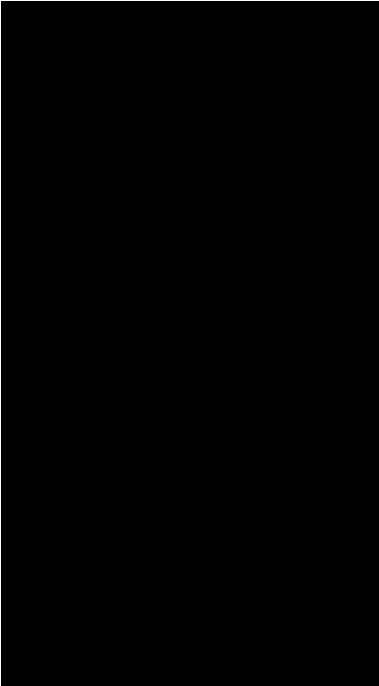


OPERATION & MAINTENANCE MANUAL

July 2016

Pub. No. 99590-72100



MITSUBISHI MARINE ENGINE S6M4-MTKL

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.

Foreword

This operation and maintenance manual contains detailed operation, inspection and maintenance information for engines from Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. Please be noticed that some contents are repeated among chapters for better understanding.

Please read and understand this manual thoroughly before proceeding with operation, inspection, and maintenance work.

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

Please observe the laws and regulations in the country or region where the engine is used.

Limited Warranty

During the warranty period, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET) will repair and replace all defective products, which are returned, if such defective are found to be manufacturing defects by investigation. For warranty period, contact your local dealer.

MHI's warranty is limited to the compensation work of repair or replacement of parts.

The warranty coverage is effective for the original purchaser only. Those to whom ownership is later transferred are not provided with the warranty.

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- ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. makes no warranties, either expressed or implied, except as provided in this manual, including, but not limited to, warranties as to market-ability, merchantability, fitness for a particular purpose or use, or against infringement of any patent.
 - ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. will not be liable for any damages or consequential damages, including, but not limited to, damages or other costs resulting from any abuse, misuse, misapplication of the engine and devices which supplied by us.
 - ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. will not be liable for any damages or personal injuries resulting from any modification, without our written permission, of the engine and devices which supplied by us.
 - ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. will not be liable for any damages or production losses caused by the use of fuel, engine oil and/or long life coolant (LLC) that we are not recommended.
 - ♦The owner of the engine is responsible for the performance of the required maintenance listed in this operation manual.

When performing the maintenance, follow the instructions in the service manual published by Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. may deny the warranty coverage if the engine or part has failed due to inadequate or improper maintenance.

Important Information

- ♦To avoid the potential hazard, accident prevention activities must be planned methodically and conducted continually by considering all aspect of engine operation, maintenance and inspection. All involved personnel, including managers and supervisors, should actively participate, recognize their roles and organize themselves and their work to ensure a safe environment.
- ♦The foremost safety objective is to prevent accidents which may result in injury or death, or equipment damage.
- ♦Always observe laws or regulations of the local or federal/national government.
- ♦MHIET cannot foresee all potential dangers of the engine, potential dangers resulting from human error and other causes, or a 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 instructions 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 engine owner must provide thorough safety guidance to the operators. Also attach the warning and operational decals 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 give this manual to the new owner although we do not warrant the engine. Also inform MHIET of the name and address of the new owner of the engine.
- ♦This manual is copyrighted and all rights are reserved. No part of this manual, including illustrations and technical references, may be photocopied, translated, or reproduced in any electronic medium or machine readable form without prior written consent from Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.
- ♦For improvement of the engine, the contents in this manual are subject to change at any time without notice.
- ♦Pictures or illustrations in this manual may differ from the engine you have purchased.
Please note that, depending on specifications, items described in this manual may differ from those on your engine in shape, or may not be installed on your engine.
- ♦Please contact your MHIET dealer if you need more information or if you have any questions.
- ♦If the manual is lost or damaged, please obtain a new copy at your MHIET dealer without delay.

Warning Indication

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

- ♦Warning Statements in This Manual
- ♦Warning Labels Attached on the Engine

Warning Statements

The warning statements in this manual describe potential danger in operation, inspection, and maintenance of the engine, using the five symbols below 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.

Please understand the instructions described in this manual well, and handle the engine according to the instructions.



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



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



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



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

Note:

Indicates important or useful information related to the operation and maintenance of the engine.

Units of Measurement

Measurements are based on the International System of Units (SI), and they are converted to the metric system units shown in { } in this manual. Conversion rates are as follows:

- ♦Pressure: $1 \text{ MPa} = 10.197 \text{ kgf/cm}^2$
- ♦Torque: $1 \text{ N}\cdot\text{m} = 0.10197 \text{ kgf}\cdot\text{m}$
- ♦Force: $1 \text{ N} = 0.10197 \text{ kgf}$
- ♦Power, output: $1 \text{ kW} = 1.341 \text{ HP} = 1.3596 \text{ PS}$
- ♦Rotation speed: $1 \text{ min}^{-1} = 1 \text{ rpm}$
- ♦Kinetic viscosity: $1 \text{ mm}^2/\text{s} = 1 \text{ cSt}$

Abbreviations, Standards and Others

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

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Chapter 1 BASIC SAFETY PRECAUTIONS

Fire and Explosion Protection



WARNING

Keep Flames Away

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



Wipe off spilled fuel, oil, and LLC immediately and thoroughly. Spilled fuel, oil, and LLC may ignite and cause a fire. Store fuel and engine oil in a well-ventilated area. Make sure that the caps of fuel and engine oil containers are tightly closed.

Keep Engine Surrounding Area Tidy and Clean

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

Remove dust, dirt, and other foreign substances accumulated on the engine and surrounding area. Such materials can cause a fire or overheating. In particular, clean the top surface of the battery after maintenance work is completed. Dust can cause a short-circuit.

Pay Attention to Engine Room Ventilation

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

Do Not Open Side Covers 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.

If fresh air flows into the crankcase while the engine is overheated, oil mist can be ignited and exploded.

Pay Attention to Fuel, Oil and Exhaust Gas Leak

If any fuel, oil, or exhaust gas leak is found, immediately stop the engine. After the engine has completely cooled down, repair the leak.

If oil/fuel splashes or leaks on the hot surfaces of the engine, or if exhaust gas comes in contact with flammable materials, it can cause property damage or personal injury.

Use Explosion-Proof Light

When inspecting fuel, engine oil, cooling water, battery electrolyte, etc., use a flameproof light. An ordinary lighting apparatus may ignite gas and cause an explosion.

Prevention of Electric Short Circuit

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

Short-circuit, which may result in fire, is caused by a loose terminal or damaged cable/wire. Inspect terminals, cables, and wires, and repair or replace faulty parts before proceeding with any work.

Keep Fire Extinguishers and First-Aid Kit Handy

Keep fire extinguishers handy and become familiar with the usage. Keep a first-aid kit at the designated place where it is easily accessible by anyone at any time.



Prepare an emergency action plan in the event of fire or accident. Provide an emergency evacuation route and contact points and means of communication in case of emergency.

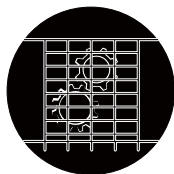
Stay Away From Rotating and Moving Parts



WARNING

Keep Rotating Parts Covered for Safety

Make sure the protective covers attached to the engine rotating parts are correctly installed. Repair any damaged or loose covers. During operation, never remove protective covers such as front cover, fuel injection pump coupling cover, and alternator cover that enclose rotating parts.



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

Never remove the protective covers.

Checking Work Area for Safety Before Starting

Before starting the engine, make sure no one is near the engine and no tools are left on or near the engine.

Alert people in the area when starting the engine.

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

Stay Away From Moving Parts During Operation

Stay away from rotating parts of the engine while the engine is running.

Do not place any objects which might be easily entangled near the rotating parts.



If any part of the clothing or tool is caught in rotating parts, it could result in serious injury or death.

Lockout and Tagout

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

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, place the battery switch to the OFF position and attach a "DO NOT OPERATE" or similar caution sign to the starter switch.

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

Be Sure to Stop Engine Before Inspection/Maintenance

Be sure to stop the engine before proceeding with any inspection and maintenance work. Never attempt to make any adjustments on the engine parts while the engine is running.

Entanglement in rotating parts can result in serious injury or death.

Always Put Turning Tool Back in Place After Use

Be sure to remove all turning tools after maintenance and inspection work has been completed. Starting the engine with the turning tools inserted or with the turning gear engaged can lead to not only engine damage but also personal injuries.

Prevention of Exhaust Gas Poisoning

WARNING

Pay Attention to Ventilation When Operating Engine

Check exhaust pipes and pipe joints for gas leaks.

Exhaust gas from the engine may contain harmful substances to human body. Operating the engine in a poorly-ventilated area can cause gas poisoning.



Prevention of Hearing Loss

CAUTION

Wear Ear Plugs

Always wear ear plugs when entering the machine room (engine room).

Combustion sound and mechanical noise generated by the engine can cause hearing problems.



Fall Prevention

WARNING

Lift Engine Carefully

To lift the engine, use slings strong enough to support the weight of the engine.

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

During the lifting process, keep the engine in a well-balanced position by paying attention to the center of gravity of the engine.

The hangers attached to the engine are designed to lift the engine only. When the engine is equipped with marine gear, take care so that extra load will not impose on the engine hangers.

Keep the angle formed by slings that is 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.

Attach wire ropes to the hangers after removing the pipe near the hanger.

If the sling comes into contact with the engine parts directly, place a cloth or other soft padding to avoid damage to the engine parts and sling. If necessary, remove the engine parts.



Do Not Climb Onto the Engine

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

When working in a high place such as the upper part of engine, use a step, or work platform, and be careful not to fall off.

Climbing on the engine may not only damage engine parts but also cause a falling-down accident which can result in a personal injury.

Always Use a Stable Foothold During Maintenance

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

Do not stand on a decrepit stool or parts box. Otherwise it may result in personal injury.

Do not put any unnecessary objects on a work platform.



Burn Protection



CAUTION

Do Not Touch Engine During or Immediately After Operation

Do not touch any part of 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 with the gauge.



Be Careful When Opening and Closing of Coolant Expansion Tank Cap

Never open the coolant expansion tank cap while the engine is running or immediately after stopping. Stop the engine and open the cap after the coolant temperature has dropped sufficiently.

To open the coolant expansion tank cap, open slowly to release the pressure in the tank.

The coolant is hot while the engine is running and immediately after stopping. If the coolant expansion tank cap is opened while the coolant is hot, steam and hot water may blow out and result in burns. To avoid a risk of getting scalded by steam, wear thick rubber gloves or wrap a cloth around the cap.

When fastening the coolant expansion tank cap, be sure to tighten securely.

Refill Coolant Only After the Coolant Temperature Dropped

When adding coolant, check that the coolant temperature is lowered to the room temperature with a water temperature gauge. Adding coolant immediately after engine shutdown may result in burns.

Do Not Remove Heat Shields

The inlet and exhaust systems, which become extremely hot while the engine is running, are provided with various heat shields. Do not remove these heat shields. If any of these heat shields have been removed due to unavoidable circumstances during the work, be sure to restore them after the work is completed.

Burn Prevention When Changing Oil

Before draining oil or changing oil filters, wear leather gloves or be sure to check the engine temperature. If hot oil or parts touch your skin, it can cause burns.

Be Careful When Handling Fuel, Engine Oil, and Coolant (LLC)



CAUTION

Use Specified Fuel, Engine Oil, and LLC Only

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

Use of any other fuel, oil, or coolant (LLC) than the specified one, or improper handling may cause various damages to the engine.

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

Handle LLC Carefully

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

If coolant (LLC) is accidentally swallowed, induce vomiting immediately and seek medical attention. If coolant (LLC) gets in your eyes, flush them immediately with plenty of water and seek medical attention. If coolant (LLC) splashes onto your skin or clothing, wash it away immediately with plenty of water.

Keep flames away from LLC. The LLC is highly flammable and can easily catch a fire if exposed to a flame.

Proper Disposal of Waste Oil, LLC, and Coolant

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

Be sure to dispose of waste oil, LLC, coolant, and other environmentally hazardous waste in accordance with the applicable laws and regulations.

When Abnormality Occurs



Stop Operation Immediately If You Notice Any Abnormality

Stop the operation immediately if you notice any unusual noise, odor, or vibration during operation. When an emergency occurs, press the emergency stop button to stop the engine. If the cause of problem cannot be located after stopping, contact your MHIET dealer. Continuous operation by neglecting an unusual symptom could cause serious or fatal accident.

Do Not Add Coolant Immediately After a Sudden Stop Due to Overheating

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

Adding coolant while the engine is hot may cause damage to cylinder heads, etc. due to a sudden drop of temperature. Add coolant gradually after the engine has completely cooled.

Be Careful When Starting After an Abnormal Stop

Do not restart immediately after an abnormal stop. If the engine stops or is brought to a stopped condition with an abnormality, find out the cause, repair the failed part, and then restart the engine. Continued operation of the engine without proper repairs and maintenance could result in serious engine problems.

Stop Engine Immediately When Engine Oil Pressure is Dropped

When abnormal engine oil pressure drop is observed, stop the engine immediately, and inspect the lubrication system to locate the cause. Continued engine operation could cause bearings and other parts to seize.

If Belt Breaks, Stop Engine Immediately

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

Battery Safety Precautions



Be Careful When Handling Battery

- Never use flames or allow sparks near the battery. The battery releases flammable hydrogen gas and oxygen gas. Any flames or sparks in the vicinity of battery could cause an explosion.
- Do not use the battery when the battery fluid level is below the "LOWER LEVEL" mark. It may result in an explosion.
- Do not short the battery terminals with a tool or other metal object.
- When removing battery, always remove the plug from the negative (-) terminal first. When connecting battery, always connect the plug to the positive (+) terminal first.
- Before charging the battery, remove all battery cables, and then charge the battery in a well ventilated area.
- Make sure the cable clamps are securely attached to the battery terminals. A loose cable clamp can cause sparks, which may result in an explosion.
- Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.
- Battery fluid contains dilute sulfuric acid. Careless handling of the battery can lead to a sight loss and/or skin burns. Also, do not swallow the battery fluid.
- Wear protective goggles and rubber gloves when working with the battery (e.g. when adding water or charging the battery).
- If battery fluid is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to clean thoroughly.
- The battery fluid can cause sight loss if splashing into your eyes. If it gets into your eyes, immediately flush it away with plenty of clean water, and seek immediate medical attention.
- If you accidentally swallow battery fluid, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.
- If the battery does not fully recover after charging for 24 hours or more, do not use the battery.



Other Precautions


CAUTION

Do Not Tamper

Unauthorized modification of the engine will void your warranty.

Modification of the engine may not only cause damage to the engine but also may result in personal injury.

If you need to modify the engine, contact your MHIET dealer.

Always Use Mitsubishi Genuine Parts

Be sure to use Mitsubishi genuine parts for Mitsubishi engines. DO NOT use imitation parts.

Also, be sure to use fuel, engine oil, and LLD which recommended in this manual.

Observe Safety Rules at Work Site

Observe the safety rules established at your workplace.

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

When working in a team for two or more people, use specified hand signals to communicate among workers.

Wear Proper Work Clothing and Protective Gears

Wear a hard-hat, a face shield, safety shoes, a dust mask, gloves, ear plugs, and other protective gears as needed. When handling compressed air, wear safety goggles, a hard-hat, gloves, and other necessary protective gears. Working without wearing proper protective gears could result in serious injury.

Never Break the Seals

To ensure proper engine operation, the fuel control links are sealed to prevent the injection volume and rotational speed settings from tampering. Removing these seals of the engine will void the warranty. The following problems may occur if these seals are removed.

- Rapid wear of moving and rotating parts
- Engine troubles such as seizure and damage of engine parts
- Sudden increase of fuel and lubricating oil consumption
- Poor engine performance due to improper balance between fuel injection volume and governor control, or a serious accident due to overrunning of the engine

Perform Pre-Operation Inspection and Periodic Inspections

Be sure to conduct the pre-operational inspection and periodic inspection as described in this manual.

Failure to conduct specified the pre-operational inspection or periodic inspection may cause various problems and damage to the engine and its parts, which may result in serious accidents.

Break-in the Engine

For the first 50 hours of a new engine or the engine that has been overhauled, operate the engine under a light load for break-in.

Operating a new engine or an engine that has been overhauled, in which the parts are not yet well fitted each other, in a severe condition during the break-in period shortens the service life of the engine.

Warm-Up the Engine Before Use

After starting the engine, run the engine at a low idling speed until the coolant temperature reaches approx. 50°C [122°F]. Start the practical work after this operation is completed.

Warm-up operation circulates lube oil through the engine and contributes to a longer service life and economical operation.

However, do not perform the warm-up operation for longer than necessary. It may cause accumulation of carbon in the cylinder, and cause faulty combustion.

Cool Down the Engine Before Stopping

Before stopping the engine, operate the engine at a low idling speed for 5 to 6 minutes to cool down.

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

During cooling operation, check the engine for abnormalities.

Do Not Operate the Engine in an Overloaded Condition

If overload symptoms such as black exhaust smoke is observed, reduce the load immediately and assure the proper output and load.

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

Do Not Splash Water on Engine

Do not allow water or rainwater to enter the engine through the air inlet or exhaust opening.

Do not wash the engine during operation. Cleaning fluid (water) can be sucked into the engine.

Starting the engine with water inside the combustion chambers can cause the water hammer effect which may result in the internal engine damage and serious accident.

Pay Attention to Pre-cleaner Maintenance

For maintenance of the engine equipped with pre-cleaner, be sure to observe the instructions below.

- ♦Wash pre-cleaner periodically. If pre-cleaner is clogged, exhaust temperature will increase because sufficient intake air for combustion is not supplied, and as a result, a failure may occur.
- ♦Never service the pre-cleaner during engine operation. The turbocharger may suck foreign substances into the engine, and could result in serious accidents.
- ♦When removing the pre-cleaner, take care so that foreign substances accumulated on the pre-cleaner will not enter the inside of the engine. When the pre-cleaner is removed, immediately cover the air inlet with a plastic film, etc. to prevent foreign substances from entering the engine.

Use Proper Tools for Maintenance Work

Always keep in mind to select most appropriate tools for the work, and use them correctly. If a tool is damaged, replace it with a new one.

Do Not Operate Starter for a Long Duration

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

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

Do Not Turn Off the Battery Switch During Operation

Do not turn off the battery switch during operation.

If the battery switch is turned OFF when the engine is running, it stops the operation of meters and also may deteriorate alternator diode and transistor.

Engine Transportation Precautions

When transporting the engine on a truck, consider the engine weight, width, and height to ensure safety.

Abide by the road traffic law, road vehicles act, vehicle restriction ordinance, and other pertinent laws.

Do Not Rotate the Engine in Reverse Direction

When rotating the engine by hands, be sure to rotate the engine in its normal rotation direction. If the engine is rotated in the opposite direction, the seawater pump impeller will be broken.

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 MHIET dealer.

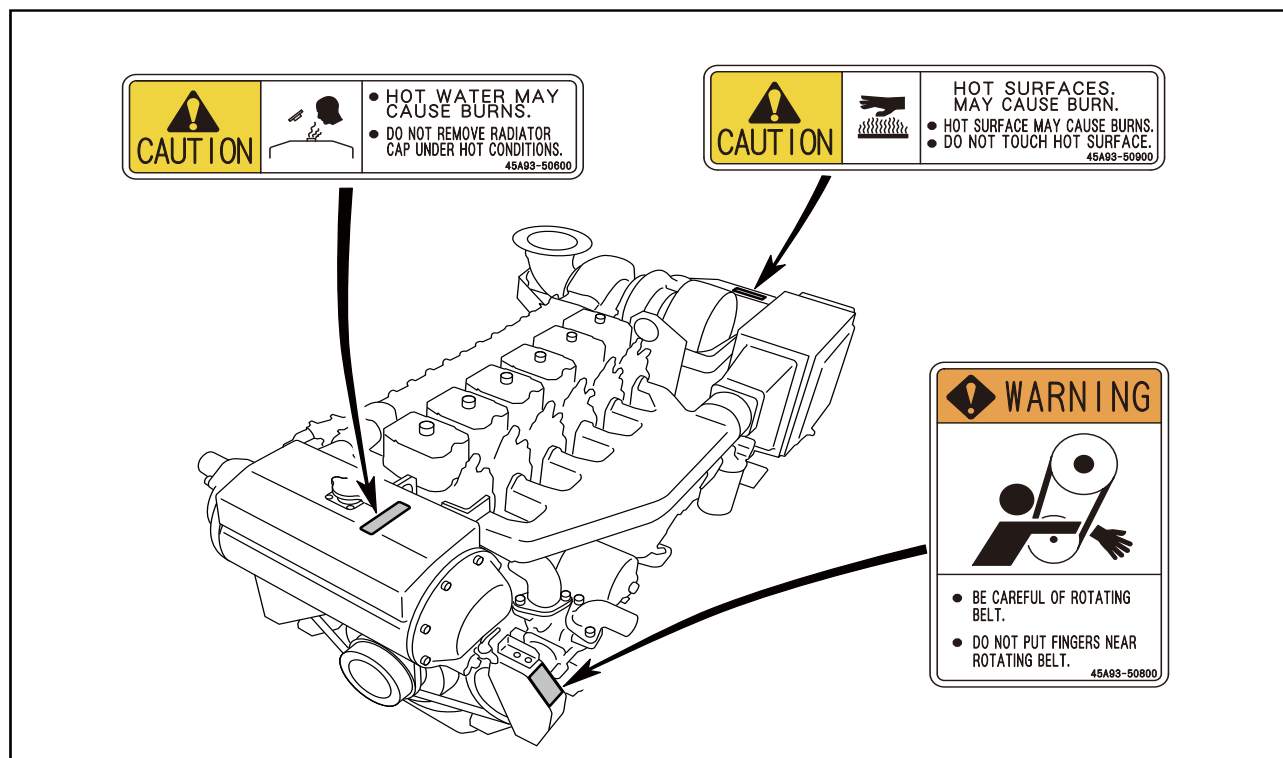


Fig. 1-1 Warning Labels

Chapter 2 NAME OF PARTS

Engine External Views

This external diagram shows the standard type of the engine. The installed equipment and shapes may vary depending on the specifications.

