

**MITSUBISHI
MARINE ENGINE**

S12R-T2MPTK

OPERATION & MAINTENANCE MANUAL

Issued: September 2012

Pub. No. 291T1-00120

CAUTION

- Read this Operation & Maintenance Manual, and conduct the engine operation, inspection and maintenance only after sufficiently understanding the description.
- Please keep this Operation & Maintenance Manual with related manuals at a suitable place for quick reference when needed.

INTRODUCTION

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 before proceeding with operation, inspection, and maintenance work.

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

■ California, U.S.A.- Proposition 65 warning statement



WARNING: Breathing diesel engine exhaust exposes you to chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

- Always start and operate the engine in a well-ventilated area.
- If in an enclosed area, vent the exhaust to the outside.
- Do not modify or tamper with the exhaust system.
- Do not idle the engine except as necessary.

For more information go to www.P65warnings.ca.gov/diesel.

Limited Warranty

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. will repair or replace the product, which returned to us during the warranty period, when we judge that the product or a part of the products is defective in material and/or workmanship after conduct-ing inspection. For warranty period, contact a dealer of Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. 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.

♦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 recom-mended.

♦The owner of the engine is responsible for performing regular maintenance described in this 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 a part of the engine 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 aspects 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 and regulations of the local or federal/national government.
- ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. 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.
- ♦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 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 the warranty does not transfer to the new owner. 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 of the product in this manual may differ from those of the product you have. Please note that, depending on specifications, the 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.
- ♦Knowing the exact running time of the engine is very important. For safety operation, be sure to install the engine hour meter so that you know the exact running time and can conduct a timely maintenance that is described in this manual.

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 Affixed on the Engine

Warning Statements

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

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

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



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



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



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



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

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

Units of Measurement

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

- ♦ Pressure: 1 MPa = 10.197 kgf/cm²
- ♦ Torque: 1 N•m = 0.10197 kgf•m
- ♦ Force: 1 N = 0.10197 kgf
- ♦ Horsepower: 1 kW = 1.341 HP = 1.3596 PS
- ♦ Rotation speed: 1 min⁻¹ = 1 rpm
- ♦ Kinetic viscosity: 1 mm²/s = 1 cSt

Abbreviations, Standards and Others

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

Regulation for the Prevention of Air Pollution From Ships

Engine International Air Pollution Prevention Certificate and Technical File

The engine you have purchased is provided with "Engine International Air Pollution Certificate" (EIAPP-certificate) which proves the NOx regulation compliance of MARPOL 73/78 Annex VI, regulation for the Prevention of Air Pollution from Ships, and "Technical File." The ship which is built after 1 January 2000 must be equipped with the marine use engine that complies with the NOx regulations. EIAPP-certificate and Technical File must be kept onboard all the time. If you fail to do so, you may receive penalties for violations.

Owner's Responsibilities Confirming the Engine Maintenance Description (With Signature)

NOx regulation approval engine conditions such as part names and adjustment values are described in the Technical File. When you repair or maintain the engine, you must follow the instructions and perform the repair or maintenance work properly. Ship-owner, captain and chief engineers have a responsibility to confirm the parts changed and adjusted, and record every detail of work to "Maintenance Records for Parameters" in the Technical File with signatures.

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Chapter 1 BASIC SAFETY PRECAUTIONS

Fire and Explosions Prevention



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

Ventilation of Engine Room

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 Cover Until Engine Cools

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

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

Watch Out for Fuel, Oil and Exhaust Gas Leaks

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

If oil/fuel is sprayed or leaking onto hot surfaces of the engine, or if exhaust gas comes in contact with flammable materials, it may ignite and you could burn yourself or it may cause damage to the engine.

Use Explosion-Proof Lighting Apparatus

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.

Prevent Electrical Wires From Short-Circuiting

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

Short-circuits, which possibly resulting in fire, can be 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 a First-Aid Kit Handy

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



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

Stay Clear of All Rotating and Moving Parts



Install Protective Covers Around Rotating Parts

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

Never remove protective covers.

Check Work Area for Safety

Before starting the engine, make sure no one is near the engine and 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 startup operation, do not operate the engine.

Stay Clear of 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 caught in rotating parts, 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 tag to the starter switch.

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

Stop the Engine Before Servicing

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

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

Always Restore Engine Turning Tools After Use

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

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.

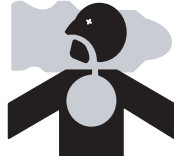
Exhaust Fume Poisoning Prevention

WARNING

Operate Engine in a Well-Ventilated Area

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.



Ears Protection

WARNING

Wear Ear Plugs

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

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



Falling Down Prevention

WARNING

Lift Engine Carefully

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

Hitch 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 contacts 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 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 Prepare a Stable Scaffold

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 Prevention

CAUTION

Do Not Touch the Engine During or Immediately After Operation

Do not touch any part of the engine during or immediately after operation. You could burn yourself.



To conduct maintenance and inspection work, wait until the engine has cooled sufficiently by checking the temperature with the temperature 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 discharge the pressure inside 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 Lowered

When adding coolant, make sure that coolant temperature is sufficiently lowered using temperature gauge. Adding coolant immediately after engine shutdown may result in burns.

Never Remove Heat Shields

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

Be Careful of Burns 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 Only Specified Fuel, Engine Oil and LLC

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

Use of any other fuel, gas, oil or LLC than the specified ones, or improper handling may cause various engine problems and malfunctions.

Obtain the MSDS issued by the oil and LLC suppliers, and follow the directions 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 swallowed, you would suffer from inflammation, irritation or poisoning. Should coolant (LLC) be accidentally swallowed, induce vomiting immediately and seek medical attention. Should coolant (LLC) enter 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. 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.

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

If Problem Occurs

CAUTION

Stop Operation Immediately If You Notice Any Unusual Symptoms

Stop the operation immediately if you notice any unusual noise, odor or vibration during operation. In case of emergency, press the emergency stop button to stop the engine. Contact a dealer of MHIET. If the cause of problem cannot be located after stopping. Continuous operation 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 water 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.

