to 90°C [158 to 194°F]
Oil Temperature (oil pan)	110°C [230 °F] or lower
Exhaust temperature	550 °C [1022 °F] or lower
Intake air pressure	0.15 to 2.5 MPa {1.5 to 2.5 kgf/cm^2} [21 to 36 psi]

Note: (a) When the oil pressure drops below 0.29 MPa {3 kgf/cm^2} [42.7 psi] in normal operation, or below 0.10 MPa {1 kgf/cm^2} [14.2 psi] at low idling, stop the engine immediately. Be sure to locate the cause of problem and correct it before restarting the engine.

(b) When the high temperature alarm switch is activated in normal operation, change the engine operation immediately to low idling operation until the engine temperature decreases to the normal operating level. Then, operate the engine for another 5 or 6 minutes for cooling before stopping the engine. Be sure to locate the cause of problem and correct it before restarting the engine.

Stopping

⚠ CAUTION

Stopping the engine abruptly while engine parts are hot due to high-speed operation can be a cause for heat up of the engine parts and shorten the service life of the engine. Before stopping the engine, let it idle at low speed for 5 to 6 minutes to cool down, and check the engine for abnormalities.

Never accelerate the engine immediately before shutting it down.

Do not restart the engine immediately after abnormal shut down. When the engine stops with alarms, be sure to locate the cause of the problem and correct the problem before restarting the engine. After restarting the operation, check the engine for abnormalities again. If abnormalities still exist, contact your Mitsubishi dealer.

Engine stopping method changes depending on the specifications.

Follow the instructions according to the specifications of the equipment.

Emergency stop

⚠ CAUTION

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

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

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

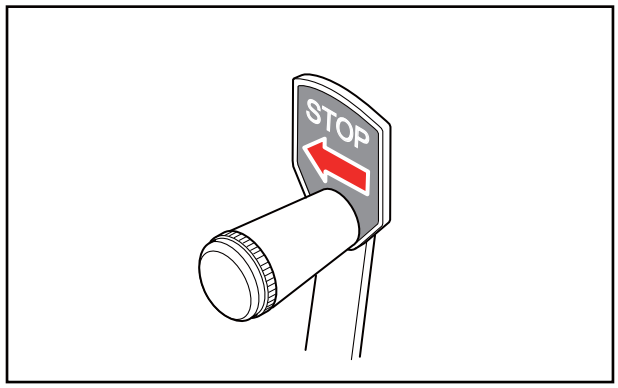

Fig. 3-25 Manual stop lever

Inspection after stopping

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

Recommended fuel

WARNING

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

Use a diesel fuel that meets "ASTM diesel fuel oil No.2-D" (JIS K2204 diesel fuel).
It is necessary to use fuel that has a pour point suitable for the ambient temperature. Choose the fuel type from the following chart.

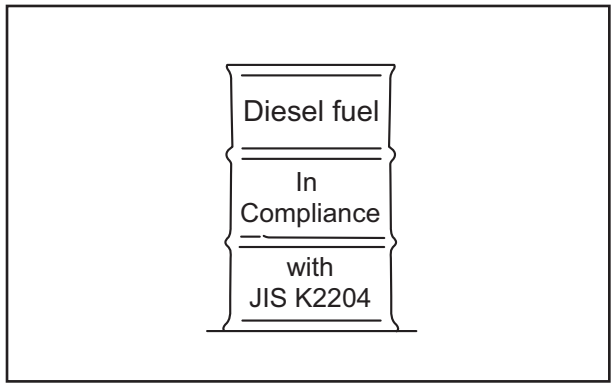

Fig. 4-1 Recommended fuel

Table 4-1 Recommended fuel

Specification	Classification
JIS K2204, 2205	TYPE 1, TYPE 2, TYPE 3
ASTM D975	No.1-D, No.2-D
BS 2869	CLASS A1, CLASS A2
DIN 51601	DIESEL-FUEL
ISO 8217	DMX-CLASS

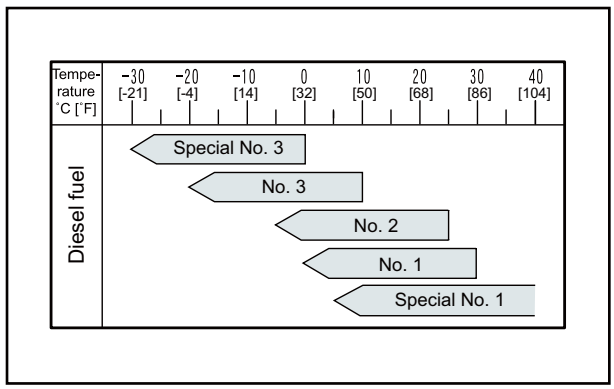

Fig. 4-2 Recommended fuel according to ambient temperature

Handling fuel

When using fuel stored in a storage tank, leave it to sit for more than 24 hours so that dust and water can settle at the bottom. Then, use the upper clean fuel.
Fill up the fuel tank or service tank after each operation.
This prevents water from mixing with fuel in the tank and also gives time for dust and water to separate and settle at the bottom of the tank.
Before refilling, clean the areas around the caps thoroughly and remove the caps from the drum and tank. Also clean your hands and the hose before refueling. When using a hand-operated pump, be careful not to pump water or sediment accumulated at the bottom of the storage tank.
Be sure to use a strainer when filling fuel tank. For a complete filtration, it is recommended to use a clean lint-free cloth together with the strainer.

Table 4-2 Recommended and limit values of fuel property

Properties		Recommend value	Limit value	Properties
Flash point		As stipulated by regulation	As stipulated by regulation	JIS K 2204, 2205 Diesel fuel: 50 °C [122°F] or higher
Distil-lation	Initial boiling point	170°C [338°F] or above	170°C [338°F] or above	JIS K 2254
	90 % distillate temperature	330 to 380°C [626 to 716°F]	330 to 380°C [626 to 716°F]	
Pour point		6°C [42.8°F] minimum below ambient temperature	6°C [42.8°F] minimum below ambient temperature	JIS K 2269
Cloud point		Below ambient temperature	Below ambient temperature	
Carbon residue (10 % bottom oil)		0.4 weight % or lower	1.0 weight % or lower	JIS K 2270
Cetane number		45 or higher	45 or higher	
Cetane index (new type)		45 or higher	45 or higher	JIS K 2280-1996
Kinematic viscosity		2.0 mm^2/s or higher at 30°C [86°F] 8.0 mm^2/s or lower at 50°C [122°F] 10.5 mm^2/s or lower at 40°C [104°F] 16.0 mm^2/s or lower at 30°C [86°F]	2.0 mm^2/s or higher at 30°C [86°F] 8.0 mm^2/s or lower at 50°C [122°F] 10.5 mm^2/s or lower at 40°C [104°F] 16.0 mm^2/s or lower at 30°C [86°F]	
Sulfur content		0.2 weight % or lower	1.0 weight % or lower	JIS K 2541 0.05 weight percent (same as diesel fuel) is recommended.
Water content and sediment		0.1 volume % or lower	0.1 volume % or lower	JIS K 2275
Ash content		0.03 weight % or lower	0.03 weight % or lower	JIS K 2272
Copper plate corrosion (100°C [212°F], 3 hrs.)		No.3 or lower	No.3 or lower	ASTM - No.3 JIS K 2513 - Discoloration No.3
Density at 15°C [59°F]		0.83 to 0.87 g/cm^3	0.80 to 0.87 g/cm^3	
Caulking		75 % carbonization or less at 250°C [482°F] 55 % evaporation or less at 230°C [446°F] Tar-free at 180°C [356°F]	Should not be carbonized 100% at 250 °C [482 °F]	Fed791B (U.S.A.) 250°C [482°F]×24Hr 230°C [446°F]×24Hr 180°C [356°F]×48Hr
Aromatics substances (by HPLC)		38 volume % or lower	38 volume % or lower	JIS K 2536 Total of aromatic content
Asphaltene		0.1 weight % or lower	0.1 weight % or lower	
Foreign substances		5.0 mg/l or lower	5.0 mg/l or lower	JIS B 9931 Including foreign substances in the fuel pipe lines

Recommended engine oil

CAUTION

Use only the engine oils recommended in this manual. Never use other oils.
The use of inappropriate or inferior oils will result in sticking of piston rings, seizure between piston and cylinder, or premature wear of bearings and moving parts, and significantly shortens the service life of the engine.

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

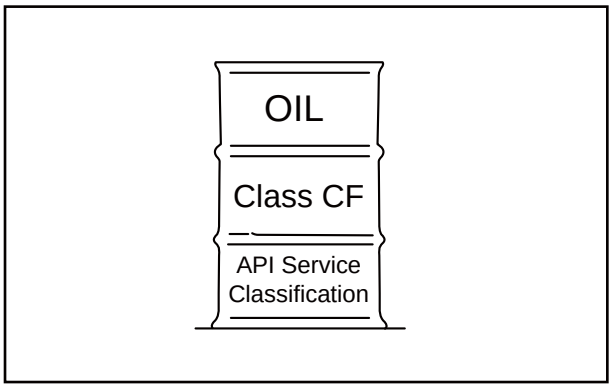

Fig. 5-1 Recommended engine oil

Handling engine oil

WARNING

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

CAUTION

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

When handling oil in greater than the legally specified quantities, be sure to have the work performed by a service station in compliance with the law. When removing oil from the engine or oil can, use an oil pump. Do not suck oil with the mouth to siphon it.
Be sure to close the cap on the oil can after use.
Keep oil in a well-ventilated place and out of direct sunlight.
Be sure to obtain the MSDS of the engine oil used and follow the instructions of the MSDS.

Properties of engine oil and its influence on engine performance

Engine oil lubricates the engine and greatly influences the performance and durability of the engine.
Distinctive differences of engine oil from other oils are that engine oil lubricates hot sections adjacent to the combustion chamber and is strongly affected by the combustion products. Engine oils, therefore, are required to have cooling, sealing, deterging, and neutralizing abilities in addition to the lubricating function.
Because diesel engines especially produce acid products such as sulfuric acid due to the sulfur content of the fuel and soot due to imperfect combustion that contaminates oils, engine oils for diesel engines must have capabilities not only to withstand severe lubricating conditions, but also to neutralize acid products to prevent them from agglomerating and depositing.
The function of performance required for engine oils is shown below:

- Good detergent dispersibility for high temperature applications, for preventing contamination and deposition of sludge and soot.
- Excellent acid neutralizing capability to inhibit oxidization due to sulfur content of fuel.
- Good oxidation stability that withstands long hours at high temperature.
- Appropriate viscosity to maintain lubricity and low temperature startability.
- Good rust and corrosion resistance to water.
- Good foam resistance to prevent the lubricating quality from lowering due to oxidation.

Main properties of engine oil

Detergent dispersibility

Engine oil performance degrades through oxidation and also by external causes. Acid products such as sulfuric acid due to sulfur content of fuel become insoluble sludge. Incomplete combustion of fuel creates soot in oil.
This sludge and soot in oil are accumulated in the groove or on the inner surface of piston rings and will result in seizure or wear of the piston rings, or it will lower heat transfer of the piston rings drastically. Dispersibility of engine oil is to disperse sludge and soot in oil in order to prevent it from depositing.

Viscosity

Oils flow with difficulty at lower temperatures, and flow smoothly at high temperatures. The oil viscosity is a property that indicates resistance to flow. This property of viscosity directly relates to low temperature startability, lubricity, fuel consumption by friction loss, and oil consumption.
For identification of an oil's viscosity, SAE (Society of Automotive Engineers) numbers are widely used. The property of engine oils is identified not only by viscosity number that shows thickness and thinness of viscosity at particular temperature, but also by viscosity index that shows the changes in oil viscosity with changes in temperature.
The viscosity of engine oil identified by the number of SAE shows the thickness or thinness of viscosity at particular temperature.
When the viscosity index of oil is high, it means the change of viscosity due to temperature is small.
The viscosity index (VI)-100 of oil is generally applied to diesel engine oil. Oils indicated by, for instance, VI-100 are called single grade oil, which fall under one range of viscosity. There are also oils called "multi-grade oil" for which viscosity falls under two ranges of viscosity and they are indicated by, for instance, SAE 15W-40, which means that at a lower temperature, the oil has 15W grade, and at a higher temperature it has a 40W grade. ("W" indicates the suitability of oil for colder temperature). In other words, SAE15W-40 indicated on oil demonstrates SAW15 grade of viscosity at a lower temperature and 40 grade viscosity at a higher temperature.