Front View

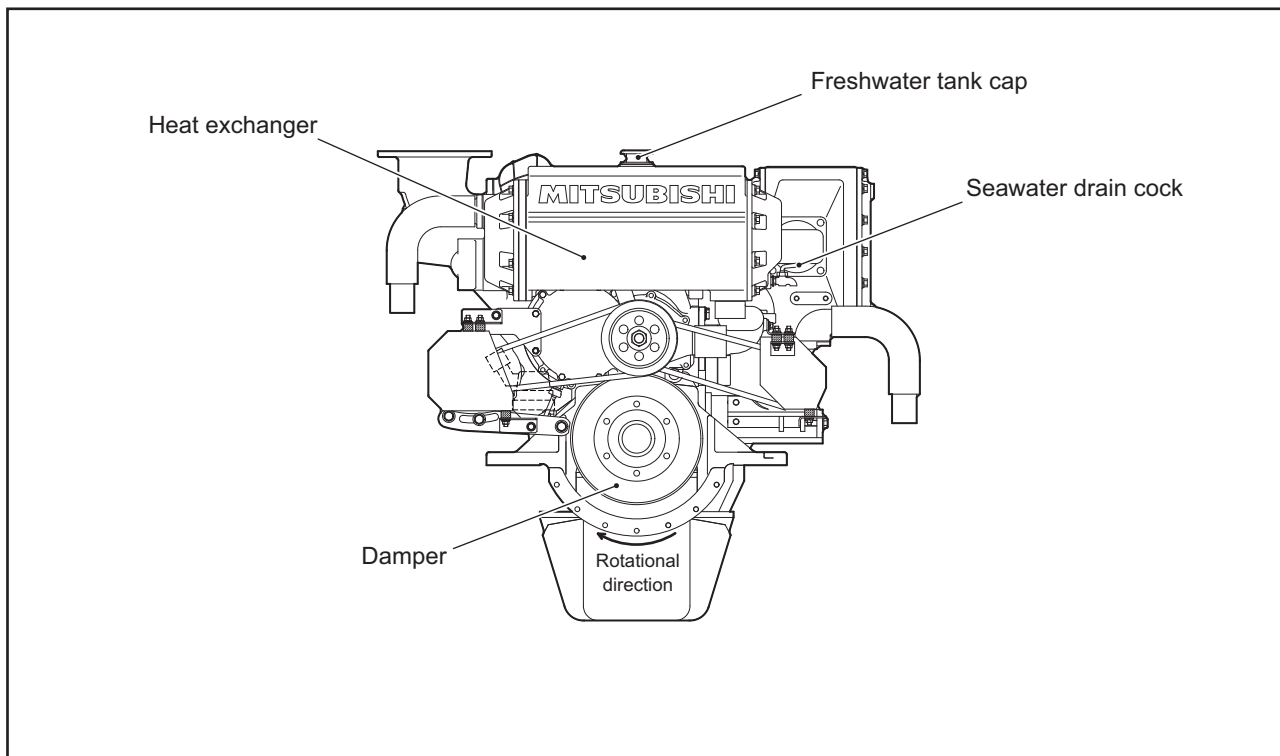


Fig. 2-1 Engine Front View

Rear View

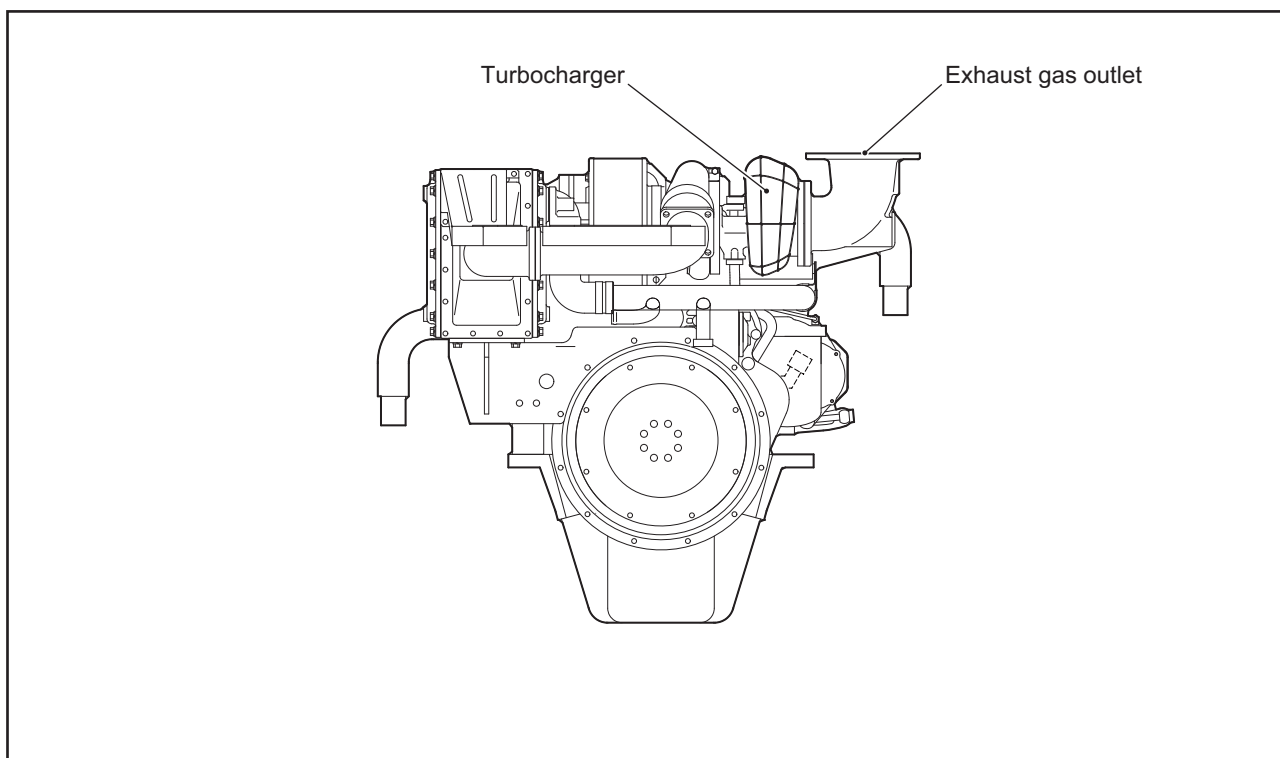


Fig. 2-2 Engine Rear View

Left View

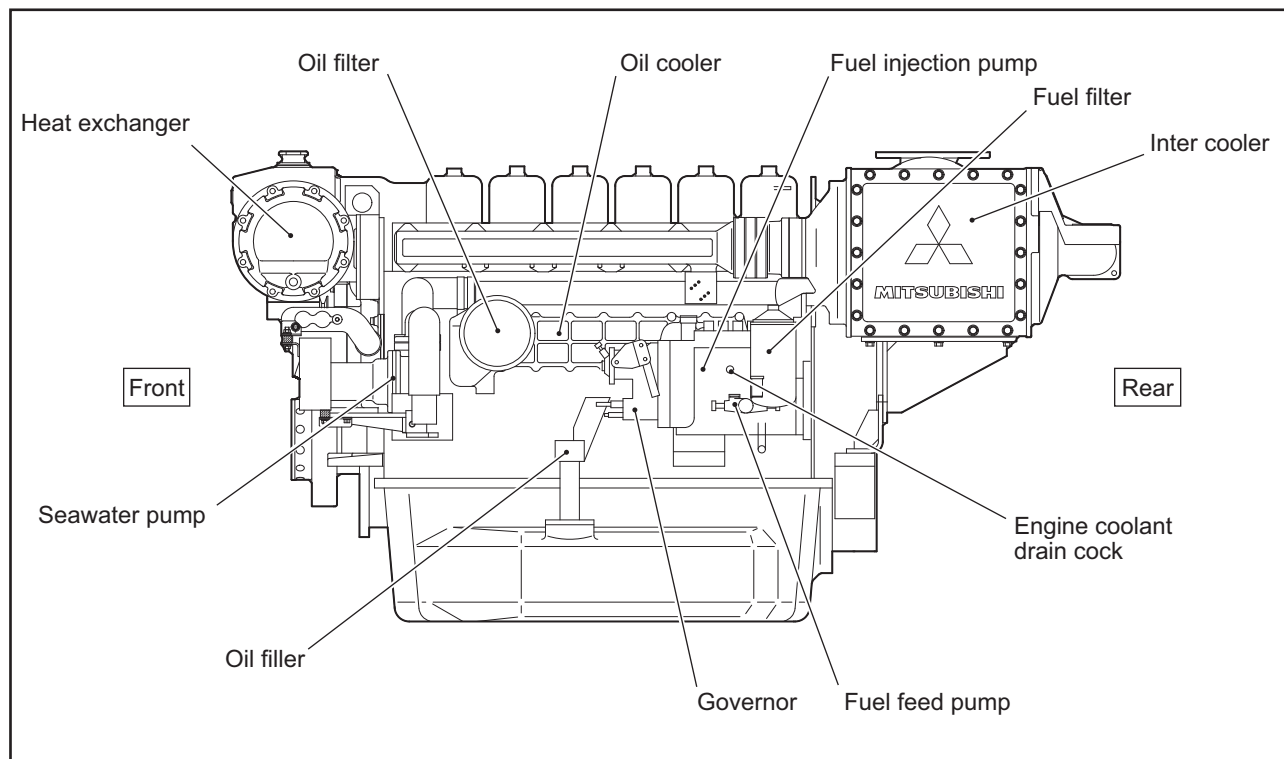


Fig. 2-3 Left Side View of Engine

Right View

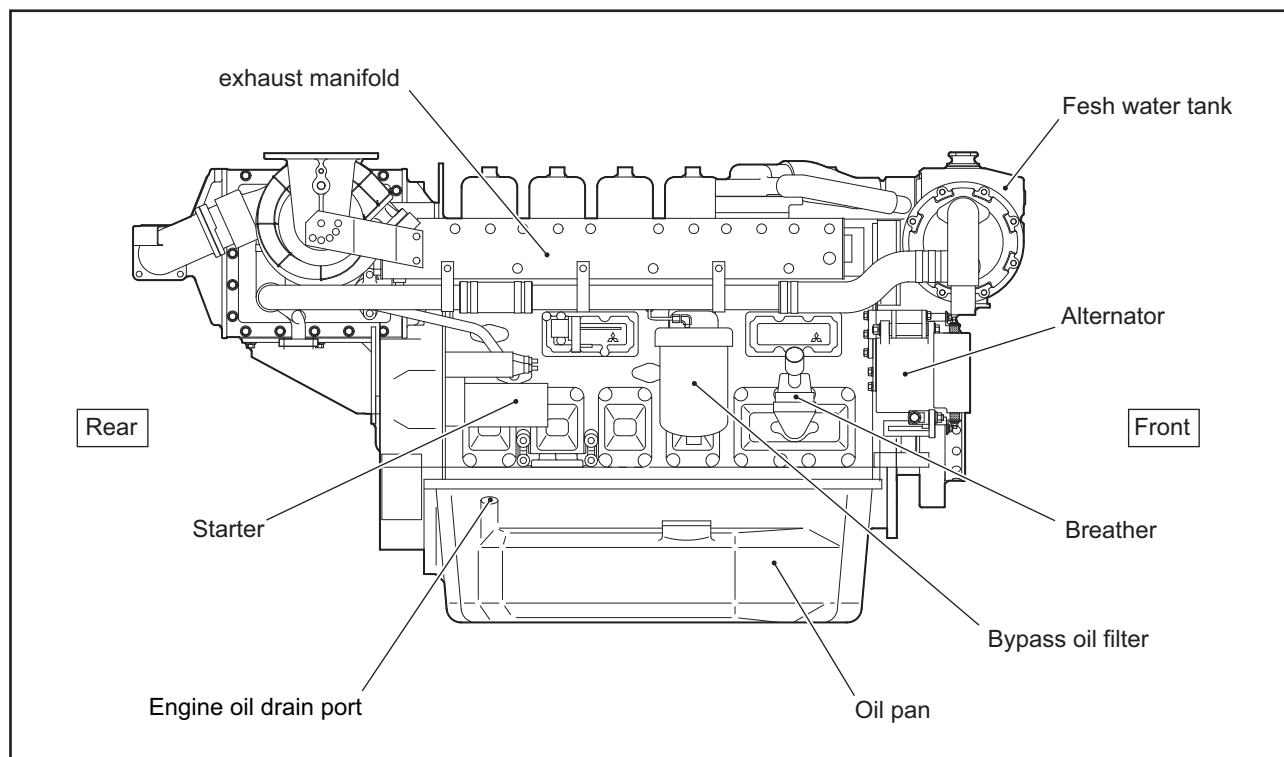


Fig. 2-4 Right Side View of Engine

Operating Device

Speed Control Lever

The engine rotational speed can be adjusted with the speed control lever.

To increase the rotational speed, turn the lever to H (high-speed rotation) side and to decrease, turn the lever to L (low-speed rotation) side. The rotational speed can be adjusted over the full range of engine rotational speeds.

When you rotate the lever clockwise, the lever is locked in that position (speed).

To release the lock and move the lever, rotate the lever counterclockwise. When you lock, be sure to rotate the lever fully clockwise so as not to come loose due to vibrations, etc.

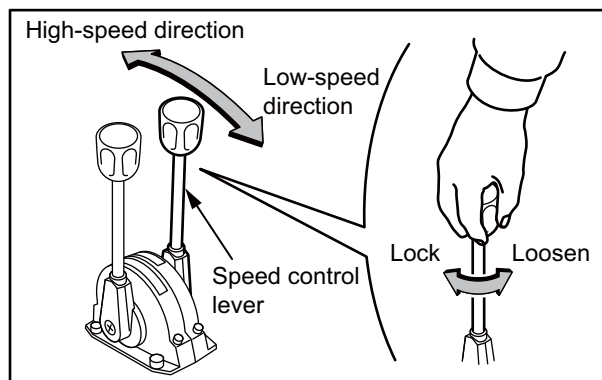


Fig. 2-5 Speed Control Lever

Direction Lever

CAUTION

When shifting the clutch, be sure to securely place the clutch in position, F (Forward), R (Reverse) or N (Neutral). If the clutch lever is not firmly engaged in one of these positions, there is a risk for wearing or burning of clutch plates by slipping.

The marine gear can be shifted to F (Forward), R (Reverse), or N (Neutral) position with the direction lever.

Note: When the engine is equipped with a starter interlock, the lever must be placed in the N (neutral) position to start the engine.

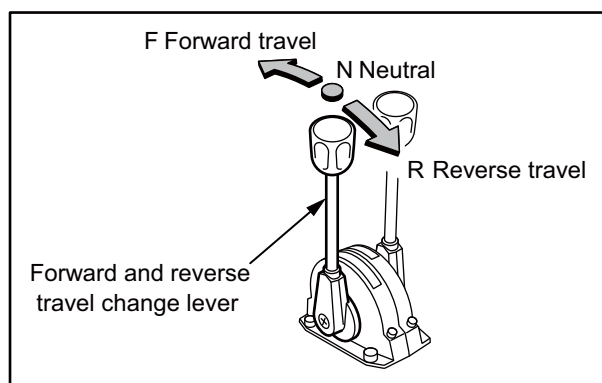


Fig. 2-6 Direction Lever

Stop Knob

CAUTION

Keep pulling the stop knob until the engine is completely stopped. If you stop the lever halfway, the engine may start again. If the engine starts again or there is abnormality, pull the stop knob immediately.

To stop the engine, pull the stop knob.

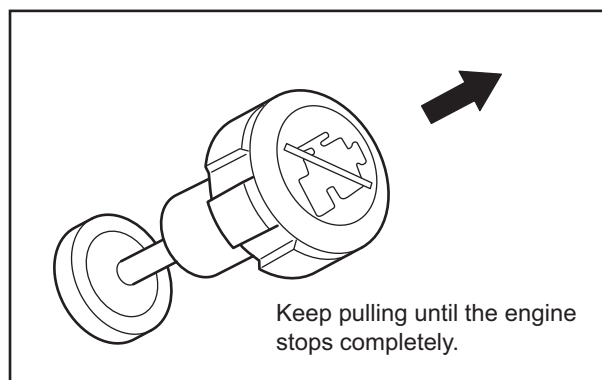


Fig. 2-7 Stop Knob

Transmitters for Instruments

The engine is equipped with the devices which transmit signals to instruments and equipment used for operation. Be sure to understand the role of these devices.

Oil Pressure Unit

Detects the oil pressure.

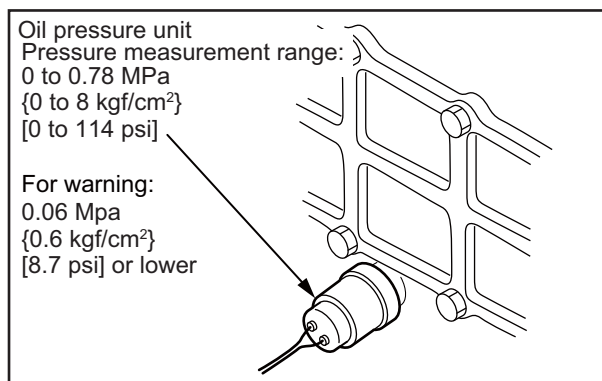


Fig. 2-8 Oil Pressure Unit

Thermo Unit

Detects the engine coolant temperature.

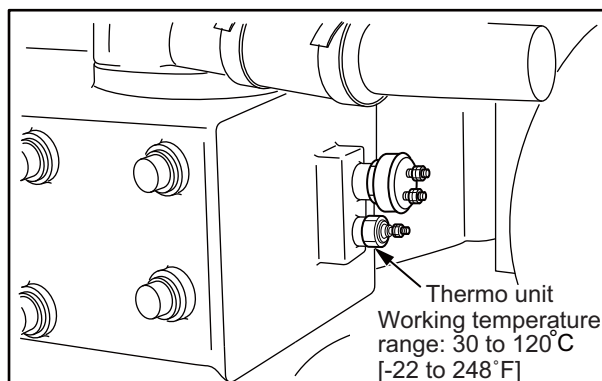


Fig. 2-9 Thermo Unit

Rotation Pickup

The pickup device is mounted on the timing gear case and detects the engine speed.

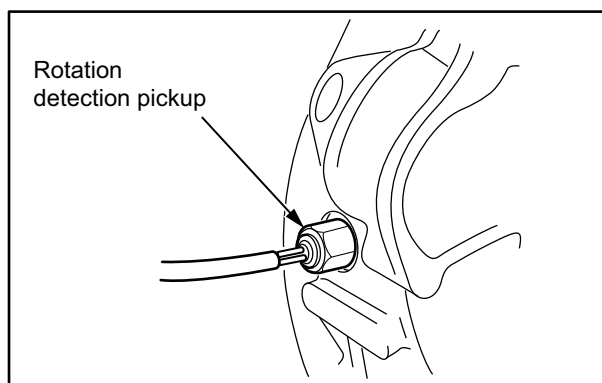


Fig. 2-10 Rotation Pickup

Intake Pressure Sensor

The engine is equipped with the intake pressure sensor to detect intake pressure.

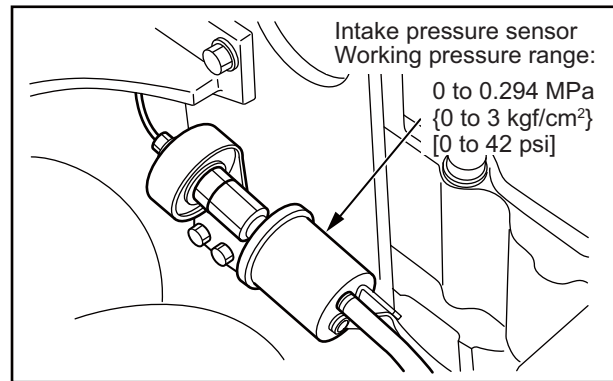


Fig. 2-11 Intake Pressure Sensor

Engine Protection Devices

Thermo Switch

When the engine coolant temperature rises to the set temperature, the thermo switch is activated to stop the engine.

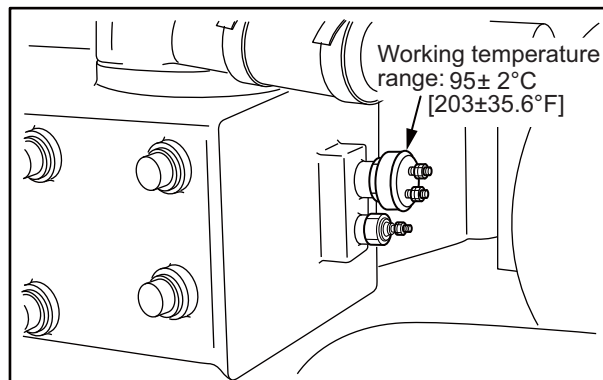


Fig. 2-12 Thermo Switch

Oil Filter Differential Pressure Alarm Switch

The oil filter alarm switch is activated to generate an alarm when the difference in oil pressure between inlet and outlet of oil filter becomes large and reaches the specified value due to clogged filter.

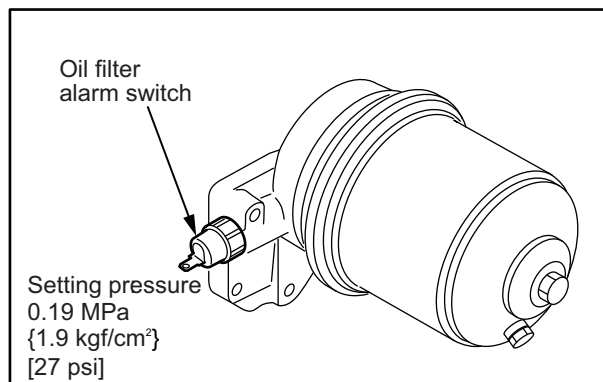


Fig. 2-13 Oil Filter Alarm Switch

Instrument Panel

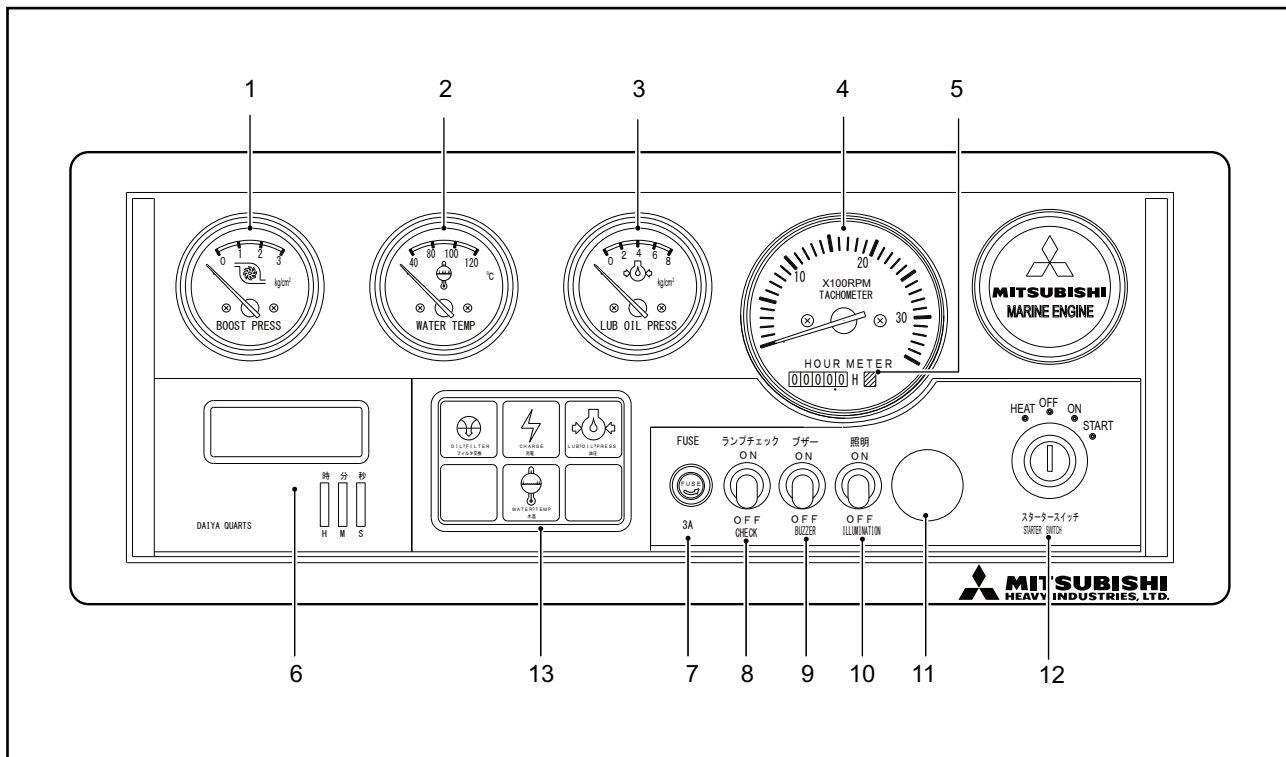
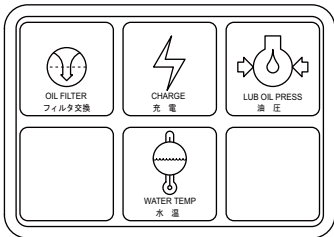


Fig. 2-14 Instrument Panel

Table 2-1 Instrument Panel

No.	Name	Function
1	Manifold pressure gauge	Indicates the engine manifold air pressure.
2	Coolant temperature gauge	Indicates the temperature of the engine coolant (freshwater). (Standard temperature at rated speed: 70 to 80°C [158 to 176°F]) If the gauge indicates 95°C [203°F] or above, the engine is overheating.
3	Lubricating oil pressure gauge	Indicates engine oil pressure. (Standard pressure at rated speed: 0.44 to 0.59 MPa {4.5 to 6.0 kgf/cm ² })
4	Engine speed meter (Tachometer)	Indicates the rotational speed of engine (RPM).
5	Accumulated operating hour meter (Hour meter)	Indicates the operating time of engine. Maintenance can be scheduled by reading this meter. Remember that the hour meter counts time if the starter switch is in the "ON" position even if the engine is not running. Be sure to turn the starter switch to the "OFF" position when the engine is stopped.
6	Time display and adjustment buttons	Always displays the clock time since it is battery-powered type. (Battery: alkaline button cell battery LR44) Set the clock time using adjustment buttons. "Hour" button: one press advances one hour, continuous press to advance faster. "Minutes" button: one press advances one minute, and continuous press to advance faster. "Second" button: to set clock time (minutes) accurately, use this button. When pressing buttons, use a coin or something smooth. Do not use anything with a sharp edge like a screwdriver.
7	Fuse	A barrel type 3A fuse is located inside the cap. If the warning light does not illuminate when the starter switch is turned ON, the fuse may have blown. Check the fuse, and if it has blown, replace with new one.
8	Light check switch	When the starter switch is in the "ON" position, turn this switch ON to make sure the warning lights will illuminate. Check this during start-up inspection.