Avoid Restart Immediately After Abnormal Stop

After abnormal stop, do not restart immediately. If the engine stops due to abnormality, check and remedy the cause of the problem before starting again. 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

CAUTION

Handle Battery Correctly



- ◆ 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 could cause an explosion.
- ◆ Do not use the battery when the battery electrolyte level is below the "LOWER LEVEL" mark. Continual use 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.
- ◆ Remove all battery cables, then charge the battery in a well ventilated area.
- ◆ Make sure the cable clamps are securely installed on the battery terminals. A loose cable clamp can cause sparks that may result in an explosion.
- ◆ Before servicing electrical components or conducting electric welding, set the battery switch to [Open/OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.
- ◆ Battery electrolyte contains dilute sulfuric acid. Careless handling of the battery can lead to loss of sight and/or skin burns. Also, do not swallow the battery electrolyte.
- ◆ Wear protective goggles and rubber gloves when working with the battery (e.g. when adding water or charging battery).
- ◆ If battery electrolyte is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to thoroughly clean.
- ◆ The battery electrolyte can cause 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 electrolyte, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.
- ◆ If the battery does not fully recover after 24 hours charging or more, do not use the battery.

Other Cautions



CAUTION

Never Modify Engine

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 have to modify the engine, please contact a dealer of MHIET.

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 Work Clothing and Protective Gear

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

Never Break Seals

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

- ♦ Rapid wear of sliding and rotating parts.
- ♦ Failure due to seizure or damage of parts.
- ♦ Considerably increased consumption of fuel and lubricating oil.
- ♦ Degradation of performance due to improper balance between fuel injection volume and governor operation or overrunning, which could result in a serious accident.

Perform All Specified Pre-operation Inspections and Periodic Inspections

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

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

Break-in 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 new engines or engine that has been overhauled in a severe condition during the break-in period shortens the service life of the engine.

Warm-up Engine Before Use

After starting the engine, run the engine at a low idling speed until the coolant temperature become approx 50°C [122°F]. Start the actual work after this operation is completed. Warm-up operation circulates the lubricant through the engine, and thereby, individual engine parts are well lubricated before they are subjected to heavy loads.

Warm-up operation circulates lubricant 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. Carbon deposits form in the cylinder, which may result in incomplete combustion.

Conduct Cooling Operation Before Stopping the Engine

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.

Never Operate the Engine Under Overload

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.

Protection of Engine Against Water Entry

Do not allow rainwater, etc. 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.

Conduct Proper Maintenance of Pre-cleaner

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 operate the engine without pre-cleaner. The turbocharger may suck particles of foreign materials into the engine and could result in serious accidents.
- When removing the pre-cleaner, take care so that foreign material accumulated on the pre-cleaner will not enter the inside the engine. When the pre-cleaner is removed, immediately cover the air inlet with a plastic film, etc. to prevent foreign material from entering the engine.

Use of Tools Optimum for Each Work

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

Avoid Prolonged Starting Operation

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

Continuous operation of the starter will drain the battery power 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.

Precautions for Transporting Engines

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

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

Do Not Rotate Engine in Reverse

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.

Operate Clutch at Low Idling Speed

Changing direction with the clutch selector, between neutral and forward, or between neutral and reverse, must be always done at 50% rated engine speed or lower. If clutch operation is conducted during high speed rotation, it could cause damage to the marine gear.

Shift Clutch Properly

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.

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 a dealer of MHIET.



