OPERATION & MAINTENANCE MANUAL

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MITSUBISHI MILLER CYCLE GAS ENGINE

GS16R

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
ENGINE & TURBOCHARGER, LTD.

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.

Pub. No. 99400-30130

Limited warranty

The manufacturer will repair or replace parts returned to the manufacturer when the manufacturer judges after inspection that the parts are defective in material and/or workmanship.
The manufacturer's warranty is limited to the repair work or replacement of parts for the defective parts only.
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.

Important information

- To avoid potential hazard, accident prevention activities must be planned methodically and conducted continually by considering all aspects of engine operation, maintenance and inspection.
  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 that 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.
- This manual is copyrighted and all rights are reserved. No part of this manual, including illustrations and technical references, may be reproduced, photocopied, translated, or reproduced in any electronic medium or machine readable form without prior written consent from the manufacturer.
- The contents in this manual are subject to change 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 in shape, or may not be installed on the product you have.
- Please contact your Mitsubishi dealer if you need more information or if you have any questions.
- If you lose or damage this manual, obtain a new copy at your Mitsubishi dealer as soon as possible.

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 an imminently 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, can 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

Abbreviations, standards and others

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

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Chapter 1 BASIC SAFETY PRECAUTIONS

⚠ WARNING

Fire and explosion

Keep flames away

Do not use fire near around the engine (in the engine room). Fuel vapor or other gas can catch fire and produce dangerous situations.
Wipe off spilled engine oil and LLC (Long Life Coolant) immediately and thoroughly. Engine oil or LLC left on hot surfaces can ignite and cause fire.
Store engine oil in a well ventilated area. Make sure that the cap of container is tightly closed.

Do not operate if you notice a gas leak

If you notice a gas leak, do not operate the engine, or immediately stop the engine. Close the main gas valve, call out “FIRE BURN,” and ventilate the area quickly. Failure to do so can result in serious accidents such as an explosion and fire, or gas poisoning.

Handle gas pipe with caution

Before disassembling the gas pipe, close the main gas valve securely, and discharge gas completely from the inside of the pipe. If a large amount of gas remains inside the pipe, an explosion, fire or other serious accident could occur.

Keep engine surrounding area tidy and clean

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

Avoid accessing crankcase 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 gas, oil and exhaust gas leakage

If a fuel, oil and exhaust gas leak is found, repair the leakage immediately.
Spilled fuel or oil on a hot surface of the engine, or exhaust gas discharged directly to a combustible material may cause a fire and result in personal injury and/or damage to equipment.

Use explosion-proof lighting apparatus

When using a lighting apparatus to check for engine oil, coolant or battery fluid level, always use an explosion-proof one. 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.

Always beware of gas leakage

Check the gas shut-off device periodically for gas leakage. If gas leakage is suspected during operation, immediately stop the engine, react quickly to prevent the gas from spreading, and ventilate the engine room. If the engine is not used for a long period of time, close the main gas valve to avoid accidental fire or explosion.

Overhaul for safety

Overhaul the engine periodically without fail, and be sure to replace gaskets and packings. Operating the engine with damaged gaskets or packings could cause crankcase gas explosion, resulting in serious accidents.

Beware of unburned gas

Before restarting the engine, or when starting it after a start failure has occured, close the gas supply valve and crank the engine with the starter to relieve all unburned gas from the exhaust pipe and cylinders. Any unburned gas remaining in the exhaust pipe and cylinders can cause explosion, resulting in personal injury.

Fire hazard

The engine, muffler and exhaust gas become very hot during engine operation. Keep combustibles (wood chips, paper, explasives, etc.) away from the engine and the surrounding areas to prevent fire.
The engine must be used at least 1 m [3.3 ft.] away from buildings and other equipment to prevent possible fire caused by engine heat.

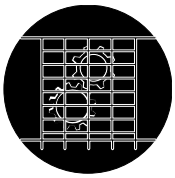
Danger of flue explosion

Make sure that the resistance of the flue and exhaust duct of the gas engine is lower than the specified standard. Do not use the flue or exhaust duct of the gas engine for a high-temperature exhaust gas of a boiler or other equipment.
Neglecting to do so can result in an explosion of the flue and exhaust duct of the gas engine, causing a serious accident.

⚠ WARNING

Stay clear of all rotating and moving parts

Install protective covers around rotating parts

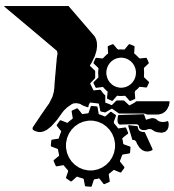


Make sure the protective covers of the engine are correctly installed.
Repair any damaged or loose covers.
Never remove the protective covers of rotating parts during operation.
When the engine is coupled to the radiator or other equipment, install protective covers around the exposed connecting belt and coupling.
Never remove protective covers.

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

Keep engine stopped during servicing

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

Use dedicated tool to turn engine

When turning the engine for inspection or service, be sure to use the dedicated turning tool or turning gear, and do not use the starter to rotate the engine. Use of the starter can cause entanglement by rotating parts.

Always restore engine turning tools after use

Do not forget to remove the tools which have been used for turning the engine during inspection or servicing, after the procedure is finished. Remember also that the turning gear must be returned to the operating condition before starting the engine.
Starting the engine with the turning tools inserted or with the turning gear in engagement can lead to not only engine damage but also personal injuries.

⚠ WARNING

Be careful of burns

Do not touch engine during or immediately after operation

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 coolant pressure cap when the engine is hot.

Never open the coolant pressure cap while the engine is operating or immediately after the engine stopped. Before opening the cap, stop the engine and allow the coolant temperature to drop sufficiently.
When opening the cap, cover the cap with a cloth or use thick rubber glove, and then slowly open the cap to release the inner pressure.
When closing the cap, be sure to tighten securely.
The engine coolant is hot during engine operation and immediately after operation. If the coolant pressure cap is opened when the engine is hot, steam and hot water may blow out, possibly resulting in scalding.

Drain oil only after engine has cooled

Drain oil when the engine and oil are cold.
Oil is very hot immediately after the operation. Draining hot oil can cause burns.

Wear protective clothing when repairing oil leaks

When repairing oil leaks, be sure to wear protective goggles, mask and clothing to prevent burns by hot oil.
Oil is very hot and under high pressure in an operating engine. If oil leaks and splashes, it can cause burns.

Be cautious of abnormal oil mist generation

If the engine is shut down due to abnormal generation of oil mist, move away from the engine immediately, and do not open the crankcase until the engine cools sufficiently. Opening the crankcase or side inspection cover immediately after the engine stops can result in an ignition or explosion, causing serious burns or other injuries.

Be careful of high-tension cables

Never touch high-tension cables while the engine is operating. Touching high-tension cables during engine operation can cause an electric shock and other hazards.

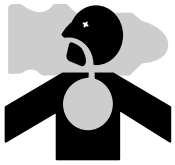
Be careful of plug cord

Never touch the plug cord while the engine is operating.
Touching the plug cord during engine operation can cause burns and other hazards.

⚠ WARNING

Be careful of exhaust fume poisoning

Operate the engine in a well-ventilated area



If the engine is installed in an enclosed area, and the exhaust gas is ducted outside, ensure that there is no exhaust gas leak from duct joints.
Exhaust gas from the engine contains carbon monoxide and other harmful substances. Operating the engine in an ill-ventilated area can produce gas poisoning.

⚠ WARNING

Be careful of fuel gas poisoning

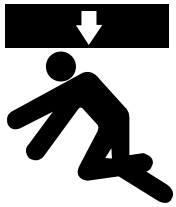
Be extremely alert to gas leakage

If gas leakage is suspected in an enclosed area, react quickly to prevent the gas from spreading, and ventilate. Gas may cause serious injury such as poisoning or suffocation.

⚠ WARNING

Be careful of falling down

Lift engine carefully



To lift the engine, always use a correct wire rope capable of withstanding the engine weight.
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 degrees. 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 parts to fall off 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.

⚠ WARNING

Protect ears from noises

Wear ear plugs

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

⚠ CAUTION

Be careful of handling fuel gas, engine oil and LLC

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

Use only the fuel gas, oil and LLC specified in this manual, and handle them carefully.
Use of any other fuel gas, oil or LLC, or improper handling may cause various engine problems and malfunctions.
Obtain the Material Safety Data Sheets (MSDS) issued by the gas, 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.

Proper disposal of waste oil and coolant (LLC)

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

⚠ CAUTION

Service battery

Handle 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 the cables, attach the cable to the positive (+) terminal first.
- Charge the battery in a well-ventilated area, with all filling hole plugs removed.
- Make sure the cable clamps are securely installed on the battery terminals. A loose cable clamp can cause sparks that may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or disconnect the cable from the negative (-) battery terminal to cut off the electrical current.
- Electrolyte (battery fluid) contains dilute sulfuric acid. Careless handling of the battery can lead to the loss of sight and/or skin burns. Also, keep the battery fluid off the mouth.
- Wear protective goggles and rubber gloves when working with the battery (when adding water, charging, etc.).
- If electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to thoroughly clean.
- The battery fluid can cause blindness if splashing into 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.

⚠ CAUTION

When abnormality occurs

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

If the engine stops suddenly or if you have no choice but to 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.

⚠ CAUTION

Other cautions

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.

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 overhualed engines in a severe condition during the break-in period shortens the service life of the engine.

Avoid operating engine at resonance generating speed

Do not operate the engine at resonance generating speed to prevent torsional vibration.
If the engine is allowed to operate at resonance generating speed and produces torsional vibration, the crankshaft can break and cause serious accidents.

Warm up the engine before use

When starting the engine, follow the time schedule and warm up the engine for 3 minutes, then operate the engine with applying load.
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.

Never operate the engine in an overloaded condition

Overloading causes not only high fuel consumption but also excessive heat load. And it will shorten the service life of the engine.

Conduct cooling operation before stopping the engine

Before stopping the engine, conduct cooling operation for 3 minutes following time schedule.
Stopping the engine immediately after high-load operation will cause engine parts to heat up and shorten the service life of engine.
During the 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.

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.

Properly maintain the air cleaner

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

- Do not maintain the air cleaner while the engine is in operation. Operating the engine without the air cleaner can suck particles of foreign matter into the engine and could result in serious accidents.
- When removing the air cleaner, use care to prevent dust trapped in the air cleaner from entering the engine. After removing the air cleaner, immediately cover the air inlet port with plastic sheet or similar means to prevent dust from entering the engine.
- If the engine is equipped with a dust indicator, conduct maintenance only when the clog warning sign appears.

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 fo 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.

Do not operate the starter for a prolonged time

When startup congestion occurs, locate the cause and repair the problem securely before restart the engine. Continuous operation of the starter will drain the battery power and cause seizing of the starter.

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.

Beware of short-circuiting to prevent fire

If electrical wires have marks cause by short-circuiting, locate the cause and repair the problem to ensure safety.
If left uncorrected, short-circuiting can occur repeatedly and cause a fire.

Handle cleaning solvents carefully

Use cleaning solvents only in a well-ventilated place, and do not swallow them or allow them to contact the skin.
Cleaning solvents contain harmful substances, and can cause poisoning or other health problems.

Observe operating condition and collect data regularly

Observe the engine operating condition and collect operating data regularly to discover signs of abnormalities in early stages.
If the engine is operated without regular observation or periodic data collection, symptoms of malfunctions cannot be discovered in early stages, and this can result in the generation of serious problems in the engine.

Ventilate the engine room sufficiently

Be sure to provide sufficient 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 appropriate ventilation system before installing the engine.

⚠ CAUTION

About warning labels

Maintenance of warning labels

Make sure all warning/caution labels are legible.

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

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

Replace damaged or fractured labels with new ones.

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

To obtain new warning labels, contact your local Mitsubishi dealer.

Fig. 1-1 Warning labels

Chapter 2 NAME OF PARTS

Engine external diagrams

The external diagram is for the standard type of the engine.The installed equipment and shapes differ according to the engine type.