Table 2-1 Instrument Panel

No.	Name	Function
9	Buzzer stop switch	When the warning buzzer goes off, turn this switch OFF to stop the buzzer. Always keep this switch in the "ON" position during operation.
10	Illumination switch	Turn this switch ON to illuminate gauges.
11	Stop knob	To stop the engine, pull the stop knob. A stop button (option) is available.
12	Starter switch	HEAT (Preheat): To make starting easier during cold season, turn the key to the HEAT position before turning to the START position to warm the air heater. OFF (Switch Off): Return the key to the OFF position when the engine is stopped. The key can be removed or inserted in this position as the supply of electric current to the circuits of gauges is stopped. ON (Switch ON): Place the key in this position after the engine has started (during operation). Electricity flows through the electrical circuits of gauges and warning indicators/lights. START (Start-up): Turn the key to the START position to start the engine. Release the key when the engine has started. The key automatically returns to the ON position.
13	Warning light	Filter warning light (oil filter clogging warning light) The light comes on when oil filter is clogged. Replace oil filter when the light comes on. (Oil filter alarm switch ON: Pressure difference across the oil filter is 0.19 MPa {1.9 kgf/cm²} [27.56 psi]) Charge warning light (battery charge fault light) The light illuminates when there is a fault in charging system. Check the charging system if the light illuminates. Note: Note that this light normally illuminates for several seconds immediately after starting the engine.
	 Water temperature warning light (coolant temperature rise warning light) Illuminates when the fresh water coolant temperature rises abnormally. If this light illuminates, run the engine at minimum idling speed, and then stop the engine. Check the cooling system after the engine has cooled down. (Temperature at which thermo switch turns ON: 95°C [197°F]) Note: The warning buzzer will goes off when the oil pressure warning light or water temperature warning light comes on.	Oil pressure warning light (lubricating oil pressure drop warning light) The light comes one when the lubricating oil (engine oil) pressure drops abnormally. Stop the engine at once, and check the lubricating system. (Oil pressure that triggers the switch: 0.06MPa {0.6kgf/cm²} [8.7 psi])

Preparation for Operation of New or Overhauled Engine

Before proceeding with operation of a new or overhauled engine, conduct the inspections described in this section. Note that, for second and subsequent operations, follow the instructions described in the "Normal Engine Operation" (3-9).

Preparation of Fuel System

CAUTION

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

CAUTION

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

Priming the Fuel System

WARNING

When fuel overflows from the air vent plug, wipe thoroughly with a cloth. Spilled fuel can cause a fire.
After bleeding air, lock the priming pump securely. If lock is loose, the priming pump may be damaged, and a fire may occur from fuel leaking.

While feeding fuel with the priming pump, bleed air from the location closest to the fuel tank, that is, in the order of the oil-water separator, fuel filter, and fuel injection pump.

Priming Pump Cap - Handling

1. Turn the priming pump counterclockwise to unlock.
2. Move the priming pump up and down several times to feed fuel and bleed air.
3. After bleeding air, turn the priming pump clockwise to lock. Be sure to lock securely.

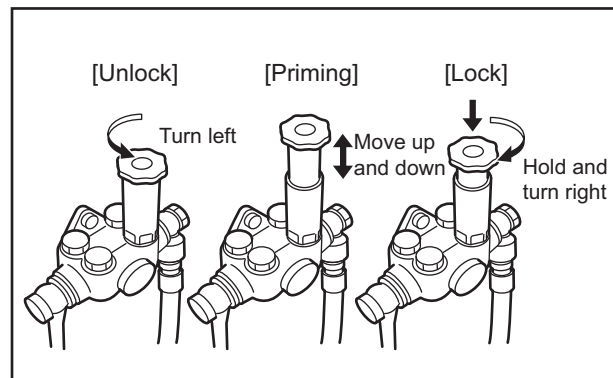


Fig. 3-1 Priming Pump Cap - Handling

Oil-Water Separator - Bleed Air

Suction type piping

1. Loosen air vent plug of oil-water separator.
2. Close valve A on the piping and open valves B and C located across the manual wing pump.
3. Feed fuel using the lever of manual wing pump.
4. When the fuel flowing from the air vent plug no longer contains air bubbles, tighten the air vent plug.
5. Securely close valves B and C located across the manual wing pump, and open the valve A on the piping.

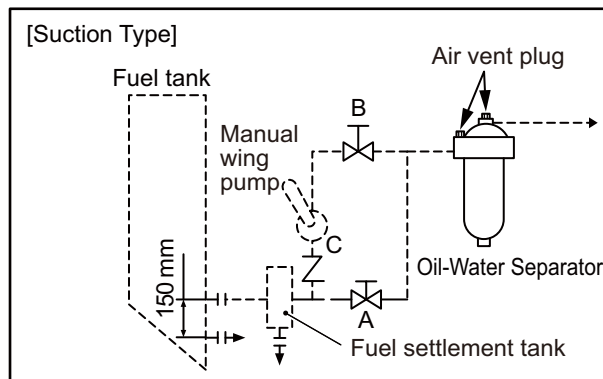


Fig. 3-2 Bleeding Air from Oil-Water Separator (Suction Type)

Drop head type piping

1. Loosen air vent plug of oil-water separator.
2. When the fuel flowing from the air vent plug no longer contains air bubbles, tighten the air vent plug.

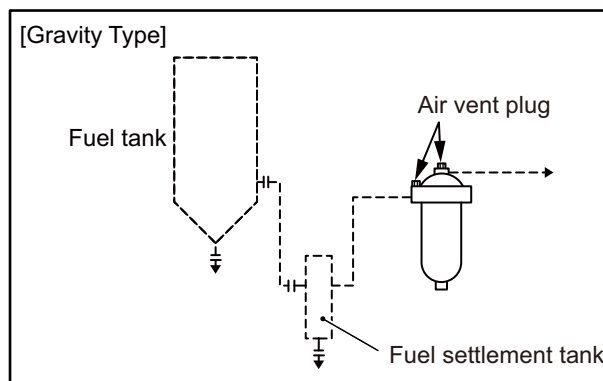


Fig. 3-3 Bleeding Air from Oil-Water Separator (Gravity Type)

Fuel Filter - Bleed Air

CAUTION

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

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

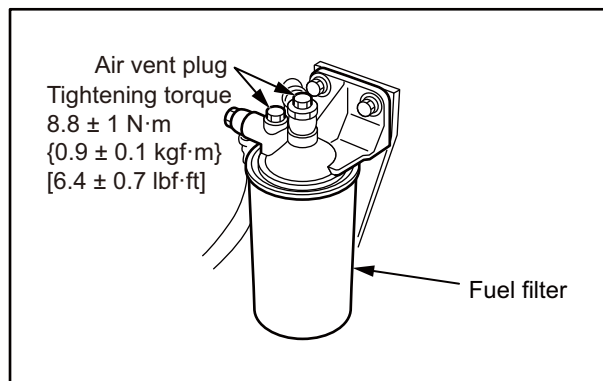


Fig. 3-4 Fuel Filter - Bleed Air

Fuel Injection Pump - Bleed Air

1. Loosen the air vent plug on the fuel injection pump about 1.5 turns.
2. Move the priming pump up and down. When the fuel flow from the air vent plug becomes free of bubbles, turn the priming pump clockwise to lock while pushing it.
3. Tighten the air vent plug on the fuel injection pump.

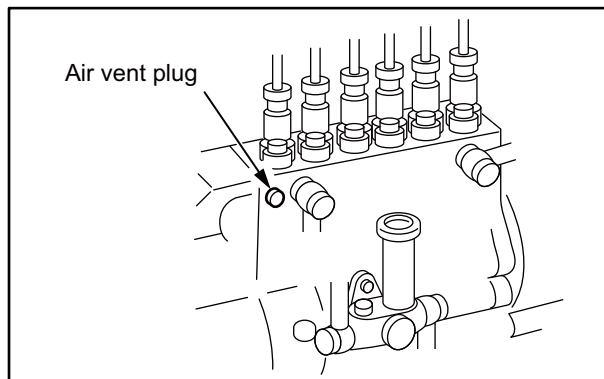


Fig. 3-5 Fuel Injection Pump - Bleed Air

Lubrication System - Prepare Engine Oil - Refill

CAUTION

Fill the engine with the specified engine oil to the specified level. If the oil level is higher than the maximum mark on the level gauge, engine oil may blow out during operation. Also, the rise of oil temperature could adversely affect engine components.

1. Remove the oil filler cap.
 2. Add 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. Check the oil level in oil pan.
 4. Pull out the oil level gauge and wipe it clean with a cloth.
 5. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
 6. The oil level should be between the maximum and minimum marks on the oil level gauge. If the oil level is low, add the specified engine oil.
 7. Check the oil pan, etc., for oil leaks. Repair if there is an oil leak.
 8. With the manual stop lever placed in pulled position, rotate the engine with starter for approximately 10 seconds to circulate oil to the engine thoroughly. Stop the rotation for 1 minute, then, repeat the rotation two or three times to circulate oil through various engine parts.
- Note: Also perform the items described under the Preparation of Cooling System.
9. Start the engine and run at a no-load and low-idling condition for 5 to 10 minutes.
 10. Stop the engine, and after 30 minutes or more has elapsed, check the oil level with the oil level gauge again and add oil to the specified level as required.
For details, refer to ["Test Run" \(3-8\)](#).

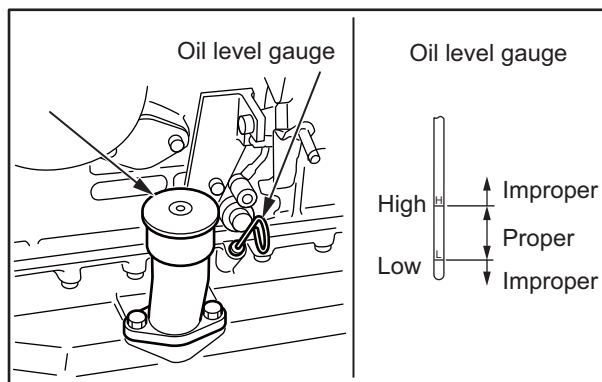


Fig. 3-6 Oil Filler and Oil Level Gauge

Cooling System - Prepare

Coolant Expansion Tank Cap - Open/Close

CAUTION

Never open the coolant expansion tank cap during the operation or immediately after stopping. Stop the engine and, after coolant has sufficiently cooled down, open the cap.

To open the coolant expansion tank cap, place a waste cloth over the cap, and loosen it about a quarter-turn to release the internal pressure.

The coolant is hot while the engine is running and immediately after stopping. If the cap is opened while the coolant is hot, you may get burned by bursts of steam. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

When tightening the coolant expansion tank cap, be sure to tighten securely.

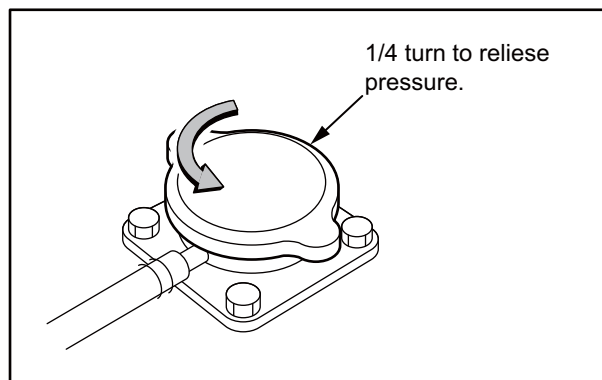


Fig. 3-7 Coolant Expansion Tank Cap

Coolant - Refill

CAUTION

To add coolant, use the same LLC concentration coolant that is currently in the cooling system.

1. Securely close the engine coolant drain cock.
2. Open the coolant filler port and add a mixture of water and coolant (LLC) having the specified concentration.

Note: Determine the quantity 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. Check the heat exchanger, etc. for coolant leaks. Repair if a leak is found.
4. When the coolant reaches the specified level, securely close the coolant fill port.
5. Place the manual stop lever in the pulled position, and crank the engine for approximately 10 seconds using the starter. Stop for approximately 1 minute, then, repeat the cranking two or three times to bleed the cooling system.

Note: Also perform the items described under the Preparation of Lubrication System.

6. Check the coolant level.
7. Also fill the reserve tank with coolant up to the "FULL" level line.

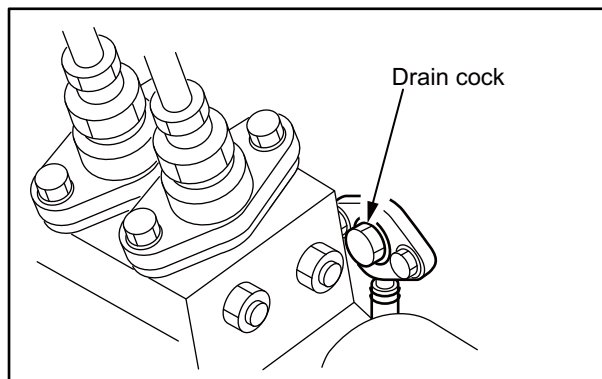


Fig. 3-8 Coolant Drain Cock (Engine Body)

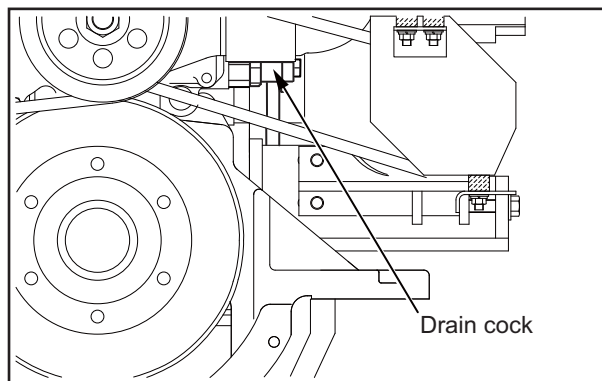


Fig. 3-9 Coolant Drain Cock (Engine Body)

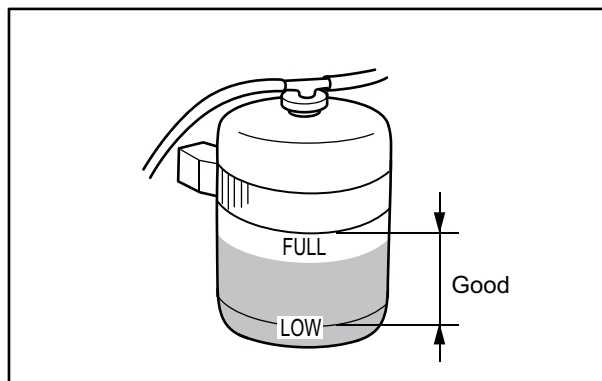


Fig. 3-10 Reserve Tank Coolant Level

Electrical System - Prepare

Battery - Check

⚠ CAUTION

Never use flames or allow sparks near the battery. The battery releases flammable hydrogen gas and oxygen gas. Any flames or sparks in the vicinity of battery could cause an explosion.

Do not use the battery when the battery fluid level is below the "LOWER LEVEL" mark. It may explode.

Do not short the battery terminals with a tool or other metal object.

When removing battery, always remove the plug from the negative (-) terminal first. When connecting battery, always connect the plug to the positive (+) terminal first.

Before charging the battery, remove all battery cables, and then charge the battery in a well ventilated area.

Make sure the cable clamps are securely attached to the battery terminals. A loose cable clamp can cause sparks, and it could result in an explosion.

Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.

Battery fluid contains dilute sulfuric acid. Careless handling of the battery can lead to a sight loss and/or skin burns. Also, do not swallow the battery fluid.

Wear protective goggles and rubber gloves when working with the battery (e.g. when adding water or charging the battery).

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

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

If you accidentally swallow battery fluid, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.

If the battery does not fully recover after charging for 24 hours or more, do not use the battery.

Note: If the specification of battery differs from those of this operation manual, follow the battery manufacturer's operation manual.

Battery Fluid Level - Check

The battery fluid evaporates during use, and the fluid level gradually decreases. The proper fluid level is between the LOWER LEVEL (Lower limit) and UPPER LEVEL (Upper limit) marks.

For the battery without level marks, the proper fluid level is about 10 to 15 mm [0.39 to 0.59 in.] above the top face of the polar plates.

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

Note: When adding distilled water, add little by little.

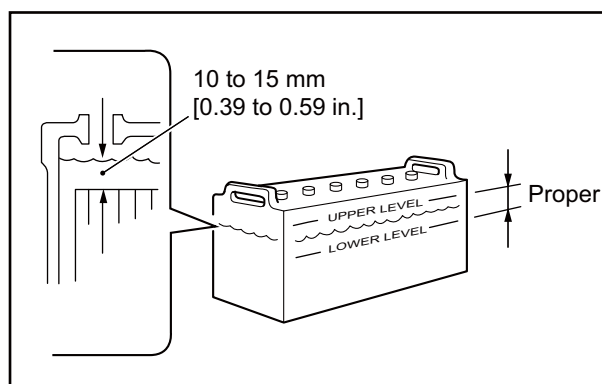


Fig. 3-11 Battery Fluid Level - Check

Test Run

To conduct a test operation, follow the procedures below:

Note: For engine operation, refer to ["Normal Engine Operation" \(3-9\)](#).

Start and Stop

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

Inspection

 CAUTION

Never open the coolant expansion tank cap during the operation or immediately after stopping. Stop the engine and, after coolant has sufficiently cooled down, open the cap.

To open the coolant expansion tank cap, place a waste cloth over the cap, and loosen it about a quarter-turn to release the internal pressure.

The coolant is extremely hot while the engine is running and immediately after the engine stops. Do not open the cap when the coolant is hot. Otherwise you may get burned by a splash of hot steam and water. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

When fastening the coolant expansion tank cap, be sure to tighten securely.

CAUTION

When adding coolant, use the same LLC concentration coolant that is currently in the cooling system.

1. Stop the engine for about 30 minutes.
2. During this period, walk around the engine to check for leaks of fluids such as fuel, engine oil, or coolant.
3. Then 30 minutes later after the engine has stopped, check the oil level with the oil level gauge.
4. If the oil level is low, add engine oil from the oil filler port. Be sure to use the engine oil of the same brand and type.
5. Open the coolant expansion tank cap and check the coolant level.
6. If the coolant level is low, add coolant to the specified level.
7. Also fill the reserve tank with coolant up to the "FULL" level line.

Normal Engine Operation

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

CAUTION

If an engine abnormality is observed during operation, stop the engine and correct the problem, or contact your MHIET dealer.

Preparations Before Operation

Always conduct daily pre-operation inspection before starting the engine for the day.

Engine Exterior - Inspect

CAUTION

Check external parts of the engine, particularly hot parts (such as exhaust manifold), or the battery for accumulation of flammable materials. Also, check leaks of fuel and engine oil. Remove dust from the top surface of the battery. If hot parts have a problem, it may cause a fire. If any abnormality is found, be sure to repair or contact your MHIET dealer.

Inspect the engine exterior as instructed below:

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Make sure fluids, such as fuel, oil, and coolant, are not leaking from the engine. If a leak is found, repair the leak, or contact your MHIET dealer.
3. Walk around and check bolts and nuts for looseness.
4. Check electric wiring for disconnection, looseness, cuts, or rubbing.
5. Make sure the following valves, plugs, or cocks are properly positioned as indicated below:
 - Fuel feed valve: open
 - Coolant drain cock (valve): closed
 - Engine oil drain plug: closed

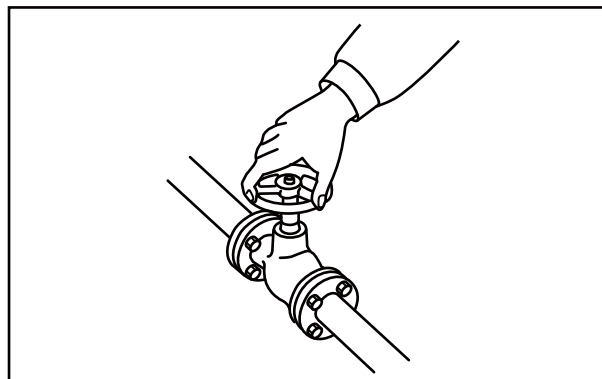


Fig. 3-12 Valve Open/Closed Position - Check

Fuel Tank Oil Level - Check



WARNING

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

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

CAUTION

Do not remove the strainer during fuel tank filling.

For the fuel to be used, refer to ["FUEL" \(4-1\)](#).

Make sure that the fuel tank is filled to the specified level.

If the fuel level is low, add fuel to the "FULL" level.

Note: If the specification of fuel tank differs from the contents of this operation manual, follow the fuel tank manufacturer's operation manual.

Oil-Water Separator - Drain Water

1. Place a pan under the drain plug of oil-water separator.
2. Loosen the air vent plug.
3. Remove the drain plug and drain water from the oil-water separator.
4. Securely close the drain plug after draining.
5. Bleed air from oil-water separator and tighten the air vent plug.

Note: For bleeding the oil-water separator, refer to ["Oil-Water Separator - Bleed Air" \(3-2\)](#).

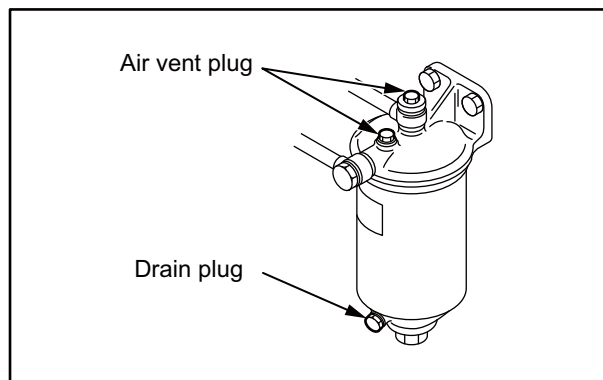


Fig. 3-13 Oil-Water Separator - Drain Water

Engine Oil Level - Check

CAUTION

Refill the engine with oil to the specified level. If the oil level is higher than the maximum mark on the level gauge, engine oil may blow out during operation. Also, the rise of oil temperature could adversely affect engine components.