Fig. 1-1 Warning Labels

Chapter 2 NAME OF PARTS

Engine External Views

Front View

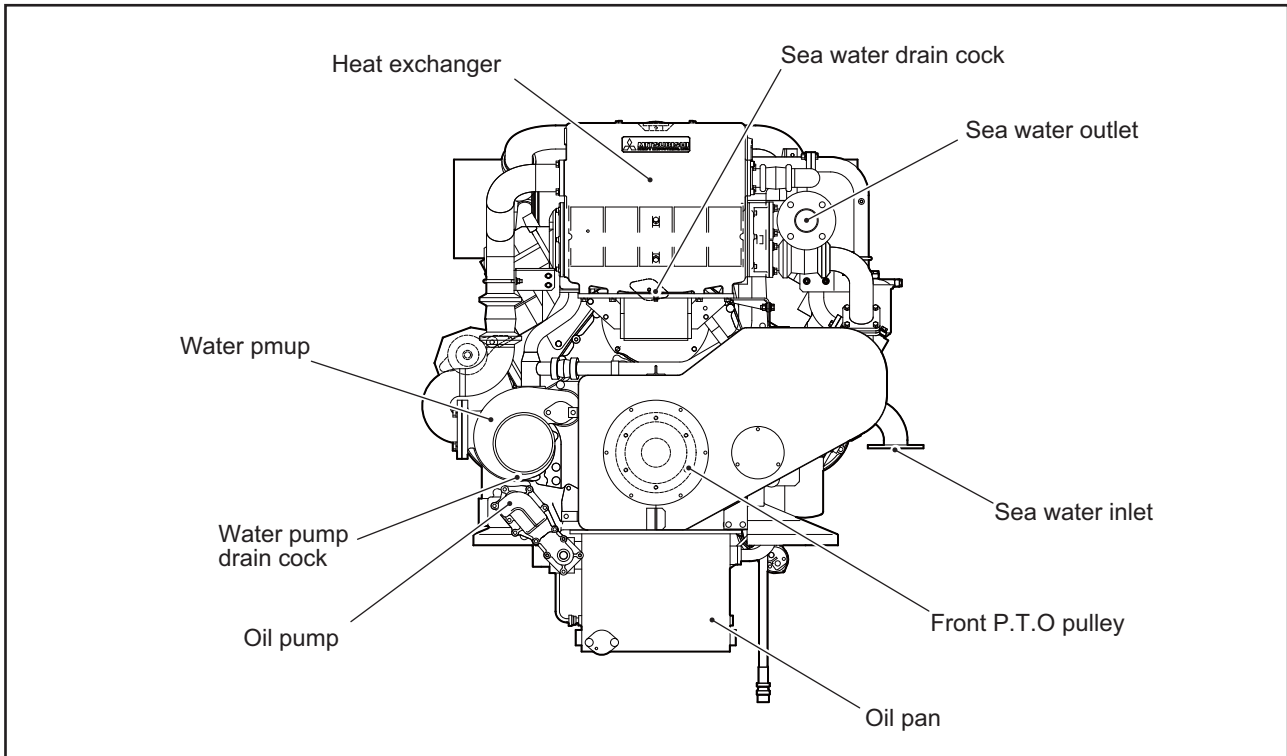


Fig. 2-1 Engine Front View

Rear View

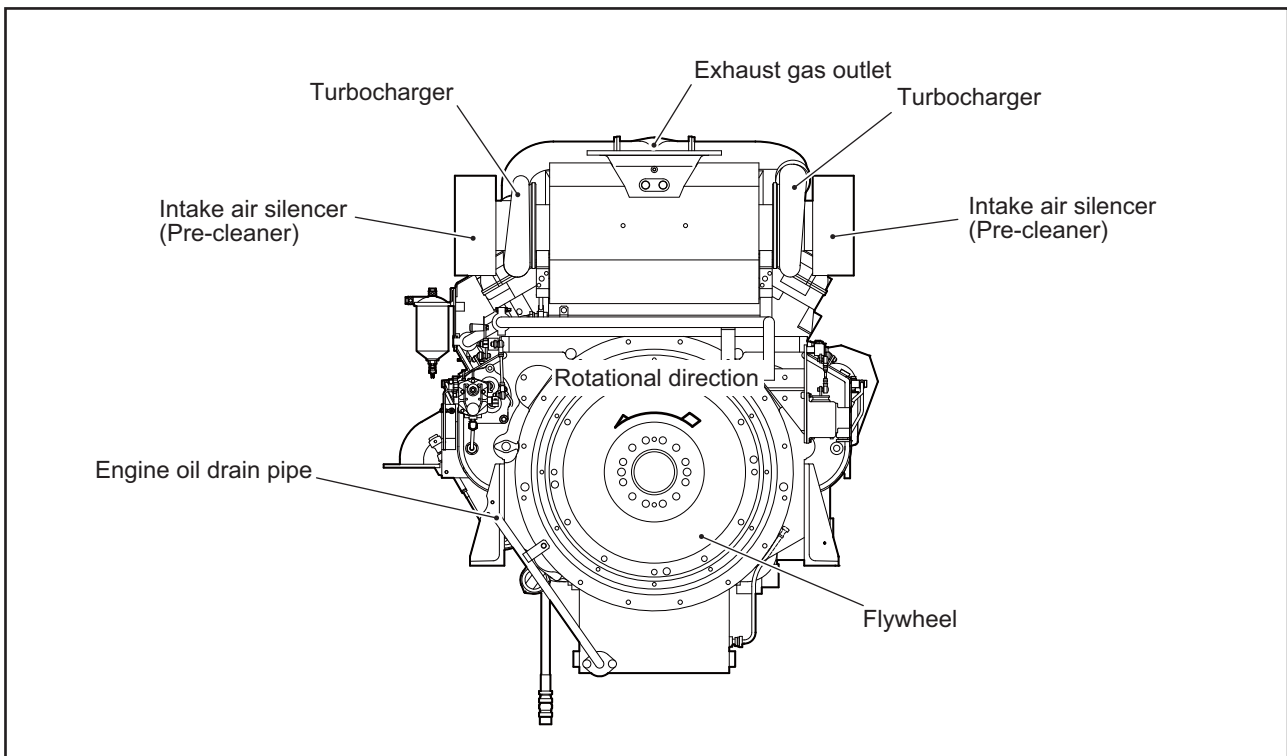


Fig. 2-2 Engine Rear View

Left View

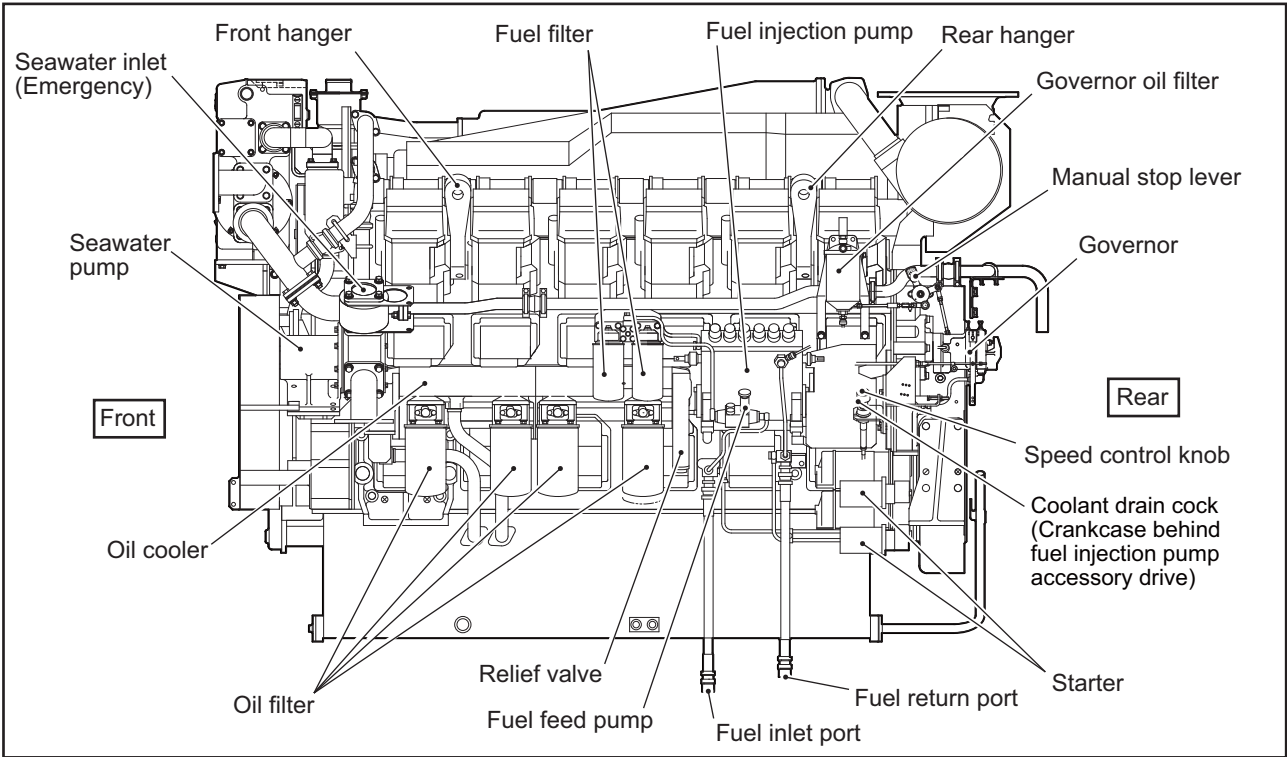


Fig. 2-3 Engine Left View

Right View

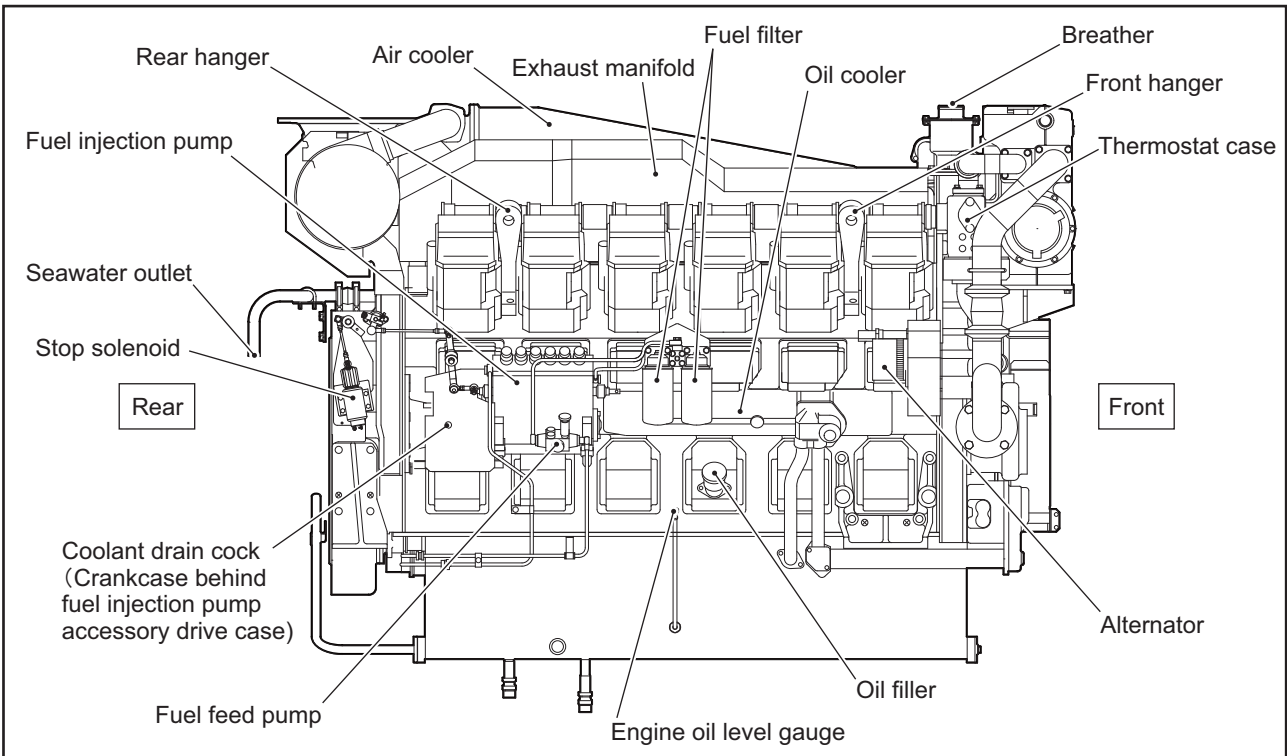


Fig. 2-4 Engine Right View

Equipment and Instruments

The installed equipment and shapes vary with specifications.

Speed Control Knob

You can adjust the engine speed in the engine room.

Turn the knob for fine adjustment of rotating speed.

Turn the knob counterclockwise for high-speed rotation, and turn it clockwise for low-speed rotation.

Press the bottom to unlock the knob.

Speed of rotation can be adjusted by moving the knob.