Selection of oil viscosity

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

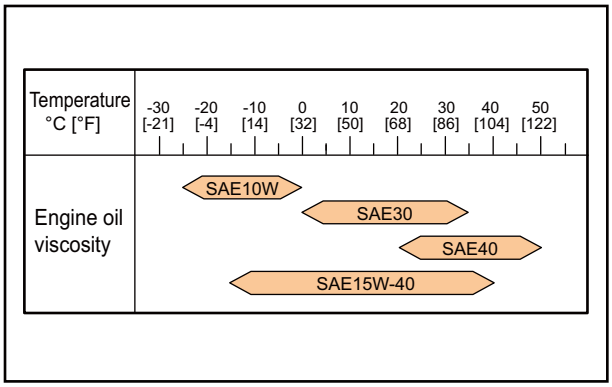

Fig. 5-2 Selection of oil viscosity

Definition of properties of engine oil

Viscosity

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

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

Total base number

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

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

Total acid number

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

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

Water content

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

Flash point

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

Insoluble

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

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

Service limits of engine oil

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

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

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

Table 5-1 Engine oil properties

Properties		Standard value	Test method
Viscosity	mm^2/s@100°C [212°F]	+30% or less -15% or more of new oil	JIS K 2283
Total base number	mgKOH/g	2.0 or more with hydrochloric acid (HCL) method 1/2 of new oil or more with perchloric acid (PCA) method	JIS K 2501
Total acid number	mgKOH/g	Up to +3.0 of new oil	JIS K 2501
Water content	Vol %	Maximum 0.2	JIS K 2275
Flash point (open cup)	°C [°F]	Over 180 [356]	JIS K 2265
Pentane insoluble	Wt %	Maximum 0.5	Comply with ASTM D893
Pentane insoluble coagulated	Wt %	Maximum 3.0	Comply with ASTM D893

Engine oil analysis service

For a long term service life of engine, Mitsubishi Heavy Industries, Ltd. offers an engine oil analysis service.

The service includes special oil sampling tools, the sample oil analysis and result data.

The engine oil analysis service provides the followings:

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

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

How to order engine oil sampling tool set

The oil sampling pump is reusable, but oil sampling bottle and suction pipe must be replaced each time.

For replacing tools, order them through the regular part supply system. The analysis fee is included in the price of the sampling bottle.

Therefore, if you sample the oil in other bottles, you will not receive our analysis service.

Also, note that optional analysis requires additional charge.

Table 5-2 Engine oil sampling tool set

Product name	Parts No.	Remarks
Engine oil sampling set	36291-19100	Contains oil sampling pump, pipes and bottles
Engine oil sampling kit	36291-00098	1 Carton:6 bottles Includes suction pipes and oil sample bottle

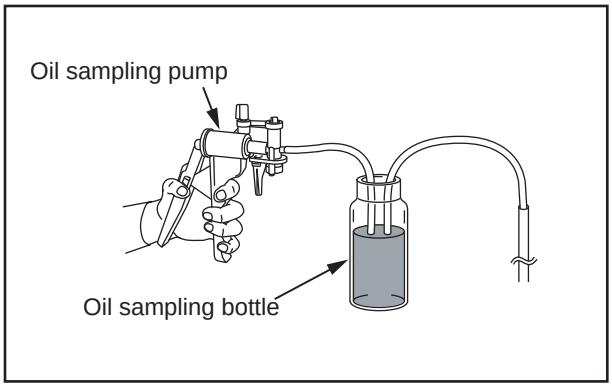

Fig. 5-3 Engine oil sampling tool set

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

Recommended water for coolant

Use soft water for the engine cooling system. The water quality must meet the requirements in the Table below.

Basically, the water quality should be within the recommended value, however, up to the limit is acceptable.

Table 6-1 Water quality standards

Item	Chemical symbol	Unit	Recommend value	Limit value	Main adverse effect	
					Corrosion and rust	Scale\ formation
PH (25 °C [77 °F])	-	-	6.5 to 8.0	6.5 to 8.5	○	○
Electrical conductivity (25°C [77°F])	-	mS/m	< 25	< 40	○	○
Total hardness	$CaCO_3$	ppm	< 95	< 100	-	○
M alkalinity	$CaCO_3$	ppm	< 70	< 150	-	○
Chlorine ion	Cl^-	ppm	< 100	< 100	○	-
Sulfuric acid ion	SO_4^{2-}	ppm	< 50	< 100	○	-
Total iron	Fe	ppm	< 1.0	< 1.0	-	○
Silica	SiO_2	ppm	< 30	< 50	-	○
Residue from evaporation	-	ppm	< 250	< 400	-	○

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

Long life coolant (LLC)

⚠ CAUTION

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

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

Genuine LLC

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

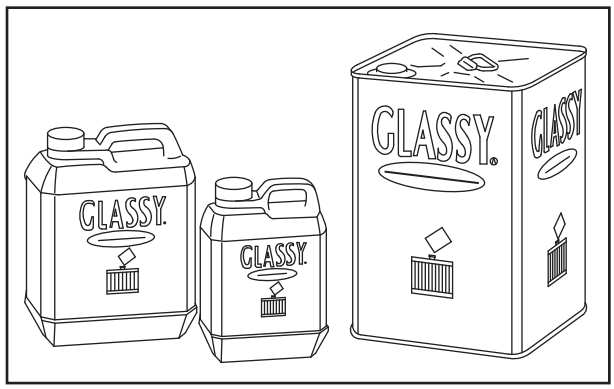

Fig. 6-1 GLASSY - LLC

Other brand LLCs

CAUTION

Never mix genuine Mitsubishi LLC with other brand LLCs. Mixing with other brand LLCs degrades the performance of the genuine Mitsubishi LLC.

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

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

Before purchasing commercial LLC, be sure to discuss the suitability of LLC with the LLC supplier.

Use only all-season LLC (non-amine type). Do not use antifreeze alone instead of LLC.

Standard for other brand LLC

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

General demands of LLC

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

LLC specification

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

Table 6-2 LLC specification

Property				Standard value
External				Not precipitation
Density				Minimum 1.112 g/cm^3 (20/20 °C) [68/68 °F] (Stock solution)
Water content				Maximum 5.0 wt % (Stock solution)
Frozen temperature		30 vol %		Maximum -14.5 °C [6 °F]
		50 vol %		Maximum -34.0 °C [-29 °F]
Boiling temperature				Minimum 155 °C [311 °F] (Stock solution)
pH				7.0 to 11.0 (30 vol %)
Bubbling character (ASTM D3306-01)		30 vol %		Maximum 4.0 ml
		33 1/3 vol %		Maximum 150 ml, Disappearance of bubble within 5 sec.
Hard water adaptability				Maximum 1.0 (50 vol %)
Metallic causticity (88 ± 2°C [190 ± 3.6°F], 336 ± 2 Hr, 30 vol % (E.G), 50 vol % (P.G))	Test Piece	Mass change	Aluminum	±0.30 mg/cm^2
			Cast iron	±0.15 mg/cm^2
			Steel	±0.15 mg/cm^2
			Brass	±0.15 mg/cm^2
			Solder	±0.30 mg/cm^2
			Copper	±0.15 mg/cm^2
		External of test piece after the examination		Not corrosion on surface excluding between test piece and spacer. Discoloration is OK.
	Bubbling while examination			Not bubbling overflow
	Properties of liquid after the examination	pH		6.5 to 11.0
		pH change		± 1.0
		Precipitation		Maximum 0.5 vol %
		External of liquid		Not remarkable discoloration, separation and gel.
Circulation metallic causticity (98 ± 2°C [208 ± 3.6°F], 1000 Hr, 30 vol % (E.G), 50 vol % (P.G))	Test Piece	Mass change	Aluminum, Cast iron, Steel, Brass, Solder, Copper	±0.30 mg/cm^2
		External of test piece after the examination		Not corrosion on surface excluding between test piece and spacer. Discoloration is OK.
	Properties of liquid after the examination	pH		7.0 to 9.0
		pH change		± 1.0
		Pre-alkalinity change		± 15%
		Precipitation		Maximum 1.0 vol %
		External of liquid		Not remarkable discoloration, separation and gel.
		Density of ion	Fe, Cu, Al, Zn, Pb, NH_4^+	Maximum 10 ppm

Table 6-2 LLC specification

Property				Standard value
Circulation metallic causticity (88 ± 3°C [190 ± 5.4°F], 1000 ± 2 Hr, 30 vol % (E.G))	Test Piece	Mass change	Aluminum	±0.60 mg/cm^2
			Cast iron	±0.30 mg/cm^2
			Steel	±0.30 mg/cm^2
			Brass	±0.30 mg/cm^2
			Solder	±0.60 mg/cm^2
			Copper	±0.30 mg/cm^2
		External of test piece after the examination		Not corrosion on surface excluding between test piece and spacer. Discoloration is OK.
	Properties of liquid after the examination	pH		6.5 to 11.0
		pH change		Maximum ±1.0
		External of liquid		Not remarkable discoloration, separation and gel.
	Condition of parts	Pump seal		Not trouble while the examination
		Inside of pump case and blade		Not remarkable corrosion
Rubber adaptability (30 vol %, 115 °C [239 °F], 360 Hr)	Silicon	Tensile strength change		-60 to 0%
		Elongation change		-40 to +20%
		Volume change		0 to +40%
		Hardness change		-20 to +10%
	Acrylonitrile butadiene rubber	Tensile strength change		0 to +10%
		Elongation change		-15 to +15%
		Volume change		0 to +40%
		Hardness change		-10 to 0%
	Ethylene propylene diene monomer	Tensile strength change		0 to +10%
		Elongation change		-30 to 0%
		Volume change		0 to +10%
		Hardness change		-10 to 0%
Storage stability vol % (30 vol %, room temperature, 6 Hr)				Maximum 0.3

Maintenance of LLC

⚠ CAUTION

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

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

Replacement intervals of LLC

CAUTION

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

Failure to renew LLC may cause malfunctions due to deterioration of anti-corrosive performance and cavitation.

The coolant containing LLC recommended in this manual should be renewed every 8000 hours or 2 years, whichever comes first, for a regular-use or general-purpose engine.

LLC concentration

When determining the LLC concentration, provide a margin of 5 °C [41 °F] below the expected lowest temperature in your region.

LLC of less than 30% concentration does not provide sufficient corrosion protection. If the LLC concentration is lower than 10%, it may accelerate corrosion.

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

Table 6-3 Recommended LLC concentration

Item	Type	External	Lowest ambient temperature (°C [°F])			
			-10°C [14°F] or above	-20°C [-4°F] or above	-30°C [-22°F] or above	-45°C [-49°F] or above
LLC concentration (%)	GLASSY	Green	30	40	50	60
	PG GLASSY	Red	40	55	70	-

Note: (a) When ambient temperature is -30°C [-22°F] or below, use Mitsubishi genuine LLC "GLASSY long life coolant (Ethylene glycol type)".

(b) The concentration above is based on Mitsubishi genuine LLC "GLASSY long life coolant (Ethylene glycol type)" or "PG GLASSY long life coolant (Non-amine type)".
For determining the accurate LLC concentration, refer to the instructions for the LLC used.

Importance of LLC

Today's trend is toward smaller and lighter engines offering greater output, lower fuel consumption and lower exhaust emission levels.
Conditions to which engine coolant is subjected, therefore, are becoming severer due to longer operating hours, higher coolant temperature and higher coolant circulating speed.
Many different materials such as steel, aluminum, copper, solder and rubber are used in the cooling system, and they are also subjected to the severe conditions described above. Those materials have different ionization characteristics, and this difference accelerates corrosion through the medium of engine coolant. To prevent such a problem, the use of LLC (long life coolant) that contains anti-corrosive additive is very important.

Characteristics of LLC additive and important notes

LLC contains several chemicals in such proportions as to produce chemical reactions that suppress corrosion (ionization) of engine parts in contact with the coolant. LLC loses its effectiveness by hours of use as well as lapse of time.
Moreover, if the chemicals are not maintained, certain chemicals in the LLC become rapidly used up and result in dissolution of metals instead of protecting metals from corrosion. Consequently, other corrosion preventing chemicals react with dissolving metals and accelerate corrosion. This condition generates more severe corrosion than when plain soft water is used. This is a typical problem caused by the use of inappropriate LLC.

Examples of abnormalities caused by LLC

Pitting of iron parts

Amines are generally effective in suppressing the rusting of ferrous metals, but they are said to cause problems for copper parts.
Dissolved copper (copper corrosion) in the cooling system deposits on iron parts and the copper deposits cause corrosion and then pitting on iron parts that have a high ionization characteristics due to galvanic or local-cell action.

Corrosion of aluminum parts

Silicate is highly effective in protecting aluminum against rusting. However, it is unstable in a solution in which the pH is 9 or lower, and can turn to gel and precipitate in the solution. For this reason, the pH is usually specified to be about 10 to ensure a high alkaline level.
This means, after silicate is used up, the high alkalinity causes chemical attacks on aluminum. To prevent this problem, proper maintenance of the coolant is required. For case example, rapid wear of mechanical seals in the water pump due to secondary effects of silicate gel formed. Corrosion of aluminum parts after silicate is consumed.