Left view

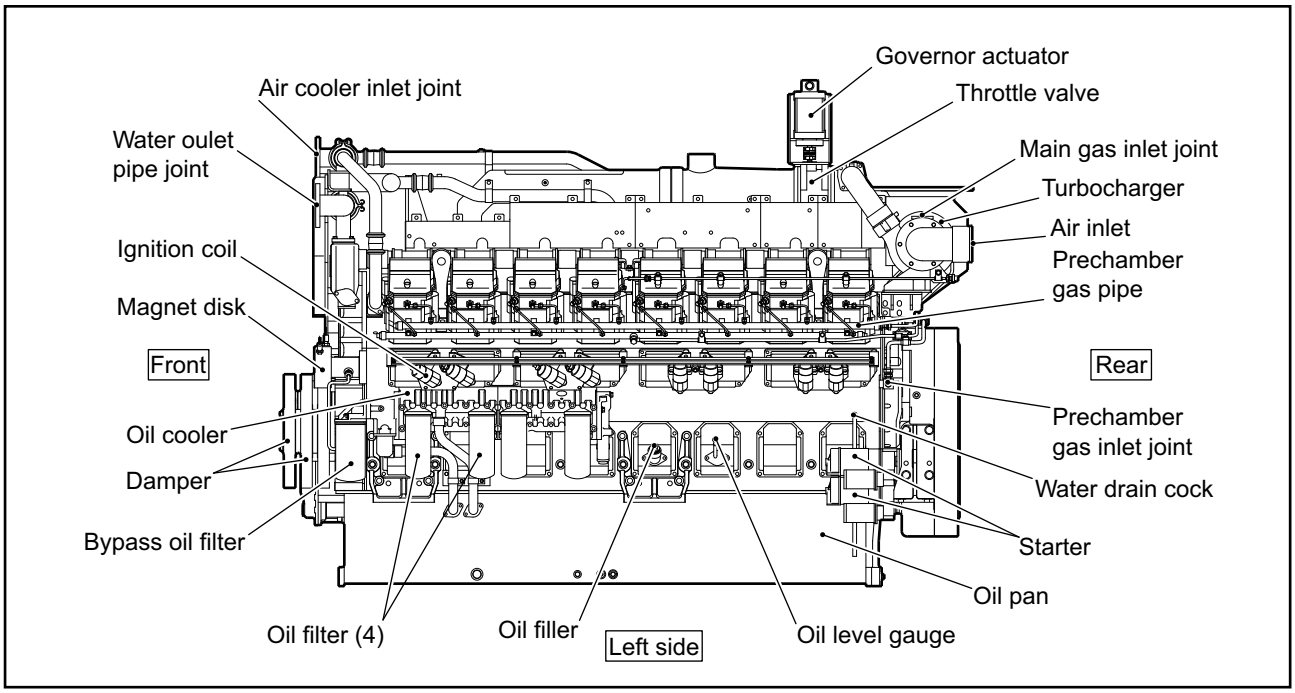


Fig. 2−1 Left view

Right view

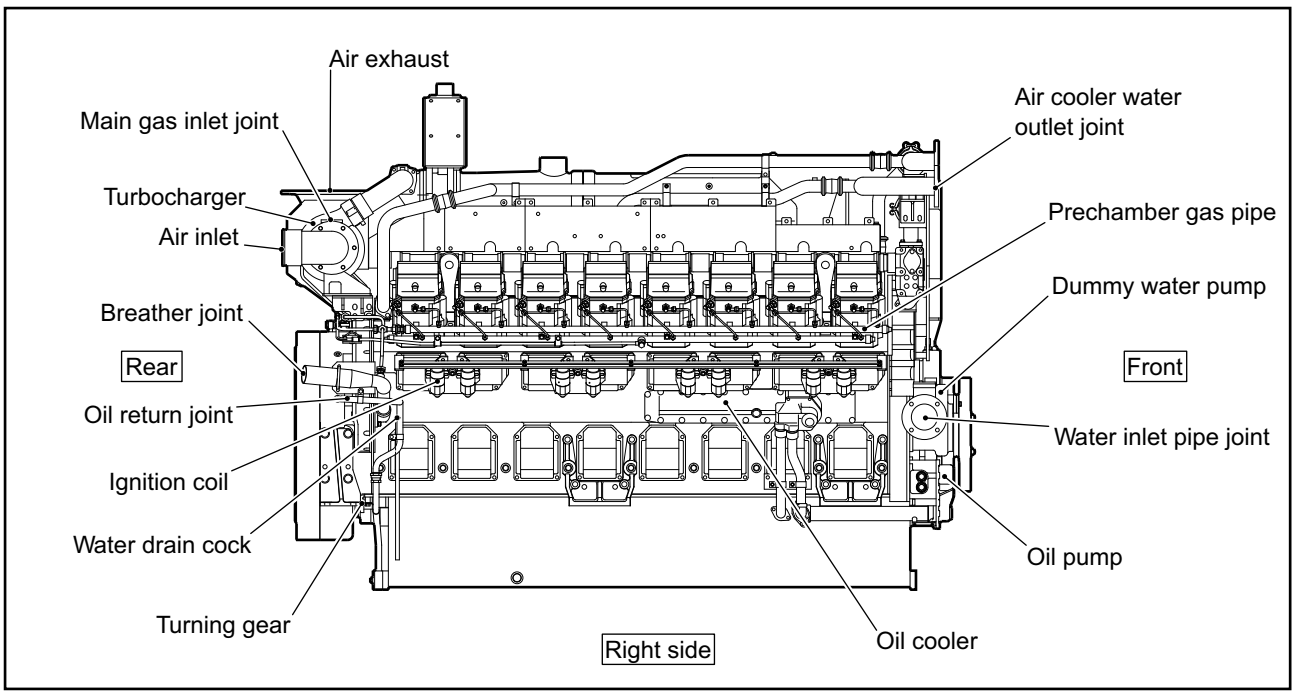


Fig. 2−2 Right view

Operation equipment

Gas fuel control system

⚠ WARNING

Do not make unnecessary adjustments since the system is pre-adjusted at the factory.
Do not open the controller cover needlessly.

The following diagram shows a standard gas fuel control system (main chamber and prechamber gas system).
Use this diagram only as a reference, since the actual configuration varies depending on the equipment specifications.
A dedicated handheld programmer is required to input and set the control values in the controller.
When it is necessary to change the control data for the adjustment of governor sensitivity and others, contact your Mitsubishi dealer.

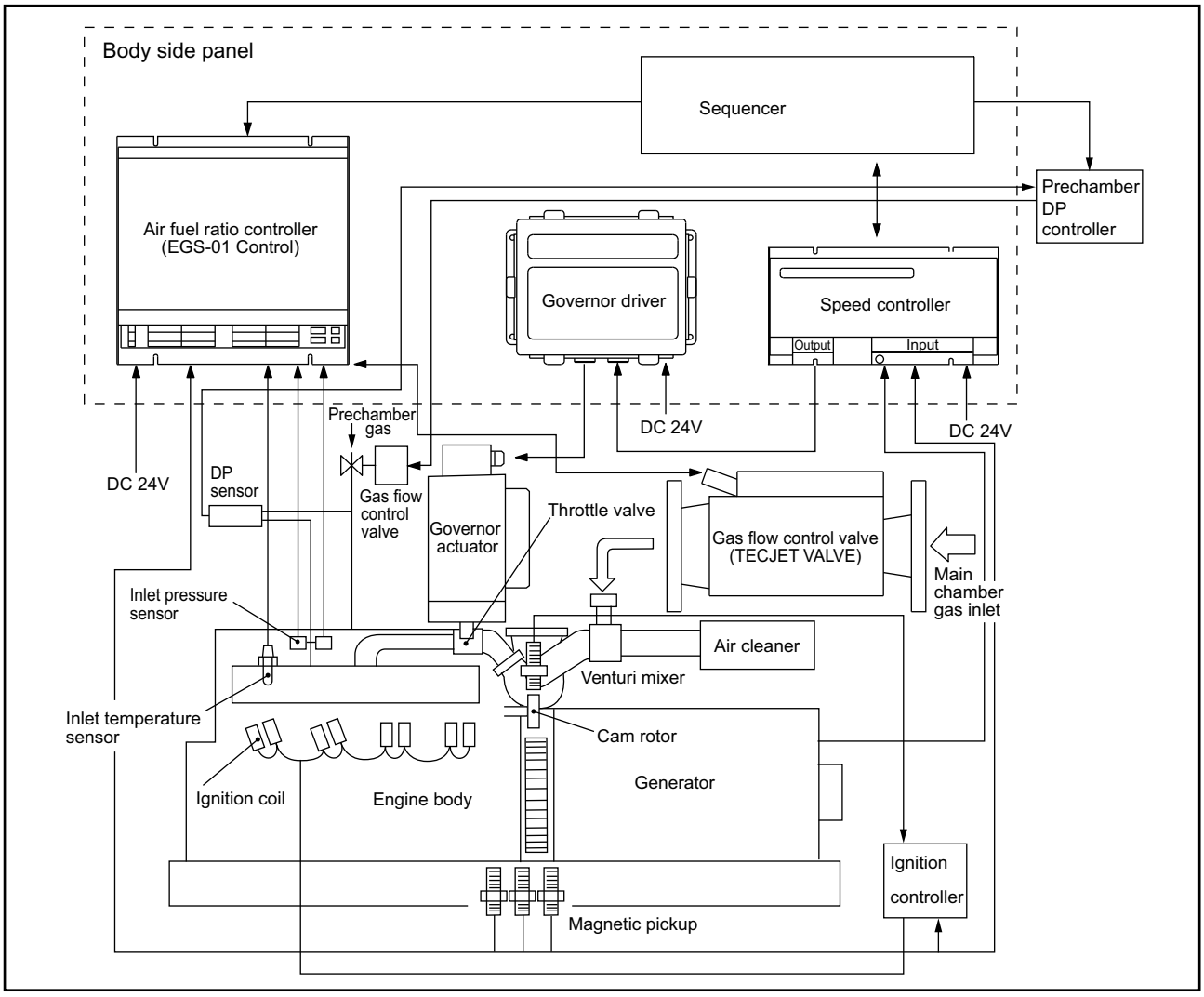


Fig. 2−3 Gas fuel control system

Instruments

This section describes the devices which transmit signals to the instruments that are necessary for operation.
Be sure to understand the function of each device before proceeding with operation.

Coolant temperature sensor

The coolant pipe has a built-in coolant temperature sensor for the detection of engine cooling water temperature.
Operating temperature range: 0 to 200°C [0 to 392 °F]

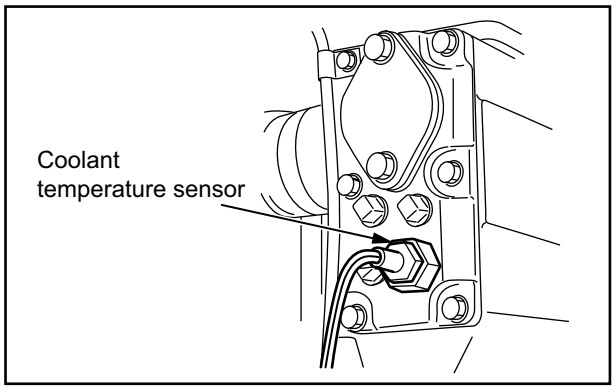


Fig. 2-4 Coolant temperature sensor

Exhaust temperature sensor

The exhaust manifold and exhaust pipe are installed with exhaust temperature sensors for the detection of engine exhaust gas temperature.
Operating temperature range: 0 to 800 °C
[0 to 1472 °F]

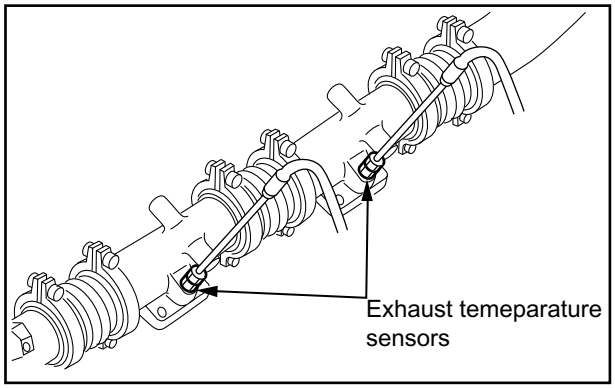


Fig. 2-5 Exhaust temperature sensor

Intake air temperature sensor

The intake air chamber is installed with an intake air temperature sensor for the detection of intake air temperature.
Operating temperature range: 0 to 100 °C
[0 to 212 °F]

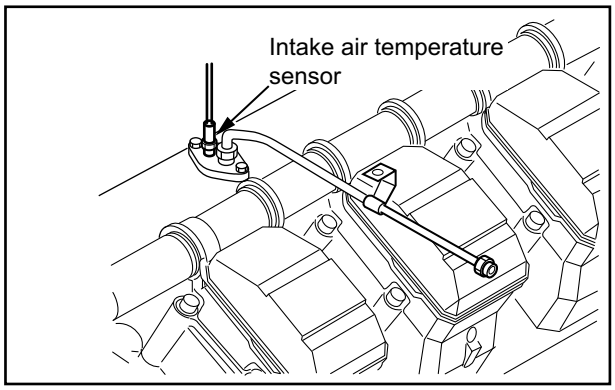


Fig. 2-6 Intake air temperature sensor

Engine oil temperature sensor

The oil pan is provided with a temperature sensor for the detection of engine oil temperature.

Temperature measuring range 0 to 200°C [0 to 392°F]

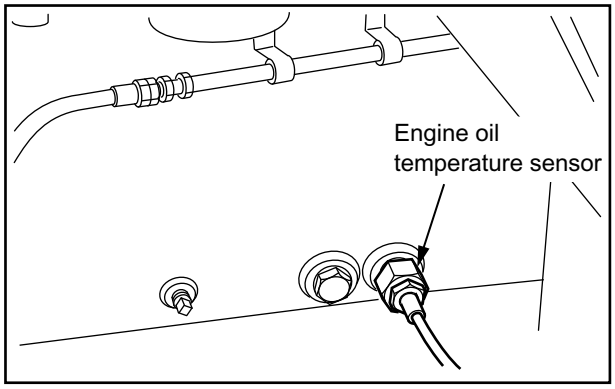


Fig. 2-7 Engine_oil_temperature sensor

Pressure send-out unit

The pressure send-out unit detects engine oil pressure.

Pressure measuring range:0 to 1.0 MPa {0 to 10 kgf/cm²} [0 to 145 psi]

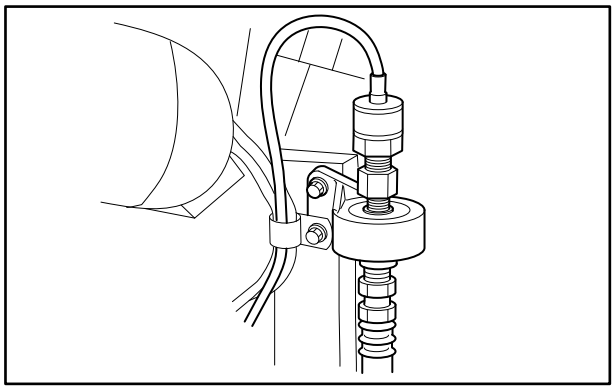


Fig. 2-8 Pressure send-out unit

Revolution pickup

The revolution pickup is installed in the timing gear case to detect the engine speed.