Pull the knob for high-speed rotation and press it for low-speed rotation.

Note: (a) When changing the speed of rotation by pressing the button, slowly operate so as to avoid rapid speed changes.

(b) After checking the condition of engine, etc. by changing the speed of rotation using this knob, place the knob in the fully pushed down position (minimum speed). If you try to lower the engine speed to the minimum using the speed control lever in the wheel house, the speed will not go lower than the preset value of the knob. Be sure to push down the knob fully after checking.

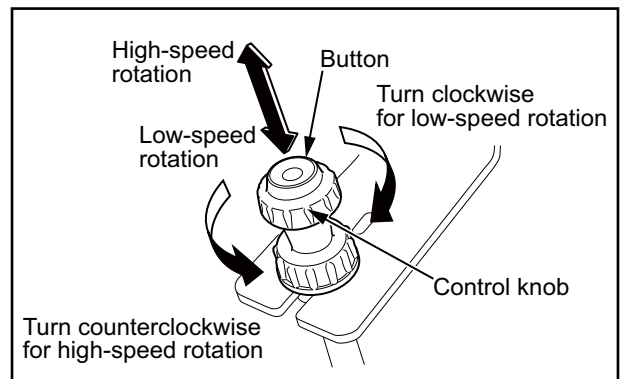


Fig. 2-5 Speed Control Knob

Manual Stop Lever

A manual stop lever is equipped to stop the engine in the event of an emergency and also for the use when the engine will not stop by the stop button.