Pitting and clogging of the radiator

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

Chapter 7 MAINTENANCE SCHEDULE

How to use the maintenance schedule

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

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

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

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

Items marked with * in the maintenance schedule require special tools or large equipment. For the servicing of those items, contact your 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 once every year. 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 regular use engine

Table 7-1 Periodic maintenance chart for regular use engine

Interval and Service item		Page
Every 50 service hours or every month	Fuel tank - Drain water	8-5
	Water separator - Drain water	8-7
First 50 service hours for a new or overhauled engine	Bolts and nuts on the engine - Retighten	*
	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.	8-11
Every 250 service hours	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.	8-11
First 250 service hours for a new or overhauled engine	Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*
Every 1000 service hours	Fuel filter - Replace	8-9
	Water separator - Inspect and Replace	8-7
	Gauze filter - Clean	8-7
	V-belt and belt tension - Inspect and Adjust	8-2
Every 2000 service hours	Fuel tank - Drain water (Replace parts as necessary)	8-5
	Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*
	Fuel injection timing - Inspect and Adjust	*
	Fuel injection nozzle - Nozzle tip replacement (Check the spray condition and adjust the fuel injection pressure after replacement)	*
	Checking Movement of the Rack (during operation) of the fuel injection pump (including the governor)	*
	Fuel pipe - Inspect	8-10
	Oil pipe - Inspect	8-13
Every 4000 service hours	Top end of the engine - Overhaul Remove the cylinder head, and inspect and service the combustion chambers.	*
	Turbocharger - Inspect	8-16
	Damper - Inspect	8-3
	Starter - Inspect	8-20
	Protection devices operation - Inspect	*
	Unit seal and Oil seal of water pump - Replace	*
	Checking LLC concentration level in the coolant	*

Table 7-1 Periodic maintenance chart for regular use engine

Interval and Service item		Page
Every 8000 service hours	Engine - Major overhaul Disassemble engine, clean, check and change major parts. [Parts to be changed] Inlet and exhaust valves, inlet and exhaust valve seats, valve rotators, valve cotters, rocker arm adjusting screws, valve push rods, bridge caps, camshaft bushings, camshaft expansion plugs, main bearings, cylinder liners, main bearing cap bolts and washers, piston rings, connecting rod bearings, damper, crankcase thrust plate and consumable items (gaskets, oil seals, O-rings, etc.) [In second overhaul, replace the following parts in addition to the parts listed above] Cylinder head bolts, valve guides, valve bridge guides, valve bridges, valve springs, tappets, camshaft thrust plates, pistons, piston pins, connecting rod bolts, connecting rod bushings, rocker bushings, fuel pipe assembly, oil pipe assembly	*
	Fuel injection pump - Inspect and Test (Replace parts as necessary)	*
	Governor - Inspect and Test (Replace parts as necessary)	*
	Protective Devices - Repair or Replace High coolant temperature, low oil pressure, overspeeding, starting failure, water supply failure, undervoltage, overvoltage, overcurrent, low coolant level in tank, low fuel level in tank, low air pressure in tank, etc.	*
	Auxiliary devices operation - Check Water heater, oil heater, oil priming pump, fuel transfer pump, governor motor, etc.	*
Every 8000 service hours or every 2 years	Coolant - Change	8-14
As required	Fuel system - Bleed air	3-2
	Radiator fins - Check and Clean	8-15
	Pre-cleaner - Clean, Inspect and Replace	8-17
	Air cleaner element - Clean, Check and Replace	8-18
	Cleaning the Inside of the Engine Breathers	*
	Stop solenoid - Inspect or Replace	*
	Couplings - Inspect or Replace	*
	Inspecting the Vibration-isolating Rubber	*

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

Periodic maintenance chart for emergency engine

Table 7-2 Periodic maintenance chart for emergency engine

Interval and Service item		Page
Every week	Engine external - Inspect (Check for leakage of fuel, oil and coolant)	3-8
	Fuel tank oil level - Check	3-9
	Engine oil level - Check	3-9
	Coolant level - Check	3-10
	Air tank air pressure - Check (air motor type or direct inlet type)	3-11
	Water leakage of air cooler - Inspect	-
	Operating the engine for maintenance (operate the engine under no load for 5 to 10 minutes) Check for ease of starting, color of exhaust smoke, abnormal vibration, abnormal noise, abnormal smell and gauge indication (oil pressure gauge, coolant temperature gauge, oil temperature gauge, exhaust temperature gauge, tachometer, etc.)	-
Every month	Engine Oil for Mixing of Fuel and Water - Inspect	8-12
	Clean fuel filter (wire element type) - Clean (Turn handle one or two times.)	-
	Fuel control link - Check	3-10
	Battery electrolyte level - Inspect	3-6
	Air tank - Drain water	3-11
	Air compressor oil level - Inspect and Refill	-
	Conducting Engine Maintenance Operation (Operate the engine with more than 1/2 load for 15 to 30 minutes) Check for ease of starting, color of exhaust smoke, abnormal vibration, abnormal noise, abnormal smell and gauge indication (oil pressure gauge, coolant temperature gauge, oil temperature gauge, exhaust temperature gauge, tachometer, etc.) Check fuel injection pump and hydraulic and electronic governor rack movement	-
Every 6 months	Checking LLC concentration level in the coolant	*
	Cleaning the Inside of the Coolant Tank	-

Table 7-2 Periodic maintenance chart for emergency engine

Interval and Service item			Page
Every 1 year	Engine mechanical	V-belt and belt tension - Inspect and Adjust	8-2
		Bolts and nuts on the engine - Check and Retighten	*
		Damper - Inspect	8-3
		Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*
		Inspecting the Vibration-isolating Rubber	*
		Foundation Bolts - Inspect	*
		Couplings - Inspect or Replace	*
	Fuel system	Fuel tank - Drain water	8-5
		Water separator - Drain water	8-7
		Fuel filters (wire-element type) - Drain water	8-8
		Fuel Injection Nozzle Spray Condition and Spray Pressure - Inspect and Adjust	*
		Fuel injection timing - Inspect and Adjust	*
		Fuel pipe - Inspect	8-10
	Engine Lubricating system	Oil pipe - Inspect	8-13
		Engine Oil Properties - Analyze	*
		Engine Oil Pressure (Maintenance operation) - Inspect and Adjust	*

Table 7-2 Periodic maintenance chart for emergency engine

Interval and Service item			Page
Every 1 year	Cooling system	Water pump - Inspect	*
		Electromagnetic Valve and Pressure Reducing Valve of the Cooling System - Inspect, Disassemble and Clean	*
		Strainer (including with/ball tap) of Cooling Water - Inspect, Disassemble and Clean	*
		Coolant Properties (when only soft water is used) - Inspect (Change coolant according to the analysis results)	*
	Air intake system	Air cleaner element - Clean, Check and Replace	8-18
		Pre-cleaner - Clean, Inspect and Replace	8-17
	Electrical system	Starter - Inspect	8-20
		Alternator - Inspect	8-20
		Specific gravity of battery electrolyte - Check	3-6
		Air Heater - Inspect	-
	Air starter system	Air strainer - Drain water and Clean	8-21
		Air tank - Inspect safety valve operation	8-21
		Air starter valve - Inspect	*
		Electromagnetic Valve and Pressure Reducing Valve - Inspect and Clean	*
		Air distribution valve - Inspect	*
		Air compressor belt tension - Inspect	*
	Protection devices operation - Inspect High coolant temperature, low oil pressure, overspeeding, starting failure, water supply failure, undervoltage, overvoltage, overcurrent. low coolant level in tank, low fuel level in tank, low air pressure in tank, etc.		*
	Auxiliary devices operation - Check Engine control, fuel transfer pump, governor motor, room ventilating fan, solenoid, storage pump, water tank ball tap, water heater, oil heater, oil priming pump, etc.		*
Every 2 years	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.		8-11
	Fuel filters (wire-element type) - Clean		8-8
	Fuel filter - Replace		8-9
	Water separator - Inspect and Replace		8-7
	Gauze filter - Clean		8-7
	Fuel control linkage ball joint - Inspect (Replace parts as necessary)		8-6
	Coolant - Change		8-14
	Thermostat - Inspect		*
	Turbocharger - Inspect		8-16
	Draining water from the exhaust muffler		8-16
	Air compressor overhaul (air motor type or direct inlet type)		*

Table 7-2 Periodic maintenance chart for emergency engine

Interval and Service item		Page
Every 4 years	Top end of the engine - Overhaul Remove the cylinder head, and inspect and service the combustion chambers.(If the abnormalities of first and second cylinders are found, inspect all cylinders.)	*
	Checking oil cooler for contamination, clogging and leakage	*
	Checking Oil Pump for Discoloration and Other External Defects	*
	Governor oil filter - Replace	8-13
	Fuel tank - Clean	8-5
	Fuel injection pump - Inspect and Test (Replace parts as necessary)	*
	Governor - Inspect and Test (Replace parts as necessary)	*
	Radiator fins - Check and Clean	8-15
	Rubber hose - Replace	*
	Pre-cleaner - Clean, Inspect and Replace	8-17
	Air cleaner element - Clean, Check and Replace	8-18
	Instruments - Repair or Replace Oil pressure gauge, coolant temperature gauge, oil temperature gauge, exhaust temperature gauge, tachometer	*
Every 8 years	Engine - Major overhaul Disassemble engine, clean, check and change major parts.	*
	Damper - Replace	*
	Oil pump - Repair or Replace	*
	Fuel injection nozzle - Nozzle tip replacement (Check the spray condition and adjust the fuel injection pressure after replacement)	*
	Rubber parts and O-rings - Replace	*
	Unit seal and Oil seal of water pump - Replace	*
	Turbocharger - Disassemble and Inspect	*
	Air cooler - Disassemble and Clean	*
	Vibration-isolating rubber - Repair or Replace	*
	Couplings - Repair or Replace	*
	Governor motor - Repair or Replace	*
	Air ventilation fan of the room - Repair or Replace	*
	Stop solenoid - Inspect or Replace	*
	Ball tap of water tank - Repair or Replace	*
	Other consumables - Replace	*

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

Periodic maintenance chart for general purpose engine

Table 7-3 Periodic maintenance chart for general purpose engine

Interval and Service item		Page
Every 50 service hours or every month	Fuel control linkage ball joint - Inspect	8-6
	Air strainer - Drain water and Clean (air motor type or direct inlet type)	8-21
	Air tank - Drain water (air motor type or direct inlet type)	3-11
First 50 service hours for a new or overhauled engine	Bolts and nuts on the engine - Retighten	*
	Engine oil, Oil filter and Bypass oil filter - Replace It is recommended to check the engine oil characteristics at the same time. The oil filters must be replaced when the filter alarm lights.	8-11
Every 250 service hours or every 1 year	Engine oil, Oil filter and Bypass oil filter - Replace The oil filters must be replaced when the filter alarm lights.	8-11
	Governor oil filter - Replace	8-13
	V-belt and belt tension - Inspect and Adjust	8-2
	Radiator fins - Check and Clean	8-15
	Draining water from the exhaust muffler	8-16
	Air tank - Inspect safety valve operation (air motor type or direct inlet type)	8-21
First 250 service hours for a new or overhauled engine	Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*
Every 1000 service hours or every 2 years	Fuel filter - Replace	8-9
	Water separator - Inspect and Replace	8-7
	Gauze filter - Clean	8-7
	Air strainer - Drain water and Clean (air motor type or direct inlet type)	8-21
	Zinc Rod - Replace	*
Every 2000 service hours or every 3 years	Bolts and nuts on the engine - Retighten	*
	Valve clearance - Inspect and Adjust (Check valve mechanism at the same time.)	*
	Fuel injection timing - Inspect and Adjust	*
	Fuel pipe - Inspect	8-10
	Oil pipe - Inspect	8-13
	Fuel injection nozzle - Nozzle tip replacement (Check the spray condition and adjust the fuel injection pressure after replacement)	*
	Protection devices operation - Inspect (high water temperature, low oil pressure, overspeed)	*
Every 4000 service hours or every 5 years	Top end of the engine - Overhaul Remove the cylinder head, and inspect and service the combustion chambers.	*
	Fuel control linkage ball joint - Inspect	8-6
	Damper - Inspect	8-3
	Air cooler - Clean	*
	Heat exchanger - Wash	*

Table 7-3 Periodic maintenance chart for general purpose engine

Interval and Service item		Page
8000 hours	Engine - Major overhaul Disassemble engine, clean, check and change major parts.	*
	Fuel injection pump - Inspect and Test (Replace parts as necessary)	*
	Governor - Inspect and Test (Replace parts as necessary)	*
	Protective Devices - Repair or Replace	*
	Auxiliary devices operation - Check	*
Every 8000 service hours or every 2 years	Coolant - Change	8-14
As required	Fuel system - Bleed air	3-2
	Air cleaner element - Clean, Check and Replace	8-18
	Pre-cleaner - Clean, Inspect and Replace	8-17

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

Engine mechanical

Engine external - Inspect

⚠ CAUTION

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

Inspect the engine exterior as described below.