When adding engine oil, use the same oil that is used in the engine.

1. Stop the engine and leave it for 30 minutes or more.
2. Pull out the oil level gauge and wipe oil off from the oil level gauge using a clean waste cloth.
3. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
4. The oil level should be between the maximum and minimum marks on the oil level gauge. If the engine oil level is higher than the high mark on the oil level gauge, drain the oil. If the oil level is low, add the specified engine oil.

For draining engine oil, refer to "[Engine Oil - Drain](#)" (8-9). For refilling engine oil, refer to "[Engine Oil - Refill](#)" (8-11).

5. Install the oil filler cap after engine oil is refilled.
6. Check the oil pan, etc., for oil leaks.

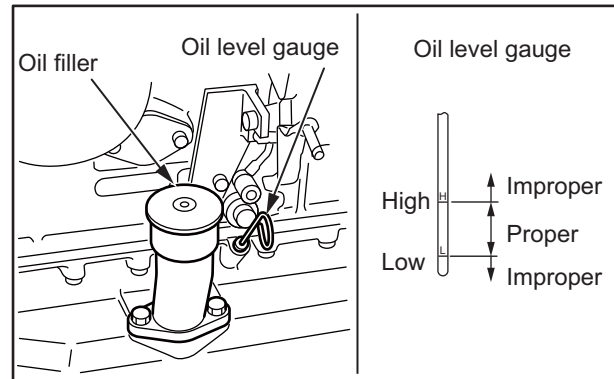


Fig. 3-14 Oil Filler and Oil Level Gauge

Coolant Level - Check

WARNING

Never open the coolant expansion tank cap during the operation or immediately after stopping. Open the cap when the coolant has sufficiently cooled down after stopping the engine.

To open the coolant expansion tank cap, place a waste cloth over the cap, and loosen it about a quarter-turn to release the internal pressure.

The coolant is hot while the engine is running and immediately after stopping. If the coolant expansion tank cap is opened while the coolant is hot, steam and hot water will blow out and you may get burned. To prevent burn injuries from hot steam, wear thick rubber gloves or wrap a cloth around the cap.

When fastening the coolant expansion tank cap, be sure to tighten securely.

CAUTION

When adding coolant, use the same LLC concentration coolant that is currently in the cooling system.

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

Note: Determine the quantity 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. Also fill the reserve tank with coolant up to the "FULL" level line.

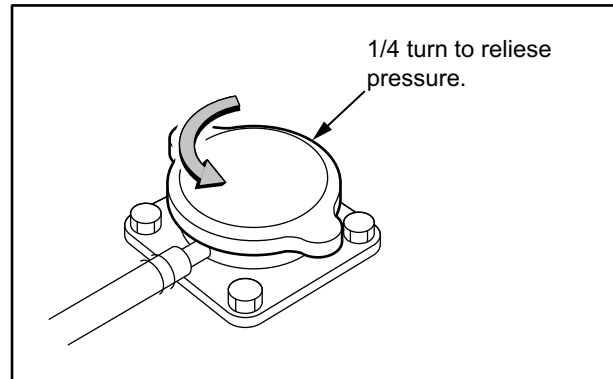


Fig. 3-15 Coolant Expansion Tank Cap

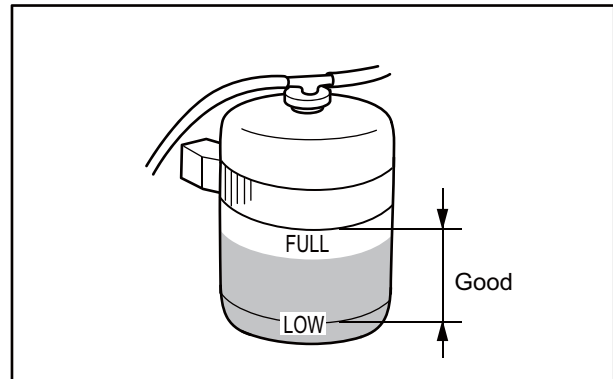


Fig. 3-16 Reserve Tank Coolant Level

Warning Indicator Light - Operation Check

1. Turn the starter switch to the "ON" position.
2. Turn the light test switch to "ON" position.
3. Make sure the lights come on. If any of the lights does not come on, check the light bulbs, etc. on the instrument panel.

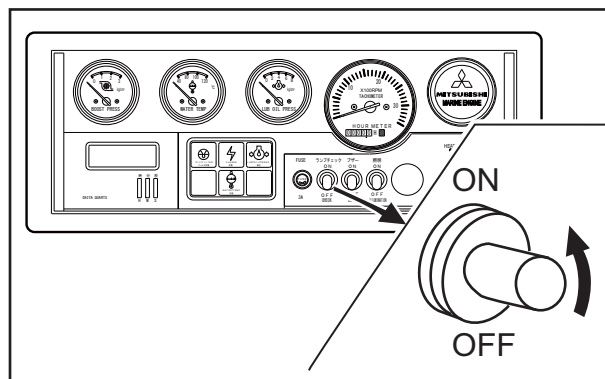


Fig. 3-17 Warning Indicator Light - Operation Check

Control Cable - Check

Check the visual appearance of control cable for flaws, deformation, discoloration, abnormal rust, etc.

Control Lever - Operation Check

Operate each lever and make sure that levers move smoothly without any looseness or restriction.

Operate the speed control lever from L (low-speed rotation) to H (high-speed rotation) and to L (low-speed rotation) position to make sure the operation of lever.

Operate the direction lever, and make sure the marine gear is correctly positioned in the "Forward", "Neutral," and "Reverse" respectively.

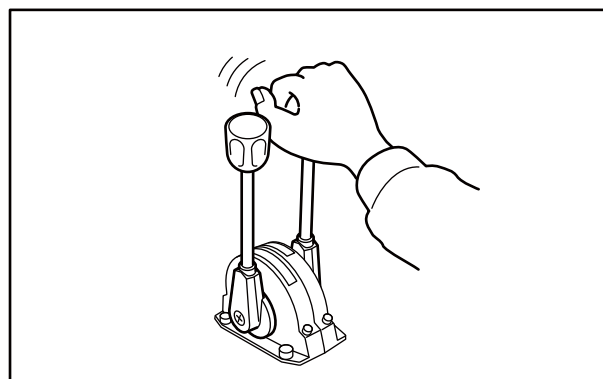


Fig. 3-18 Control Lever - Operation Check

Engine Start Up

Cautions When Starting



WARNING

Before starting the engine, check to make sure no one is near the engine and that tools are not left on or near the engine. Also alert people in the area when starting the engine.

CAUTION

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

Restart the engine after it stops completely.

Check fuel system if the engine will not start after repeating above step three to five times.

DO NOT turn the switch to "START" or "OFF" position during operation.

When the engine is not operated for a long time (one week or more), rotate the crankshaft for 10 seconds with the starter while pulling the manual stop lever. Repeat this three times with 30-second intervals between each rotation to circulate oil through the engine.

Pre-heating during cold weather should be performed within the specified time given below.

If pre-heating specified time is exceeded, it could decrease battery capacity faster, or shorten the life of air heater.

Table 3-1 Pre-heating Time in Cold Climates (Air Heater)

Ambient temperature	Preheating time
-5°C to -15°C [23°F to 5°F]	20 to 40 seconds
-15°C to -30°C [5°F to -22°F]	40 to 60 seconds

Starting Procedures

1. Open the Kingston valve.
2. Place the battery switch in the "ON" position.

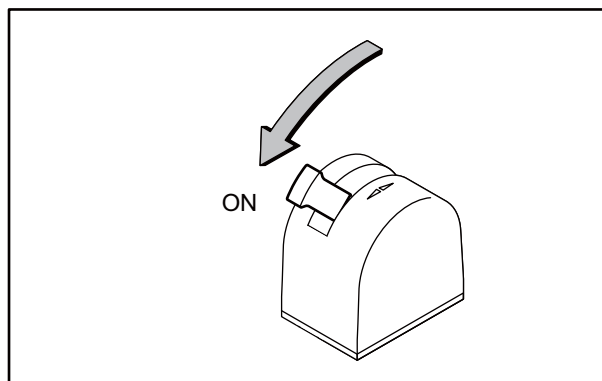


Fig. 3-19 Battery Switch "ON"

3. Place the speed control lever in the middle between "L" (low speed) and "H" (high speed) positions and place the direction lever in the "N" (neutral) position.

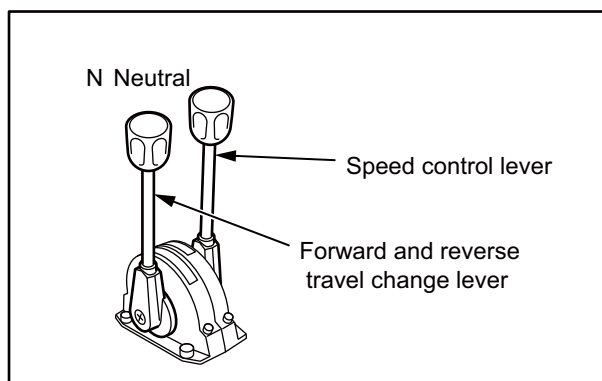


Fig. 3-20 Control Lever Start Position

4. In a cold climate, turn the starter switch key to "HEAT" until the glow signal turns red.

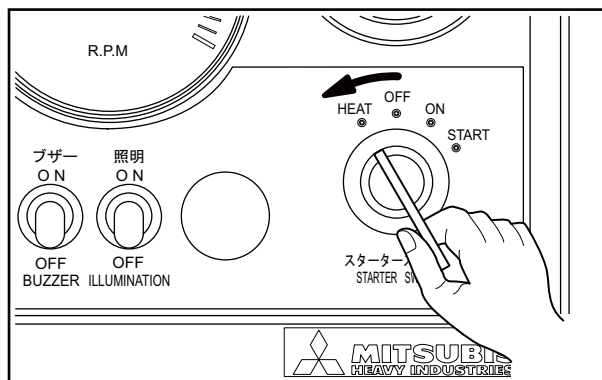


Fig. 3-21 Starter Switch "HEAT"

5. Turn the starter switch key to the "START" position to start the engine.

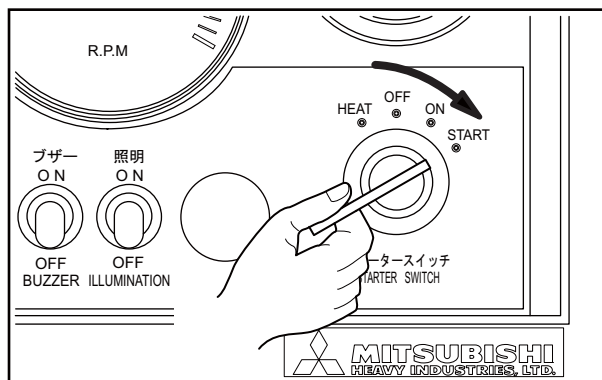


Fig. 3-22 Starter Switch "START"

6. Release the key when the engine has started. The key automatically returns to the "ON" position.

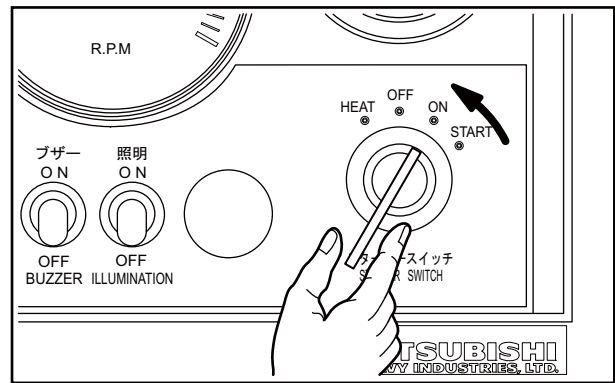


Fig. 3-23 Starter Switch "ON"

Warm-up Operation

WARNING

Stay away from rotating parts during operation. If you are caught in rotating parts, you can be seriously injured.

CAUTION

Do not conduct warm-up operation for a prolonged period of time. Accumulation of carbon in the cylinder may cause faulty combustion.

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

Warm-up the engine at low idle with no load until the coolant temperature reaches approximately 50°C [122°F].

Engine Oil Pressure - Check

During warm-up operation, make sure the engine oil pressure is within the specified range.

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

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

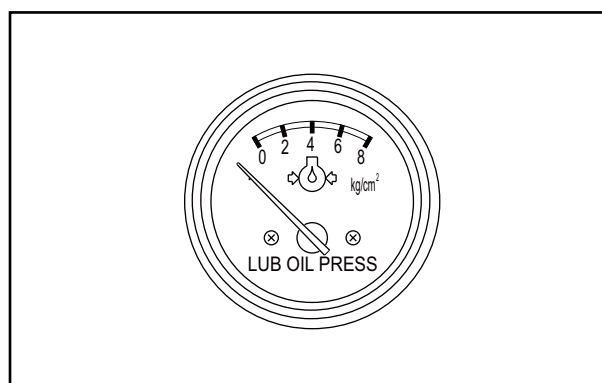


Fig. 3-24 Oil Pressure Gauge

Engine - Walk Around Check

During warm-up operation, visually inspect the engine for external damage, abnormal noise, odor, vibration, and exhaust gas color, and also inspect if fuel, engine oil, coolant, or exhaust gas is leaking from joints.

Operation

Precautions in Engine Operation

Pay Attention to Gauges and Warning Lights

CAUTION

If a gauge shows an abnormal indication or a warning light illuminates (buzzer is also activated), run the engine at idling speed, then stop the engine. After the engine stops, inspect the engine for abnormalities.

Pay Attention to Abnormal Noise

CAUTION

If the engine produces an abnormal sound during operation, stop the engine and check for the cause of noise. Continued operation can result in an unexpected accident.

Pay Attention to Exhaust Color

CAUTION

If the exhaust gas shows an abnormal color, there is a problem in the engine. Stop the engine and inspect the engine by referring to the TROUBLESHOOTING section to locate, and correct the problem.

Avoid Operating the Engine at a Speed Which Causes Resonance

CAUTION

Depending on various factors such as the ship structure, engine frame rigidly, and propeller shaft length, the engine can cause amplified vibrations. Do not operate the engine at a resonance-generating speed.

Pay Attention to Seawater Discharging Volume

CAUTION

If seawater does not circulate properly, overheating and other problems can occur. Record the amount of seawater discharged in normal operation, and regularly check the amount of discharged seawater to judge if it is normal.

Check to see if the kingston valve, seawater strainer, etc. are clogged with dust or plastic particles.

Check to see if the seawater pump impeller is damaged.

Stopping

Cautions When Stopping

CAUTION

Do not stop the engine abruptly during high-speed operation or while engine is hot. Otherwise, the engine life will be shortened. Except in a case of emergency, operate the engine at low idle speed for 5 to 6 minutes to cool the engine before stopping. Then check the engine for abnormalities.

Do not race the engine immediately before shutdown.

Do not start the engine immediately after an abnormal stop. If the engine stops with a warning alarm, be sure to locate the causes of problem, and correct the problem before starting the engine again. After starting the operation, check the engine for abnormalities again. If an abnormality is found, repair it immediately.

To stop the engine by pulling the stop knob, keep pulling the knob until the engine stops completely. If you stop halfway, the engine may start again.

Stopping Procedure

1. Place the speed control lever in the "L" (low speed) position and place the direction lever in the "N" (neutral) position.
2. Before stopping, run the engine at low idle for 5 to 6 minutes to cool the engine.
3. Keep pulling the stop knob until the engine is completely stopped.

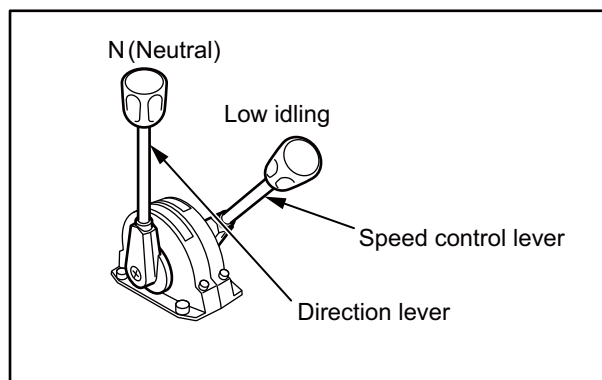


Fig. 3-25 Control Lever Stop Position

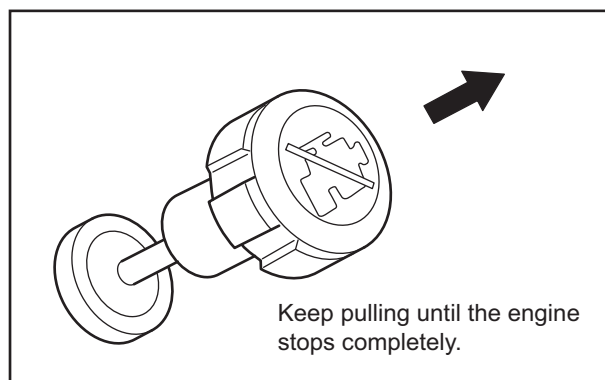


Fig. 3-26 Stop Knob

4. Turn the starter switch to the "OFF" position.

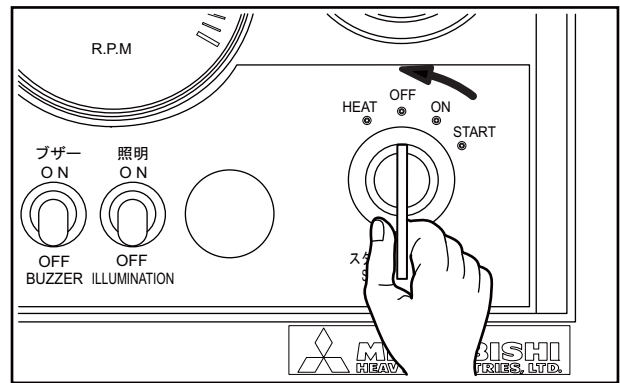


Fig. 3-27 Starter Switch "OFF"

5. Turn the battery switch to the "OFF" position.
6. Close the Kingston valve.

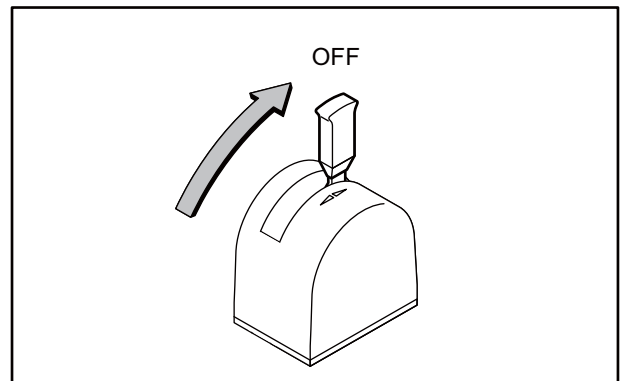


Fig. 3-28 Battery Switch "OFF"

Recommended Fuel



WARNING

Use the fuel specified in this manual only. Also, do not refill the fuel tank more than the specified level. It could lead to a fire.

Use a fuel that meets the requirements in the [Table 4-1"Recommended Fuel"](#) and [Table 4-2"Recommended Limit and Use Limit for Fuel Properties"](#) It is necessary to use fuel that has a pour point suitable for the ambient temperature.

- (a) Please use the fuel that meets the laws and regulations of the country or region where the engine is used, if the laws and regulations are applied.
- (b) When using the engine as a marine propulsion engine, be sure to mount oil-water separator on the engine.

Table 4-1 Recommended Fuel

Standard	Classification
ISO 8217	DMX-CLASS
ASTM D975	No.1-D, No. 2-D
BS 2869	CLASS A1, CLASS A2
DIN 51601	DIESEL-FUEL
JIS K2204	TYPE 1, TYPE 2, TYPE 3
EN 590	DIESEL-FUEL

Handling Fuel

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

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

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

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

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

Fuel Quality Standard

Use a fuel which meets the requirements specified in the table below.

Table 4-2 Recommended Limit and Use Limit for Fuel Properties

Item		Recommended limit	Use limit	Test method
Flash point		50°C [122°F] or higher (In accordance with the regulation)		JIS K 2265: 2007 ISO 3769 ISO 2719
Distillation	Initial boiling point	170°C [338°F] or higher		JIS K 2254: 1998 ISO 3405
	90% distillate temperature	330 to 380°C [626 to 716°F]		
Pour point (PP)		Lower than ambient temperature by 6°C [42.8°F] or more		JIS K 2269: 1987 ISO 3016
Cloud point (CP)		Below ambient temperature		JIS K 2269:1987 ISO 3015
Cold filter plugging point (CFPP)		Lower than ambient temperature by 3°C [37.4°F] or more		JIS K 2288: 2000 IP 309/96
Carbon residue (10% residual oil)		0.4 weight % or lower	1.0 weight % or less	JIS K 2270: 2000 ISO 6615 ISO 10370
Cetane number		45 or higher		JIS K 2280: 1996 ISO 5165
Cetane index (new way)		45 or higher		JIS K 2280: 1996 ISO/DIS 4264
Kinetic viscosity		2.0 mm ² /s [0.0031 in ² /s] or more at 30°C [86°F] 8.0 mm ² /s [0.0124 in ² /s] or more at 30°C [86°F]		JIS K 2283: 2000 ISO 3104
Sulfur content		0.2 weight % or less	1.0 weight % or less (Shorten lub. oil change intervals)	JIS K 2541:2000 Content as low as the diesel fuel is desirable. ISO 4260 ISO 8754
Water content and sediment		0.1 volume % or lower		JIS K 2275:1996 ISO 3733
Ash content		0.01 weight % or lower	0.03 weight % or lower	JIS K 2272:1998 ISO 6245
Copper corrosion (3 hrs at 50°C [122°F])		Discoloration = Copper plate No.3 or less		JIS K 2513: 2000 ISO 2160
Density at 15°C [59°F]		0.83 to 0.87 g/cm ³ [49.9424 to 54.3123 lb/ft ³]		JIS K 2249:1995 ISO 3675
Coking	24 hrs at 250°C [482°F]	75% carbonization or less	80% carbonization or less	Fed 791B
	24 hrs at 230°C [446°F]	55% carbonization or less	-	
	48 hrs at 180°C [356°F]	Tar-free	-	

Table 4-2 Recommended Limit and Use Limit for Fuel Properties

Item	Recommended limit	Use limit	Test method
Aromatics substances (by HPLC)	38% by volume or less		JIS K 2536: 2003
Polycyclic aromatic content	8 volume % or lower		ISO 3837
Asphaltene	0.1 weight % or lower		-
Fine foreign substances (foreign substances at fuel inlet)	5.0 mg/liter or less		JIS B 9931:2000 ISO 4405
Lubricity: MWSD (Measured mean Wear Scar Diameter) by HFRR wear test at 60°C [140°F] fuel temperature	460 μm [0.02 in.] or less (calculated wear scar diameter at WS 1.4 kPa {0.0143 kgf/cm ² } [0.2031 psi])	-	ISO 12156-1
BDF: Biodiesel fuel (FAME: Fatty Acid Methyl Ester)	BDF quality shall meet JIS K 2390, or ASTM D 6751 or EN14214. BDF blending of 5% by volume or less is approved.		JIS K 2390:2008(standard for FAME as blend stock) ASTM D 6751 EN 14214
Engine applications	For engines operated under a high load for a long period (e.c. continuous use)	For engines operated under a low load for a short period of time (e.c. stand-by use)	Selection according to applications

Recommended Engine Oil

CAUTION

Use the engine oil recommended in this manual only. Do not use any other oil.