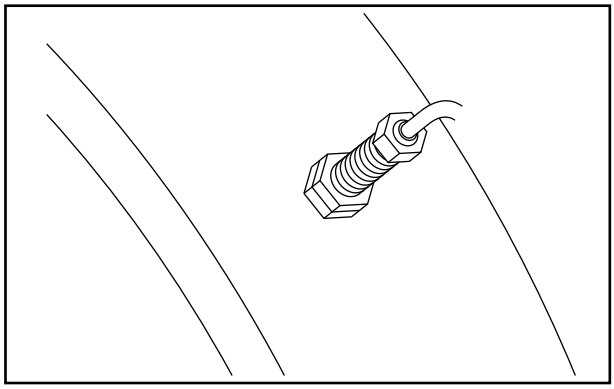


Fig. 2-9 Revolution detection pickup

Knocking sensor pickup

The knocking sensor pickup detects and supresses knocking of the engine.

DISN pickup

The DISN pickup that detects camshaft position is installed for ignition controller, DISN800.

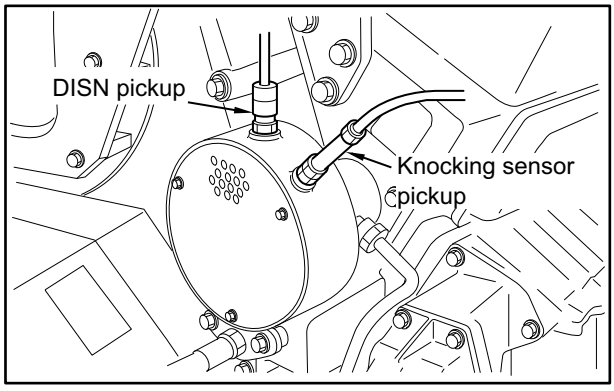


Fig. 2-10 Knocking sensor and DISN pickup

Engine Protection Devices

Oil filter alarm switch

The oil filter alarm switch activates the alarm system when the oil filter is clogged.
The switch is activated when the difference of pressures measured at before and after oil filter reaches the specified value.
When the alarm sign is given, immediately replace the oil filter with a new filter. Also renew the engine oil.

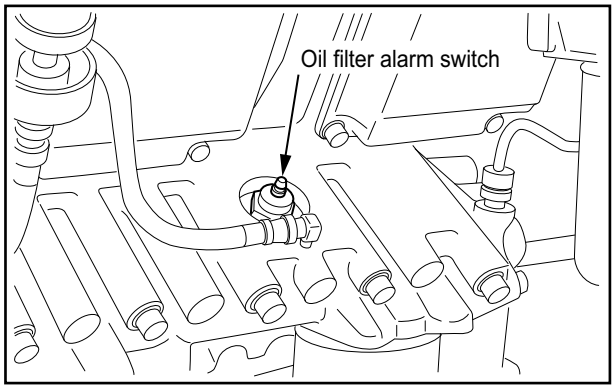


Fig. 2−11 Oil filter alarm switch

Air cleaner indicator

When the air cleaner element is clogged and the deference of pressures measured at before and after air cleaner becomes abnormally high, the air cleaner indicator shows a red sign.
Immediately clean the element or replace with a new element when the red sign appears.
After cleaning or replacing the air cleaner, press the button on the top of the indicator to reset the alarm signal. When serving the air cleaner, use care to prevent dust from entering the air cleaner. Also do not damage nor distort the element.

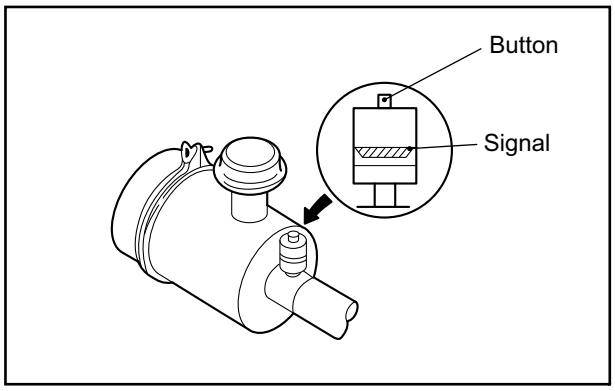


Fig. 2−12 Air cleaner indicator

Gas supply line

The gas supply line is provided with the following devices.
The diagrams show standard gas supply lines.Since the actual gas supply line varies depending on the specifications, use the diagrams only as a reference.

Main chamber gas supply line

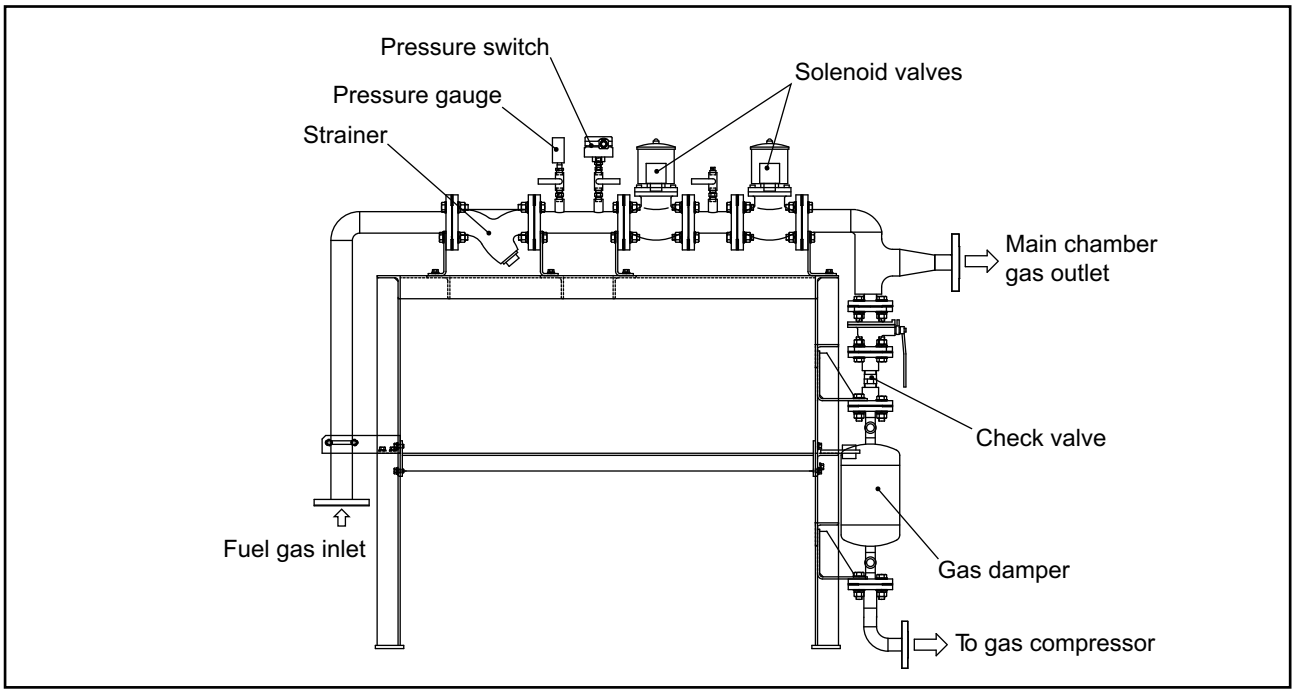


Fig. 2−13 Main chamber gas supply line

Pressure switch

The pressure switch monitors the pressure of the fuel gas and protects the engine from any pressure trouble.

Solenoid valve

The solenoid valve controls the flow of the fuel gas.
An armature, called plunger, is placed in a coil, called solenoid. The armature moves to open and close the solenoid valve.

Prechamber gas supply line

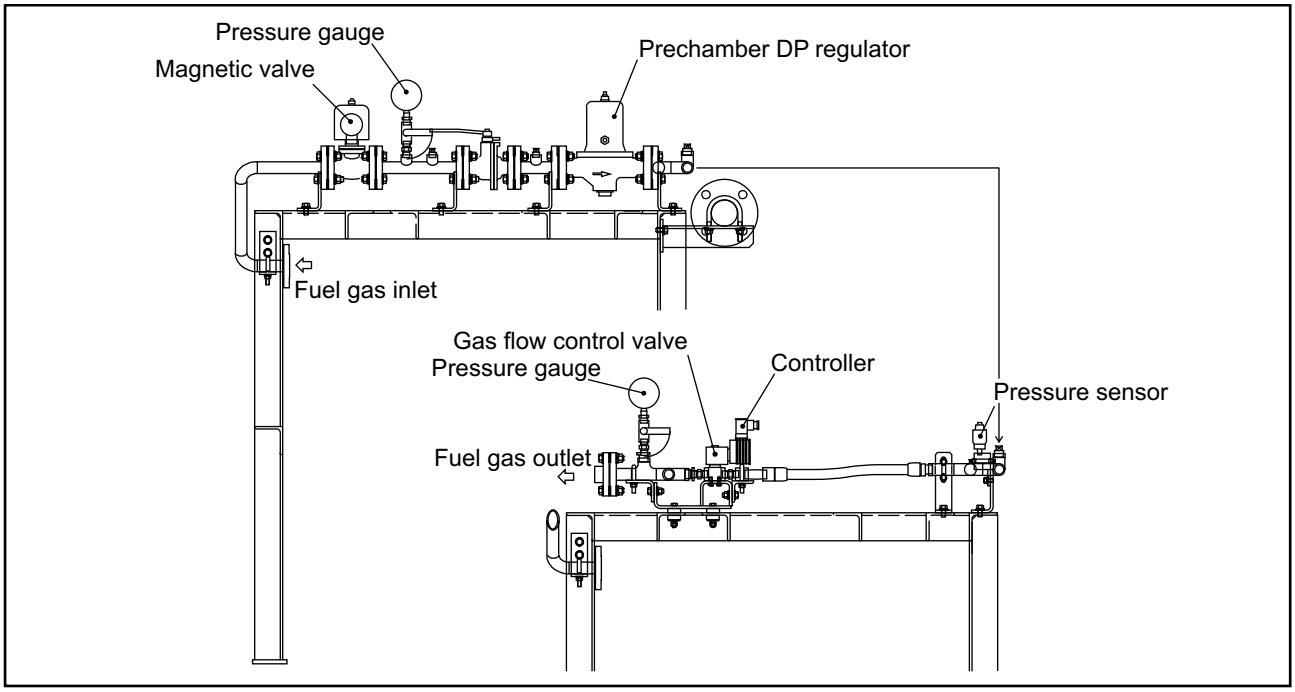


Fig. 2-14 Prechamber gas supply line

Prechamber DP regulator

The prechamber DP regulator adjusts the fuel gas to a pressure higher than the manifold pressure.

Gas flow control valve and controller

Gas flow control valve and controller adjusts the fuel gas to a flow rate that matches the engine speed and load.

Pressure sensor

The pressure sensor monitors the fuel gas pressure and manifold pressure.

Using turning gear

⚠ WARNING

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

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

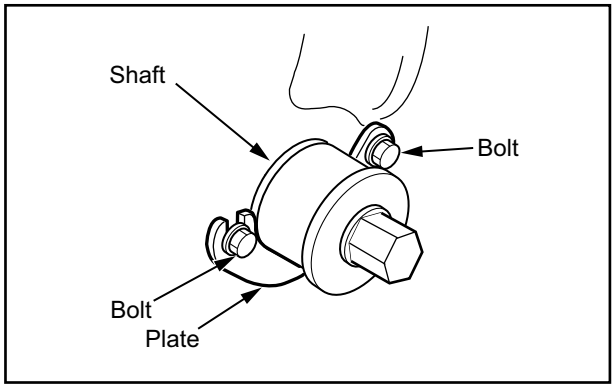


Fig. 2−15 Turning gear position(Engine in operation)

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

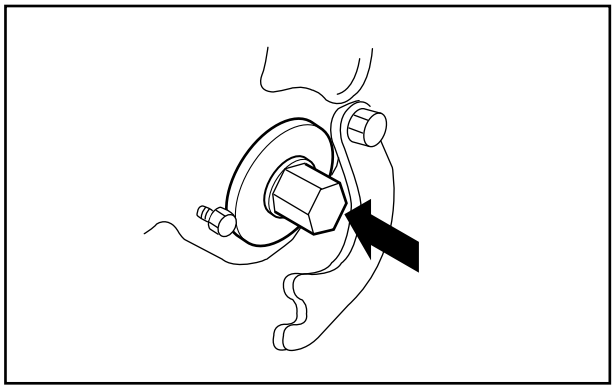


Fig. 2−16 Turning gear position(Shaft pushed in)

3. Using a socket wrench and a ratchet handle, turn the shaft.

4. After turning, pull out the shaft, insert the plate in the shaft groove, and tighten the bolts.

⚠ CAUTION

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

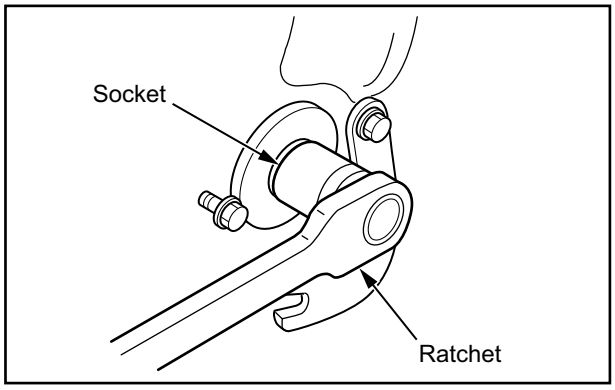


Fig. 2−17 Turning gear position(Turning shaft)

Chapter 3 OPERATION

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" (3-5).