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

V-belt and belt tension - Inspect and Adjust

CAUTION

If defects such as cuts or surface separations are found during inspection, replace the belt.
Keep oil and grease away from the belt, since they may cause the belt to slip and shorten the service life.
Excessive belt tension can cause rapid wear of the alternator bearing and shorten the service life of the belt.
Adjust the belt tension accurately by following the procedures below.

V-belt - Inspect

1. Inspect the V-belt visually for separation or damage. If any abnormality is found, replace the belt with a new one.
2. Inspect belt tension (deflection).
   Push the belt downward at the midway between pulleys. If the deflection is 10 to 15 mm [0.39 to 0.59 in.], the tension is correct.
   V-belt pushing force: Approx. 98 to 147 N {10 to 15 kgf} [22 to 32.4 lbf]
   If the deflection of belt is not within the standard, adjust the belt tension.

V-belt tension (Alternator side) - Adjust

1. Remove the belt cover.
2. Loosen all retaining bolts of the alternator and adjusting plate.
3. Operate the alternator to adjust the V-belt tension.
4. Tighten all retaining bolts of the alternator and adjusting plate.
5. Reinstall the belt cover.

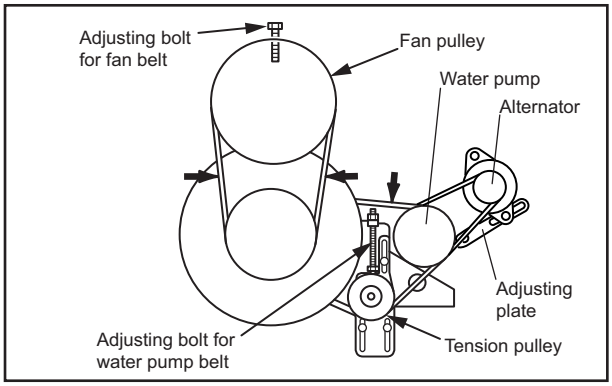

Fig. 8-1 V-belt and belt tension - Inspect and Adjust

V-belt tension (fan side) - Adjust

1. Loosen all fan bracket retaining bolts.
2. Loosen the lock nut of adjusting bolt.
3. Turn the adjusting bolt to adjust the V-belt tension.
4. After adjusting deflection, fix the lock nut.
5. Tighten all retaining bolts of the fan bracket.

V-belt tension (Water pump side) - Adjust

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

Damper - Inspect

Damper - Check visually

CAUTION

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

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

Note: If defects are found in the damper, contact your Mitsubishi dealer.

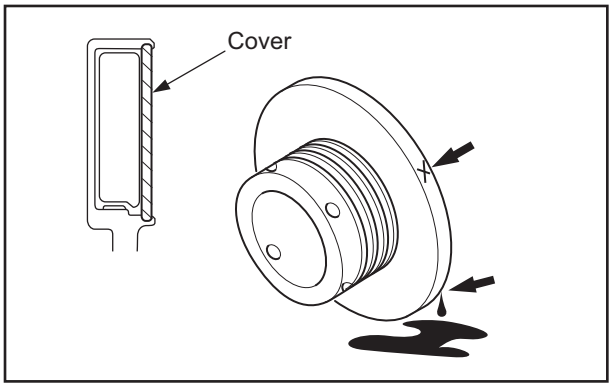

Fig. 8-2 Damper - Check visually

Damper temperature management

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

1. Make sure the temperature of the outside damper surface does not exceed the temperature that described in the following table when operating the engine with rated power for an hour.

Table 8-1 Damper temperature management

Type of damper	Continuous	Standby
Viscous damper	90°C [194°F]	100°C [212°F]
Viscous rubber damper	80°C [176°F]	90°C [194°F]

2. When installing a safety cover to damper, check ventilation carefully and make sure the damper temperature remains below the temperature specified above, with the cover in place.
3. It is recommended to use the thermo label for the temperature management of damper in regular use engine.

Thermo label - handle

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

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

1. Attach a thermo label to the periphery or front end of damper.

2. Note the maximum temperature of the thermal part of thermo label when engine stops. Note the temperature periodically, and check the abnormality of temperature alteration.

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

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

Table 8-2 Thermo label for temperature management

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

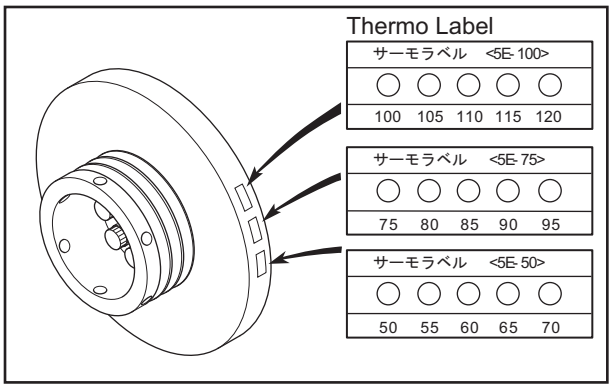

Fig. 8-3 Damper temperature management

Fuel system

Fuel system - Inspect

⚠ WARNING

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

Fuel tank - Clean

CAUTION

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

1. Close the fuel feed valve to cut off the fuel supply to the engine.
2. Prepare the fuel receiving can, place it under the drain cock.
3. Drain all fuel in the tank from drain cock on the bottom of fuel tank.
4. Clean the inside of fuel tank.
   For more information, refer to the operation manual attached to a fuel tank.
5. Add fuel to the fuel tank.
6. Open the fuel feed valve, and bleed air for the fuel system.

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

Fuel tank - Drain water

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

1. Prepare the oil pan (capacity of 2 L [0.53 U.S. gal.] or more) under the drain cock of fuel tank.
2. Open the drain cock of fuel tank and drain fuel at least 1 to 2 L [0.26 to 0.53 U.S. gal.].
3. Make sure that water and particles of foreign matter discharged with fuel. Close the drain cock.

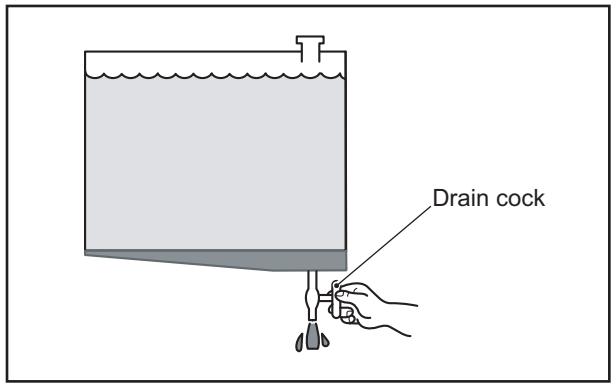

Fig. 8-4 Fuel tank - Drain water

Fuel control linkage ball joint - Inspect

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

CAUTION

If the sealed ball joints are found loosened, contact your Mitsubishi dealer. If the seal on the ball joint is broken, the warranty is invalidated.

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

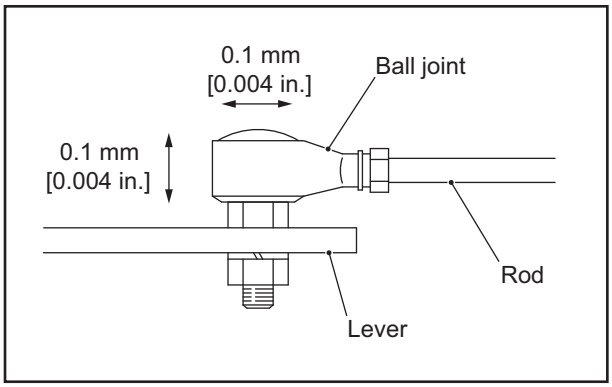

Fig. 8-5 Fuel control linkage for looseness - Inspect

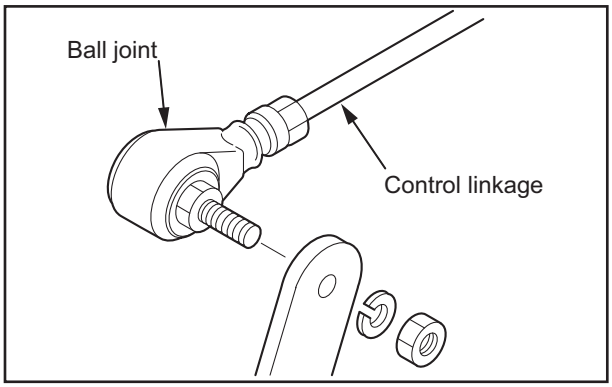

Fig. 8-6 Fuel control linkage - Remove

Water separator - Inspect and Replace

Water separator - Drain water

1. Prepare a plate, and place it under the drain cock of water separator.
2. Open the drain cock, and drain water in the water separator.
3. Close the all drain cocks after draining.

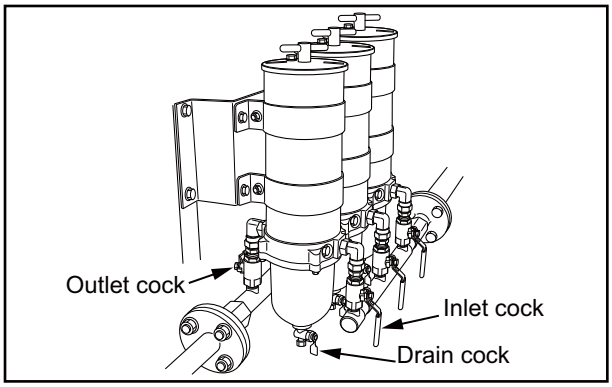

Fig. 8-7 Water separator - Drain water

Water separator element - Replace

⚠ WARNING

Open the inlet valve slowly to prevent overflowing fuel. Wrap a cloth around the water separator before the fuel may spill.

1. Close the inlet cock and outlet cock.
2. Turn the T-handle, and remove the water separator cover.
3. Open the drain cock, and drain fuel in the water separator.
4. Close the all drain cocks after draining.
5. Replace the element with a new one.
6. Fill the water separator with fuel.
7. Attach the water separator cover, and tighten the T-handle.
8. Open the inlet cock and outlet cock.

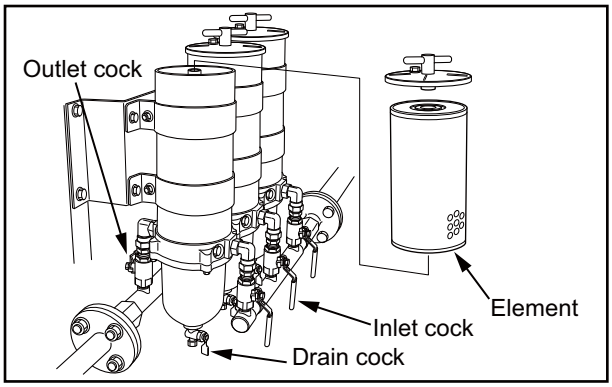

Fig. 8-8 Water separator element - Replace

Gauze filter - Clean

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

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

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

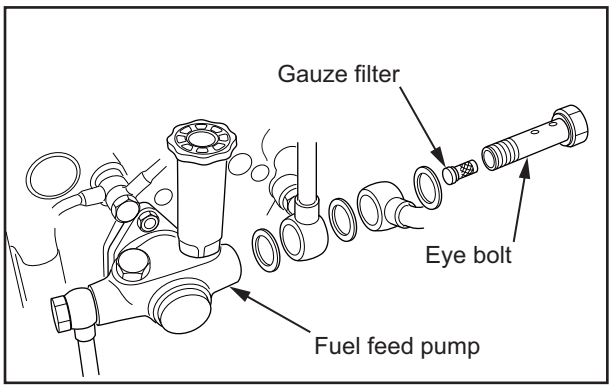

Fig. 8-9 Gauze filter - Clean

Fuel filters (wire-element type) - Drain water

⚠ WARNING

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

CAUTION

Check that the thread of the filter case and drain plug, or sealing washers. If damaged, replace them with new ones.

1. Close the fuel feed valve to cut off the fuel supply to the engine.
2. Prepare a drip pan, and place it under the fuel filters.
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: For bleeding the fuel filter, refer to "Fuel filter - Bleed air" (3-2).