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

Use only MHIET genuine engine oil for the engine. If you have to use an oil other than MHIET genuine oil, check the engine oil grade and use only the oil which meets our quality standard. Furthermore, conduct the oil analysis of used oil to review the oil replacement intervals. Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. disclaims the warranty claim for mal-functions due to the use of engine oil that does not meet our quality standard.

Genuine Engine Oil

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. offers the best suited oils, which yielded from many test, to the Mitsubishi marine engines. We highly recommend the use of our genuine engine oil. "JUKOIL New Mariner 15W-40 or 30" are developed exclusively for marine engines.



Fig. 5-1 JUKOIL New Mariner

Other Commercial Engine Oils

CAUTION

Never mix different brands of engine oil with the MHIET genuine 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.

Engine Oil Grade

For the engine oil quality, there are oil standards that are established through special engine tests based on the engine specifications and operating conditions. Among those standards, API (American Petroleum Institute) service classifications are mostly used to classify engine oils. The SAE standard specifies the viscosity only, while the API service classification indicates the quality level of engine oil.

There are different grades of diesel engine oil in API service classification. For the oil for our engines, please use the grade CF oil which is suitable to turbo/supercharged and high-load engines.

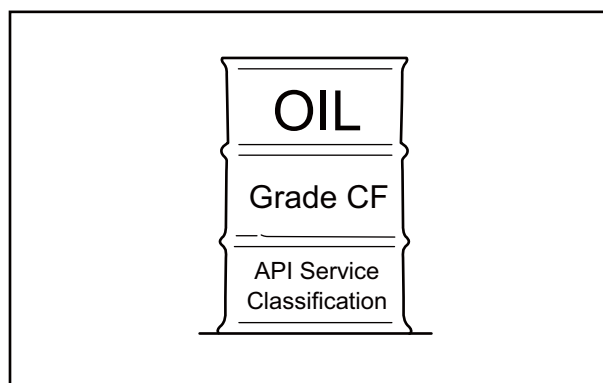


Fig. 5-2 Recommended Engine Oil

Engine Oil Quality Standard

Use engine oil that meets the requirements specified in the table below.

Table 5-1 Recommended Limits for Engine Oil Properties

Item			Unit	Recommended property value	Test method
API/JASO				Grade CF *1	-
SAE viscosity			-	15W-40	-
ASTM Color			-	L4.0	JIS K 2580 ISO 2049
Density		15°C [59°F]	g/cm ³ [lb/ft ³]	0.87 to 0.90 [54.3123 to 56.187]	JIS K 2249 ISO 3675 ISO 3838 ISO 649-4 ISO 91-1
Kinetic viscosity		40°C [104°F]	mm ² /s [in ² /s]	100 to 110 [3.94 to 4.33]	JIS K 2283 ISO 3107 ISO 2904
		100°C [212°F]		13.5 to 15.5 [0.532 to 0.610]	
Viscosity			-	-	JIS K 2283 ISO 3107 ISO 2904
Flash point			°C [°F]	225 to 250 [437 to 482]	JIS K 2265 ISO 3679 ISO 2719 ISO 2592
Base number	Hydrochloric acid method	Sulfur content in fuel	mgKOH/g	10 or higher (up to 13)	JIS K 2501 ISO 3771 ISO 6618 ISO 6619 ISO 7537
				0.2 weight % or lower	
	Perchloric acid method	Sulfur content in fuel	mgKOH/g	13 or higher (up to 16)	
				0.2 weight % or lower	
Acid number			mgKOH/g	1.5 to 2.0	JIS K 2501 ISO 3771 ISO 6618 ISO 6619 ISO 7537
Sulfur content			%	0.5 or less	JIS K 2541 ISO 4260 ISO 8754
Sulfuric acid ash			%	2.0 or less	JIS K 2272 ISO 3987 ISO 6245
Carbon residue content			%	2.0 or less	JIS K 2270 ISO 10370 ISO 6615
High temperature shear viscosity		150°C [302°F]	mPa·S	3.7 or more	JPI-5S-36-91
Pour point			°C [°F]	-25 [-13] or less	JIS K 2269 ISO 3015 ISO 3016

Table 5-1 Recommended Limits for Engine Oil Properties

Item		Unit	Recommended property value	Test method
Additive	Ca	Weight %	0.480 to 0.570	JIS K 0116 ISO 3696
	P		0.050 to 0.070	
	Zn		0.060 to 0.080	
	B		-	
	Si		0.001 or less	
	N		0.030 to 0.060	JIS K 2609
Bubbling test *2	I	mL	10/0	JIS K 2518 ISO 6247
	II		30/0	
	III		10/0	
Panel coking test *3	300°C [572°F]	mg	140 or less	FED791-3462
	325°C [617°F]		300 or less	

*1: API CF grade oil certified in the year of 2009 or before.

*2: I test temp. = 24°C [75°F], II test temp. = 93.5°C [200°F], III test temp. = 24°C [75°F] after 93.5°C [200°F]

*3: Aluminum panel temp: 300°C [572°F] and 325°C [617°F], lubrication oil temp: 100°C [212°F], splashing time: 15 seconds, Interval: 45 seconds, test time: 8 hours, and the property is the solid mass accumulated on the panel.

Selection of Oil Viscosity

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

Excessively high oil viscosity causes power loss and an abnormal rise in oil temperature, while excessively low oil viscosity accelerates wear and causes gas leak from the cylinder due to inadequate lubrication which resulting in decrease in engine output.

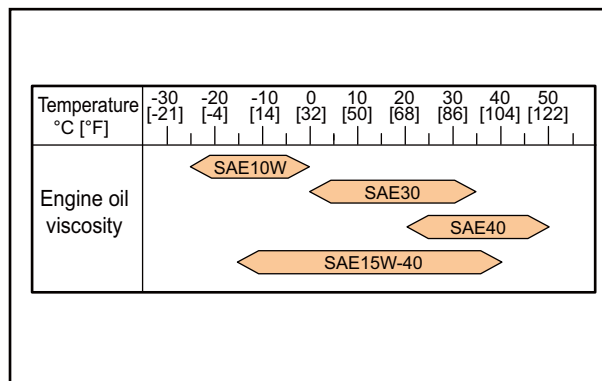


Fig. 5-3 Selection of Oil Viscosity

Handling Engine Oil

WARNING

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

When handling a large amount of engine oil more than the legally specified quantities, be sure to have the work performed in a service station operated under the provision of the law. When draining oil from the engine or oil can, use an oil pump. Do not siphon oil with a pipe using your mouth.

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

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

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

Service Limits for Engine Oil

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

The quality of engine oil and the operating condition of the engine have an influence on deterioration of the engine oil.

Change the engine oil in accordance with Chapter 7 PERIODIC MAINTENANCE CHART. The recommended oil change interval is 50 hours for the first time. And, the intervals after the first change is every 250 hours. However, only when the engine oil analyze result allows, the oil change interval may be extended. The limit of extended oil change interval is 500 hours.

Refer to the following table for the determination of engine oil performance. If any of the following properties exceeds the limit, change the engine oil with new one.

Table 5-2 Engine Oil Properties

Properties		Standard value		Test standard
Kinetic viscosity	mm ² /s [in ² /s] @100°C [212°F]	For main engine/ main generator	+30% or less rate of change from the new oil 10 [0.39] or more	JIS K 2283: 2007 ISO 3107 ISO 2909
		Emergency use Generator use	+30% or less rate of change from the new oil -20% or less rate of change from the new oil	
Base number	mgKOH/g	2.0 or more by hydrochloric acid (HCL) method 1/2 of new oil or more by the perchloric acid (PCA) method		JIS K 2501: 2003 ISO 3771
Acid number	mgKOH/g	+3.0 of new oil or less		JIS K 2501: 2003 ISO 3771
Water content	Vol %	0.2 or less		JIS K 2275: 1996 ISO 9029
Flash point (open cup)	°C [°F]	180 [356] or more		JIS K 2265: 2007 ISO 3769 ISO 2719
Pentane insolubles	Wt %	0.5 or less		Compliant to ASTM D 893
Coagulated pentane insolubles	Wt %	3.0 or less		Compliant to ASTM D 893

Definition of Properties limit of Engine Oil

Kinetic viscosity

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

The kinetic viscosity increases by contamination with blow-by gas and deterioration of the oil. Also, the viscosity decreases by contamination with fuel and molecular disconnection of the viscosity index improver. The former causes sludge accumulation in the engine and oil filter clogging. The latter causes faulty lubrication and wear.

Base number

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

Because the base number indicates the amount of dispersant detergent in oil, it can be used to estimate consumption of the basic dispersant detergent. The ability to disperse sludge declines as dispersant detergent is consumed. Thus, the base number is often used as an indication of cleaning capability decline.

Acid number

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

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

Water content

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

Flash point

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

Insolubles

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

Dispersant detergent, which is an additive in engine oil, absorbs sludge particles, and disperses them as fine particles in oil. Total insoluble density and remaining dispersibility can be obtained by measuring insoluble and coagulated insoluble (chemical specialties which stop action of disperse detergent and collect the sludge dispersed in oil) to identify the engine oil contamination level, and thereby, the insoluble value can be a marker to prevent the piston ring from seizure or premature wear.

Engine Oil Analysis Service

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

By this service, the engine oil is extracted from the engine using a sampling tool, and the sampled oil is analyzed to determine whether the oil being used is acceptable or not for use.

The followings are found by the engine oil analysis service:

- ♦The amount of fine metal powder in engine oil due to abrasion is found, by which, worn parts of the engine can be located.
- ♦Water, LLC, or salt that should not be in engine oil can be detected if presented.
- ♦Deteriorated condition of engine oil is found. You can plan the operational and maintenance countermeasures depending on the condition, and find the proper engine oil replacement intervals.

The engine oil analysis service can diagnose the internal condition of the engine without disassembling the engine.

It is highly recommended to take advantage of our engine oil analysis service so that you can find the engine condition before any malfunction occurs to the engine.

Note: In this operation manual, the word "coolant" denotes a mixture of water and LLC.

Recommended Water for Coolant

Use soft water (such as tap 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 range of the recommended values, however, up to the limit value is acceptable.

Table 6-1 Water Quality Standard

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

Long Life Coolant (LLC)

⚠ CAUTION

If you swallow coolant or LLC accidentally, induce vomiting immediately and seek medical attention. If LLC gets in your eyes, flush immediately with plenty of water and seek medical attention.

Be sure to use MHIET genuine long life coolant (LLC), "GLASSY long life coolant (ethylene glycol type)" or "PG GLASSY long life coolant (propylene glycol type)." When using an LLC other than MHIET genuine long life coolant by necessity, be sure to use the non-amine type LLC that meets our requirements. The MHIET disclaims the warranty claim for malfunctions due to the use of LLC that does not meet our requirements.

Genuine LLC

The MHIET recommends the use of our genuine long life coolant "GLASSY long life coolant (Ethylene glycol type)", and Eco-friendly product "PG GLASSY long life coolant (propylene glycol type)", which are most appropriate coolant for Mitsubishi diesel engines. Be sure to use our Genuine LLC.

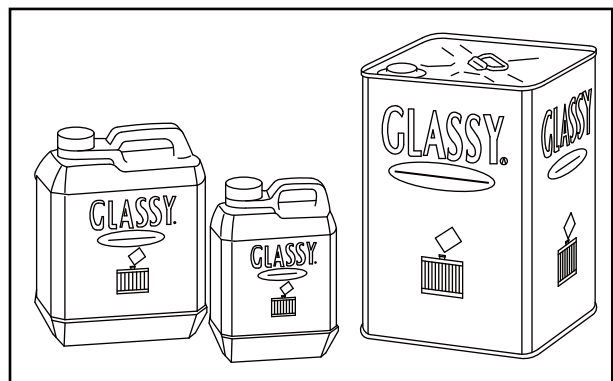


Fig. 6-1 GLASSY - LLC

Other Commercial LLCs

CAUTION

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

When using an LLC other than MHIET genuine long life coolant (LLC) "GLASSY long life coolant (ethylene glycol type)" or "PG GLASSY long life coolant (propylene glycol type)," be sure to use the LLC that meets our requirements.

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

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

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

Requirements for Other Commercial LLCs

If you must use other brand LLCs, be sure to use the LLC that meets the requirements below. The MHIET dis-claims the warranty claim for malfunctions caused by the use of LLC that does not meet our requirements.

General Quality Requirements for LLC

- LLC must be a homogeneous liquid without sediment.
- When the LLC is diluted to 30 to 60% density, the LLC shall not cause any problems such as corrosion and precipitation deposits in the engine cooling system.
- LLC shall be mixed well with other non-amine type LLC that meets this requirements and shall not separate elements included in the each product, and shall not decrease the performance of both products.
- LLC shall not corrode the container and shall not produce a precipitate when LLC is left in the container for 6 months.
- LLC shall be free from any abnormalities such as precipitates when kept in -20 to -25°C [-4 to -13°F] temperature.
- The validity period for the quality requirements for products specified herein shall be 2 years after the delivery, provided that they are stored under indoor normal temperature.

LLC Quality Standard

LLC shall be tested according to JIS K 2234, Section 7 "Test method", and satisfy the requirements. General matters and specimen sampling method shall comply with JIS K 2234.

Table 6-2 LLC Quality Standard

Test items				Standard value
Visual inspection				No precipitation
Specific gravity				Minimum 1.112 g/cm ³ [69.4199 lb/ft ³] (20/20°C) [68/68°F] (Undiluted solution)
Water content				5.0 weight % or lower (Undiluted solution)
Freezing temperature	30 vol % water solution		-14.5°C [5.9°F] or lower	
	50 vol % water solution		-34.0°C [-29.2°F] or lower	
Equilibrium reflex boiling point				155°C [311°F] or higher (Undiluted solution)
pH				7.0 to 11.0 (30 vol % water solution)
Bubbling character (ASTM D3306-01)	30 vol % water solution		4.0 ml [0.0008 gal] or less	
	33⅓ vol % water solution		150 ml [0.032 gal] or less, deforming time 5 sec. or less	
Hard water compatibility				1.0 or less (50 vol % water solution)
Metallic causticity (88±2°C [190.4±4°F], 336 ± 2 Hr), 30 vol % water solution (ethylene glycol), 50 vol % water solution (propylene glycol)	Metallic test piece	Mass change	Aluminum	±0.30 mg/cm ²
			Cast iron	±0.15 mg/cm ²
			Steel	±0.15 mg/cm ²
			Brass	±0.15 mg/cm ²
			Solder	±0.30 mg/cm ²
			Copper	±0.15 mg/cm ²
	Visual inspection of test piece after testing		Any corrosion should not be observed except for the contacting position of the test piece and spacer. Discoloration is allowed.	
	Bubble formation during test			Bubble does not overflow.
	Property of the liquid after test	pH		6.5 to 11.0
		pH change		±1.0
		Precipitation		0.5 vol % water solution or less
		Visual inspection of liquid		No significant discoloration. No significant changes such as liquid separation and gel generation

Table 6-2 LLC Quality Standard

Test items				Standard value
Circulating corrosion (98±2°C [208.4±4°F], 1000 Hr), 30 vol % water solution (ethylene glycol), 50 vol % water solution (propylene glycol)	Metallic test piece	Mass change	Aluminum, cast iron, steel, brass, solder and copper	±0.30 mg/cm ²
		Visual inspection of test piece after testing		Any corrosion should not be observed except for the contacting position of the test piece and spacer. Discoloration is allowed.
	Property of the liquid after test	pH		7.0 to 9.0
		pH change		±1.0
		Reserve alkalinity change		±15%
		Precipitation		1.0 vol % water solution or less
		Visual inspection of liquid		No significant discoloration. No significant changes such as liquid separation and gel generation
		Ion concentration	Iron, copper, aluminum, zinc, lead and ammonium ion	10 ppm or less
Circulating corrosion (88±3°C [190.4±6°F], 1000±2 Hr), 30 vol % water solution (ethylene glycol)	Metallic test piece	Mass change	Aluminum	±0.60 mg/cm ²
			Cast iron	±0.30 mg/cm ²
			Steel	±0.30 mg/cm ²
			Brass	±0.30 mg/cm ²
			Solder	±0.60 mg/cm ²
			Copper	±0.30 mg/cm ²
		Visual inspection of test piece after testing		Any corrosion should not be observed except for the contacting position of the test piece and spacer. Discoloration is allowed.
	Property of the liquid after test	pH		6.5 to 11.0
		pH change		Maximum ±1.0
		Visual inspection of liquid		No significant discoloration. No significant changes such as liquid separation and gel generation
	Condition of parts	Pump seals		Free from any malfunction, liquid leak, and abnormal noise during operation
		Pump case inner surfaces and blades		Free from remarkable corrosion

Table 6-2 LLC Quality Standard

Test items			Standard value
Rubber adaptability (30 vol % water solution, 115°C [239°F], 360 Hr)	Silicone	Tensile strength change rate	-60 to 0%
		Elongation change rate	-40 to +20%
		Volume change rate	0 to +40%
		Hardness change rate	-20 to +10%
	Nitril rubber	Tensile strength change rate	0 to +10%
		Elongation change rate	-15 to +15%
		Volume change rate	0 to +40%
		Hardness change rate	-10 to 0%
	Ethylene pro- pylene diene monomer	Tensile strength change rate	0 to +10%
		Elongation change rate	-30 to 0%
		Volume change rate	0 to +10%
		Hardness change rate	-10 to 0%
Storage stability (volumetric % water solution) (30 volumetric % water solution, room temp. 6 Hr)			0.3 or less

Maintenance of LLC

CAUTION

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

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

Replacement Intervals of LLC

CAUTION

Be sure to renew LLC (coolant) at the intervals specified in the "Periodic Maintenance Chart".

Failure to renew LLC may cause malfunctions due to protection degradation against rust and cavitations.

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

LLC Concentration (GLASSY and PG GLASSY)

- To prevent cavitations of water pump and cylinder liners, LLC concentration must be at least 30% for GLASSY (ethylene glycol) and 40% for PG GLASSY (propylene glycol) by volume under any temperature conditions throughout the year.
- Coolant anti-freeze concentration for the engine is determined by the ambient minimum temperature of the year. Maintain the coolant concentration in the range shown in the table below.

Table 6-3 Recommended LLC Concentration

Environmental temperature		Max. -10°C [14°F]	Max. -20°C [-4°F]	Max. -30°C [-22°F]	Max. -45°C [-49°F]
LLC con- centration	GLASSY (ethylene glycol)	30%	40%	50%	60%
	PG GLASSY (propylene glycol)	40%	55%	70%	90%

- Concentration must be 60% at a maximum for GLASSY (ethylene glycol) and 90% for PG GLASSY (propylene glycol). If the concentration is higher than the specification, the antifreeze effect will be lowered, or the cooling water temperature will be increased due to the lowered specific heat.
- Coolant temperature will increase by approximately 1.5°C [34.7°F] for 60% concentration of GLASSY (ethylene glycol) and approximately 3°C [37.4°F] for 90% concentration of PG GLASSY (propylene glycol). Check heat exchanger capacity of the cooling system to avoid overheating.

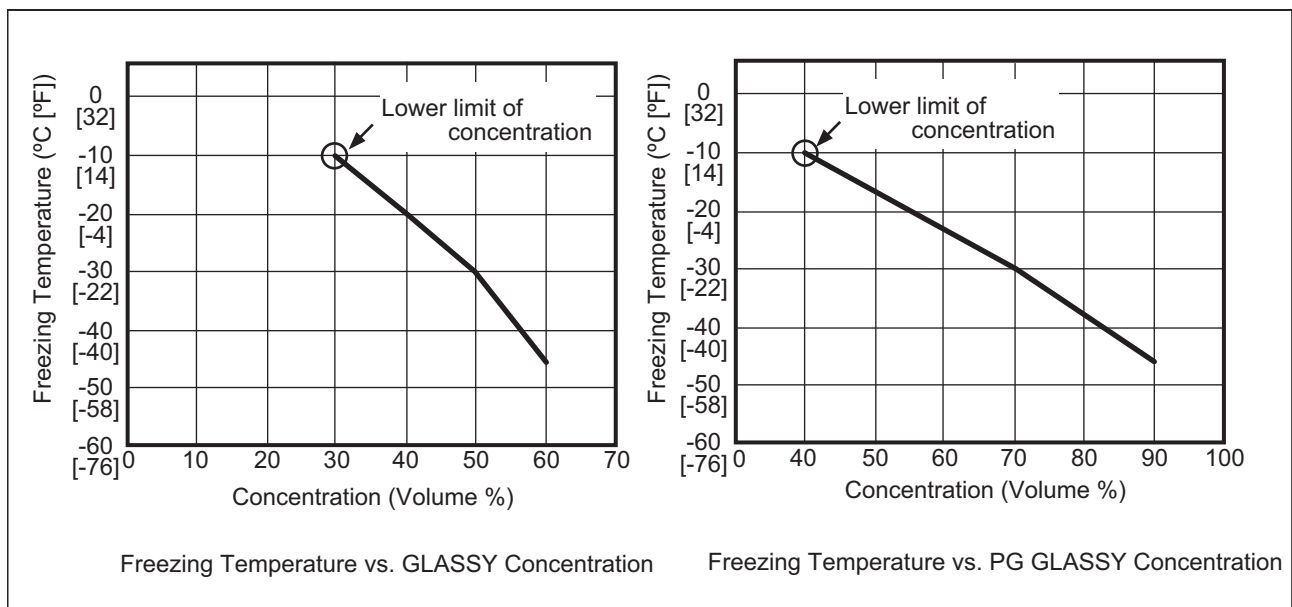


Fig. 6-2 Coolant Freezing Temperature (GLASSY and PG GLASSY)

Necessity of LLC

Today's trend is smaller and lighter engines that can offer 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.

Furthermore, many different materials such as steel, aluminum, copper, solder, and rubber are used in the cooling system, and they are also subject 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, it is necessary to use the LLC containing additives that prevent rust.

Characteristics of LLC Additives

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

Furthermore, 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 it results in corrosion of metals to be protected. Consequently, other corrosion preventing chemicals react with dissolving metals, by which corrosion is accelerated. This condition generates more severe corrosion than when plain soft water is used. This is a typical problem caused by the use of inappropriate LLC.

Examples of Abnormalities Caused by LLC (Amine Type)

Pitting of Iron Parts

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

Dissolved copper (copper corrosion) in the cooling system deposits on iron parts, and the copper deposits will 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 example, rapid wear of water pump mechanical seal due to gelification of silicate salt has been observed.

Pitting and Clogging of Heat Exchanger

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

Chapter 7 MAINTENANCE SCHEDULE

How to Use the Periodic Maintenance Chart

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

Basically, obey the standard service intervals specified in the "Periodic Maintenance Chart". However, if you notice any abnormalities such as abnormal noise, black exhaust smoke, white exhaust smoke, extremely high temperature of exhaust gas, abnormal vibration, and fuel, oil or exhaust gas leakage, be sure to conduct the inspection and maintenance work regardless of recommended service intervals in the "Periodic Maintenance Chart".

Note: Appropriate service intervals vary with usage and operating conditions as well as conditions of fuel, oil, and coolant. Check the operating record of the engine to determine the most appropriate service intervals.

(Feel free to consult a MHIET dealer regarding service intervals.)

Be sure to inspect the items which are included in the applicable interval and shorter intervals. For example, in the 2000 hour maintenance, also inspect those items listed in every 1000, 250 and 50 hours.