External inspection

Look around and under the engine for:

- Faulty electrical wiring
- Faulty or lost parts
- Loose bolts and nuts

Lubricating system

Filling engine with engine oil

1. Remove the plug from the oil filler.
2. Fill the engine with the 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 covers of all the cylinders. Lubricate the valve mechanisms and fill the camshaft oil bath with engine oil from the cylinder head.
   Oil capacity per cylinder: 0.8L
4. Reinstall the rocker covers.
5. Check the oil level of oil pan as described below:
   - Pull out the oil level gage and wipe it clean with a clean cloth.
   - Reinsert the oil level gauge all the way in the oil level guide and then pull it out again.
   - The oil level is correct if it is between maximum and minimum level marks.
   - Add the specified engine oil if it is lower the minimum level mark.
6. Check the oil pan and other parts for oil leakage. Repair the oil leakage if any.
7. Crank the engine with the starter for 10 seconds to circulate oil throughout the engine. After 1 minute of rest period, start cranking again to circulate oil throughout the engine for another 10 seconds.

CAUTION

To crank the engine, shut off the fuel gas 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.

8. Check the oil level with the oil level gauge again, and add oil if necessary.

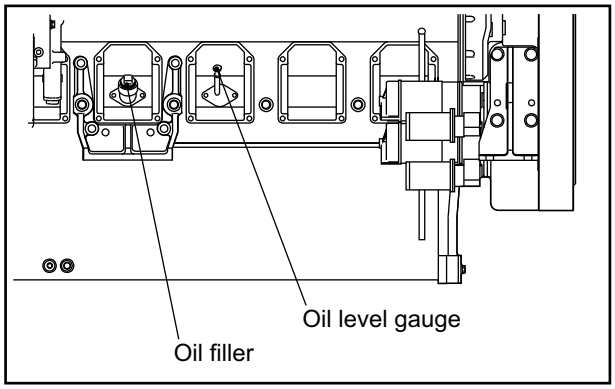


Fig. 3−1 Oil filler and oil level gauge

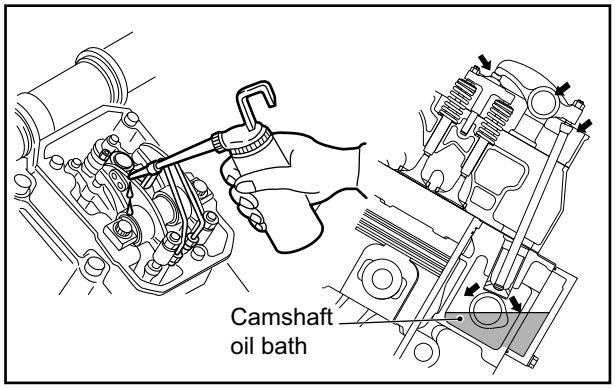


Fig. 3−2 Pouring engine oil on valve mechanisms and chamber

Cooling system

Filling cooling system with coolant

1. Make sure the drain cocks on the engine and water pump are securely tightened.
2. Remove coolant expansion tank 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 coolant pipe when adding water.

4. Check the coolant expansion tank and other parts for coolant leaks. Repair leakage if found.
5. Install the coolant expansion tank cap securely.
6. Check the coolant level in the coolant expansion tank, refill the tank if necessary.

CAUTION

Always use the coolant with the same LLC concentration for refilling.

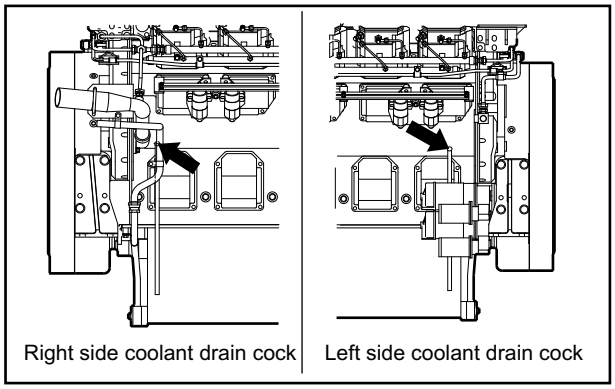


Fig. 3-3 Coolant drain cock on the engine

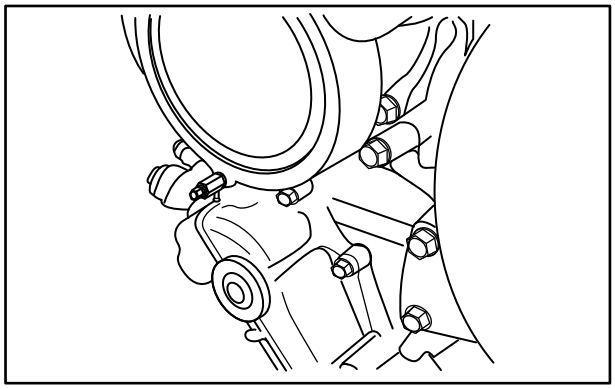


Fig. 3-4 Coolant drain cock on the dummy pump

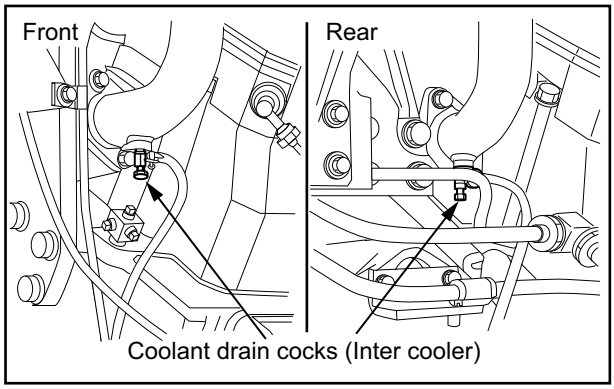


Fig. 3-5 Coolant drain cock on the intercooler

Inspecting the battery

⚠ 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. For other cautions in handling the battery, refer to "Service battery" (1-7).

Inspecting battery electrolyte level

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.

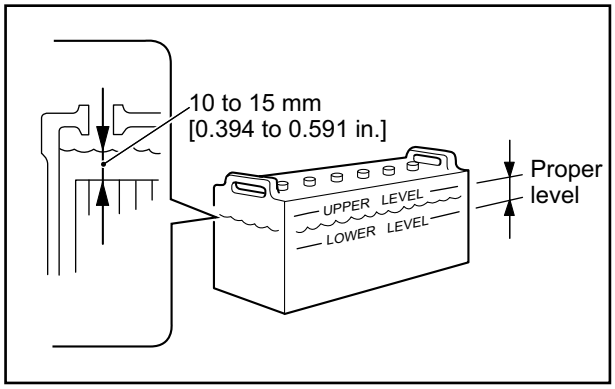


Fig. 3-6 Inspecting electrolyte level

Inspecting specific gravity of battery electrolyte

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

Table 3-1 Specific gravity of electrolyte

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

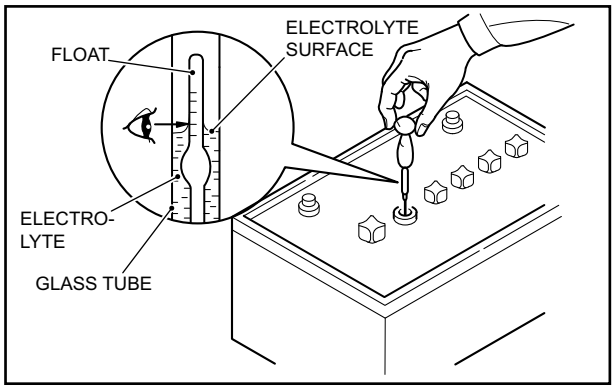


Fig. 3-7 Inspecting specific gravity of electrolyte

Normal engine operation

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

⚠ CAUTION

If any engine abnormality is observed during operation, stop the engine and correct the problem, or contact your local Mitsubishi dealer.

Preparations for operation (pre-start inspection)

Before starting the engine, always conduct the following inspection.

External inspection

⚠ 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 gas and oil leaks. Clean the top of battery with a wet cloth before starting engine, as dust on the battery can easily ignite. If any abnormality is found, be sure to repair 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 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 to such components as starter for loose.
3. Check the entire engine for leakage of fuel gas, engine oil or coolant. If leaks are found, repair the leak, or contact your Mitsubishi dealer.
4. Make sure the following valves, plugs and cocks are open or closed properly.
   Fuel gas feed valve: Open
   Coolant drain cock (plug): Closed
   Oil drain valve: Closed

Checking engine oil level (When engine is cold)

Checking by oil level gauge

CAUTION

Use the fuel specified in "FUEL" (4-1).

1. Pull out the oil level gauge and wipe it with a clean 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 plug and add engine oil of the specified type to the MAXIMUM level.
5. Install the oil filler plug after a refill.
6. Check the oil pan and other parts for oil leaks.

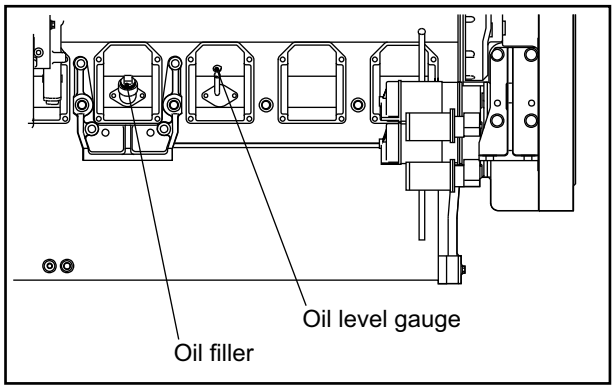


Fig. 3-8 Oil filler and oil level gauge

Checking by oil level regulator

Visually check the oil level regulator inspection window.

When the engine is not operated, the oil level regulator inspection window is filled with the oil.

Note: When the engine is operated, the oil level comes down to around middle of the inspection window.

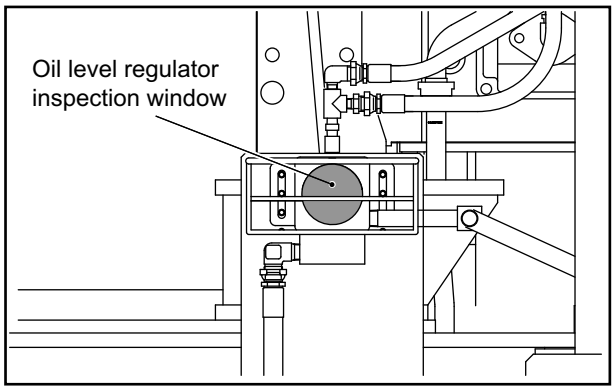


Fig. 3-9 Oil level regulator

Checking coolant level

⚠ WARNING

Remove the coolant expansion tank cap only after the engine is cooled to the room temperature. Place a cloth over the cap, and loosen the cap or stand the lever to the upright position to release internal pressure. Opening the coolant expansion tank cap while the engine is hot causes steam and hot coolant to splay out that may result in skin burns.

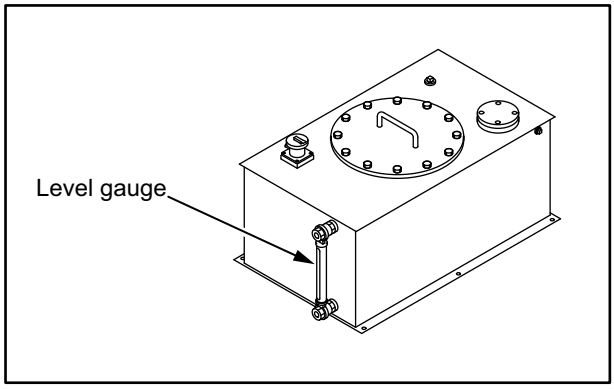


Fig. 3−10 Checking coolant level

1. Check the coolant level by level gauge of coolant expansion tank.
2. If the coolant level is low, add coolant to the specified level.

CAUTION

Always use the coolant with the same LLC concentration for refilling.

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).

Checking the air cleaner

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.

Note: For cleaning of the air cleaner element, refer to "Cleaning air cleaner element" (8-5).

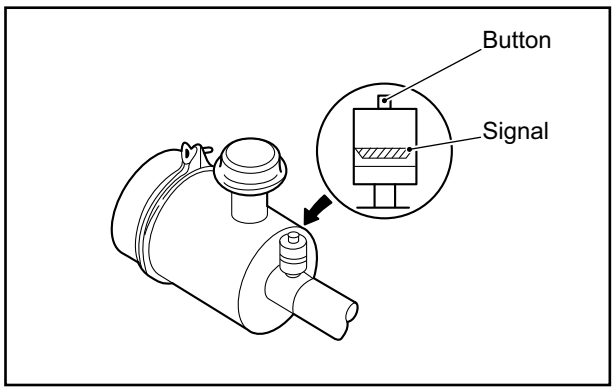


Fig. 3−11 Air cleaner indicator

Starting

⚠ WARNING

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

CAUTION

A long and continuous operation of the starter drains the battery power, and it can also burn the starter. When startup congestion occurs, locate the cause and repair the problem securely before restart the engine.