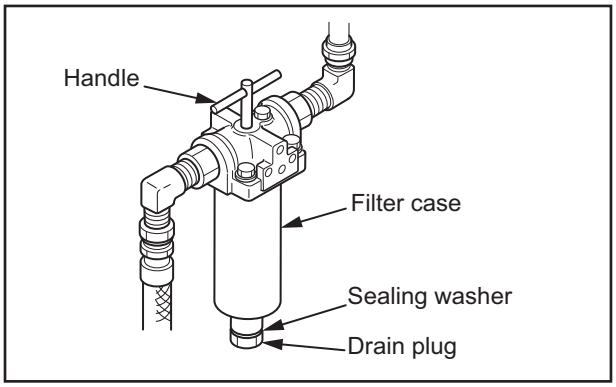

Fig. 8-10 Fuel filters (wire-element type) - Drain water

Fuel filters (wire-element type) - Clean

⚠ CAUTION

Check that the thread of the filter case and drain plug, or sealing washers. If damaged, replace them with new ones.

1. Close the fuel feed valve to cut off the fuel supply to the engine.
2. Clean the area around the fuel filters.
3. Prepare a drip pan, and place it under the fuel filters.
4. Drain fuel by removing the drain plug and the sealing washer.
5. Remove the filter case by loosening the mounting bolt at the top of the filter.
6. Remove dust and other particles from the element using the soft brush with diesel fuel.
7. Also clean inside of the case.
8. Reinstall the drain plug, the sealing washer and the filter case to the original position.
9. Bleed air from the fuel system.

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

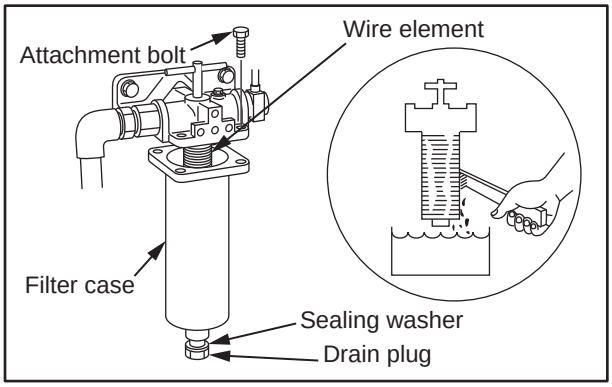

Fig. 8-11 Inside of fuel filters (wire-element type) - Clean

Fuel filter - Replace

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

WARNING

Do not use the filter of which case has dents, as it may be damaged during operation, and cause fuel leakage that becomes fire hazard.

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

CAUTION

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

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

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

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

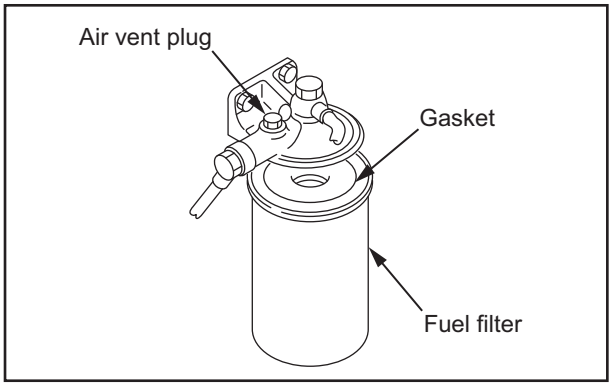

Fig. 8-12 Fuel filter - Replace

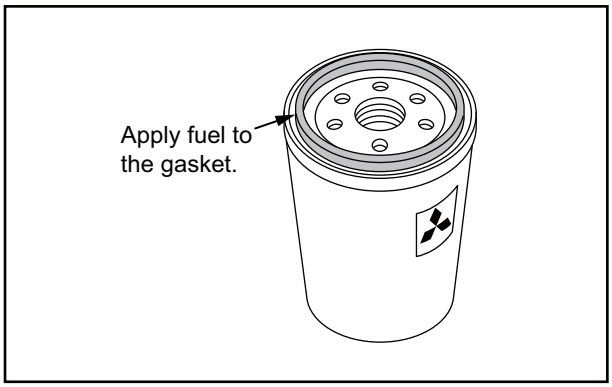

Fig. 8-13 Fuel filter

Fuel pipe - Inspect

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

Visual inspection in every 2000 service hours

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

In every major overhaul

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

In every other major overhaul

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

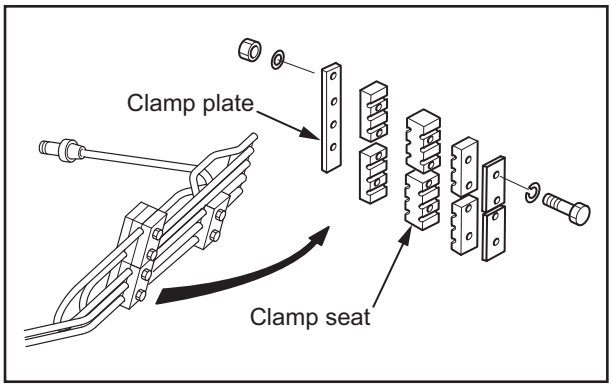

Fig. 8-14 High pressure fuel injection pipe and Clamp seat - Inspect and Replace

Low pressure fuel pipe and Clip - Inspect and Replace

Visual inspection in every 2000 service hours

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

In every other major overhaul

Replace the pipe assembly with a new one.

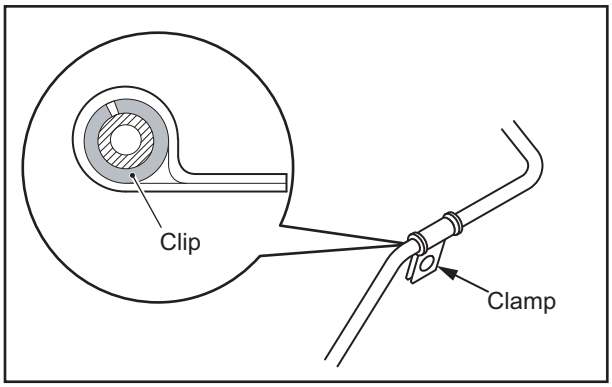

Fig. 8-15 Low pressure fuel pipe and Clip - Inspect and Replace

Lubricating system

Engine oil, Oil filter and Bypass oil filter - Replace

⚠ CAUTION

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

CAUTION

Do not dump waste oil. It is forbidden by law. Consult your Mitsubishi dealer for disposal of waste oil.

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

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

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

Engine oil - Drain

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

Engine oil - Refill

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

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

3. Check the oil level in the oil pan as follows:
4. Pull out the oil level gauge and wipe it clean with a waste cloth.
5. Insert the oil level gauge fully into the oil level gauge guide, then pull out the gauge again.
6. The correct oil level is between the MAXIMUM and MINIMUM marks on the oil level gauge.
   If the oil level is low, add engine oil of the specified type.
7. Check the oil pan and other area for oil leaks. Repair the oil leakage if any.
8. Crank the engine with the starter for 10 seconds to circulate oil throughout the engine. After 1 minute of rest period, perform the above cranking operation again to circulate oil in the engine.

CAUTION

To crank the engine, shut off the fuel supply to the engine and operate the starters.

When conducting the above cranking operation, also check the items to be inspected for the cooling system by cranking.

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

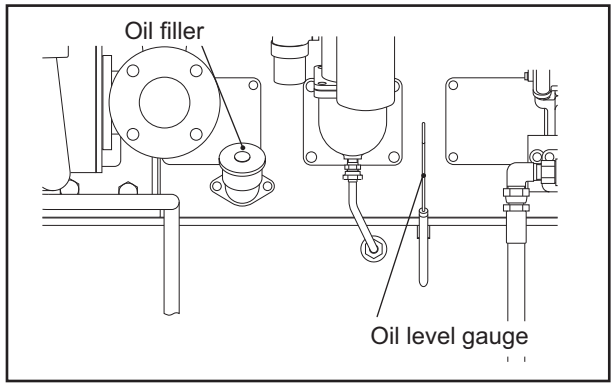

Fig. 8-16 Oil filler and oil level gauge

Oil filter and bypass oil filter - Replace

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

Note: Cut off the removed oil filters and a bypass oil filter, and check elements for metal particles. If metal particles are found, contact your Mitsubishi dealer.

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

⚠ WARNING

Do not use the filter of which case has dents, as it may be damaged during operation, and cause oil leakage that becomes fire hazard.

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

CAUTION

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

Do not dent or scratch the oil filter surfaces.

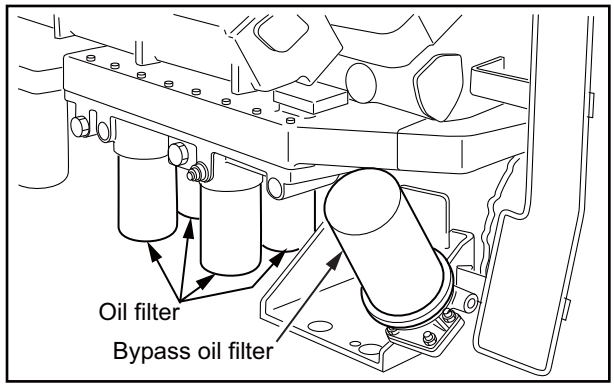

Fig. 8-17 Oil filter and bypass oil filter - Replace

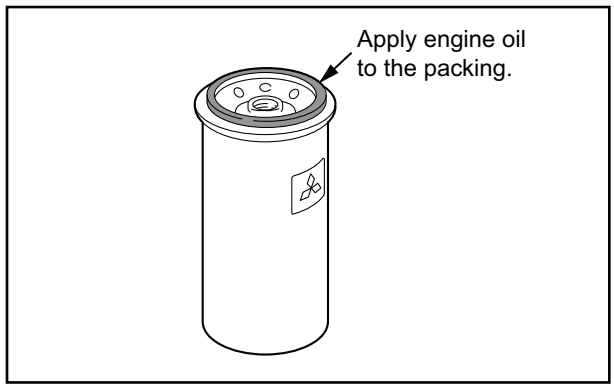

Fig. 8-18 Oil filter

Engine Oil for Mixing of Fuel and Water - Inspect

⚠ CAUTION

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

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

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

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

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

Governor oil filter - Replace

⚠ WARNING

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

1. Prepare a drip pan and place it under the governor filter.
2. Using a filter wrench, remove the governor oil filter.
3. Prepare a new governor oil filter, and clean the gasket.
4. Apply clean engine oil to gasket.
5. Screw the governor oil filter onto the filter bracket by hand.
6. Remove the plug from filter bracket, and pour engine oil until the filter is filled with out.
7. Then, reinstall the plug.
8. Operate the priming pump or wing pump to circulate engine oil. Check to make sure oil does not leak from filter mounting surface. If oil leaks, tighten the filter again.

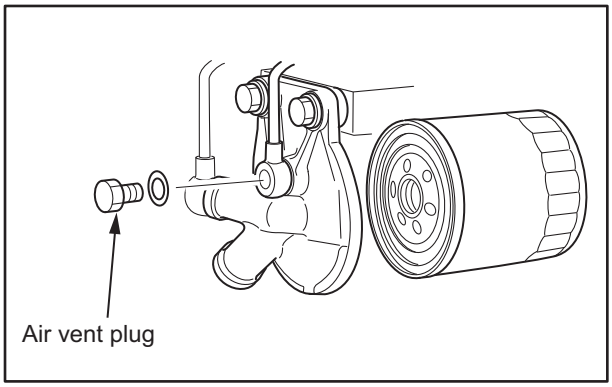

Fig. 8-19 Governor oil filter - Replace

Oil pipe - Inspect

Oil pipe and Clip - Inspect and Replace

Visual inspection in every 2000 service hours

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

In every other major overhaul

Replace the pipe assembly with a new one.

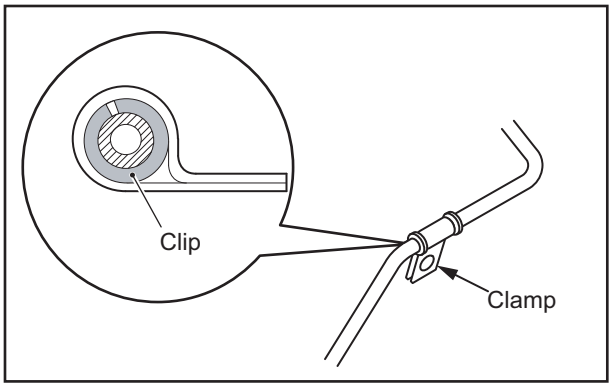

Fig. 8-20 Oil pipe and Clip - Inspect and Replace

Cooling system

Coolant - Change

⚠ WARNING

Remove the radiator cap only after the engine has cooled to room temperature. Place a waste cloth over the cap, and loosen the cap about a half-turn or stand the lever to the upright position to release internal pressure. Never open the radiator cap while the engine is hot, as it causes steam and hot coolant to blow out and could result in serious burns.
Coolant (containing LLC) drained from the engine is toxic. Never dispose of coolant into regular sewage. For disposal of used coolant, consult your Mitsubishi dealer or a industrial waste disposer.