PERIODIC MAINTENANCE CHART

Table 7-1 PERIODIC MAINTENANCE CHART

Service Intervals	Service Items	Page
First 100 hours of operation (Only once)	Engine Oil, Oil Filter, and Bypass Oil Filter - Replace	8-9
	Fuel Filter - Replace	8-7
	Valve Clearance - Inspect and Adjust	*
	Engine Exterior - Inspect	8-1
Every 100 hours	Oil-Water Separator - Drain Water	8-5
Every 250 hours	Engine Oil, Oil Filter, and Bypass Oil Filter - Replace	8-9
	Belt and Belt Tension - Inspect and Adjust	8-2
	Pre-Cleaner - Clean, Inspect, and Replace	8-19
Every 500 hours	Also check the items included in every 100 and 250 hours.	-
	Gauze Filter - Clean	8-6
Every 1000 hours	Also check the items included in every 100, 250 and 500 hours.	-
	Fuel Filter - Replace	8-7
	Oil-Water Separator Element - Replace	8-5
	Seawater Pump Impeller - Inspect	8-17
	Freshwater Pump - Lubricate	8-16
	Turbocharger Rotor - Inspect for Movement and Looseness	*
	Valve Clearance - Inspect and Adjust	*
	Fuel Injection Nozzle - Inspect and Adjust	*
Every 2000 hours or every year	Check the items included in every 100, 250, 500, and 1000 hours.	-
	High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace	8-8
	Low Pressure Fuel Pipe, Oil Pipe, and Clip - Inspect and Replace	8-8
	Fuel Injection Nozzle Tips - Replace	*
	Seawater Pump Impeller - Replace	*
	Bolts and Nuts on Exhaust and Air Inlet Pipes - Retighten	*
	Harnesses and Terminals - Inspect for Damage and Looseness	*

Table 7-1 PERIODIC MAINTENANCE CHART

Service Intervals	Service Items		Page
Every 4000 hours	Check the items included in every 100, 200, 500, 100, 250, 1000 and 2000 hours		-
	Engine Overhaul	Cylinder Head - Disassemble and Inspect, Valve System - Inspect, and Cylinder Liner - Inspect Inner Surface	*
	Belt - Replace		*
	Fuel Injection Timing - Inspect and Adjust		*
	Heat Exchanger - Clean		*
	Thermostat Operation - Check		*
	Starter - Inspect		*
	Alternator - Inspect		*
	Protection System Operation - Inspect		*
	Coolant (Fresh Water) - Change (Every 2 Years)		8-13
Every 8000 hours or 3 years, whichever comes first (8000 hours recommended)	Check the items included in every 100, 250, 500, 1000, 2000, and 4000 hours.		-
	Engine Overhaul	Piston - Check Piston Cooling Nozzle - Inspect Crankshaft - Inspect Main Bearing - Replace Thrust Plate - Replace Connecting Rod Bearing - Replace Camshaft Bushing - Inspect Cylinder Liner - Replace Piston Ring - Replace Inlet and Exhaust Valves - Replace Inlet and Exhaust Valve Seat Rings - Replace Valve Rotator - Replace	*
	Fuel Flexible Hose - Replace		*
	Fuel Injection Pump - Inspect and Test (Replace parts as needed)		*
	Governor - Inspect and Test (Replace parts as needed)		*
	Clamp Seat for High-Pressure Fuel Injection Pipe - Replace		*
	Oil Cooler - Clean		*
	Freshwater Pump Unit Seal and Ball Bearing - Replace		*
	Seawater Pump Unit Seal and Ball Bearing - Replace		*
	Thermostat - Replace		*
	Coolant Hose - Replace		*
	Freshwater Tank Cap - Replace		*
	Turbocharger - Major Overhaul		*
	Electrical Components - Inspect		*
	Relays - Replace		*

Table 7-1 PERIODIC MAINTENANCE CHART

Service Intervals	Service Items	Page
Every 16000 hours or 3 years, whichever comes first (12000 hours recommended)	Check the items included in every 100, 250, 500, 1000, 2000, 4000, and 8000 hours.	-
	Replace the following parts with new ones: Piston, connecting rod bushing, piston pin, rocker bushing, gear bushing, tap-pet, valve guide, valve spring, connection rod bolt, main bearing cap bolt, high pressure fuel injection pipe, low pressure fuel pipe, and oil pipe	*
	Cylinder Head Bolt - Inspect	*

Note: (a) Items marked with * in the maintenance schedule require special tools and specialized maintenance service. Please contact your MHIET dealer for maintenance of those items.

(b) Be sure to conduct periodic inspection at specified intervals, either service hours or years, whichever comes first.

Engine

Engine Exterior - Inspect

CAUTION

Check external parts of the engine, particularly hot parts (such as exhaust manifold), or the battery for accumulation of flammable materials. Also, check leaks of fuel and engine oil. Remove dust from the top surface of the battery. If hot parts have a problem, it may cause a fire. If any abnormality is found, be sure to repair or contact your MHIET dealer.

Inspect the engine exterior as instructed below:

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Make sure fluids, such as fuel, oil, and coolant, are not leaking from the engine. If a leak is found, repair the leak, or contact your MHIET dealer.
3. Walk around and check bolts and nuts for looseness.
4. Check electric wiring for disconnection, looseness, cuts, or rubbing.
5. Make sure the following valves, plugs, or cocks are properly positioned as indicated below:
 - Fuel feed valve: open
 - Coolant drain cock (valve): closed
 - Engine oil drain plug: closed

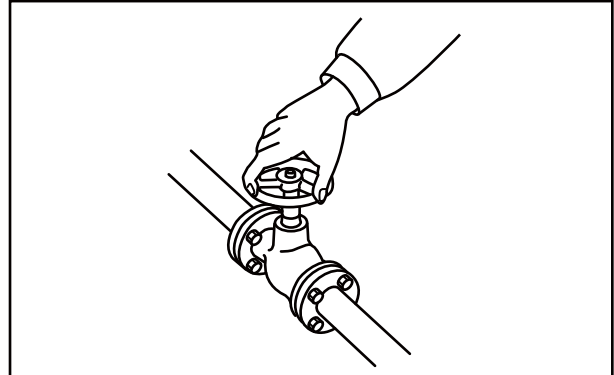


Fig. 8-1 Valve Open/Closed Position - Check

Belt and Belt Tension - Inspect and Adjust

CAUTION

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

Belts must be free from grease and oils. Grease and oils cause belts to slip and shorten their service life.

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

Adjust the belt tension properly by following the procedures below.

Belt - Inspect

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

Push the belt downward at the midway between pulleys. If the deflection is 4 mm [0.16 in.], the tension is correct.

Force on the belt: alternator side = $20 \pm 5 \text{ N}$ { $2.04 \pm 0.51 \text{ kgf}$ } [$4.50 \pm 1.12 \text{ lbf}$], seawater side = $39 \pm 5 \text{ N}$ { $3.98 \pm 0.51 \text{ kgf}$ } [$8.77 \pm 1.12 \text{ lbf}$]

If the belt deflection is not within the specified range, adjust the belt tension.

Belt Tension (Alternator Side) - Adjust

1. Remove the belt cover.
2. Loosen all retaining bolts of the alternator and adjusting plate.
3. Loosen the lock nut, and adjust the belt tension with the adjusting bolt.
4. Tighten the lock nut, and tighten all retaining bolts and nuts to fix the alternator and adjusting plate.
5. Install the belt cover.

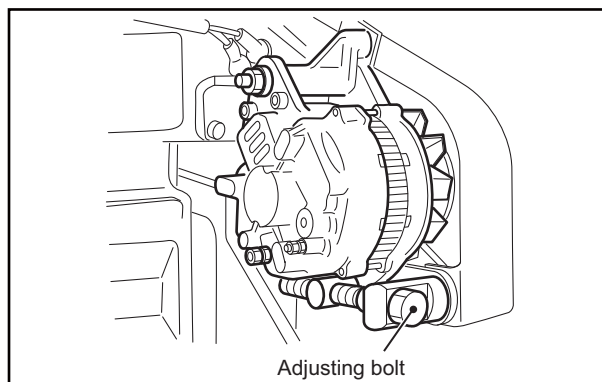


Fig. 8-2 Belt Tension (Alternator Side) - Adjust

Belt Tension (Seawater Pump Side) - Adjust

1. Loosen all the bolts and nuts that fix the sea-water pump.
2. Loosen the lock nut, and adjust the belt tension with the adjusting bolt.
3. Tighten the lock nut, and tighten all the bolts and nuts to fix the sea-water pump.

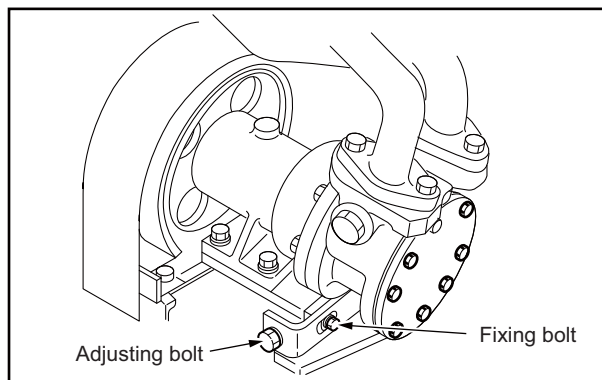


Fig. 8-3 Belt Tension (Seawater Pump Side) - Adjust

Cold Weather Operations

In cold weather, engine oil gets thicker and the coolant can freeze. As a result, the engine fails to start, or the cylinder heads and heat exchanger may be damaged. To prevent such problems, follow the instructions given below.

Fuel



WARNING

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

Replace oil with a low viscosity oil.

Use fuel that has a pour point suitable for the ambient temperature.

Note: For fuel, refer to ["FUEL" \(4-1\)](#).

Engine oil

Use engine oil suitable for the ambient temperature of the engine.

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

Coolant



CAUTION

Never open the coolant expansion tank cap during the operation or immediately after stopping. Stop the engine and, after coolant has sufficiently cooled down, open the cap.

Place waste cloth over the coolant expansion tank cap, and loosen the cap about a quarter-turn to release the internal pressure.

The coolant is hot while the engine is running and immediately after stopping. If the cap is opened while the coolant is hot, you may get burned by bursts of steam. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

When fastening the coolant expansion tank cap, be sure to tighten securely.

In cold weather the coolant can be frozen, and it may cause damage to the crankcase. Therefore, be sure to use an all-season long life coolant that has anti-freeze and anti-rust protection for the cooling system.

Note: For coolant and LLC, refer to ["COOLANT" \(6-1\)](#).

Maintenance After Cold Weather is Over

When the cold weather ends, select the fuel, engine oil and coolant suitable for the outside temperature referring to the specifications in this manual.

Seawater - Drain

When the ambient temperature drops below 0°C [32°F], the seawater used to cool the engine can freeze and cause serious problems such as seawater pump damage. Drain seawater after engine operation. For seawater draining, refer to ["Seawater - Drain" \(8-16\)](#).

Fuel system

Fuel System - Inspect

WARNING

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

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

Fuel Tank - Clean

CAUTION

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

1. Close the fuel feed valve to cut off the fuel supply to the engine.
2. Place a pan under the drain cock.
3. Drain all fuel in the tank from drain cock located at the bottom of fuel tank.
4. Clean the inside of fuel tank.
5. Add fuel to the fuel tank.
6. Open the fuel feed valve of the engine.

Note: If the specification of fuel tank differs from the contents of this operation manual, follow the fuel tank manufacturer's operation manual.

Fuel Tank - Drain Water

If fuel is contaminated with foreign substances such as dust, dirt, or water, it can cause not only decrease of output but also malfunctions of the fuel system. To avoid such problems, drain water from the fuel tank as instructed below:

1. Place a pan (capacity of 2 L [0.5 US gal.] or more) under the drain cock of fuel tank.
2. Open the drain cock of fuel tank and drain fuel at least 1 to 2 liters.
3. After making sure water and foreign material particles has been discharged together with fuel, close the drain cock.

Note: If the specification of fuel tank differs from the contents of this operation manual, follow the fuel tank manufacturer's operation manual.

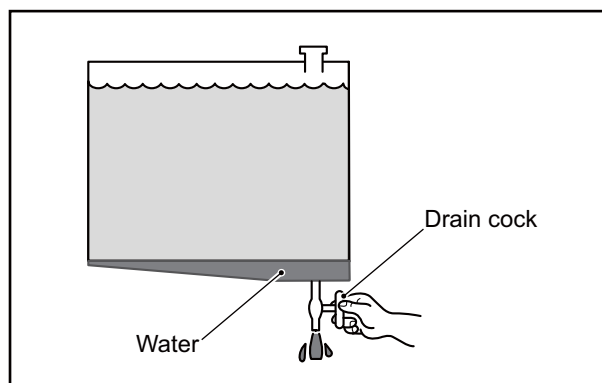


Fig. 8-4 Fuel Tank - Drain Water

Oil-Water Separator - Drain Water

1. Place a pan under the drain plug of oil-water separator.
2. Loosen the air vent plug.
3. Remove the drain plug and drain water from the oil-water separator.
4. Securely close the drain plug after draining.
5. Bleed air from oil-water separator and tighten the air vent plug.

Note: For bleeding the oil-water separator, refer to ["Oil-Water Separator - Bleed Air" \(3-2\)](#).

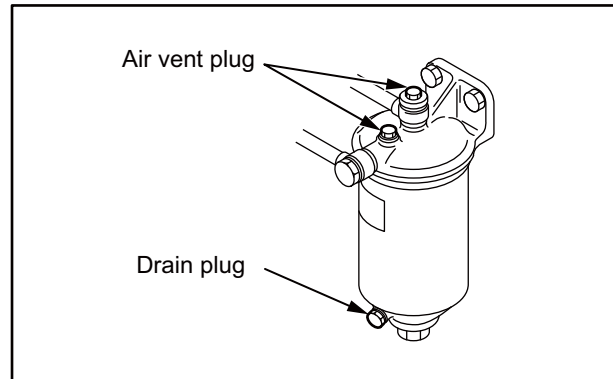


Fig. 8-5 Oil-Water Separator - Drain Water

Oil-Water Separator Element - Replace

1. Place a pan under the oil-water separator.
2. Loosen the air vent plug.
3. Loosen the drain plug and drain fuel from the filter.
4. Remove the center bolt.
5. Clean the case.
6. Replace the element and O-ring with new ones.
7. Make sure that the O-ring is fitted in the case, and then, install the case.
8. Be sure to bleed air from the fuel system after the element is replaced.

Note: (a) For bleeding air from fuel system, refer to ["Priming the Fuel System" \(3-1\)](#).

- (b) Check for fuel leaks from the case mounting portion when you operate the engine next time. If a leak is found, retighten the center bolt.

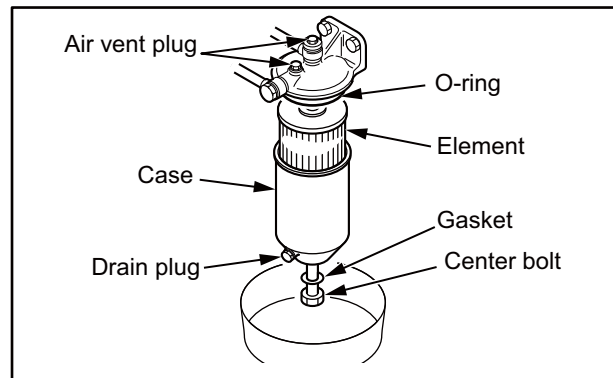


Fig. 8-6 Oil-Water Separator Element - Replace

Gauze Filter - Clean

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

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

Note: For bleeding the fuel filter, refer to ["Fuel Filter - Bleed Air" \(3-2\)](#).

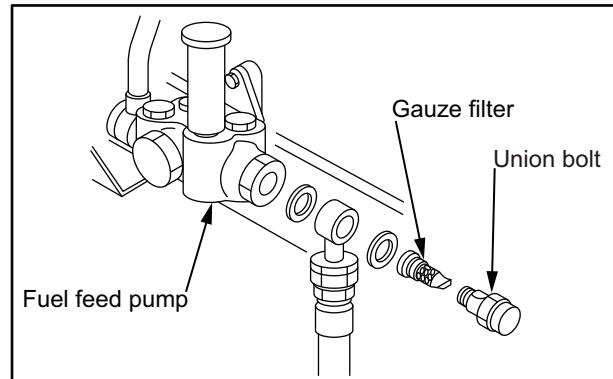


Fig. 8-7 Gauze Filter - Clean

Fuel Filter - Replace

1. Clean the area around the fuel filters.
2. Place a tray under the fuel filters.
3. Using a filter wrench, remove the fuel filters.
4. Wipe off fuel on the fuel filter cartridge mounting surface of the filter bracket with a waste cloth.
5. Prepare new fuel filter, and make sure that gasket is properly seated in the groove.



WARNING

If the filter case is dented, do not use the filter. Filter in dented case may be damaged during operation, leading to fuel leaks, which eventually may result in a fire.

6. Apply clean fuel to the gasket of the new fuel filter.
7. Install the fuel filter to the filter bracket. When the gasket comes in contact with the mounting surface of the filter bracket, further rotate 3/4 or a full turn.

CAUTION

Hand tighten the fuel filter. Do not tighten with a filter wrench.

Be careful not to dent or scratch the fuel filter surfaces.

8. After the new fuel filter has been installed, bleed the fuel filter.

Note: For bleeding the fuel filter, refer to ["Fuel Filter - Bleed Air" \(3-2\)](#).

9. Start the engine and run at an idle speed for several minutes.
10. Make sure that there is no fuel leak from the fuel filter mounting face. If the leak is found, loosen the fuel filter and check the gasket for damage. If there is no damage, retighten the fuel filter.

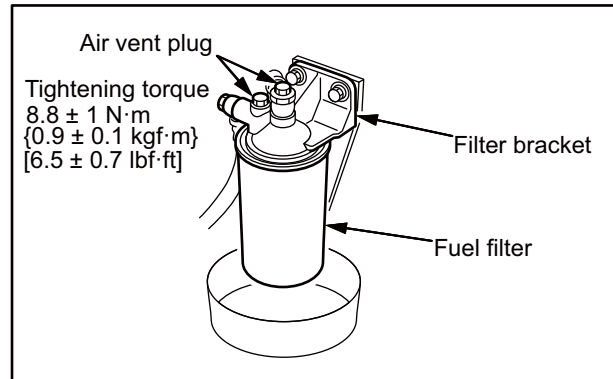


Fig. 8-8 Fuel Filter - Replace

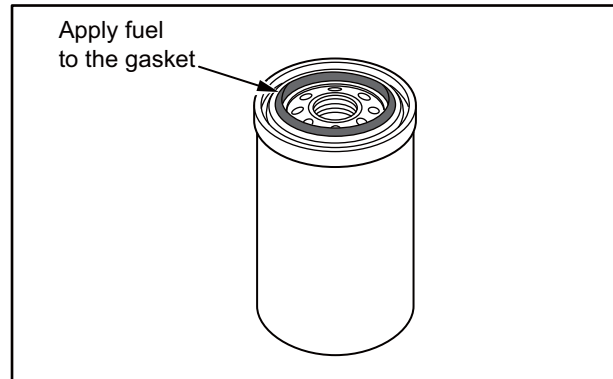


Fig. 8-9 Fuel filter

Fuel Pipe - Inspect

WARNING

Do not use any clamps such as harness for the high- and low-pressure pipes.

Also make sure the fuel pipes do not contact with other pipes and objects.

If contacted, a fire disaster may occur due to a pipe hole made by abrasion between pipes.

High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

Visual Inspection

Check the clamp seat for cracks and wear. Check the high pressure fuel injection pipe for wear. If defective, replace the clamp seat with a new one. Replace the high pressure fuel injection pipe with a new one if needed.

During Every Major Overhaul

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

During Every Other Major Overhaul

Replace all the high pressure fuel injection pipes with new ones.

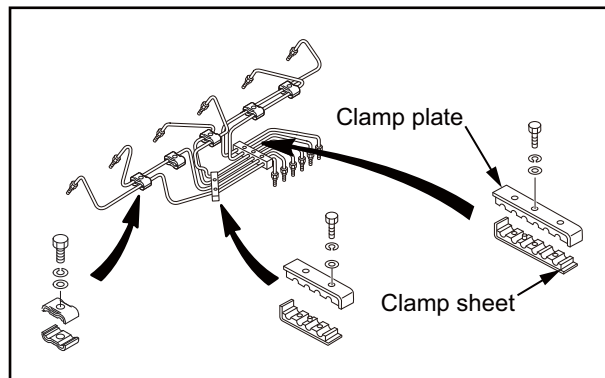


Fig. 8-10 High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

Low Pressure Fuel Pipe, Oil Pipe, and Clip - Inspect and Replace

Visual Inspection

Loosen the clamp retaining bolts and check for clip wear and metal contact between pipe and clamp. If defective, replace the pipe assembly with a new one.

During Every Other Major Overhaul

Replace the pipe assembly with a new one.

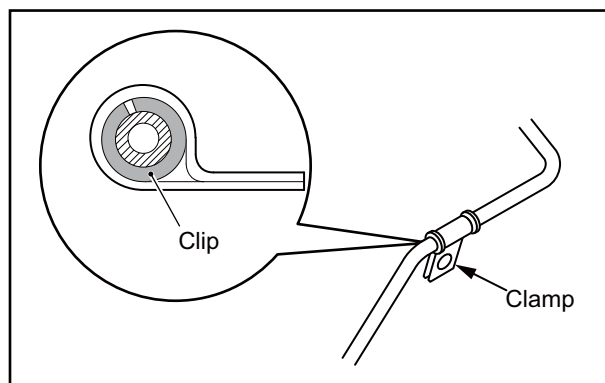


Fig. 8-11 Low Pressure Fuel Pipe, Oil Pipe, and Clip - Inspect and Replace

Lubrication System

Engine Oil, Oil Filter, and Bypass Oil Filter - Replace

CAUTION

Before draining engine oil, make sure the oil has cooled down.

When draining oil or replacing oil filters, be sure to wear gloves. Hot engine oil and parts can cause burns.

CAUTION

Do not dump drain oil down the drain. It is forbidden by the law. For the disposal of drained oil, consult with your MHJET dealer.

Engine oil, oil filter, and bypass oil filter should be changed at the same time.

Also engine oil analysis is recommended when you change the engine oil.

Do not reuse oil filter elements, as they are a paper type. When replacing filter elements, also replace gaskets with new ones.

Engine Oil - Drain

1. Connect the engine oil drain plastic hose to the drain pump.
2. Drain engine oil by operating the drain pump.

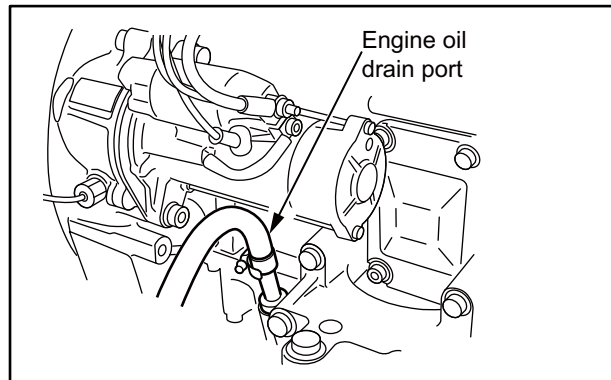


Fig. 8-12 Engine Oil - Drain

Oil Filter and Bypass Oil Filter - Replace

CAUTION

Replace the oil filter and bypass oil filter during not only regular inspection and maintenance intervals but also when the oil filter alarm light turns on.

1. Clean the area around oil filters.
2. Place oil pans under oil filters and bypass oil filter.
3. Remove the drain plug and drain the engine oil from the filter.
4. Remove the center bolt and remove the filter case and element.