You can stop the engine by moving the manual stop lever, which is located in the fuel control link, in the "STOP" direction.

If the engine will not stop even after the manual stop lever is moved to the "STOP" position, cut off the fuel supply to the engine.

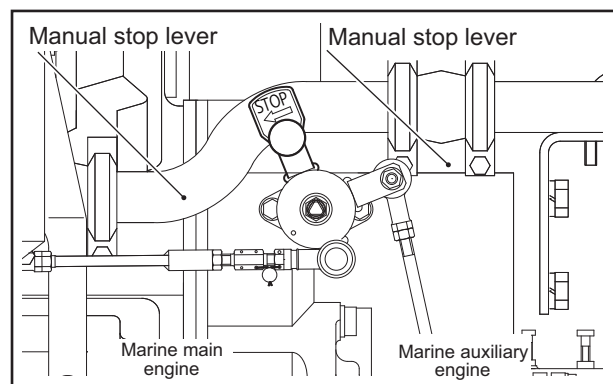


Fig. 2-6 Manual Stop Lever

Stop Solenoid

The stop solenoid is used for normal shutdown of engine operation.

The stop solenoid moves the rack of the fuel injection pump to stop fuel injection, thus shutting down the engine.

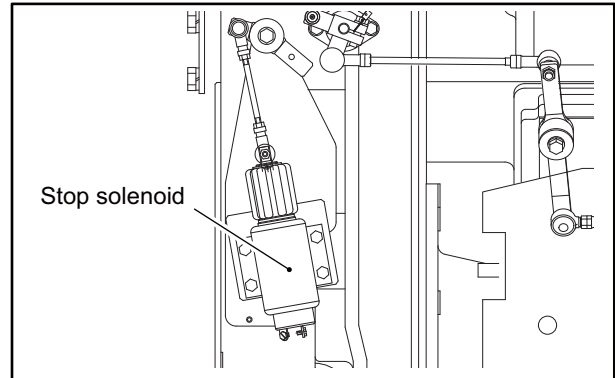


Fig. 2-7 Stop Solenoid

Operation Position Selector Switch

This switch is used to select the operation position, either in the engine room or wheel house.

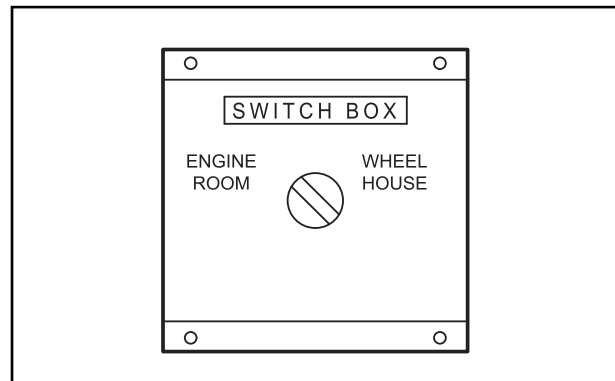


Fig. 2-8 Operation Position Selector Switch

Transmitters to Instruments

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

Oil Pressure Unit

Detects the oil pressure.

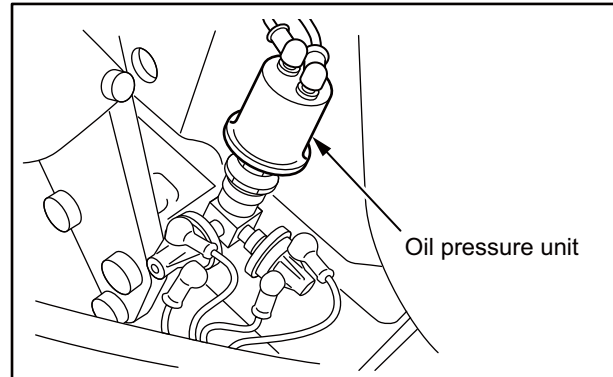


Fig. 2-9 Oil Pressure Unit

Revolution Detection Pickup

Located on the timing gear case, and detects engine speed at all times.

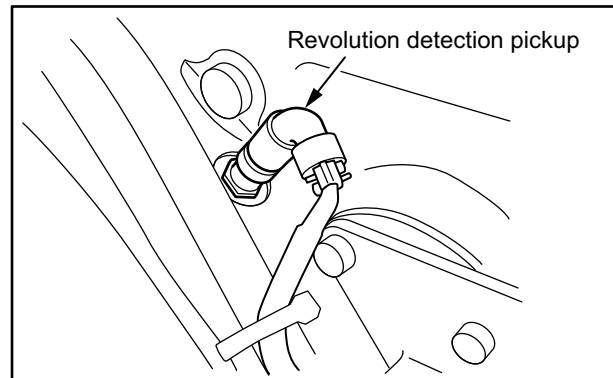


Fig. 2-10 Revolution Detection Pickup

Intake Pressure Sensor

A intake pressure sensor is equipped to detect intake pressure.

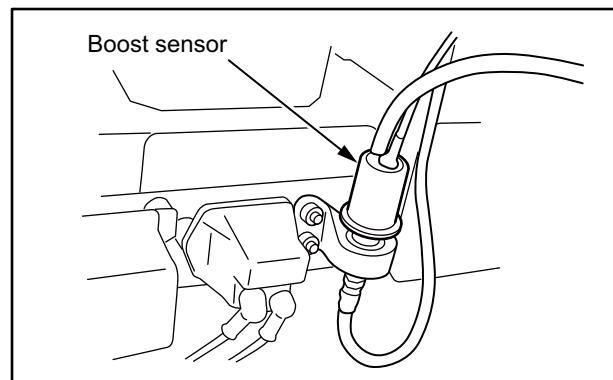


Fig. 2-11 Intake Pressure Sensor

Engine Protection Devices

Oil Pressure Switch

There are two oil pressure switches, the one activates a alarm and the other stops the engine when engine oil pressure has dropped and reached the set pressure.