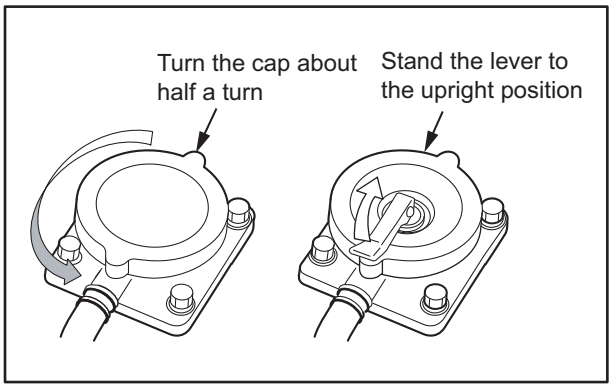

Fig. 8-21 Radiator cap

CAUTION

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

Coolant - Drain

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

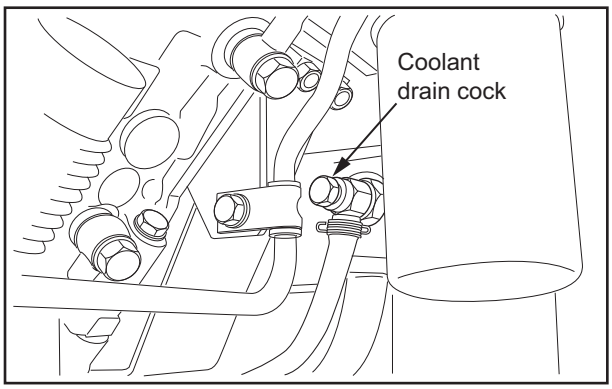

Fig. 8-22 Coolant drain cock (engine)

Cooling system - Clean

CAUTION

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

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

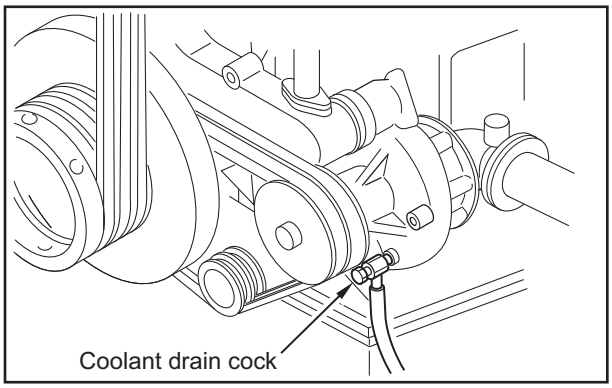

Fig. 8-23 Coolant drain plug (water pump)

Coolant - Refill

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

Note: Determine the amounts of LLC and water to be added by using the LLC concentration chart. For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

3. Pour in water (soft water with minimal impurities, such as tap water) slowly to the full level.
4. Check the radiator and other parts for coolant leaks. If a coolant leak is found, repair it.
5. When coolant reaches the full level, close the radiator cap securely.
6. Shut off the fuel supply and crank the engine for about 10 seconds or less using the starter. Wait for about 1 minute, then repeat the above cranking operation to remove air from the cooling system of the engine.

CAUTION

To crank the engine, shut off the fuel supply to the engine and operate the starters.

7. Check the coolant level in the radiator.
   If the engine is equipped with a reserve tank, fill the reserve tank with coolant to the full level as well.

CAUTION

When adding coolant, use a coolant that has the same LLC concentration as the coolant already in the radiator.

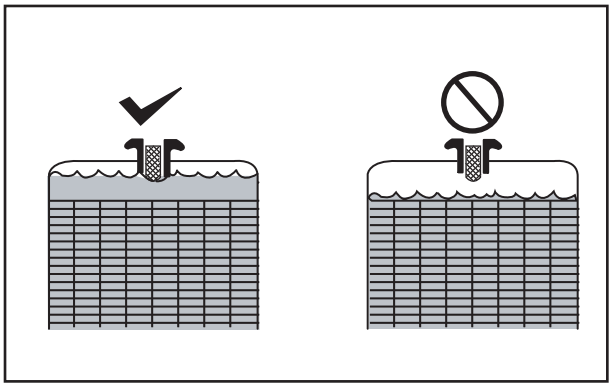

Fig. 8-24 Radiator coolant level

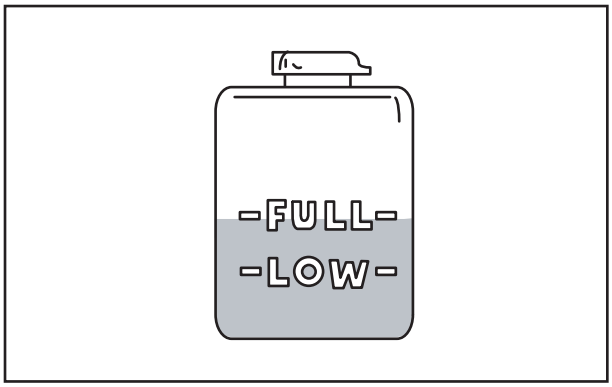

Fig. 8-25 Reserve tank

Radiator fins - Check and Clean

⚠ CAUTION

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

Check the radiator fins for holes and cracks.
To clean the radiator fins, blow compressed air from the opposite direction of the normal air flow.

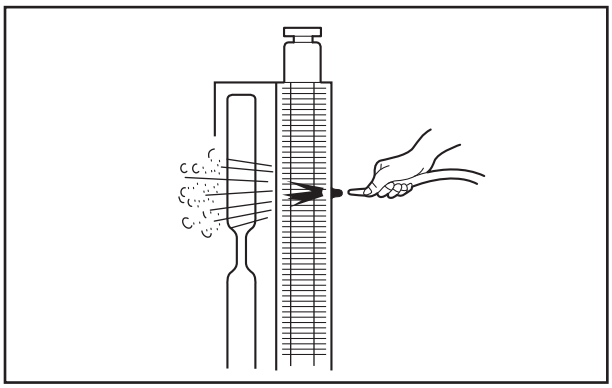

Fig. 8-26 Radiator fins - Clean

Inlet and exhaust systems

Turbocharger - Inspect

⚠ CAUTION

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

CAUTION

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

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

Note: When removing and inspecting turbocharger, contact your Mitsubishi dealer.

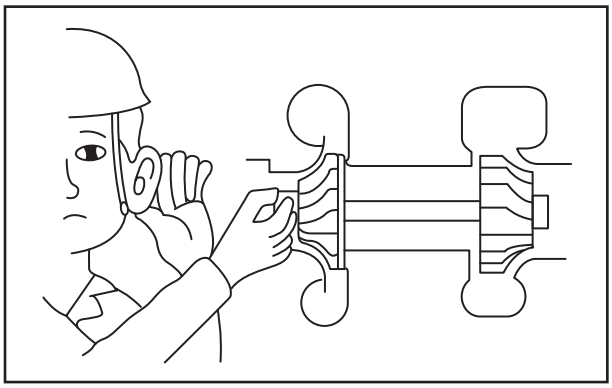

Fig. 8-27 Turbocharger - Inspect

Draining water from the exhaust muffler

⚠ CAUTION

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

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

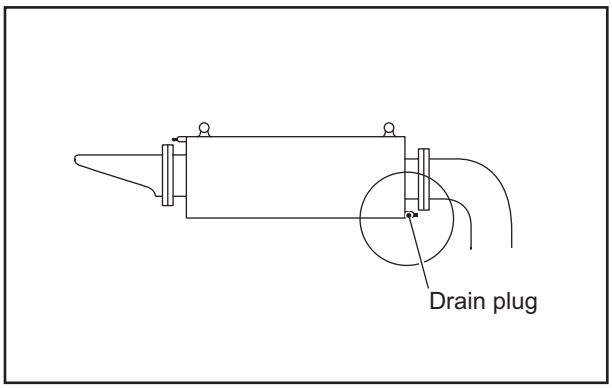

Fig. 8-28 Draining water from the exhaust muffler

Pre-cleaner - Clean, Inspect and Replace

⚠ CAUTION

Never service the pre-cleaner while the engine is running. Servicing the pre-cleaner while the engine is in operation can cause particles of foreign matter to enter the engine and result in rapid wear of parts, leading to a shorter service life of the engine.

The pre-cleaner is equipped to the silencer of the turbocharger to prevent foreign items such as dust from sucking and keep the engine clean for optimum performance. Be sure to clean the pre-cleaner as described below.

1. Remove the pre-cleaner from the silencer, and hand-wash the pre-cleaner with a mild detergent.
2. Rinse the pre-cleaner with fresh water.
3. After drying thoroughly, inspect the pre-cleaner for defect. If any defect are found, replace the pre-cleaner with a new one.
4. After cleaning, inspecting or changing the pre-cleaner, reinstall it to the silencer.

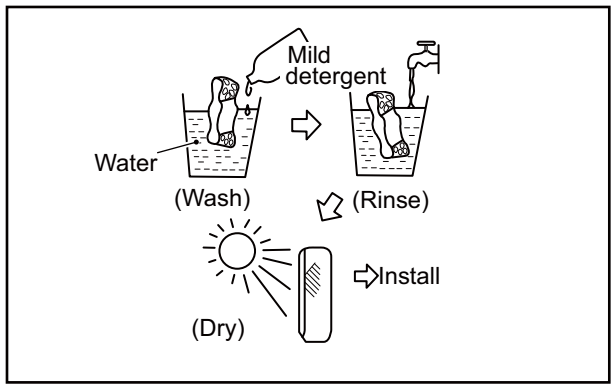

Fig. 8-29 Pre-cleaner - Clean

Air cleaner element - Clean, Check and Replace

⚠ CAUTION

When handling compressed air, wear safety goggles, a dust mask, a hardhat, gloves and other necessary protective gear. Works without wearing proper protective gear could result in serious injuries.
Never service the air cleaner while the engine is running. Servicing the air cleaner while the engine is in operation can cause particles of foreign matter to enter the engine and result in rapid wear of parts, leading to a shorter service life of the engine. Never knock or hit the element.

CAUTION

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

1. Remove the air cleaner cap and wing bolt.
2. Remove the air cleaner element from the body.
3. Blow compressed air (0.69 MPa {7 kgf/cm^2} [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 the outside along the pleats. Then, blow compressed air on the outside and inside surface again.
5. After cleaning, hold the element near a light bulb to illuminate the inside, to check for defects such as cuts, pinholes or local wear.
6. If any defect is found, replace the air cleaner element with a new one.
7. Reassemble the air cleaner element as it is.

CAUTION

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

Reset the indicator by pressing the reset button to erase a red sign after installing the clean or new element.

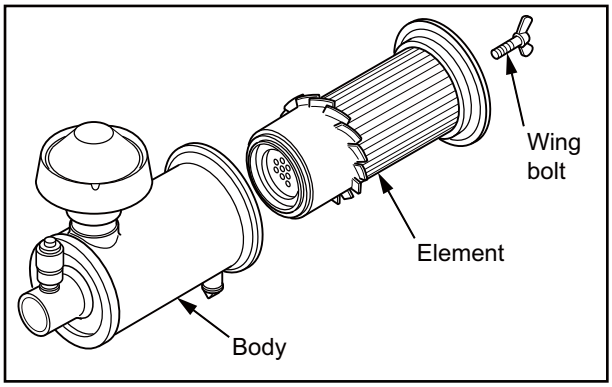

Fig. 8-30 Air cleaner element - Remove

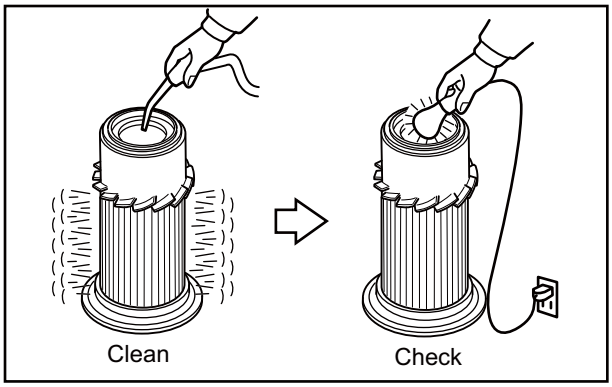

Fig. 8-31 Air cleaner element - Clean and Check

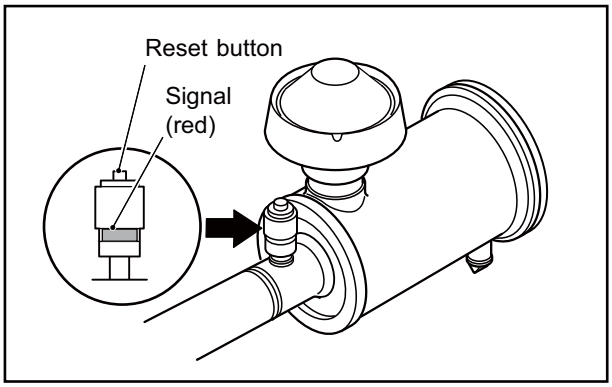

Fig. 8-32 Air cleaner - Check

Electrical system

Battery - Inspect

WARNING

If battery electrolyte is spilled on your skin, flush immediately with plenty of water. If battery electrolyte enters the eyes, flush them immediately with lots of fresh water and seek medical attention at once.