The starting method varies depending on the application and specifications. Start the engine according to the specified procedure.

Warming-up operation

⚠ WARNING

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

CAUTION

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

After the engine starts, operate at no load min. rated speed for 3 to 10 minutes to warm up.

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 indicates higher pressure than normal (0.49 to 0.64 MPa (5 to 6 kgf/cm²) [71 to 93 psi]) immediately after the engine starts since the oil temperature is low. This does not denote an abnormality. The pressure gradually lowers to the normal level as the oil temperature rises.

External inspection during warming-up

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

Note: The leaks will not be seen on the prechamber gas line (engine side) since it is negative pressure during no load operation and middle range load operation. Inspect it when engine operates with full load.

Operation

⚠ 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

Be sure to provide sufficient 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 of new engine or overhauled engine, operate the engine under light load at lower speed than the normal operation 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 battery charge but also causes malfunctioning of instruments and deteriorates 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.

Note: For abnormal exhaust gas conditions, refer to "Other problems and countermeasures" (11-3).

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

Table 3−2 Standard values at rated speed

Item	Standard value
Engine oil pressure gage	0.49 to 0.64 MPa (5 to 6.5 kgf/cm²) [71 to 92 psi]
Coolant temperature	70 to 90 °C [158 to 194°F]

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

(b) When the high temperature alarm switch is activated in normal operation, change the engine operation immediately to no-load idling (600 min^{-1}) condition until the engine temperature decreases to normal operating level. Then, operate the engine for another 3 minutes for cooling before stopping the engine. Before restarting the engine, check and correct the cause of the problem.

Stopping

⚠ CAUTION

The sudden engine stop at high speed operation creates a local abnormal high temperature rise, and shortens the service life of engine. Except in an emergency, be sure to conduct cooling operation for 3 minutes following the time schedule before stopping the engine.
Stopping the engine immediately after high-load operation will cause engine parts to heat up and shorten the service life of engine. During the cooling operation, check the engine for abnormalities.
Do not restart the engine immediately after abnormal shut down. When the engine stops with a warning alarm, be sure to locate the cause of the problem and correct the problem before restarting the engine. And 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.

Inspection after stopping

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

Chapter 4 FUEL

Natural gas fuel recommendation

⚠ CAUTION

Use the recommended natural gas fuel only.
When using any other gas fuel, consult your Mitsubishi dealer.

Chapter 5 Engine Oil

Recommended types of engine oil

Use Nippon Mitsubishi TES Oil GXL-193B, or Idemitsu Kosan Co.,Ltd Aporoil Cogene Alpha CG40M. Improper or inferior oil can cause excessive wear of bearings and moving parts, which shortens the engine life. It also causes sticking of piston rings and seizing of pistons in the cylinders, which may result in a major damage of the engine.

Table 5-1 Physical requirements (Nippon oil corporation TES Oil GXL-193B)

Item	Standard
Density	0.855 g/cm³ (15 °C [59 °F])
Flash point	258 °C [496 °F] (COC、PM)
Kinematic viscousity	138.3 mm²/s (40 °C [104 °F]) 16.7 mm²/s (100 °C [212 °F])
Viscousity index	129
Total acid number	1.9 mgKOH/g
Total base number	9.2 mgKOH/g (HCL) 8.4 mgKOH/g (PCA)
Aulfated ash content	0.96 WT%
Carbon residue	0.99 %

Table 5-2 Physical requirements (Idemitsu Kosan Co.,Ltd Aporoil Cogene Alpha CG40M)

Item	Standard
Density	0.876 g/cm³ (15 °C [59 °F])
Flash point	254 °C [489 °F] (COC、PM)
Kinematic viscousity	128.4 mm²/s (40 °C [104 °F]) 15.46 mm²/s (100 °C [212 °F])
Viscousity index	125
Total acid number	1.37 mgKOH/g
Total base number	10.7 mgKOH/g (HCL) 8.64 mgKOH/g (PCA)
Aulfated ash content	0.98 WT%
Carbon residue	-

Handling engine oil

⚠ WARNING

Before filling 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 plug.

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 of more than the legally specified quantities, be sure to have the work performed by a service station in compliance with the legal regulations.

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

Chapter 6 COOLANT

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

Recommended water for coolant

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

Table 6−1 Water quality standards

Item	Chemical symbol	Unit	Recommended	Limit	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_2^{4-}	ppm	<50	<100	○	-
Total iron	Fe	ppm	<1.0	<1.0	-	○
Silica	SiO_2	ppm	-	<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 long life coolant (LLC) as coolant, because it prevent not only freezing of coolant but also rusting of the cooling system.
Use an all-season, non-amine type LLC.

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) 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 well proportioned to match the metals used in the cooling system, 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 heat exchanger

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.

Genuine LLC

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. recommends the use of our genuine long life coolant “GLASSY”, which is the most appropriate coolant for Mitsubishi gas engine.

Other brands of LLC

CAUTION

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

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. does not warrant the engine if LLC of another brand is used.

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.

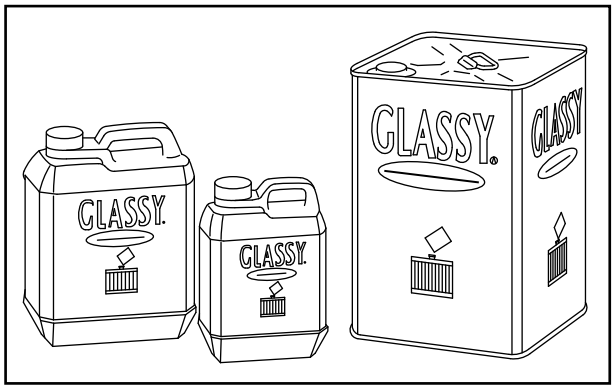


Fig. 6−1 GLASSY - LLC

Maintenance of coolant

⚠ 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 your Mitsubishi dealer.

Replacement intervals of coolant

CAUTION

Be sure to renew coolant at the specified intervals in this manual.

Failure to renew coolant may cause malfunctions due to 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 [9°F] below the expected lowest temperature in your region. Maintain the LLC concentration between 30 and 55% t roughout the year.

LLC of less than 30% concentration does not provide sufficient corrosion protection.LLC of more than 55% concentration can adversely affect its freezing protection characteristic and cause the engine to overheat easily.

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

Table 6−2 LLC concentration

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

Note: The concentration above is based on genuine Mitsubishi GLASSY long life coolant.
For determining the accurate LLC concentration, refer to the instructions for the LLC used.

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. When you think the engine should be serviced more frequently due to particular operating conditions, adjust intervals accordingly.

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.

Service the items with shorter intervals that correspond to the interval of the service being conducted. (Example) During the inspection conducted at "Every 4000 Service Hours", also perform service items listed under "Every 2000 Service Hours" and "Every 1000 Service Hours".
Items marked with * in the maintenance schedule require special tools or large equipment. For the servicing of those items, consult a Mitsubishi dealer.

For the following service items, the indicated tests details are as follows.
Inspecting protection device operations

- Close the contact of each protection device to check the operation of the stop solenoid and the conductivity of the alarm circuit.
- Thermal switch operation test
- Oil pressure switch operation test
- Engine overspeed test
- Engine startup congestion test
- Coolant water cut-off sensor operation test
- Low voltage, voltage overload and current overload sensor operation test
- Low coolant tank level sensor operation test
- Others

Inspection of auxiliary device operations

- Water heater operation test
- Oil heater operation test
- Oil priming pump operation test
- Fuel gas compressor operation test
- Governor actuator operation test
- Others

Engine top overhaul
On the top overhaul, remove the cylinder heads, inspect the cylinder head, combustion chamber area, and other main components. Also replace the parts of these components.
For details of top overhaul, consult your Mitsubishi dealer.

Engine major overhaul
On the major overhaul, disassemble the engine fully, inspect main components and replace the parts.
For details of major overhaul, consult your Mitsubishi dealer.

Maintenance schedule for gas engine

Table 7−1 Maintenance schedule for gas engine(1 / 2)

Service item		Page or Service classification
First 250 service hours of new or reconditioned engine		
	External inspection for loose bolts and nuts	–
	Changing engine oil, oil filters and bypass oil filter	8-7
	Changing oil filters and bypass oil filter	8-8
	Inspecting and adjusting valve clearance	*
Every 1000 service hours		
	Checking air cooler for water leaks and oil drain	8-1
	Checking gas supply for gas leaks (by using gas leak detection fluid or soapy water)	8-1
	Checking silencer for exhaust gas leaks	8-2
	Inspecting and adjusting ignition plugs	8-3
	Inspecting and adjusting ignition timing	*
	Cleaning air cleaner element	8-5
	Cleaning, replacing mesh demister	8-5
	Inspecting the battery (Gravity : from 1.26 to 1.28)	8-6
	Checking LLC concentration of coolant	*
Every 2000 service hours		
	Changing engine oil, oil filters and bypass oil filter	8-7
	Changing oil filters and bypass oil filter	8-8
	Inspecting and adjusting valve clearance (Inspecting valve mechanism at same time)	*
	Changing air cleaner element	8-10
	Replacing ignition plugs	8-10
Every 4000 service hours		
	Inspecting damper	8-11
	Inspecting starters	8-12
	Inspecting governor actuator coupling (Visually inspect abnormalities)	8-12
	Inspecting gas fuel devices, Inspecting gas pressure switch, Cleaning gas strainer, Inspecting gas cut-off valve, Inspecting gas regulator	8-12
	Inspecting turbocharger (Axial thrust and manual rotation test)	*
	Inspecting prechamber valve holder assembly	*

Table 7-1 Maintenance schedule for gas engine(2 / 2)

Service item		Page or Service classification
Every 8000 service hours		
	Changing coolant	8-12
	Overhaul turbochargers	*
	Overhaul starters	*
	Cleaning water heat exchanger	*
	Overhaul gas cut-off valve	*
	Maintenance of prechamber gas compressor (Changing drive belt, cleaning strainer)	*
	Checking and cleaning air cooler	*
	Checking protective devices indicator	*
	Cleaning oil supply tank	*
	Cleaning coolant expansion tank	*
	Checking and replacing coolant rubber hoses	*
	Checking and adjusting cylinder heads	*
	Checking and servicing prechamber chamber	*
	Removing cylinder heads, checking and servicing aroung combustion chambers	*
Every 16000 service hours		
	Changing damper	*
	Changing starter	*
	Changing cylinder liner	*
	Overhaul gas regulator	*
	Overhaul governor	*
	Overhaul gas compressor	*
	Overhaul auxiliary components	*

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

High pressure gas equipment inspection chart

Table 7-2 High pressure gas equipment inspection chart(1 / 3)

Equipment	Item	Daily inspection	Periodic inspection	Frequency		
				Every month	Every 6 months	Every year
			O:Recommended frequency	◎ :Standard frequency		
Gas pipe system	Leakage check	Check for abnormal odors and noise.	Conduct inspection with a leak detector or soapy water.			○
	Corrosion and mechaninal damage	Inspect visually.	Examine the pipes and surrounding area, and check the gas pipe instructions.			○
Valves and other accesories	leakage check	Check for abnormal odors and noise.	Conduct inspection with a leak detector or soapy water.		◎	○
	Valve and cock operation check	Check for obstruction in the surrounding area.	Check the cocks for looseness, and check the handle operation.			○
	Strainer clog check		Remove the strainer and check for clogging, damaged screen, scratches on packing, and other abnormalities.			○
	Cleaning of exterior	Inspect visually.	Clean the external surfaces of the gas pipe, cut-off valves, regulating valve, other accesories, and control panel.	○		
Booster regulator	Suction and discharge pressure check	Check the gauge pressure.				
	Drive section and bearing check	Check visually for abnormal vibrations, noise and heating.	Check vibrations, bearing temperature, and coolant flow rate and temperature.			○
	Shaft seal leakage	Check for abnormal odors.	Conduct inspection with a leak detector, or test with soapy water.			○
Pressure regulator	Operation check	Check the gauge presure.				

Table 7−2 High pressure gas equipment inspection chart(2 / 3)

Equipment	Item	Daily inspection	Periodic inspection	Frequency		
				Every month	Every 6 months	Every year
Safety cut-off valve and emergency cut-off valve	Operation abnormalities	Check for abnormal vibrations, noise and heating.	Check the cut-off operation.		◎	○
	Insulation resistance measurement		Measure the insulation resistance of the cut-off valves, and make sure the insulation resistance exceeds the standard.			○
	Internal leakage	Check for the pressure rise in the downstream of the cut-off valves, or pressure in the upstream.	Measure the flow rate at the cut-off valves with a measuring cylinder (bubbling test), and make ure internal leaks are within allowable range.		◎	○
Combstion monitoring device	Function abnormality check		Make sure a misfire signal is generated after the safety switch operation time.		◎	○
Pressure switch	Operation condition check		Check for setting deviation. Operate the pressure switches, and check the safety cut-ooff valves, corresponding device operations and alarms.			○
Vibration detector	Function abnormality detection		Check manually for operation abnormalities.			○
Pressure gauge and temperature gauge	Indication abnormality check	Check for abnormal vibrations and pulsation	Check if the indications are correct by comparing with reference standards.			○
Backflow prevention device	Function abnormality check		Check by removing or applying back pressure.			○
Gas leak alarm	System function abnormality check		Trigger the alarm by using a test gun, and make sure the safety cut-off valves and other devices operate properly.			
	Validity period check		Make sure that the validly periods have not expired.		◎	○
Safety valves			Make sure the safety valves operate at set values.			○
Emergency open valve (EOV)			Check for abnormal operation.			○

Table 7-2 High pressure gas equipment inspection chart(3 / 3)

Equipment	Item	Daily inspection	Periodic inspection	Frequency		
				Every month	Every 6 months	Every year
Air intake/ exhaust facilities	Abnormality check	Check if the dampers are open to the specified angles.	Check the blower outlet pressure, current, etc.			
			Check the air duct inlet and outlet screens for clogging and abnormalities.	○		
Exhaust equipment	Abnormal heating check	Check if there are combustibles in the surrounding area.	Check the surfaces for overheating, and measure the temperature.			○
	Clog check		Measure the draft pressure and exhaust gas temperature.			○
	Exhaust gas damper	Inspect visually.	Check the damper operation. Check for gas leaks and opening angle abnormality.		◎	○

Chapter 8 PERIODIC INSPECTION AND MAINTENANCE PROCEDURES

Every 1000 service hours

Checking air cooler for water leaks and oil drain

Check air cooler for water leak at water pilot hole on the connecter.