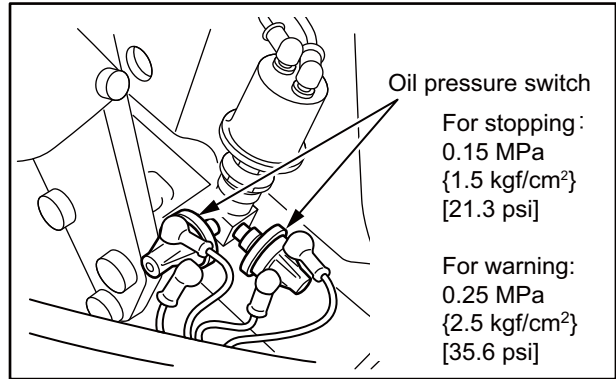


Fig. 2-12 Oil Pressure Switch

Thermo Switch

The engine is equipped with a thermo switch that stops the engine when the coolant temperature has increased and reached the preset temperature.

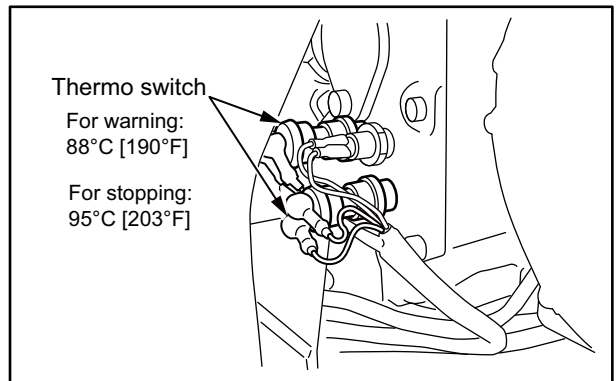


Fig. 2-13 Thermo Switch

Instrument Panel

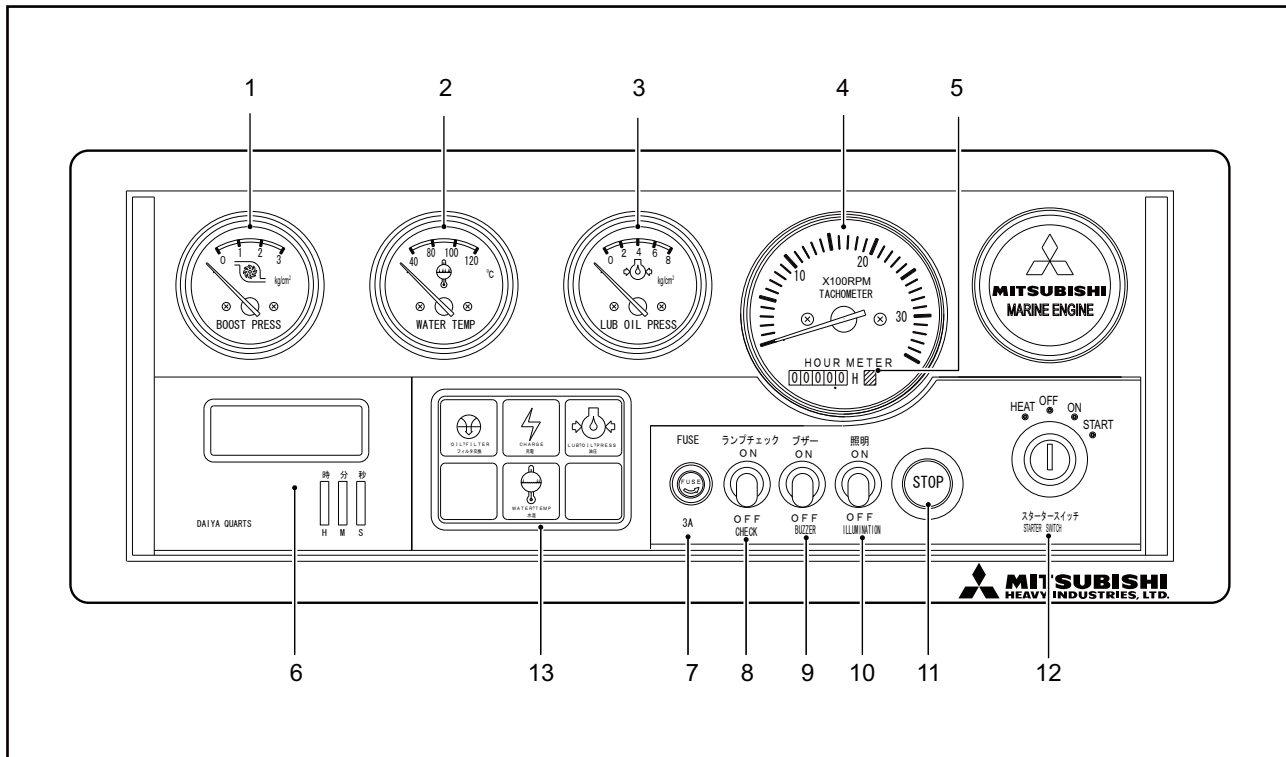


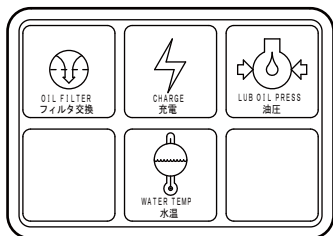
Fig. 2-14 Instrument Panel

Table 2-1 Instrument Panel

No.	Name	Function
1	Manifold pressure gauge	Indicates manifold air pressure in the engine.
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 } [63.8 to 85.6 psi])
4	Engine speed tachometer	Indicates the rotational speed of engine (RPM).
5	Hour meter (Accumulated operation time)	Indicates the operating time of engine. Maintenance can be scheduled by reading this meter. If the starter switch is in "ON" position, time is added to the meter even if the engine is not running. Be sure to turn the starter switch to "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	There is barrel type 3A fuse inside the cap. If warning lamp does not glow when the starter switch is turned to "ON", the fuse may have blown. Check the fuse, and if it has blown, replace it.
8	Light check switch	When the starter switch is in "ON" position, turn this switch to make sure the warning lights will glow. 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 "ON" position during operation.
10	Illumination switch	Turn this switch "ON" to illuminate gauges.
11	Engine stop button	Press this button to stop the engine. When the button is pressed, stop solenoid will be energized for about ten seconds. During this period, the engine cannot be restarted.
12	Starter switch	<p>OFF (Switch Off): Return the key to OFF position when the engine is stopped. The key can be removed or inserted in this position since electrical circuits of gauges are disconnected.</p> <p>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/lamps.</p> <p>START (Start-up): Turn the key to "START" position to start the engine. Release your hand from the key when the engine has started. The key returns to "ON" position automatically.</p>