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

Battery electrolyte level - Inspect

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

For the battery without level lines, the correct fluid surface level is about 10 to 15 mm [0.394 to 0.591 in.] above the top of the plates.

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

Note: When adding distilled water, pour in carefully.

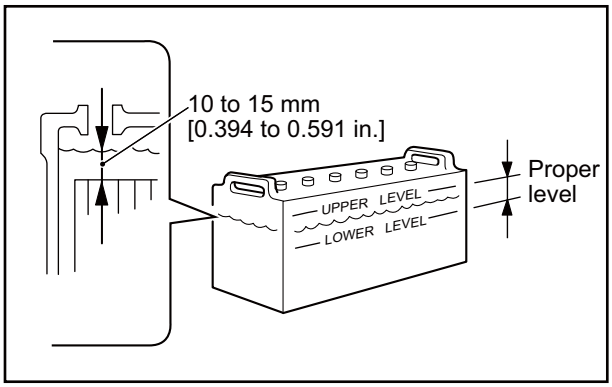

Fig. 8-33 Battery electrolyte level - Inspect

Specific gravity of battery electrolyte - Check

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

Table 8-3 Specific gravity of electrolyte

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

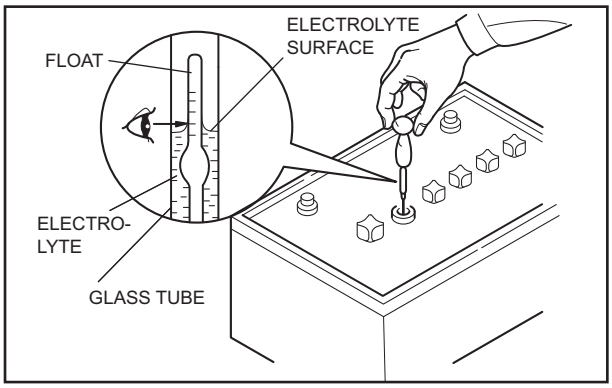

Fig. 8-34 Specific gravity of battery electrolyte - Check

Starter - Inspect

Check the exterior of the starters for damage.

If the starters are dusty, blow dirt using compressed air.

Note: If the starters are defective, consult a Mitsubishi dealer.

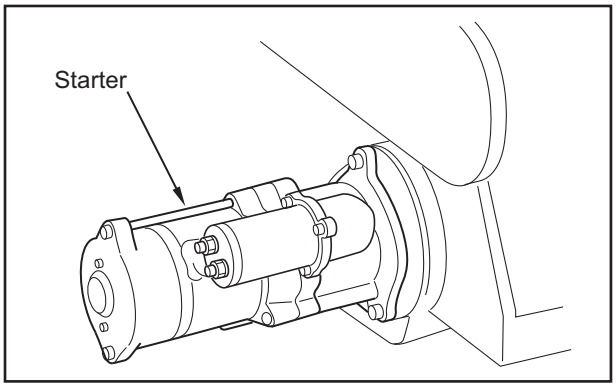

Fig. 8-35 Starter - Inspect

Alternator - Inspect

Visually check the alternator for damage.

If the alternators are dusty, blow dirt using compressed air.

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

Note: If defects are found in the alternator, contact your Mitsubishi dealer.

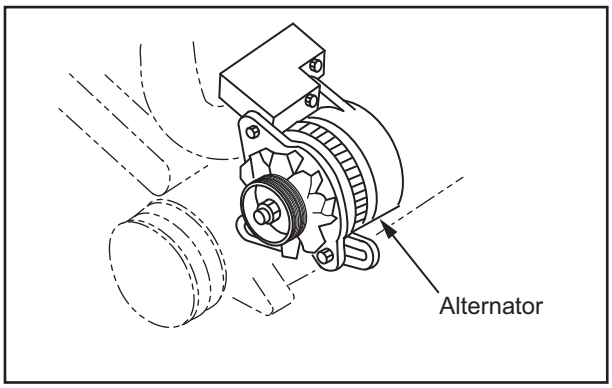

Fig. 8-36 Alternator - Inspect

Air starter system

Air strainer - Drain water and Clean

1. Close the handle for starting of the air 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. Reassemble the air strainer as it is.
6. Open the starting air handles slowly.

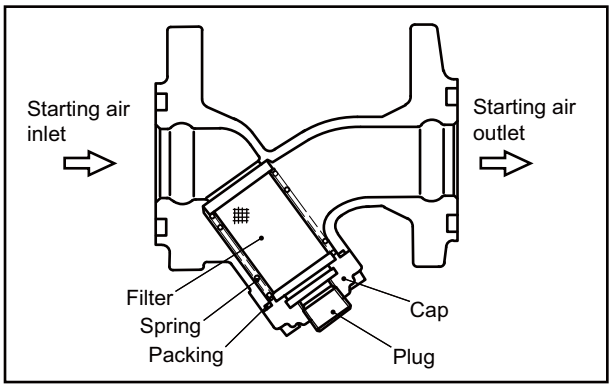

Fig. 8-37 Air strainer - Drain water and Clean

Air tank - Drain water

CAUTION

There are 2 places for draining water in the air tank: drain valve on the top of air tank, and drain handle on the bottom of drain separator.

1. Open the drain valve slowly, and check that water in the tank is drained from drain pipe.
2. After water is drained and the air is discharged in the tank, tighten the drain valve firmly.
3. Loosen the drain handle on the bottom of drain separator. Check that water in the drain separator is discharged from the drain pipe.
4. Close the drain handle after draining water firmly.

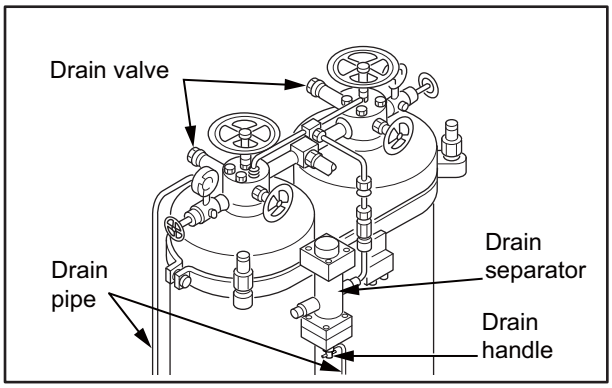

Fig. 8-38 Air tank - Drain water

Air tank - Inspect safety valve operation

1. Open the inlet valve of air tank and air pressure gauge valve.
2. Fill air with the air compressor.
3. Check to make sure the safety valve opens to relieve pressure when the air pressure value in the tank is over the standard.
   Pressure in the air tank: 2.94 MPa
   {30 kgf/cm^2} [427 psi]
   Safety valve operating pressure (open): 3.14 MPa
   {32 kgf/cm^2} [455 psi]
   Safety valve operating pressure (close): 2.84 MPa
   {29 kgf/cm^2} [412 psi]
4. If defective in safety valve operation, contact a Mitsubishi dealer.

Chapter 9 LONG-TERM STORAGE

CAUTION

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

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

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

Preparation for storage

1. Drain the engine oil in-use, pour new oil.
2. Prepare a fuel mixture containing 50% rust-preventive oil (NP-9), and fill the fuel tank with it.
3. Operate the engine at a speed of 800 to 1000 min^{-1} (idling) for 5 to 10 minutes under no load.
4. Immediately before stopping the engine, spray volatile corrosion inhibitor (VCI) through the inlet port to prevent rust on the air intake system.
5. With the engine stopped, drain the fuel mixture from the fuel tank.
6. Apply rust-preventive oil (NP-3) liberally on the exposed sections of the machining.
7. Seal the air inlet, exhaust outlet, breather and other openings with an adhesive cloth tape.
8. Loosen the V-belt.
9. Wrap adhesive cloth tape on the terminals of the starters and alternator, and seal the openings. Cover these sections with polyethylene sheet or processed polyethylene paper, and place desiccants in the polyethylene covers.
10. Disconnect the cables from the battery terminals, and charge the battery. Clean the terminals, apply a thin coat of grease to the terminals, and store the battery in a cool and dry room.
11. Cover the entire engine.

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

(b) It is not necessary to drain coolant since it contains LLC. (Add LLC to increase the concentration to between 30 to 60%.)

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

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

Recommended rust-preventive oil and corrosion inhibitor

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

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

Maintenance during storage

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

Using the engine after storage

1. Remove the cover from the engine.
2. Connect a fully charged battery.
3. Remove the covers from the starters and alternator.
4. Adjust the tension of belt.

Note: For the adjustment of belt tension, refer to "V-belt and belt tension - Inspect and Adjust" (8-2).

5. Remove sealing tapes from the openings of the engine.
6. Connect pipes.

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

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

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

8. Inspect the entire engine.
9. Remove the rocker covers, and lubricate the valve mechanisms.
10. Shut off the fuel supply and crank the engine for about 10 seconds. (Then repeat this cranking 3 times at intervals of about 1 minute or more.)

CAUTION

To crank the engine, shut off the fuel supply to the engine and operate the starters.

11. Make sure the engine oil pressure rises.
12. Start the engine.

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

13. Conduct a warm-up operation for a sufficient duration.
14. Apply load and increase the engine speed to the rated speed.

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

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

Operating the engine for maintenance

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

1. With the fuel shut off (press the engine stop button to shut off the fuel injection), operate the starter twice at intervals of about 10 seconds and check to see if the engine oil pressure increases.
2. After the engine starts, operate under no load for 5 to 10 minutes.

Note: For engine operation, refer to "OPERATION" (3-1).

Lifting the engine

⚠ WARNING

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

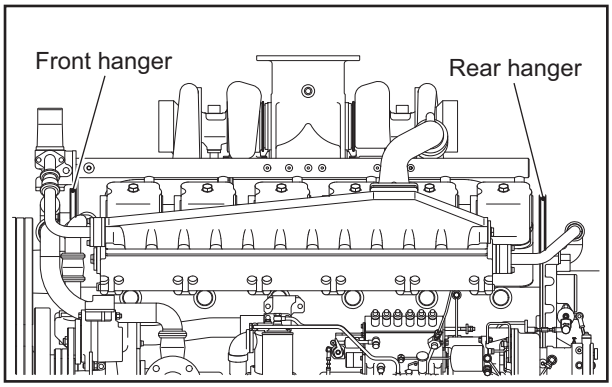

Fig. 10-1 Lifting hanger

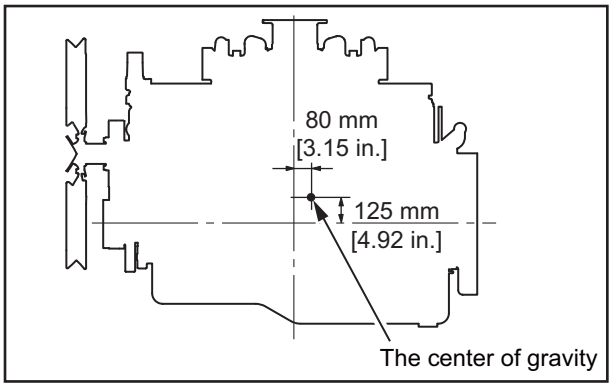

Fig. 10-2 Engine's center of gravity

Chapter 11 TROUBLESHOOTING

General precautions

Contact your Mitsubishi dealer for repair service

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

Considerations before work

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

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

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

Cautions against contamination

Dust and particles of foreign matter 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.

Cautions regarding parts handling

Handle parts carefully.

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

Work safety

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

Use correct tools and perform work with utmost caution.