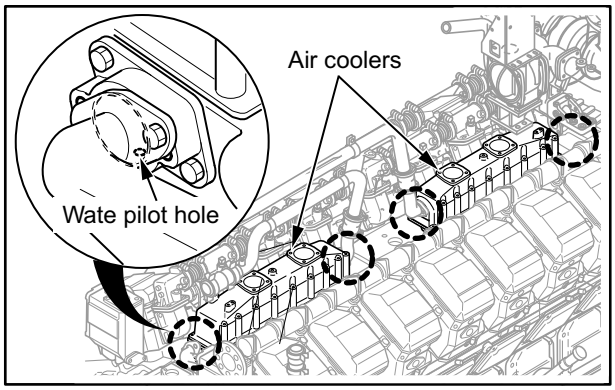


Fig. 8−1 Checking air cooler for water leaks

Open the oil and water drain cock, and drain oil and water. Check that whether amount of drain water is large abnormally or not.
Be sure to close the drain cock after checking.

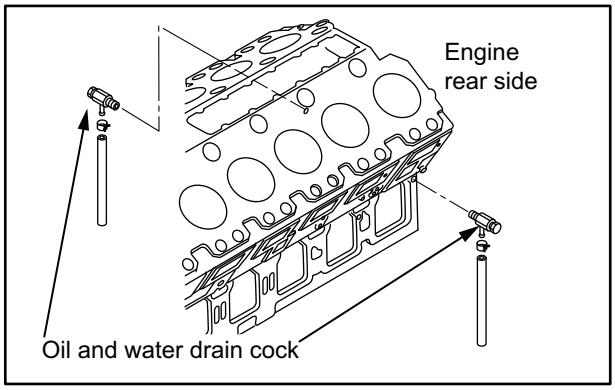


Fig. 8−2 Oil and water drain cock

Checking gas supply for gas leaks

Check gas supply line for gas leak by applying gas leak detection fluid or soapy water.
Also, check the gas leak detector.

CAUTION

Pay attention to that there are negative pressure line partly in the gas line.

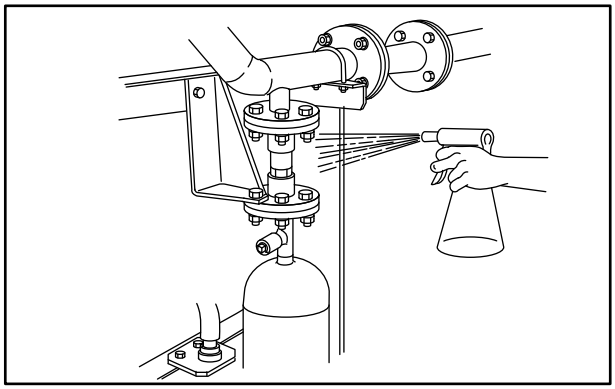


Fig. 8−3 Checking gas supply for gas leaks

Checking silencer for exhaust gas leaks

Check the silencer for exhaust gas leak.

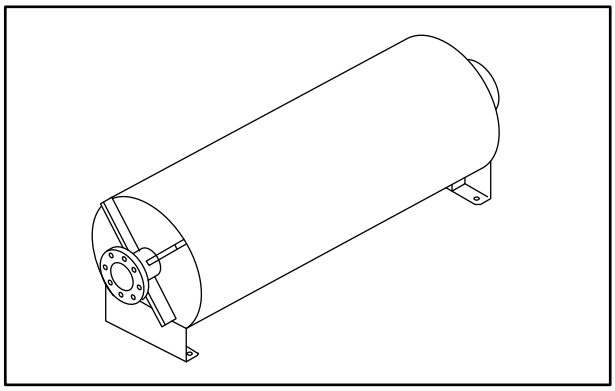


Fig. 8-4 Checking silencer for exhaust gas leaks

Inspecting and adjusting ignition plugs

Removing ignition plugs

1. When disconnecting the ignition plug cable, take hold of the cap portion.

2. Before removing the ignition plug cable, clean the area to prevent dust and dirt from getting inside the cylinders.
Use plug wrench (35A91-08200), extension bar (35A91-08300) and slide handle (35A91-08400) to remove and install the ignition plugs.

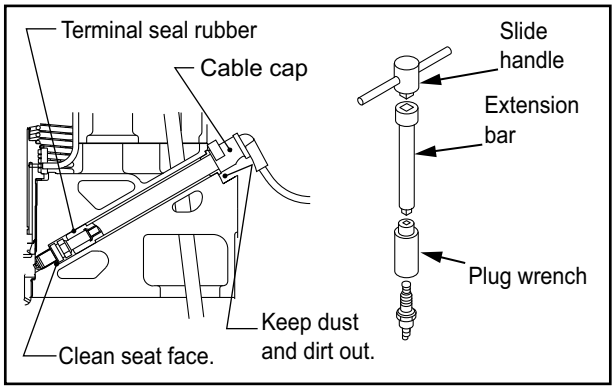


Fig. 8−5 Removing and installing ignition plugs

Checking ignition plugs

Check the plugs and replace them if defective.

- Perspiration
- Check the porcelain insulator for damage.
- Check the trace of flash-over.
- Check the electrodes for severe erosion or wear.
- Check for excessive carbon deposits. (If carbon deposits are not excessive, the plug can be cleaned with a cleaner or a wire brush.)
- Check the gasket for damage.
- Check the firing tip for severe burning.
- Check that the pulg gap is in the standard value by using microscope.

Note :(a) If the ignition plug is covered with black carbon or looks smoldered, the air-fuel mixture may be too rich, the intake air may be extremely limited or excessive plug gaps may be causing misfires.

(b) If the ignition plug is whitish, the air-fuel mixture may be too lean, the ignition timing may be too advanced or the ignition plugs may not be tightened properly.

(c) When reinstalling the ignition plugs after inspection, be sure to clean the electrodes and adjust the plug gaps.

(d) If the plug gaps are excessive, or electrode tips wears rapidly, the prechamer gas may be extremely thin, or the plug gap may be excessive from the first.

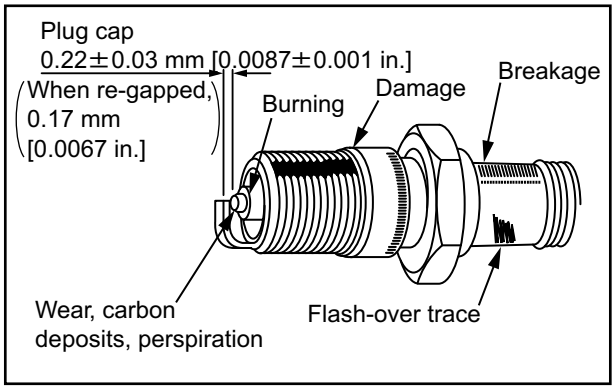


Fig. 8−6 Checking ignition plugs

Installing ignition plugs

⚠ CAUTION

Be sure to tighten the ignition plugs to the specified torque.
Excessive tightening force can damage the threads of the ignition plugs.

1. Make sure the glass section of each ignition plug is free of oil and dirt.If it is dirty, a flash-over can result.
   When installing new ignition plugs, be sure to check and adjust the plug gap of each ignition plug.
2. Apply anti-seize compund "Never seez high temeperature stainless grade" (37594-01700) to the threads of each ignition plug, making sure that compound does not extend to the electrode section. Apply compound to 8 to 9 threads from top of plug, and 1/4 round.
3. Install an ignition plug to a cylinder head, and tighten to the specified torque.
   Ignition plug tighening torque:
   20N·m{2 kgf·m}[14.75 lbf·ft]
4. Apply a small amount of talc powder (baby powder) to the inside of terminal seal rubber, and connect the ignition plug cable.

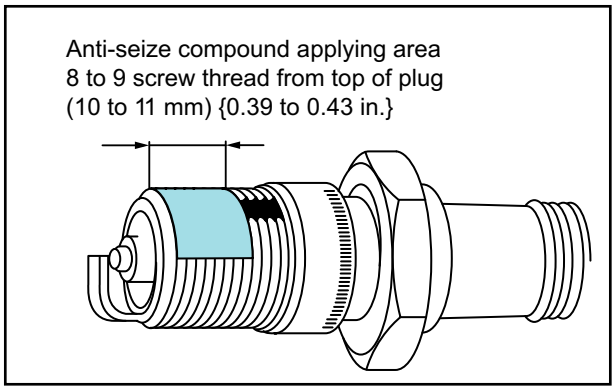


Fig. 8−7 Applying anti-seize compound

Cleaning air cleaner element

⚠ CAUTION

When using compressed air for cleaning, wear a protective face shield, goggles, and other protective gears.

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

Do not clean the element by bumping or tapping.

Replace element every 2000 service hours since cleaning element is not enough for continuous use.

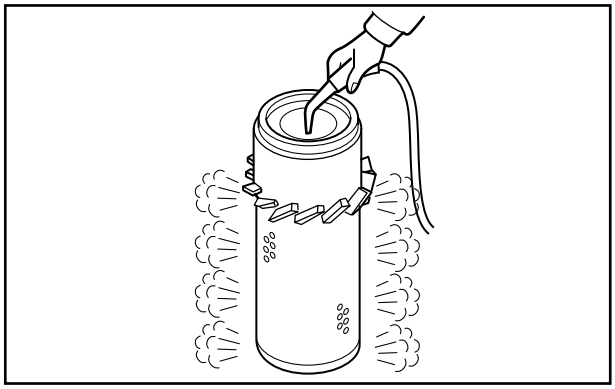


Fig. 8−8 Cleaning air cleaner element

1. Blow compressed air to the inside of element along the length of pleats. The maximum air pressure is 0.69 MPa (7 kgf/cm²) [100 psi].
2. Insert a light into cleaner element and inspect. Discard the element if rips or tears are found.
   If the indicator still shows RED shortly after the installation of the cleaner element, change the used element.

Cleaning, replacing mesh demister

1. Remove the mesh demister cover, and remove the filter and mesh pad.
2. Wash the mesh demister case and cover to remove oil.
3. Inspect the filter and mesh pad. If they are extremely dirty with oil, replace with new parts.

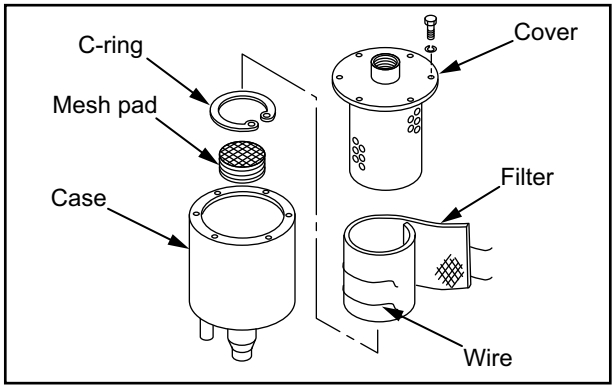


Fig. 8−9 Cleaning/replacing mesh demister

Inspecting the battery

⚠ 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. For other cautions in handling the battery, refer to "Service battery" (1-7).

Inspecting battery electrolyte level

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.

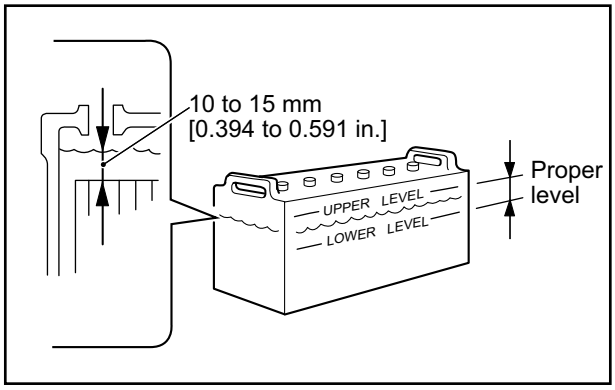


Fig. 8−10 Checking electrolyte level

Inspecting specific gravity of battery electrolyte

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

Table 8−1 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

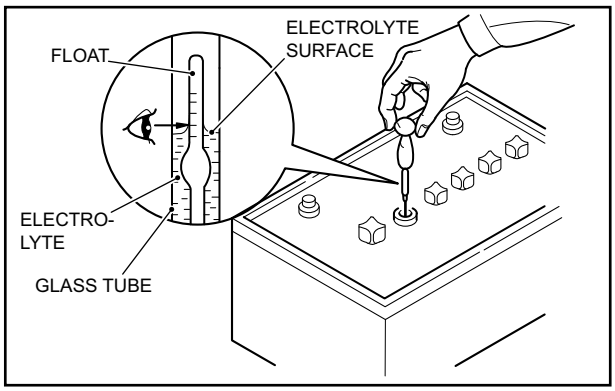


Fig. 8−11 Checking specific gravity of electrolyte

Every 2000 service hours

Changing engine oil, oil filters and bypass oil filter

⚠ CAUTION

To drain oil or change oil filter, wear gloves. Hot engine oil and parts can cause burns.