13	Warning light	<p>Filter warning light (oil filter clogging warning light) Not used in this specification.</p> <p>Charge warning light (battery charge fault light) The light comes on when there is a fault in charging system. Check the charging system when the light comes on. Note: Note that this light illuminates for several seconds immediately after starting the engine.</p> <p>Water temperature warning light (coolant temperature rise warning light) The light comes on when the coolant (fresh water) temperature rises abnormally. If this light comes on, run the engine at no load 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: 88°C [190°F]) Note: The warning buzzer will goes off when the oil pressure warning light or water temperature warning light comes on.</p> <p>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: 0.25 MPa {2.5 kgf/cm²}[36.3 psi])</p>



About Stop Panel

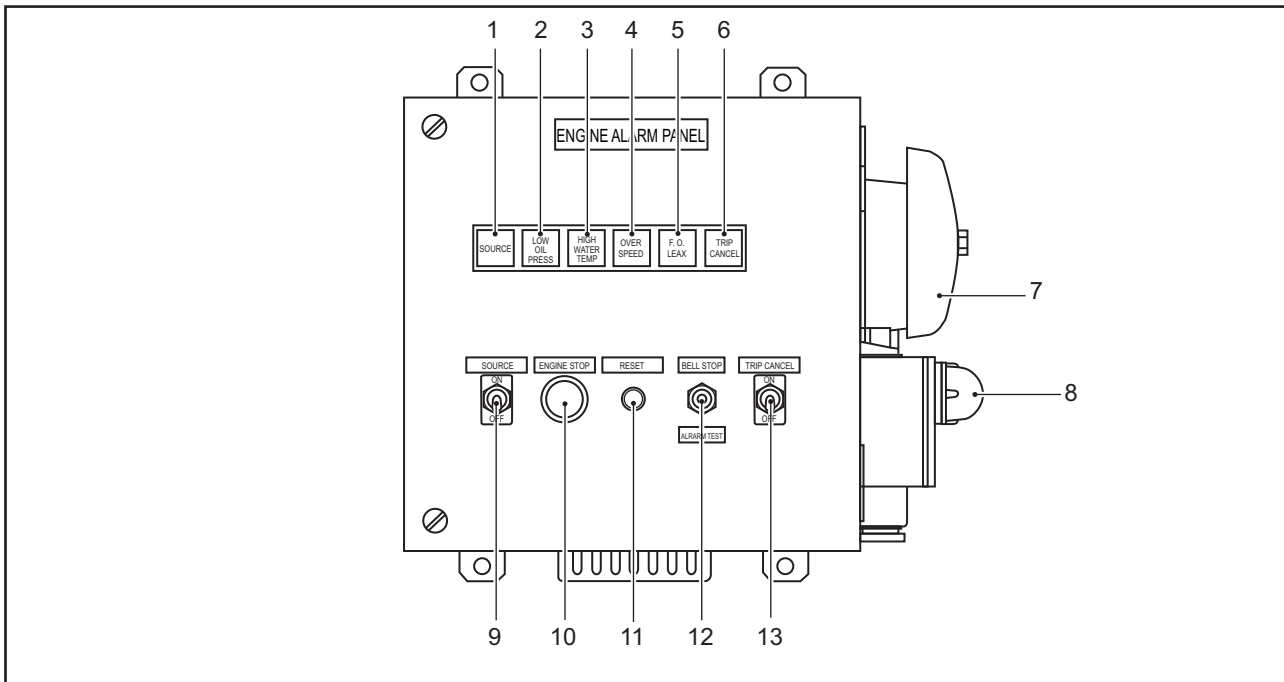


Fig. 2-15 Stop Panel
Table 2-2 About Stop Panel

No	Name	Function
1	SOURCE light	The light comes on when the instrument panel power is turned on.
2	LOW OIL PRESS light	Engine stops and light comes on when there is abnormal engine oil pressure drop. (Oil pressure that triggers the switch: 0.15 MPa {1.5 kgf/cm ² } [21.8 psi])
3	OVER SPEED light	Engine stops and light comes on when the engine is overspeeded. (1888 min ⁻¹)
4	HIGH WATER TEMP light	Engine stops and light comes on when the coolant temperature rises abnormally. (Temperature at which thermo switch turns ON: 98°C [208°F])
5	F.O. LEAK light	The light comes on when fuel leak occurs.
6	TRIP CANCEL light	The light comes on when the trip function is cancelled.
7	Warning bell	This warning bell will ring when an abnormal condition occurs.
8	Warning light	This warning light will come on when an abnormal condition occurs.
9	SOURCE switch	Turn this switch to ON position to activate the instrument panel.
10	ENGINE STOP button	The engine stops when this button is pressed.
11	RESET button	Press "RESET" button to start the engine again after an abnormal stop.
12	BELL STOP / ALARM TEST button	To check operation of stop panel, press down this lever while the starter switch is on. All warning lights will glow. Check this during start-up inspection. When warning bell rings, raise the lever to stop the bell ringing.
13	TRIP CANCEL switch	TRIP function can be cancelled temporarily by turning this switch to ON position.