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

Troubleshooting

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

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

Cause		Remedies
Electrical system	Faulty wire connection	⬧Check the DC fuse. ⬧Check wiring connection between battery, starter and starter switch
	Insufficiently charged battery	⬧Check alternator. (Refer to P8-20) ⬧Check and adjust V-belt. (Refer to P8-2)
	Faulty battery	⬧Check specific gravity of battery electrolyte. (Refer to P3-6) ⬧Charge battery ⬧Change battery.
	Faulty starter or starter relay	⬧Consult a Mitsubishi dealer.
Lubricating system	Oil viscosity too high	⬧Use appropriate engine oil. (Refer to P5-1)
	Excessive oil	⬧Check the level of engine oil and the fuel tank. (Refer to P3-9)
Engine mechanical	Rapid wear of sliding parts, or locked	⬧Consult a Mitsubishi dealer.

The starter cranks, but the engine does not start

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

Cause		Remedies
Fuel system	Run out of fuel, blocked pipe	⬧Inspect fuel tank, refill, bleed air. (Refer to P8-5) ⬧Check fuel pipes, valves.
	Improper fuel property	⬧Use appropriate fuel. (Refer to P4-1) ⬧Remove dust, water impurities. (Refer to P8-5)
	Fuel leakage in fuel pipes and injection pipes.	⬧Check faults and retighten fuel pipes and injection pipes. ⬧Consult a Mitsubishi dealer.
	Clogged fuel filter	⬧Inspect and replace fuel filter. (Refer to P8-9) ⬧Gauze filter - Clean (Refer to P8-7)
	Faulty fuel feed pump	⬧Consult a Mitsubishi dealer.
	Faulty fuel injection pump	⬧Check the rack operation. ⬧Consult a Mitsubishi dealer.
	Faulty fuel injection nozzle	⬧Consult a Mitsubishi dealer.
Air intake system	Insufficient amount of air	⬧Clean, inspect and replace pre-cleaner. (Refer to P8-17) ⬧Clean, inspect and replace air cleaner element. (Refer to P8-18)
Control system	Faulty governor	⬧Check the linkage operation. (Refer to P3-10) ⬧Consult a Mitsubishi dealer.
Engine mechanical	Low compression pressure	⬧Consult a Mitsubishi dealer.

Output decrease

Table 11-3 Output decrease

Cause		Remedies
Fuel system	Improper fuel property	♦Use appropriate fuel. (Refer to P4-1)
	Clogged fuel filter	♦Inspect and replace fuel filter. (Refer to P8-9) ♦Gauze filter - Clean (Refer to P8-7)
	Faulty fuel feed pump	♦Consult a Mitsubishi dealer.
	Faulty fuel injection pump	♦Consult a Mitsubishi dealer.
	Faulty fuel injection nozzle	♦Consult a Mitsubishi dealer.
	Faulty fuel injection timing	♦Check fuel injection pump couplings. ♦Consult a Mitsubishi dealer.
	Improper amount of fuel injection	♦Check fuel injection pump rack stroke. ♦Check left and right bank. ♦Consult a Mitsubishi dealer.
Cooling system	Overheat, overcooled	♦Check fan and heat exchanger. ♦Check control system. ♦Consult a Mitsubishi dealer.
Inlet and exhaust systems	Insufficient amount of air	♦Check turbocharger. (Refer to P8-16) ♦Clean, inspect and replace pre-cleaner. (Refer to P8-17) ♦Clean, inspect and replace air cleaner element. (Refer to P8-18) ♦Check intake air pressure and leakage of intake air. ♦Check intake air temperature and ventilation device. ♦Consult a Mitsubishi dealer.
	Increase resistance of exhaust air.	♦Check turbocharger. (Refer to P8-16) ♦Check exhaust pipes and silencer. ♦Consult a Mitsubishi dealer.
Engine mechanical	Low compression pressure	♦Consult a Mitsubishi dealer.
	Faulty valve timing	♦Consult a Mitsubishi dealer.
	Rapid wear of sliding parts	♦Consult a Mitsubishi dealer.
Control system	Faulty governor control	♦Consult a Mitsubishi dealer.

Exhaust smoke is white or blue

Table 11-4 Exhaust smoke is white or blue

Cause		Remedies
Fuel system	Improper fuel property	⬧Check cetane index, and use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	⬧Check fuel injection pump couplings. ⬧Consult a Mitsubishi dealer.
	Faulty fuel injection nozzle	⬧Consult a Mitsubishi dealer.
	Uneven fuel injection	⬧Check ignition noise, exhaust smoke temperature, left and right bank balance. ⬧Consult a Mitsubishi dealer.
	Incorrect fuel injection timing	⬧Consult a Mitsubishi dealer.
Lubricating system	Combustion of engine oil	⬧Check the level of engine oil and lubrication system. (Refer to P3-9) ⬧Consult a Mitsubishi dealer.
Cooling system	Overcooled	⬧Check radiator. (Refer to P8-15) ⬧Check control system. ⬧Thermostat - Inspect ⬧Consult a Mitsubishi dealer.
Engine mechanical	Faulty valve timing	⬧Consult a Mitsubishi dealer.
	Low compression pressure	⬧Consult a Mitsubishi dealer.

Exhaust smoke is black or charcoal

Table 11-5 Exhaust smoke is black or charcoal

Cause		Remedies
Fuel system	Improper fuel property	⬧Use appropriate fuel. (Refer to P4-1)
	Faulty fuel feed pump	⬧Consult a Mitsubishi dealer.
	Faulty fuel injection pump	⬧Consult a Mitsubishi dealer.
	Faulty fuel injection nozzle	⬧Consult a Mitsubishi dealer.
	Faulty fuel injection timing	⬧Check fuel injection pump couplings. ⬧Consult a Mitsubishi dealer.
	Uneven fuel injection	⬧Check exhaust smoke temperature, left and right bank balance. ⬧Consult a Mitsubishi dealer.
Inlet and exhaust systems	Insufficient amount of air	⬧Check turbocharger. (Refer to P8-16) ⬧Clean, inspect and replace pre-cleaner. (Refer to P8-17) ⬧Clean, inspect and replace air cleaner element. (Refer to P8-18) ⬧Check intake air pressure and leakage of intake air. ⬧Check intake air temperature and ventilation device. ⬧Consult a Mitsubishi dealer.
	Increase resistance of exhaust air.	⬧Check turbocharger. (Refer to P8-16) ⬧Check exhaust pipes and silencer. ⬧Consult a Mitsubishi dealer.
Engine mechanical	Low compression pressure	⬧Consult a Mitsubishi dealer.
	Faulty valve timing	⬧Consult a Mitsubishi dealer.
	Rapid wear of sliding parts	⬧Consult a Mitsubishi dealer.
Control system	Increase in load	⬧Check control system and governor controller. ⬧Consult a Mitsubishi dealer.

Fuel consumption is high

Table 11-6 Fuel consumption is high

Cause		Remedies
Fuel system	Faulty fuel injection nozzle	•Consult a Mitsubishi dealer.
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Consult a Mitsubishi dealer.
	Improper fuel property	•Use appropriate fuel. (Refer to P4-1)
	Fuel leakage in fuel pipes and injection pipes.	•Check faults and retighten fuel pipes and injection pipes. •Consult a Mitsubishi dealer.
Cooling system	Overcooled	•Check radiator. (Refer to P8-15) •Check control system. •Thermostat - Inspect •Consult a Mitsubishi dealer.
Inlet and exhaust systems	Insufficient amount of air	•Check turbocharger. (Refer to P8-16) •Clean, inspect and replace pre-cleaner. (Refer to P8-17) •Clean, inspect and replace air cleaner element. (Refer to P8-18) •Check intake air pressure and leakage of intake air. •Check intake air temperature and ventilation device. •Consult a Mitsubishi dealer.
	Increase resistance of exhaust air.	•Check turbocharger. (Refer to P8-16) •Check exhaust pipes and silencer. •Consult a Mitsubishi dealer.
Engine mechanical	Low compression pressure	•Consult a Mitsubishi dealer.
	Faulty valve timing	•Consult a Mitsubishi dealer.
	Rapid wear of sliding parts	•Consult a Mitsubishi dealer.

Engine oil consumption is high

Table 11-7 Engine oil consumption is high

Cause		Remedies
Fuel system	Faulty fuel injection timing	♦Check fuel injection pump couplings. ♦Consult a Mitsubishi dealer.
Lubricating system	Oil leakage to the outside of engine	♦Check oil leakage. ♦Consult a Mitsubishi dealer.
	Engine oil viscosity too low	♦Use appropriate oil viscosity. (Refer to P5-3)
	Engine oil temperature is high.	♦Check amount of engine oil and lubrication system. (Refer to P3-9) ♦Check oil cooler and oil thermostat ♦Consult a Mitsubishi dealer.
Cooling system	Overheating	♦Check radiator. (Refer to P8-15) ♦Check control system. ♦Thermostat - Inspect ♦Consult a Mitsubishi dealer.
Inlet and exhaust systems	Spread oil to intake part	♦Check oil leakage to the turbocharger. ♦Consult a Mitsubishi dealer.
	Wear of valve operating system	♦Consult a Mitsubishi dealer.
Engine mechanical	Wear of sliding parts	♦Consult a Mitsubishi dealer.
Control system	Increase in load	♦Check control system and governor controller. ♦Consult a Mitsubishi dealer.

Overheating

Table 11-8 Overheating

Cause		Remedies
Cooling system	Low coolant level	•Check coolant leakage •Check coolant level. (Refer to P3-10)
	Faulty water pump operation	•Consult a Mitsubishi dealer.
	Faulty thermostat operation	•Consult a Mitsubishi dealer.
	Faulty radiator operation	•Check and clean radiator and radiator cap. (Refer to P8-XX.)
Control system	Increase in load	•Check fuel injection pump rack stroke. •Check control system and governor controller. •Consult a Mitsubishi dealer.
Engine mechanical	Rapid wear of sliding parts	•Consult a Mitsubishi dealer.

Low engine oil pressure

Table 11-9 Low engine oil pressure

Cause		Remedies
Lubricating system	Insufficient amount of engine oil	•Check amount of engine oil and lubrication system. (Refer to P3-9)
	Faulty engine oil property (viscosity)	•Analyze oil property. Use appropriate engine oil. (Refer to P5-1)
	Oil temperature too high	•Check coolant system. •Consult a Mitsubishi dealer.
	Oil filter clogged	•Inspect and replace oil filter. (Refer to P8-11)
	Faulty oil pump operation	•Consult a Mitsubishi dealer.
	Faulty relief valve operation	•Consult a Mitsubishi dealer.
Control system	Faulty pressure unit operation	•Check control system and wire. •Consult a Mitsubishi dealer.
Engine mechanical	Increase in load	•Check control system and governor controller. •Consult a Mitsubishi dealer.
	Rapid wear of sliding parts	•Consult a Mitsubishi dealer.
	Increase clearance of sliding part.	•Consult a Mitsubishi dealer.

When fuel has run out

When fuel runs out during engine operation and the engine has stopped, restart the engine as described below.

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

Chapter 12 MAIN SPECIFICATIONS

Main specifications

Table 12-1 Main specifications

Item	Specifications
Engine model	S12A2
Type	Water-cooled 4-stroke cycle, turbocharged with air cooler
Number of cylinders, arrangement	12 - V
Bore×Stroke	ø150 × 160 mm [5.91 × 6.30 in.]
Total displacement	33.93 L [2070 cu.in.]
Combustion type	Direct injection system
Compression ratio	13.9 : 1
Firing order	1 - 12 - 5 - 8 - 3 - 10 - 6 - 7 - 2 - 11 - 4 - 9
Rotation direction	Counterclockwise as viewed from flywheel side
Dimensions (L×W×H) The value in parentheses shows the size when the large type oil pan is installed.	Approx. 2060 mm × 1382 mm × 1542 (1613) mm [81.10 in. × 54.41 in. × 60.71 (63.50) in.]
Dry weight	Approx. 3400 kg [7496 lb.]
Fuel	Diesel fuel
Fuel injection pump	BOSCH S3S or S7S
Governor	Mechanical hydraulic or electrical type
Fuel filter	Paper-element type
Fuel injection nozzle	Hole type
Initial fuel injection pressure	21.57 MPa {220 kgf/cm^2} [3129 psi]
Lubricating system	Forced lubrication (pressure feed by oil pump)
Lubrication oil	Class CF oil (API service classification)
Engine oil capacity	Oil pan: approx. 100 L [26.42 U.S. gal.], whole engine: approx. 120 L [31.70 U.S. gal.]
Oil filter	Paper-element type
Oil cooler	Water cooled multi-plate
Cooling system	Forced water cooling
Cooling water capacity	Approx. 100 L [26.42 U.S. gal.] (in engine only)
Starting system	Electrical or pneumatic type
Starter	24V DC - 7.5 kW × 2
Alternator	24V DC - 30 A
Turbocharger	Mitsubishi TD10 or TD13
Flywheel	Equivalent of SAE. 18in
Flywheel housing	Equivalent of SAE. No.0

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

(b) The special specification may differ according to the above standard specification.

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