Note: Cut off the oil filter elements and bypass oil filter elements that have been removed, and check elements. Consult with your MHIET dealer if metal particles are found in the elements.

5. Thoroughly wipe off oil on the oil filter mounting surface of the filter bracket with a clean cloth.
6. Prepare new filter elements, gaskets and O-rings. Be sure to use genuine parts.
7. Apply clean engine oil on gasket.
8. Install oil filters and bypass oil filter on the filter bracket. When the filter case comes into contact with the mounting surface of the filter bracket, further rotate the center bolt 1/2 to 3/4 turn.

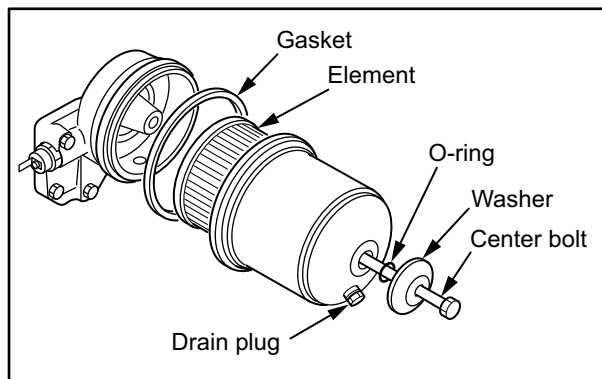


Fig. 8-13 Oil Filter - Change

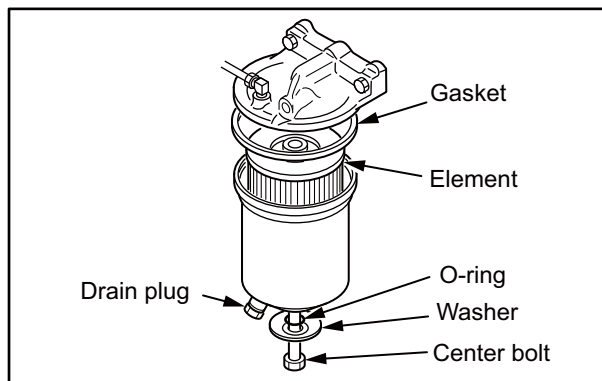


Fig. 8-14 Bypass Oil Filter - Change

Engine Oil - Refill



CAUTION

Fill the engine with the specified engine oil to the specified level. If the oil level is higher than the maximum mark on the level gauge, engine oil may blow out during operation.

Also, the rise of oil temperature could adversely affect engine components.

When adding engine oil, always use the same engine oil.

1. Stop the engine for about 30 minutes.
2. Remove the oil filler cap.
3. Add 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 in oil pan as follows:
5. Pull out the oil level gauge and wipe it clean with a cloth.
6. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
7. The oil level should be between the maximum and minimum marks on the oil level gauge.
If the oil level is low, add the specified engine oil.
8. Check the oil pan, etc., for oil leaks. Repair if there is an oil leak.
9. With the stop lever placed in pulled position, rotate the engine with the starter for 10 seconds to feed oil to the engine. Stop the rotation for 1 minute, then, repeat the rotation two or three times to circulate the engine oil to each engine parts.
Note: Also, perform the items described under the Preparation of Cooling System.
10. Check the oil level with the oil level gauge again, and add oil to the specified level.

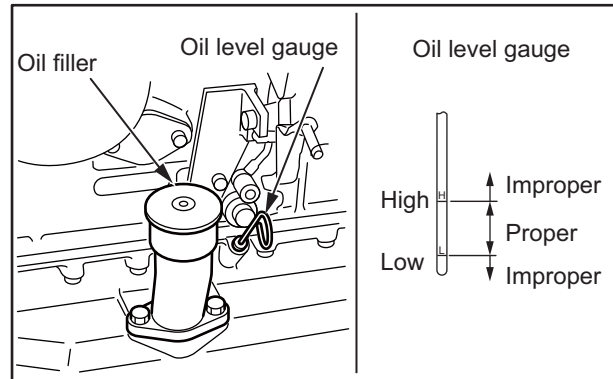


Fig. 8-15 Oil Filler and Oil Level Gauge

Ingress of Fuel and Water In Engine Oil - Inspect

CAUTION

If the engine operation is continued with fuel or water mixed in the engine oil, the engine oil viscosity will decrease and this can cause serious problems such as bearing seizure.

Extract 1 to 2 liters [0.26 to 0.53 US gal.] of engine oil, and check for abnormal odor and discoloration to determine if the oil is contaminated with fuel and water.

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

If water is mixed, oil may turn milky white.

If fuel or water is mixed with the engine oil, find the cause and repair. If the repair seems to be difficult, consult with your MHIET dealer.

If the coolant enters the engine oil during operation, moisture vapor is discharged from the breather.

In such case, locate the fuel or water leak, and repair properly.

Note: If oil leaks from oil cooler, oil will float in water in the freshwater tank. Also, LLC that is not miscible with oil will accumulate at the bottom of oil pan.

Cooling System

Coolant (Fresh Water) - Change

CAUTION

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

Coolant Expansion Tank Cap - Open/Close

CAUTION

Never open the coolant expansion tank cap during the operation or immediately after stopping. Stop the engine and, after coolant has sufficiently cooled down, open the cap.

To open the coolant expansion tank cap, place a waste cloth over the cap, and loosen it about a quarter-turn to release the internal pressure.

The coolant is hot while the engine is running and immediately after stopping. If the cap is opened while the coolant is hot, you may get burned by bursts of steam. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

When tightening the coolant expansion tank cap, be sure to tighten securely.

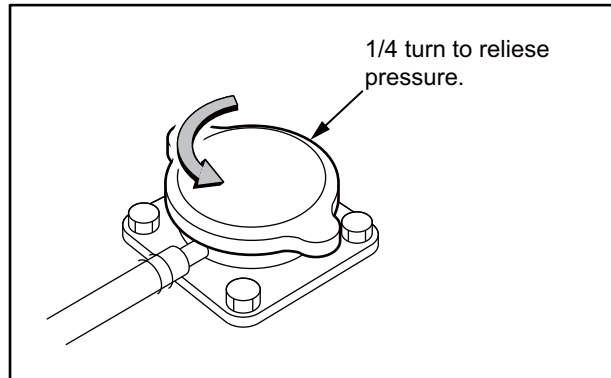


Fig. 8-16 Coolant Expansion Tank Cap

Coolant - Drain

1. After making sure the engine has cooled, open the coolant expansion tank cap.
2. Place a pan under the engine coolant drain cock to catch coolant and open the drain cock.

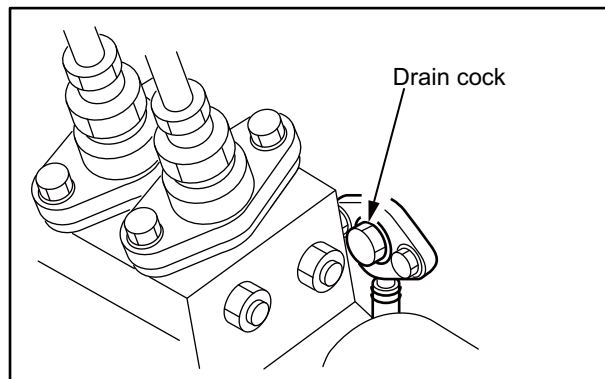


Fig. 8-17 Coolant Drain Cock (Engine Body)

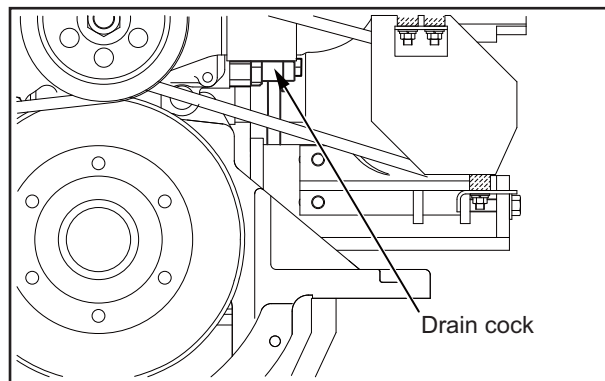


Fig. 8-18 Coolant Drain Cock (Engine Body)

Cooling System - Clean

CAUTION

Wash the cooling system before operating the engine for the first time, or before starting the engine after it has been in storage under coolant drained condition.

1. Close coolant drain cocks and plugs.
2. Pour a cleaning solution (a solution that is non-corrosive to rubber and metals) into the cooling system, and operate the engine at 800 to 900 min⁻¹ for about 15 minutes, then drain the cleaning solution.
3. Close coolant drain cocks and plugs.
4. Add fresh water and operate the engine at 800 to 900 min⁻¹ for about 10 minutes.

Repeat the above rinsing steps until the draining water becomes clear and clean.

Coolant - Refill

CAUTION

To add coolant, use the same LLC concentration coolant that is currently in the cooling system.

1. Securely close the engine coolant drain cock.
2. Open the coolant filler port and add a mixture of water and coolant (LLC) having the specified concentration.

Note: Determine the quantity 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. Check the heat exchanger, etc. for coolant leaks. Repair if a leak is found.
4. When the coolant reaches the specified level, securely close the coolant fill port.
5. Place the manual stop lever in the pulled position, and crank the engine for approximately 10 seconds using the starter. Stop for approximately 1 minute, then, repeat the cranking two or three times to bleed the cooling system.

Note: Also perform the items described under the Preparation of Lubrication System.

6. Check the coolant level.
7. Also fill the reserve tank with coolant up to the "FULL" level line.

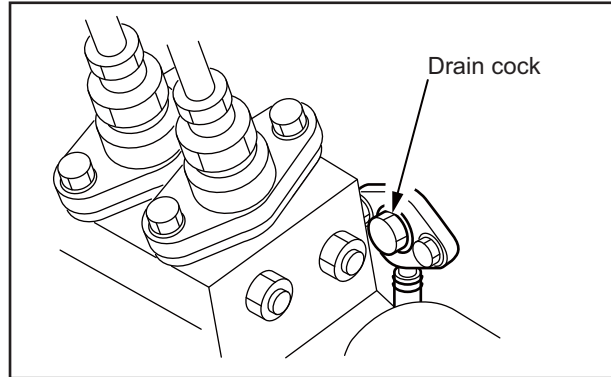


Fig. 8-19 Coolant Drain Cock (Engine Body)

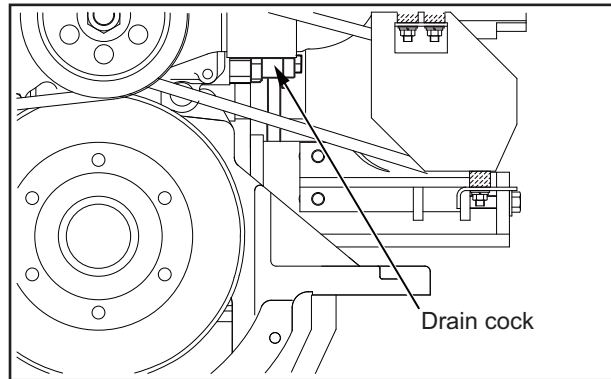


Fig. 8-20 Coolant Drain Cock (Engine Body)

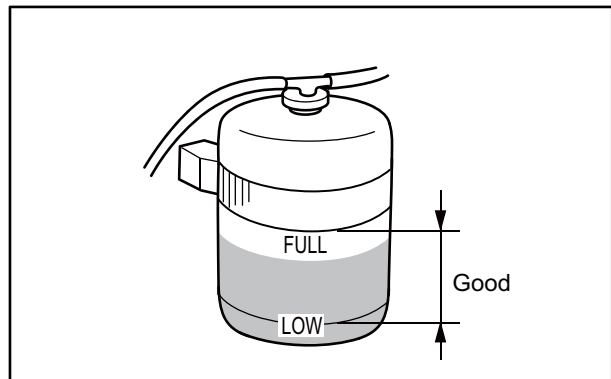


Fig. 8-21 Reserve Tank Coolant Level

Freshwater Pump - Lubricate

WARNING

Thoroughly wipe off excess grease. It can cause a fire.

1. Remove the cap from the grease cup.
2. Using a grease gun, fill the cup with grease fully.
3. Install the cap on the grease cup.

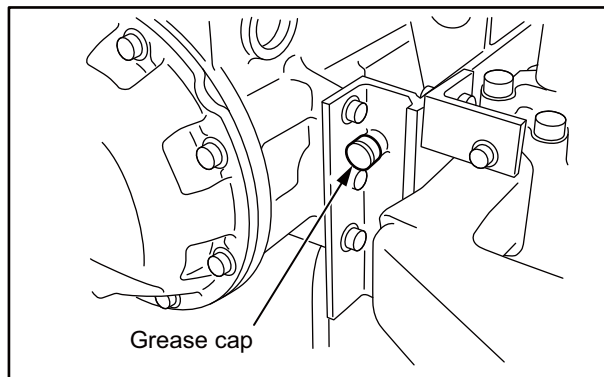


Fig. 8-22 Freshwater Pump - Lubricate

Seawater - Drain

When the ambient temperature drops below 0°C [32°F], the seawater used to cool the engine can freeze and cause serious problems such as seawater pump damage. To prevent such problems, drain the seawater after engine operation by following the procedures below:

1. Make sure that the kingston valve is closed.
2. Open seawater drain cocks and plugs, and drain seawater.
3. Remove the seawater pump cover, and drain seawater from the seawater pump.

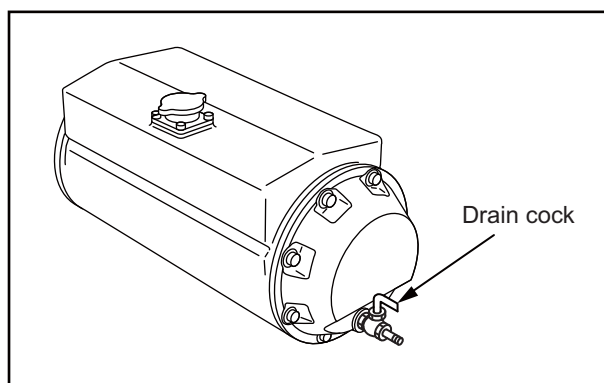


Fig. 8-23 Seawater Drain Cock (Heat Exchanger)

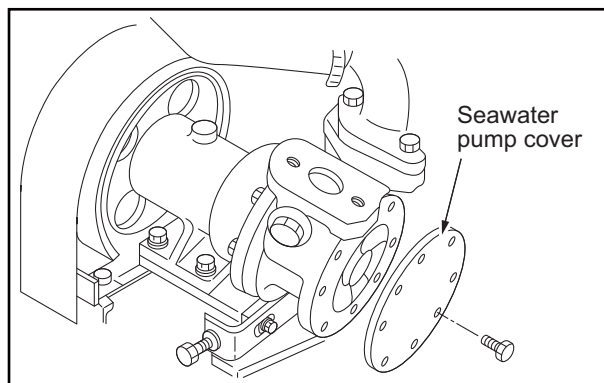


Fig. 8-24 Seawater Pump Cover

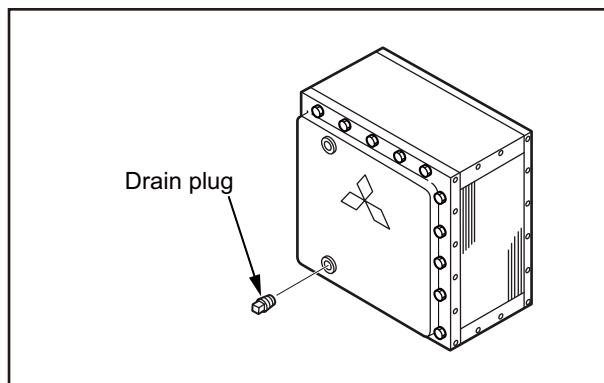


Fig. 8-25 Seawater Drain Plug (Intercooler)

Seawater Pump Impeller - Inspect

CAUTION

When installing the impeller, pay attention to the orientation of impeller blades. The impeller may be broken if it is incorrectly installed.

1. Remove the seawater pump cover.
2. Remove the impeller using a puller.
3. Check the impeller for damage, cracks, and if any defects are found, replace the impeller with a new one.
Check the inside the case, and if damaged, replace it with a new one.
Check the cam, and if damaged or worn, replace it with a new one.
4. While paying attention to the orientation of impeller, install the impeller to the seawater pump case.
5. Install the cover with O-ring to the pump case.

Note: Because of simple structure, the puller is not included in the special tools.

Please use commercially available puller or make it by yourself.

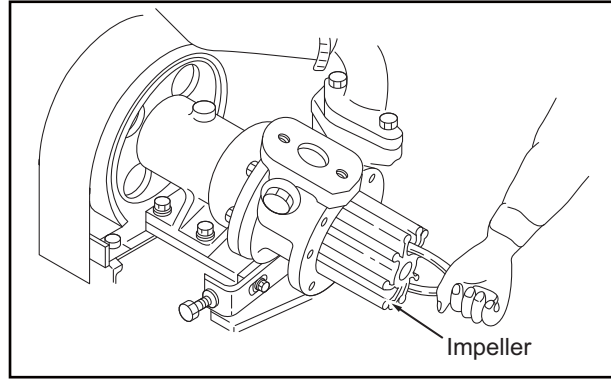


Fig. 8-26 Seawater Pump Impeller - Inspect

Inlet and Exhaust Systems

Turbocharger - Inspect

CAUTION

Inspect the turbocharger when the engine is cold. Before inspection, make sure that the compressor wheel is not rotating.

CAUTION

The turbocharger inspection should be also conducted if the color of the exhaust gas is abnormal. Do not allow foreign objects to enter the turbocharger.

Disconnect the pipe on the inlet side. Hold the compressor wheel nut by hand and move in the axis direction and from right to left and up and down to check for looseness or contact with surrounding parts. Turn the wheel to check if it rotates smoothly. Replace if defective.

Note: When the inspection requires the removal of turbocharger, contact your MHIET dealer.

Also check the compressor wheel fins for discoloration and breaks, and check for rubbing between compressor wheel and housing.

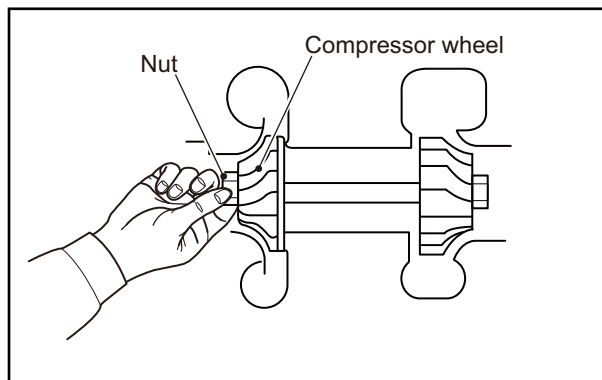


Fig. 8-27 Turbocharger - Inspect

Pre-Cleaner - Clean, Inspect, and Replace

CAUTION

Never conduct the maintenance of pre-cleaners during engine operation. If foreign particles enter the engine, it accelerates wear of parts and shortens the service life of the engine.

The pre-cleaner that is attached to the silencer of the turbocharger catches foreign particles included in intake air and keep the engine in clean condition for optimum performance. Always keep it clean as instructed below.

1. Remove the pre-cleaner from the silencer, and hand-wash the pre-cleaner with a mild detergent.
2. Rinse the pre-cleaner with fresh water.
3. After drying thoroughly, inspect the pre-cleaner for damage such as breaks. If breaks or etc. are found, replace the pre-cleaner with a new one.
4. After the pre-cleaner is cleaned, inspected or replaced, install the pre-cleaner on the silencer.

Note: If the pre-cleaner is torn, gets thinner or stretched due to cleaning, replace it with a new one.

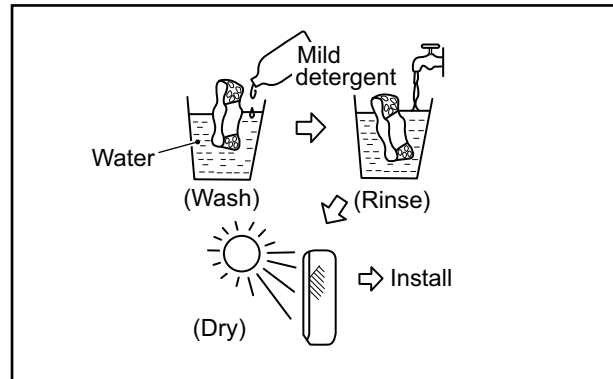


Fig. 8-28 Pre-Cleaner - Wash

Electrical System

Battery - Check

⚠ CAUTION

Never use flames or allow sparks near the battery. The battery releases flammable hydrogen gas and oxygen gas. Any flames or sparks in the vicinity of battery could cause an explosion.

Do not use the battery when the battery fluid level is below the "LOWER LEVEL" mark. It may explode.

Do not short the battery terminals with a tool or other metal object.

When removing battery, always remove the plug from the negative (-) terminal first. When connecting battery, always connect the plug to the positive (+) terminal first.

Before charging the battery, remove all battery cables, and then charge the battery in a well ventilated area.

Make sure the cable clamps are securely attached to the battery terminals. A loose cable clamp can cause sparks, and it could result in an explosion.

Before servicing electrical components or conducting electric welding, set the battery switch to the [Open/OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.

Battery fluid contains dilute sulfuric acid. Careless handling of the battery can lead to a sight loss and/or skin burns. Also, do not swallow the battery fluid.

Wear protective goggles and rubber gloves when working with the battery (e.g. when adding water or charging the battery).

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

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

If you accidentally swallow battery fluid, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.

If the battery does not fully recover after charging for 24 hours or more, do not use the battery.

Note: If the specification of battery differs from those of this operation manual, follow the battery manufacturer's operation manual.

Battery Fluid Level - Check

The battery fluid evaporates during use, and the fluid level gradually decreases. The proper fluid level is between the LOWER LEVEL (Lower limit) and UPPER LEVEL (Upper limit) marks.

For the battery without level marks, the proper fluid level is about 10 to 15 mm [0.39 to 0.59 in.] above the top face of the polar plates.

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

Note: When adding distilled water, add little by little.

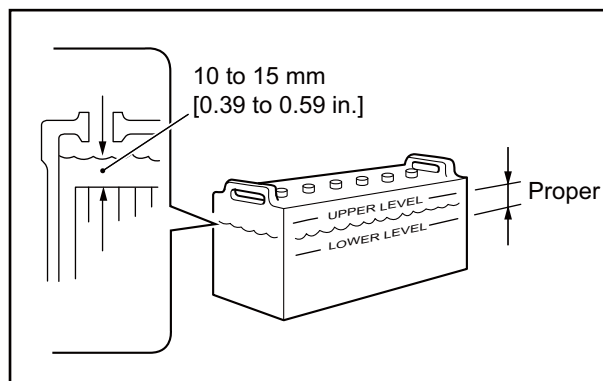


Fig. 8-29 Battery Fluid Level - Check

Specific Gravity of Battery Electrolyte - Check

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

Table 8-1 Specific Gravity of Battery Electrolyte

Specific gravity at 20°C [68°F]	Condition	Remedy
From 1.26 to 1.28	Good	-
From 1.22 to 1.26	Almost good	Charge
1.22 or less	Not good	Charge

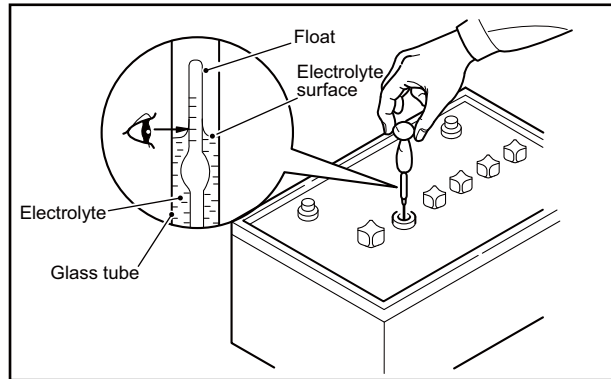


Fig. 8-30 Specific Gravity of Battery Electrolyte - Check

Starter - Inspect

Visually inspect the starter and ring gear for damage.