CAUTION

Disposal of discharged oil is legally restricted. Contact your Mitsubishi dealer for disposal of waste oil.
When changing engine oil, renew oil filters and bypass oil filter.
Also it is recommended to conduct an analysis of engine oil properties at the time of engine oil change.
Never wash and reuse oil filters, as their elements are paper type. When replacing filters, always replace gaskets with new ones.

Draining engine oil

After the engine has stopped and during engine is still hot, drain engine oil from the engine oil drain port.

Note: A sucking-up draining should be avoided.

Changing oil filters and bypass oil filter

⚠ WARNING

Do not use the filter that has dent or on its case.
It may damage the filter, or may cause an oil leak, which could result in a fire during operation.

CAUTION

Do not use the filter wrench to install filters. Use hands to prevent filters from damaging.

1. Clean the area around the oil filters.
2. Place a drip pan under the oil filters and a bypass oil filter.
3. Using a filter wrench, remove oil filters and a bypass oil filter.

Note: Inspect the removed oil filter and bypass oil filter and check elements for metal particles. If metal particles are found, contact your Mitsubishi dealer. Change oil filters and a bypass oil filer whenever the filter alarm turns on.

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

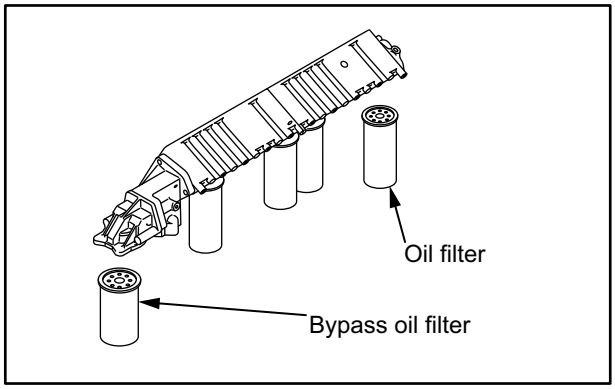


Fig. 8−12 Oil filters and bypass oil filter

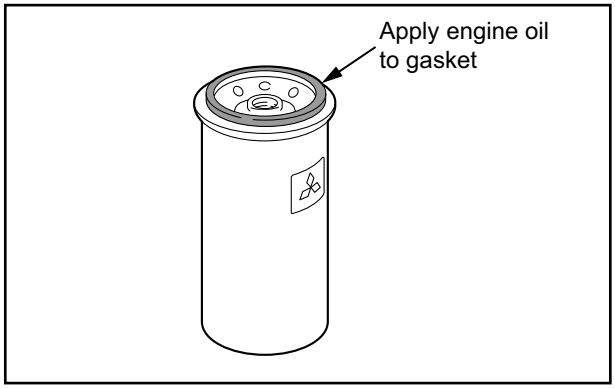


Fig. 8−13 Oil filter

Refilling engine oil

1. Make sure engine oil drain plug is closed.
2. Remove the oil filler plug.
3. Fill the engine with the 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).

4. Check the oil level of oil pan as described below:Pull out the oil level gauge and wipe it with a clean cloth.
5. Insert the oil level gauge fully into the oil level gauge guide, then pull the gauge out again. 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.
6. Check the oil pan and other parts for oil leaks. Repair any oil leakage found.
7. Shut off the fuel supply and crank the engine for about 10 seconds or less using the starters, and wait for about 1 minute.
8. Perform the above cranking operation again to circulate oil in the engine.

CAUTION

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

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

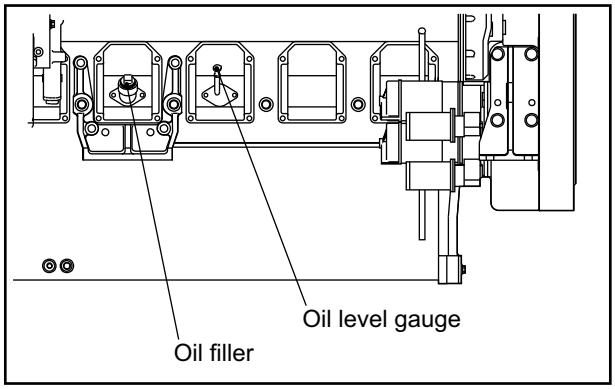


Fig. 8-14 Oil filter and oil level gauge

Changing air cleaner element

⚠ CAUTION

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

1. Remove the air cleaner cap.
2. Remove the wing nut holding the filter element in place, then pull the element out of the body. Install a new filter.

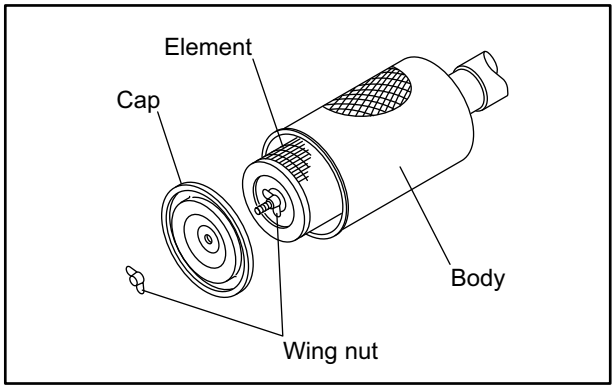


Fig. 8-15 Changing air cleaner element

Replacing ignition plugs

Replace the ignition plugs with new parts.
If the ignition plugs have not deteriorated excessively, they can be re-gapped and reused after checked according to the 1000-hour inspection and adjustment procedure.
Regarding the procedures for removal and installation of ignition plugs, refer to"Inspecting and adjusting ignition plugs" (8-3).
Before installing new ignition plugs, check to make sure the plug gap of each ignition plug is as specified. When reusing ignition plugs, adjust the plug gap to 0.17mm [0.008 in.].
When installing ignition plugs, apply anti seize compound "Never seez high temperature stainless grade" (37594-01700) to the threads, making sure that compound does not extend to the electrode section or bearing surface, and tighten to the specified torque.
Ignition plug tighening torque:
20N·m{2 kgf·m}[14.75 lbf·ft]

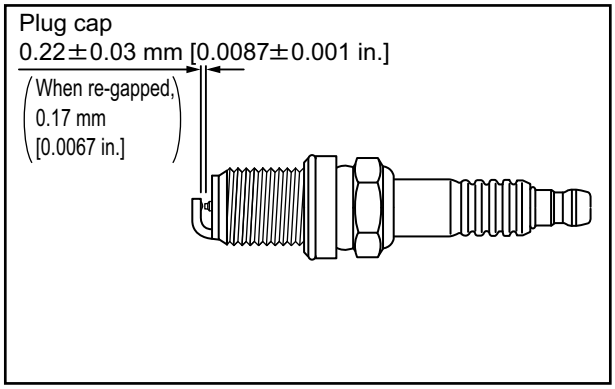


Fig. 8-16 Plug gap

Every 4000 service hours

Inspecting damper

External inspection of damper

⚠ 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 the vibration damper is defective, contact your Mitsubishi dealer.

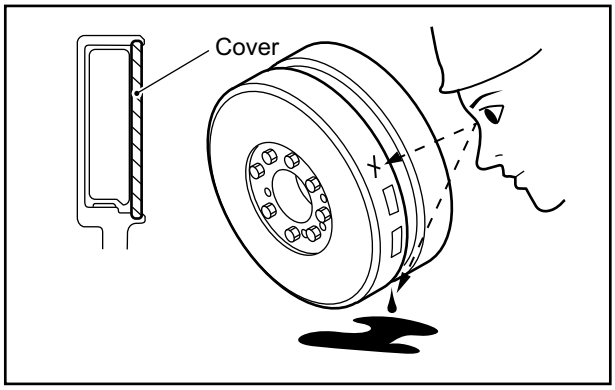


Fig. 8−17 External inspection of damper

Damper temperature management

For making damper function well, heat of damper must be dissipated from its surface to prevent excessive damper heating. Before the shipment of engines, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. inspects each engine to ensure proper operating temperature of damper. However, since damper temperature changes with the ambient conditions, it is important to observe the following instructions and provide sufficient ventilation for damper by considering factors such as layout of equipment.

1. In the case of regular use engine, make sure the temperature of the outside damper surface does not exceed 80°C [176°F] after the engine operation at the rated output for 1 hour, and for emergency engine 90°C [194°F].
   It is recommended to use the thermo label for the temperature management of damper in regular use engine.
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.

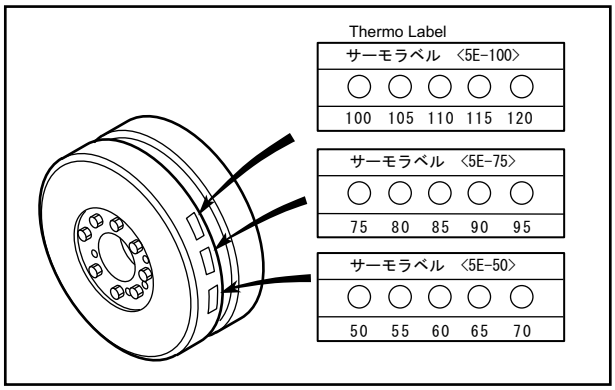


Fig. 8−18 Managing damper temperature

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]

Inspecting starters

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.

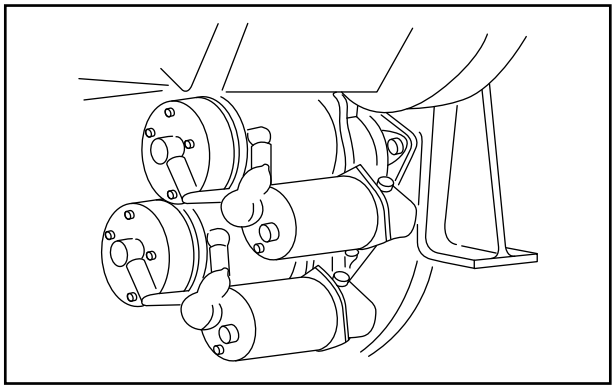


Fig. 8−19 Inspecting starters

Inspecting gas fuel devices

Inspect the gas fuel devices to make sure there is no abnormality.

- Inspect the gas pressure switch.
- Clean the gas strainer.
- Inspect the gas cut-off valve.
- Inspect the gas regulator.
- Check the gas line outlet of the gas valve for gas leakage.

For details, refer to "High pressure gas equipment inspection chart" (7-4).

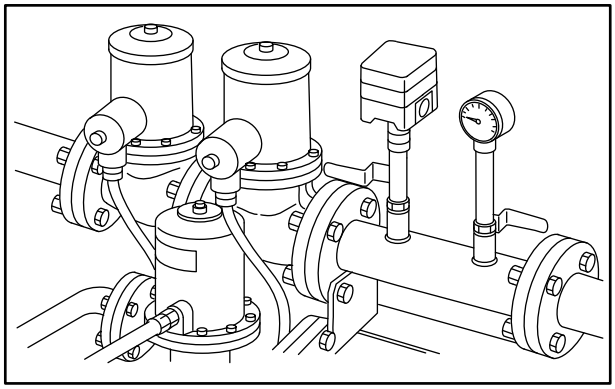


Fig. 8−20 Inspecting gas fuel devices

Inspecting governor actuator coupling

1. By looking from the periphery of the governor actuator coupling, check the coupling for twist and crack. If an abnormality is found, replace with a new part.
2. Check to make sure that the hexagon-head bolts on the coupling are tightly screwed. If loose, tighten the bolts.

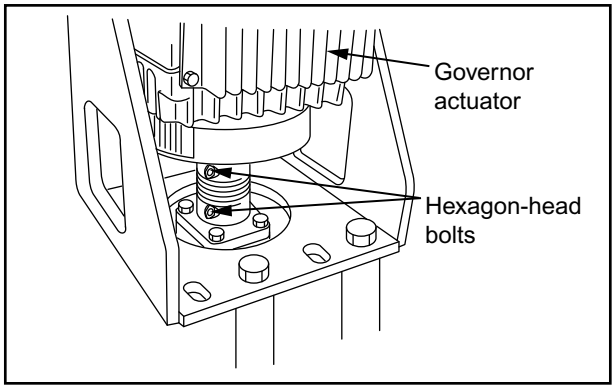


Fig. 8−21 Inspecting governor actuator coupling

Every 8000 service hours

Changing coolant

⚠ WARNING

To remove the coolant expansion tank cap, wait until the engine is cooled to the room temperature. Place a cloth over the cap, and loosen the cap or stand the lever to upright position to release internal pressure. Opening the coolant expansion tank cap while the engine is hot causes steam and hot coolant to blow out and can result in skin 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.

CAUTION

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

Draining coolant

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 coolant expansion tank cap.
3. Place coolant receiving cans under the drain cocks on the engine, and open the drain cocks to drain coolant.