Note: If the starter is defective, contact your MHIET dealer.

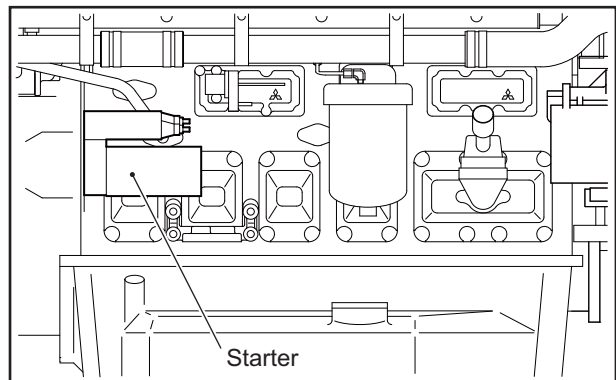


Fig. 8-31 Starter - Inspect

Alternator - Inspect

Visually inspect the alternator for damage.

Remove the belt and turn the pulley by hand to check if it rotates smoothly. Check the pulley for wear.

Also, visually inspect the inside of alternator for dust and salt accumulation because the alternator is an air cooling type.

Note: If the alternator is defective, contact your MHIET dealer.

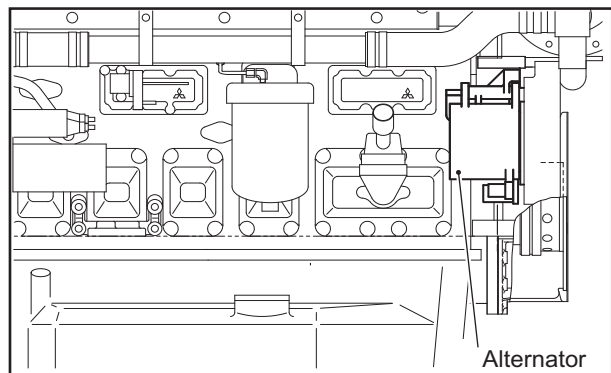


Fig. 8-32 Alternator - Inspect

Chapter 9 LONG-TERM STORAGE

CAUTION

If the engine is not in use for more than 3 months, the internal engine parts can rust, and it may cause damage to the engine.

For long-term engine storage, be sure to follow the instructions below.

Storing Engine in an Inoperable Condition for 3 Months up to 1 Year

Preparation for Storage

1. Drain engine oil, and fill the engine with new oil.
2. Prepare a fuel mixture containing 50% rust-preventive fuel (NP-9), and fill the fuel tank with it.
3. Run the engine at no load idle speed for 5 to 10 minutes.
4. Immediately before stopping the engine, gradually spray volatile corrosion inhibitor (VCI) (approximately 1g) through the inlet port to prevent rust in the air intake system.
5. Stop the engine, and drain the mixed fuel from the fuel tank.
6. Fill the fuel tank with fuel to protect the fuel tank from rusting.
Note that FRP tanks do not require any kind of corrosion protection.
7. Apply a sufficient quantity of anti-rust oil (NP-3-2) to the exposed machined surfaces.
8. Cover the air inlet, exhaust outlet, breather, etc., with an adhesive cloth tape or plastic film.
9. Loosen the belt.
10. Apply a thin coat of grease to the starter and alternator terminals and cover the openings. Also place desiccants inside the openings and cover the openings with polyethylene sheet or processed polyethylene paper.
11. Disconnect the cables from the battery terminals, and charge the battery. Clean the terminals, apply a thin coat of grease to the terminals, and store the battery in a cool and dry room.
12. Cover the entire engine.

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

(b) It is not necessary to drain coolant since it contains LLC. (LLC must be the specified concentration. For the LLC concentration, refer to ["LLC Concentration \(GLASSY and PG GLASSY\)" \(6-6\)](#).)

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

Recommended Rust-Preventive Oil and Corrosion Inhibitor

Table 9-1 Recommended Rust-Preventive Oil and Corrosion Inhibitor

JIS		Recommended product	Intended use
K 2246	NP-3-2	Nippon Oil Corporation Anti Rust P-1600	Exposed machined surfaces
	NP-9	Nippon Oil Corporation Anti Rust P-2400	Prevention of rust in fuel system
	NP-10-2	Nippon Oil Corporation Anti Rust P-230	Prevention of rust in lubricating system
Z 1519	-	Ryokou Chemical Co., Ltd. VCI Diana ND volatile corrosion inhibitor	Prevention of rust in air intake system

Maintenance During Storage

Charge the battery once a month. Check battery fluid level, and then charge the battery.

When Using Engine After Storage

1. Remove the cover that has been placed over the entire engine.
2. Connect a fully charged battery.
3. Remove the cover from the starter and alternator.
4. Adjust the belt tension.

Note: Refer to ["Belt and Belt Tension - Inspect and Adjust" \(8-2\)](#) for the belt tension adjustment.

5. Remove sealing tapes that have been covered the openings of the engine.
6. Connect pipes and hoses.
7. Fill the fuel tank with fuel, and bleed air from the fuel system.

Note: For bleeding fuel system, refer to ["Priming the Fuel System" \(3-1\)](#).

8. Check the engine oil and coolant level.
9. Inspect every part of the engine.
10. Remove the rocker covers, and lubricate the valve mechanisms.
11. With the manual stop lever placed in the pulled position, crank the engine for approximately 10 seconds using the starter. Stop the operation for approximately 1 minute, then, repeat the operation two or three times.
12. After starting, make sure the engine oil pressure rises.
13. Conduct a warm-up operation for a sufficient duration to fully lubricate all the components.

Note: For engine starting procedure, refer to ["Engine Start Up" \(3-14\)](#).

14. Apply load and increase the engine speed to the rated speed.

Storing Engine in an Operable Condition

If the engine is not be used for an extended period of time, internal engine parts can rust and lose oil film. As a result, the engine may seize when it is started. To prevent such risks, operate the engine periodically.

Operation for Maintenance Purpose

Operate the engine at least once a month as instructed below:

1. With the manual stop lever placed in the pulled position, crank the engine for approximately 10 seconds using the starter. Stop the operation for approximately 1 minute, then, repeat the operation two or three times.
2. After starting, make sure the engine oil pressure rises.
3. Operate the engine about 5 to 10 minutes under no load.

Note: For engine starting procedure, refer to ["Engine Start Up" \(3-14\)](#).

Lifting Engine

WARNING

To lift the engine, use wire ropes, shackles, and slings which is strong enough to support the weight of the engine.

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

Consider the engine's center of gravity, and maintain the balance during lifting.

The hangers attached to the engine are designed for lifting the engine only. When lifting the engine equipped with a marine gear, etc., take care so that the load is not imposed only on the hangers of the engine.

Keep wire rope sling angles within 60 degrees. If the angle exceeds this limit, excessive load will be imposed on the hangers and this could damage the hangers and result in a serious accident.

Attach wire ropes to the hangers after removing the pipe cover near the hanger. To prevent damage to the engine and wire ropes, use a cloth or other soft padding so that the wire ropes will not come in contact with the engine.

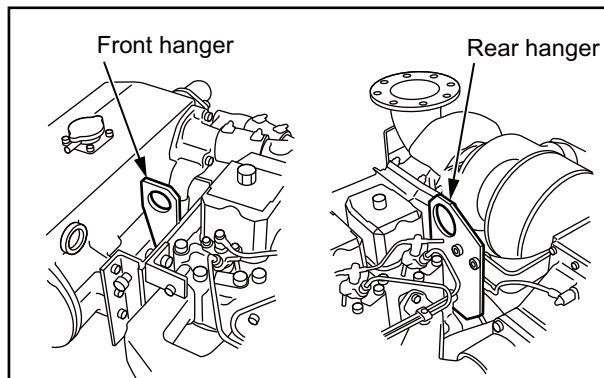


Fig. 10-1 Lifting Hangers

General Precautions

Contact Your MHIET Dealer for Repair Service

Except for relatively simple maintenance work such as changes and refilling of fuel, engine oil, and coolant, the repair work of the engine that has malfunctioned may require special equipment or involves dangerous work. If the engine failed, contact your MHIET dealer.

Considerations Before Proceeding with Corrective Action

Before taking any actions, 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 manner.

When disassembling any part of the engine, pay close attention to the disassembly sequence so that you can effectively assemble as they were.

Cautions Against Contamination

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

When disassembling any part of the engine, take measures to prevent dust and foreign materials from entering.

Cautions for Parts Handling

Handle parts carefully.

When replacing parts with new ones, order only genuine parts by referring to the parts catalogue.

Safety Working Practices

Be sure to use a tool suitable for nuts. Using a wrong size tool can cause damage to nuts and may result in injury.

Use appropriate tools and perform work with the utmost care.

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

Troubleshooting

Tends To Overheat

CAUTION

Remove the coolant expansion tank cap only after the engine has cooled down sufficiently. To open the coolant expansion tank cap, open slowly to release pressure. Do not open the coolant expansion tank cap while the engine is hot to avoid burns due to hot steam and water.

Do not stop engine immediately after hard or extended operation. The engine may be seized due to the coolant temperature rise. Be sure to run the engine at a low idle speed to cool the engine.

Add coolant gradually after the engine has completely cooled. Do not add coolant while the engine is hot. Cylinder head, etc. could be damaged.

The coolant temperature rise warning light comes on (the warning buzzer also goes off) if the engine overheats. If you keep operating the engine uninterrupted with load, it will lead to problems such as knocking, lubrication failure, or seizure. Follow the instructions below when the engine overheats.

1. Stop sailing (or work) at once, and run the engine at a low idle to cool down the engine.
2. After stopping the engine, and only after the engine has completely cooled, add coolant up to the coolant expansion tank's neck.
3. Check the followings:
 - ♦Cooling freshwater capacity
 - ♦Leaks from cooling system
 - ♦Belt tension and damage
 - ♦Seawater pump impeller damage

If you have not found any problems after checking above, consult with your MHIET dealer.

When Engine Oil Pressure is Abnormal

If the engine continues to be operated under abnormal decrease in engine oil pressure, it could lead to bearing seizure, etc. If the lubrication oil pressure warning light glows with warning buzzer, stop the engine at once, and follow the instructions below.

Table 11-1 Procedures When Abnormal Decrease in Engine Oil Pressure Occurs

Inspection item	Remedy	Referred page
Engine oil level decrease	Refill	8-11
Oil viscosity is too low	Use engine oil of appropriate viscosity suitable to ambient temperature	5-1
Clogged oil filter	Oil Filter - Replace	8-10
Engine oil leaks	Contact your MHIET dealer.	
Lubricating oil pressure warning light failure		

Note: In general, immediately after starting the engine, oil pressure gauge reads higher the normal pressure because the oil temperature is low. The pressure will be back to the normal pressure as the temperature rises.

Problems, Probable Causes, and Solutions

The Starter Does not Crank or Cranks Slowly, Resulting in Start Failure

Table 11-2 The Starter Does not Crank or Cranks Slowly, Resulting in Start Failure

Possible cause		Solution
Electrical system	Faulty wire connection	♦Fuse - Inspect ♦Wiring connection of each relay between battery, starter, and starter switch - Inspect
	Battery charge failure	♦Alternator - Inspect (Refer to P8-21) ♦Belt - Inspect and Adjust (Refer to P8-2)
	Weak battery	♦Specific gravity of battery electrolyte - Check (Refer to P8-21) ♦Battery - Charge ♦Battery - Replace
	Faulty starter or faulty safety relay	♦Contact your MHIET dealer.
Lubricating system	Oil viscosity too high	♦Use appropriate engine oil. (Refer to P5-1)
	Excessive oil level	♦Engine oil level - Check (Refer to P3-11)
Engine	Sliding parts rapid wear or lock	♦Contact your MHIET dealer.

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Starter Cranks, but Engine Does Not Start

Table 11-3 Starter Cranks, but Engine Does Not Start

Possible cause		Countermeasures
Fuel system	Run out of fuel, blocked pipe	•Fuel tank - Inspect, Refill, and Air bleed (Refer to P8-4) •Fuel pipes and valves - Inspect
	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1) •Dust, water, or impurities - Remove (Refer to P8-4)
	Fuel leaks from fuel line or injection pipe	•Fuel lines and injection pipes - Check and Retighten •Contact your MHIET dealer.
	Clogged fuel filter	•Fuel filter - Inspect and Replace (Refer to P8-7) •Oil-water separator element - Inspect and Replace (Refer to P8-5) •Gauze filter - Clean (Refer to P8-6)
	Fuel feed pump malfunction	•Contact your MHIET dealer.
	Fuel injection pump malfunction	•Fuel injection pump rack stroke - Inspect •Contact your MHIET dealer.
	Fuel injection nozzle malfunction	•Contact your MHIET dealer.
Air intake system	Insufficient amount of intake air	•Inlet system - Clean and Inspect •Contact your MHIET dealer.
Control system	Governor malfunction	•Contact your MHIET dealer.
Engine body	Compression pressure drop	•Contact your MHIET dealer.

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Poor Output

Table 11-4 Low output

Possible cause		Countermeasures
Fuel system	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1)
	Clogged fuel filter	♦Fuel filter - Inspect and Replace (Refer to P8-7) ♦Gauze filter - Clean (Refer to P8-6)
	Fuel feed pump malfunction	♦Contact your MHIET dealer.
	Fuel injection pump malfunction	♦Contact your MHIET dealer.
	Fuel injection nozzle malfunction	♦Contact your MHIET dealer.
	Faulty fuel injection timing	♦Fuel injection pump drive coupling - Inspect ♦Contact your MHIET dealer.
	Improper maximum injection volume	♦Fuel injection pump rack stroke - Inspect ♦Contact your MHIET dealer.
Cooling system	Overheating or overcooling	♦Belt - Inspect and Adjust Tension (Refer to P8-2) ♦Seawater pump impeller and drive shaft - Inspect (Refer to P8-17) ♦Heat exchanger - Inspect ♦Control system - Inspect ♦Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	♦Turbocharger - Inspect (Refer to P8-18) ♦Pre-cleaner - Clean, Inspect and Replace (Refer to P8-19) ♦Intake air pressure and intake air leaks - Inspect ♦Intake air temperature - Inspect ♦Contact your MHIET dealer.
	Increase of exhaust resistance	♦Exhaust pipe - Inspect ♦Contact your MHIET dealer.
Engine body	Compression pressure drop	♦Contact your MHIET dealer.
	Faulty valve timing	♦Contact your MHIET dealer.
	Rapid wear of sliding parts	♦Contact your MHIET dealer.
Control system	Governor malfunction	♦Contact your MHIET dealer.
Rig	Excessive load	♦Propeller and propeller shaft - Inspect ♦Deposits - Remove

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Exhaust Smoke is White or Blue

Table 11-5 Exhaust Smoke is White or Blue

Possible cause		Solution
Fuel system	Improper fuel properties	•Check cetane index, and use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	•Fuel injection pump drive coupling - Inspect •Contact your MHIET dealer.
	Fuel injection nozzle malfunction	•Contact your MHIET dealer.
	Uneven volume of fuel injection	•Ignition noise and exhaust smoke temperature - Inspect •Contact your MHIET dealer.
	Incorrect fuel injection timing	•Contact your MHIET dealer.
Lubricating system	Combustion of engine oil	•Engine oil level - Check (Refer to P3-11) •Contact your MHIET dealer.
Cooling system	Over cooling	•Control system - Inspect •Thermostat - Inspect •Contact your MHIET dealer.
Engine	Faulty valve timing	•Contact your MHIET dealer.
	Compression pressure drop	•Contact your MHIET dealer.

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Exhaust Smoke is Black or Charcoal

Table 11-6 Exhaust Smoke is Black or Charcoal

Possible cause		Countermeasures
Fuel system	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1)
	Fuel feed pump malfunction	•Contact your MHIET dealer.
	Fuel injection pump malfunction	•Contact your MHIET dealer.
	Fuel injection nozzle malfunction	•Contact your MHIET dealer.
	Faulty fuel injection timing	•Fuel injection pump drive coupling - Inspect •Contact your MHIET dealer.
	Uneven volume of fuel injection	•Exhaust gas temperature - Check •Contact your MHIET dealer.
Inlet and Exhaust systems	Insufficient amount of intake air	•Turbocharger - Inspect (Refer to P8-18) •Pre Cleaner - Clean, Inspect, and Replace (Refer to P8-19) •Intake air pressure and intake air leaks - Inspect •Intake air temperature and ventilation system - Inspect •Contact your MHIET dealer.
	Increase of exhaust resistance	•Turbocharger - Inspect (Refer to P8-18) •Exhaust pipe - Inspect •Contact your MHIET dealer.
Engine body	Compression pressure drop	•Contact your MHIET dealer.
	Faulty valve timing	•Contact your MHIET dealer.
	Rapid wear of sliding parts	•Contact your MHIET dealer.
Load system	Excessive load	•Load system - Inspect •Contact your MHIET dealer.
Rig	Excessive load	•Propeller matching - Adjust

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Excessive Fuel Consumption

Table 11-7 Excessive Fuel Consumption

Possible cause		Countermeasures
Fuel system	Fuel injection nozzle malfunction	•Contact your MHIET dealer.
	Faulty fuel injection timing	•Fuel injection pump drive coupling - Inspect •Contact your MHIET dealer.
	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1)
	Fuel leaks from fuel line or injection pipe	•Fuel lines and injection pipes - Check and Retighten •Contact your MHIET dealer.
Cooling system	Over cooling	•Control system - Inspect •Thermostat - Inspect •Contact your MHIET dealer.
Inlet and Exhaust systems	Insufficient amount of intake air	•Turbocharger - Inspect (Refer to P8-18) •Pre-cleaner - Clean, Inspect and Replace (Refer to P8-19) •Intake air pressure and intake air leaks - Inspect •Intake air temperature and ventilation system - Inspect •Contact your MHIET dealer.
	Increase of exhaust resistance	•Turbocharger - Inspect (Refer to P8-18) •Exhaust pipe - Inspect •Contact your MHIET dealer.
Engine body	Compression pressure drop	•Contact your MHIET dealer.
	Faulty valve timing	•Contact your MHIET dealer.
	Rapid wear of sliding parts	•Contact your MHIET dealer.
Rig	Excessive load	•Propeller alignment - Adjust

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Excessive Engine Oil Consumption

Table 11-8 Excessive Engine Oil Consumption

Possible cause		Solution
Fuel system	Faulty fuel injection timing	•Fuel injection pump drive coupling - Inspect •Contact your MHIET dealer.
Lubricating system	Oil leaking on outside engine	•Oil leaks - Inspect •Contact your MHIET dealer.
	Engine oil viscosity too low	•Use the oil having appropriate viscosity. (Refer to P5-1)
	Excessive engine oil temperature	•Engine oil level - Check (Refer to P3-11) •Oil cooler and oil thermostat - Inspect •Contact your MHIET dealer.
Cooling system	Overheating	•Control system - Inspect •Thermostat - Inspect •Contact your MHIET dealer.
Inlet and Exhaust systems	Oil entry to the air chamber	•Contact your MHIET dealer.
	Worn parts in valve system	•Contact your MHIET dealer.
Engine	Rapid wear of sliding parts	•Contact your MHIET dealer.
Load system	Excessive load	•Load system - Inspect •Contact your MHIET dealer.

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Overheating

Table 11-9 Overheating

Possible cause		Solution
Cooling system	Insufficient coolant level	•Coolant leaks - Inspect •Coolant level - Check (Refer to P3-12)
	Water Pump faulty operation	•Contact your MHIET dealer.
	Faulty thermostat operation	•Contact your MHIET dealer.
Load system	Excessive load	•Load system - Inspect •Contact your MHIET dealer.
Engine	Rapid wear of sliding parts	•Contact your MHIET dealer.

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

Engine Oil Pressure Drop

Table 11-10 Engine Oil Pressure Drop

Possible cause		Solution
Lubricating system	Low engine oil level	•Engine oil level - Check (Refer to P3-11)
	Faulty engine oil property (viscosity)	•Oil property analysis. Use appropriate engine oil. (Refer to P5-1)
	Oil temperature too high	•Cooling system - Check • Contact your MHIET dealer.
	Clogged oil filter	•Oil filter and bypass oil filter - Inspect and Replace (Refer to P8-10)
	Faulty oil pump operation	•Contact your MHIET dealer.
	Faulty relief valve operation	•Contact your MHIET dealer.
Control system	Faulty pressure unit operation	•Control system and wiring - Inspect •Contact your MHIET dealer.
Engine	Rapid wear of sliding parts	•Contact your MHIET dealer.
	Increased clearance of sliding part	•Contact your MHIET dealer.
Load system	Excessive load	•Load system - Inspect •Contact your MHIET dealer.

Note: The table above also includes the parts that MHIET does not supply. For inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.

When Fuel has Run Out

When the engine stops due to fuel runs out while engine is running, restart the engine as described below:

1. Turn the starter switch to the "OFF" position.
2. Add fuel in the fuel tank.
For refilling fuel tank, refer to ["Fuel Tank Oil Level - Check" \(3-10\)](#).
3. Bleed air from the fuel system.
For bleeding fuel system, refer to ["Priming the Fuel System" \(3-1\)](#).
4. Start the engine.
For engine starting procedure, refer to ["Engine Start Up" \(3-14\)](#).

Chapter 12 MAIN SPECIFICATIONS

Main Specifications

Table 12-1 Main Specifications

Item	Specifications
Engine model	S6M4-MTKL
Continuous output	366 kW {498 PS} / 2471 min ⁻¹
Type	Vertical, water-cooled, 4-stroke cycle, turbocharged with intercooler
No. of cylinders - Arrangement	6 cylinders, in-line
Bore × Stroke	ø119 × 135 mm [4.69 × 5.31 in.]
Displacement (declared value)	9.0 L [549 cu in.]
Combustion system	Direct injection system
Compression ratio	14.5 : 1
Firing order	1-5-3-6-2-4
Direction of rotation	Counterclockwise as viewed from the stern
Dimensions (L × W × H)	1841 × 1024 × 970 mm [72.48 × 40.31 × 38.19 in.]
Dry weight	Approximately 965 kg [2127 lb.]
Fuel	Diesel fuel (Representative engine test fuel oil: fuel composition DMX (diesel fuel))
Fuel injection pump	DENSO NB type
Fuel filter	Cartridge type paper-element
Fuel injection nozzle	Hole type
Fuel injection starting pressure	22.6 MPa {230.5 kgf/cm ² } [3277.9 psi]
Governor	Mechanical centrifugal type (all-speed control)
Lubricating method	Forced lubrication (pressure feed by oil pump)
Lubricating oil	Grade CF, CH-4 (API service classification)
Engine oil capacity	Approximately 43 L [11.36 US gal.]
Oil filter	Cartridge type paper-element
Oil cooler	Water-cooled, multi-plate type
Cooling method	Seawater cooled multi-tubular method
Cooling freshwater capacity	Approximately 32 L [8.45 US gal.]
Starting system	Electric start
Starter	DC 24V - 5 kW
Alternator	24V - 35A
Turbocharger	Mitsubishi TD09

Note: The specifications above are subject to change without notice.

July 2016

OPERATION & MAINTENANCE MANUAL

S6M4-MTKL

Pub. No. 99590-72100