Cleaning the cooling system

1. Close 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 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.

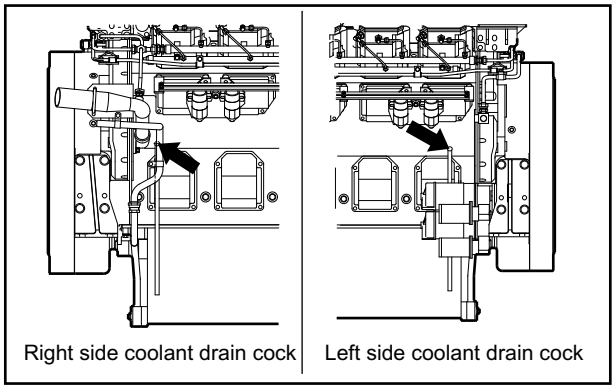


Fig. 8−22 Coolant drain cock on the engine

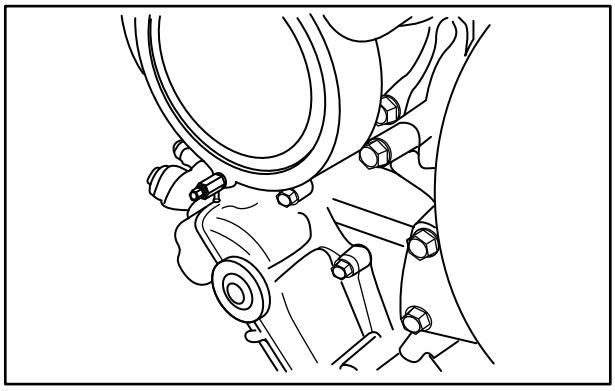


Fig. 8−23 Coolant drain cock on the dummy water pump

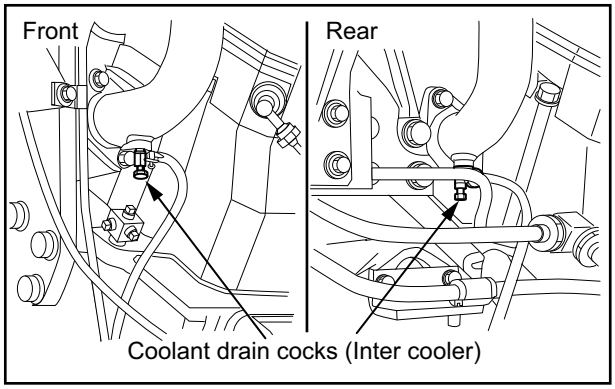


Fig. 8−24 Coolant drain cock on the intercooler

Refilling coolant

1. Make sure drain cocks and plugs are closed tightly.
2. Remove coolant expansion tank cap, and pour in undiluted LLC.

Note: Determine the amounts of LLC and water to be added by using the LLC concentration chart. For coolant, refer to "COOLANT" (6-1). For 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 coolant expansion tank and other parts for coolant leakage. If coolant leakage is found, repair it.
5. When coolant reaches the full level, close the coolant expansion tank cap securely.
6. Crank the engine for about 10 seconds or less using the starters. Wait for about 1 minute, then repeat the above cranking operation again to remove air from the coolant pipe.

CAUTION

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

7. Check the coolant level in the coolant expansion tank.

CAUTION

When adding coolant, use the coolant having the same LLC concentration as the coolant already in the coolant expansion tank.
After changing the coolant, air exists inside the cooling system. When this air is discharged by engine operation, the coolant level is reduced. Until this air is discharged completely, refill the coolant expansion tank with coolant frequently.

Chapter 9 LONG-TERM STORAGE

Long-term storage

The following describes how to store the engine in a non-operable condition for three months or more and in an operable condition for three months or more.
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 engine in non-operable condition for 3 months or more

Preparation for storage

1. Drain engine oil, and pour in rust-preventive oil (NP-10-2) into the engine.
2. Operate the engine at a speed of 800 to 1000 min^{-1} (idling) for 5 to 10 minutes under no load.
3. Immediately before stopping the engine, spray volatile corrosion inhibitor (V.C.I.) through the inlet port to prevent rust on the air intake system.
4. Apply rust-preventive oil (NP-3) liberally on the exposed sections of the machining.
5. Seal air inlet, exhaust outlet, breather and other openings with an adhesive cloth tape.
6. 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.
7. Disconnect 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.
8. Cover the entire engine.

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

(b) If is not necessary to drain coolant sice it contains LLC. (Add LLC to increase the conc ntration between 30 and 60%.)

(c) Post a sign at an easily noticeable place to warn that the rust-preventive oil in the engine must be replaced with engine oil before operating the engine for the first time after storage.

(d) New engine oil can substitute for rust-preventive oil (NP-10-2).

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-1400	Prevention of rust on exposed machine surfaces
	NP-10-2	Nippon Oil Corporation Anti Rust P-230	Prevention of rust in lubricating system
Z1519	-	Ryoukou Kagaku V.C.I. Diana 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.
4. Remove sealing tapes from the openings of the engine.
5. Drain rust-preventive oil, and pour in appropriate engine oil.

Note: For engine oil, refer to "Engine Oil" (5-1).

6. Inspect the entire engine.
7. Remove the rocker covers, and lubricate the valve mechanisms.
8. 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.

CAUTION

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

9. Make sure the engine oil pressure rises.
10. Start the engine.

Note: For starting the engine, refer to "Normal engine operation" (3-5).

11. Conduct a warm-up operation for a sufficient duration.
12. 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, operate the starters twice at intervals of about 15 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 "Normal engine operation" (3-5).

Chapter 10 TRANSPORTATION

Lift the engine carefully

⚠ WARNING

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

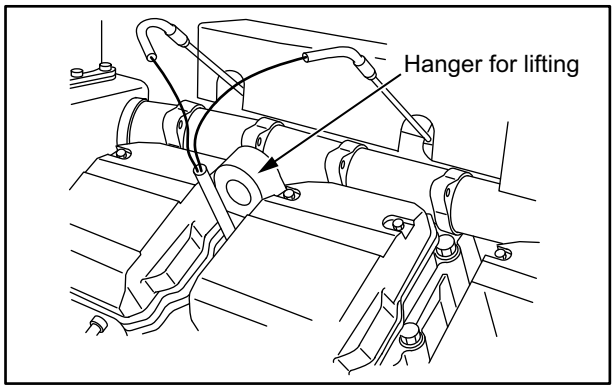


Fig. 10−1 Hangers for lifting

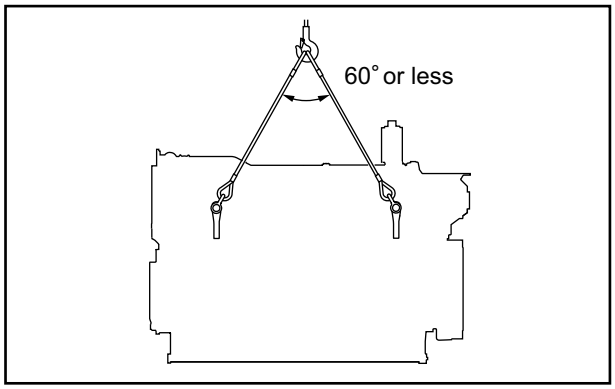


Fig. 10−2 Attaching wire ropes

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 engine oil and coolant. In the event of the engine failure, contact your Mitsubishi dealer.

Consideration 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 catalog.

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 part or personal injury.

How to troubleshoot

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

Problem	Cause		Remedy
Start failure	Electrical system	Blown fuse	Change fuse.
		Faulty wiring connection between battery and starter switch	Connect wire correctly.
		Faulty wiring connection between battery, starters and starter switch	Connect wire correctly.
		Specific gravity of battery fluid too low	Charge battery.
		Faulty battery	Install new battery.
		Faulty starter or starter relay	Consult a Mitsubishi dealer.
	Lubricating system	Oil viscosity too high	Use appropriate engine oil. Refer to "Engine Oil" (5-1).
	Engine mechanical	Faulty moving parts (Interference between valves and pistons, or foreign matter in cylinders)	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

Problem	Cause		Remedy
Engine does not start	Fuel gas system	Fuel gas is not provided	Provide fuel gas
		Damaged fuel gas pipe, Loose fuel gas pipe connection	Consult a Mitsubishi dealer.
		Improper fuel gas pressure	Adjust gas pressure setup.
		Gas-air ratio incorrect	Readjust gas regulator. Readjust Gas-air ratio controller
		Dust or water mixed in fuel gas	Remove dust or water.
		Clogged gas strainer	Clean.
		Clogged and leak of fuel gas pipe	Clean, repair.
		Gas solenoid valve defective	Consult a Mitsubishi dealer.
	Air intake system	Clogged air cleaner	Clean or replace pre-cleaner. Refer to "Cleaning air cleaner element" (8-5).
		Colgged muffler, exhaust pipe.	Clean.
	Engine mechanical	Compression pressure low (damaged cylinder liner, piston or piston ring, or faulty valve spring or seat ,or faulty seal gas valve of pre-chamber) or faulty spark plug.	Consult a Mitsubishi dealer.

Other problems and countermeasures

Engine output is low

Table 11-3 Engine output is low

Cause	Remedy
Engine oil viscosity too high	Use recommended engine oil Refer to "Engine Oil" (5-1).
Insufficient air intake (clogged air cleaner)	Clean air cleaner element, or replace if necessary. Refer to"Cleaning air cleaner element" (8-5).
Clogged gas strainer	Clean.
Faulty ignition plug	Clean, repair, replace.
Incorrect fuel injection timing	Adjust.
Insufficient cooling (overheating)	Clean cooling system interior, replace parts.
Incorrect valve clearance	Adjust.
Low compression pressure (worn cylinder liners, worn piston rings, etc.)	Disassemble and repair, replace parts, consult a Mitsubishi dealer.

Fuel gas consumption is high

Table 11-4 Fuel consumption is high

Cause	Remedy
Gas-air ratio incorrect	Readjust gas regulator. Readjust Gas-air ratio controller
Faulty ignition plug	Clean, adjust, replace, consult a Mitsubishi dealer.
Incorrect ignition timing	Adjust, consult a Mitsubishi dealer.
Insufficient intake air (improper ventilation, clogged air cleaner)	Clean air cleaner element, or replace if necessary. Refer to "Cleaning air cleaner element" (8-5).
Low compression pressure (worn piston liners, worn piston rings, etc.)	Disassemle and repair, replace parts, consult a Mitsubishi dealer.

Engine oil consumption is high

Table 11-5 Engine oil consumption is high

Cause	Remedy
Excessive amount of engine oil	Maintain correct oil level. Refer to "Lubricating system" (3-2).
Engine oil viscosity too low	Use recommended engine oil Refer to "Engine Oil" (5-1).
Engine oil leakage	Retighten, replace parts, consult a Mitsubishi dealer.
Worn cylinder liners, worn piston rings	Disassemble and repair, replace parts, consult a Mitsubishi dealer.
Worn valve stem seals	Replace parts, consult a Mitsubishi dealer.

Engine overheats

Table 11-6 Engine overheats

Cause	Remedy
Low coolant level	Add coolant. Refer to "Cooling system" (3-3).
Coolant leakage	Retighten, replace parts.
Faulty inter cooler cooling water circulation pump	Consult a Mitsubishi dealer.
Faulty thermostat	Consult a Mitsubishi dealer.
Dust on heat exchanger	Clean, consult a Mitsubishi dealer.

Engine oil pressure is faulty

Table 11-7 Engine oil pressure is faulty

Cause	Remedy
Insufficient amount of engine oil	Maintain correct oil level. Refer to "Lubricating system" (3-2).
Engine oil viscosity too low	Use recommended engine oil Refer to "Engine Oil" (5-1).
Clogged oil filter	Replace oil filters. Refer to"Changing engine oil, oil filters and bypass oil filter" (8-7).
Faulty oil pump	Clean, replace, consult a Mitsubishi dealer.
Faulty relief valve	Replace, consult a Mitsubishi dealer.
Faulty pressure switch	Replace, consult a Mitsubishi dealer.

Chapter 12 MAIN SPECIFICATIONS

Main specifications

Table 12−1 Main specifications

Engine model	GS16R-PTK
Type	Water-cooled 4-stroke cycle, turbocharged with intercooler
Number of cylinders, arrangement	16-V
Bore × Stroke (mm [in.])	170 × 180 [6.70 × 7.10]
Total displacement (L [cu.in.])	65.37 [3989]
Combustion type	Spark ignition lean combustion system with precombustion chambers
Compression ratio (B.T.D.C. base)	15:1
Firing order	1-9-6-14-2-10-4-12-8-16-3-11-7-15-5-13
Rotation direction	Counterclockwise as viewed from flywheel
Dimensions (L×W×H (mm) [in.])	2843 × 1820 × 2151 [111.9 × 71.7 × 84.7]
Dry weight (kg [lbs])	6500 [14330]
Firing system	Spark ignition type
Governor	Electronic governor
Main chamber gas supply pressure	0.98 to 2.45 kPa [100 to 250 mmAq]
Prechamber gas supply pressure	166.7 to 245.2 kPa [1.7 to 2.5 kgf/cm²]
Lubricating system	Forced circulation type (pressure feed by oil pump)
Lubrication oil	Nippon Oil Corporation TES Oil GXL-193B Idemitsu Kosan Co.Ltd Aporoil Cogene Alpha CG40M
Engine oil capacity (liter [U.S.gal])	Whole engine: approx. 385 [101.7]
Oil filter	Paper element
Oil cooler	Water cooled multi-plate
Cooling system	Force water cooling
Cooling water capacity (liter [U.S. gal])	Approx. 170 [44.9] (in engine only)
Starting system	Electrical start
Starter	24V-7.5kW×2
Turbocharger	Mitsubishi TD13
Flywheel	S.A.E.in.21
Flywheel housing	S.A.E.in.#00

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