Using Manual Turning Gear

WARNING

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

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

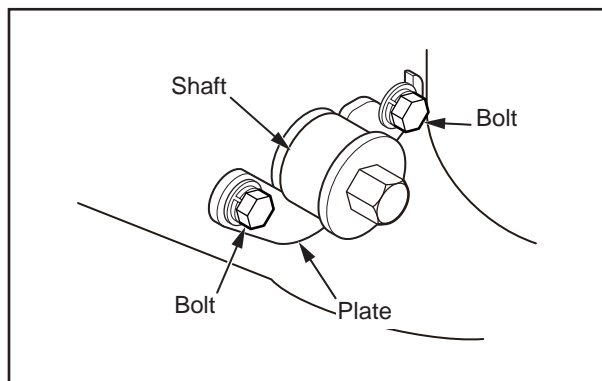


Fig. 2-16 Manual Turning Gear Position (While Engine is Running)

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

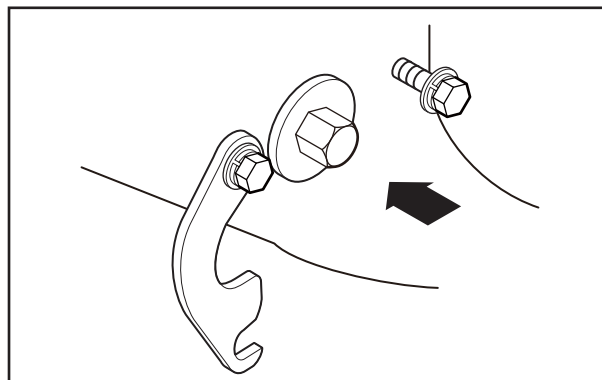


Fig. 2-17 Manual Turning Gear Position (When Shaft Pushed-in)

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

CAUTION

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

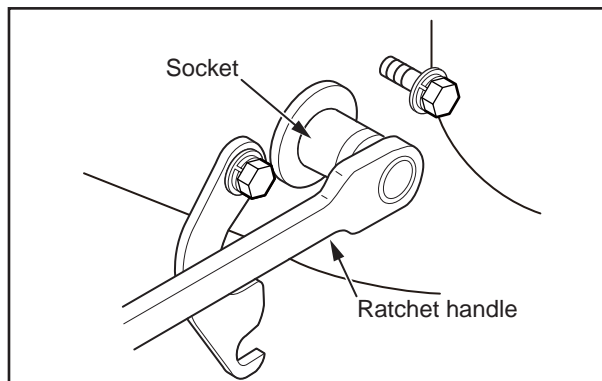


Fig. 2-18 Manual Turning Gear Position (When Turning Shaft)

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 operation onward, 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).

1. Make sure the inside of the fuel tank and the fuel supply pipes to the engine are thoroughly clean.
2. Close the fuel tank drain valve.
3. Fill fuel tank with fuel.
4. Remove the fuel feed pipe and check the discharged fuel for foreign materials such as dust.
5. Install the fuel feed pipe to the engine fuel inlet port.

Bleeding Air from Fuel System

WARNING

When fuel overflows from the air vent plug, wipe thoroughly with a cloth. Spilled fuel can cause a fire. After air bleeding, lock the priming pump securely. If lock is loose, the priming pump may be damaged, causing a fuel leak, which may result in a fire.

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 air bleeding, turn the priming pump clockwise to lock. Be sure to lock securely.

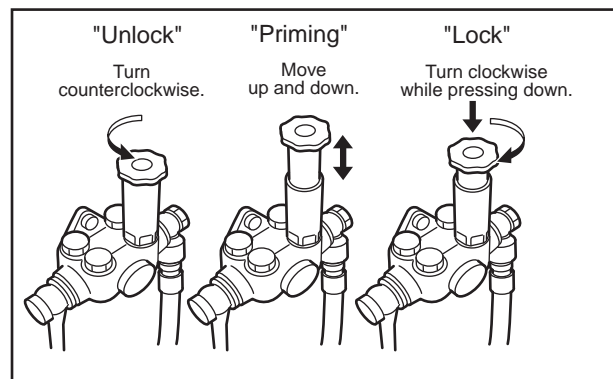


Fig. 3-1 Priming Pump Cap - Handling

Oil-Water Separator - Bleed Air

For Suction Type

1. Loosen air vent plug of oil-water separator.
2. Close valve A on the piping and open valves B and C located front and behind 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 front and behind the manual wing pump, and open the valve A on the piping.

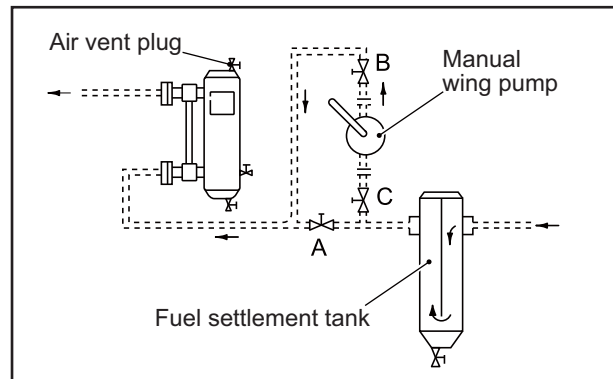


Fig. 3-2 Air Bleeding from Oil-Water Separator (Suction Type)

For Gravity Type

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.

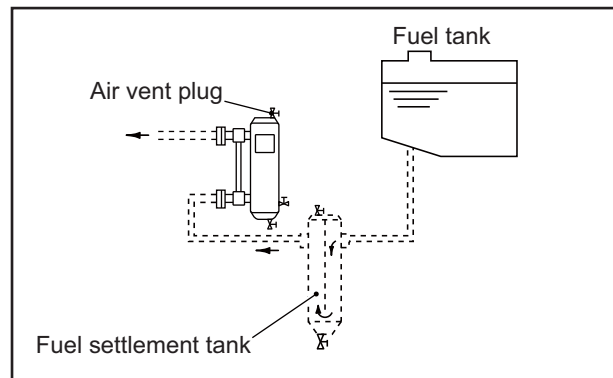


Fig. 3-3 Bleeding air from Oil-Water Separator (Gravity Type)

Fuel Filter - Bleed Air

CAUTION

If 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.

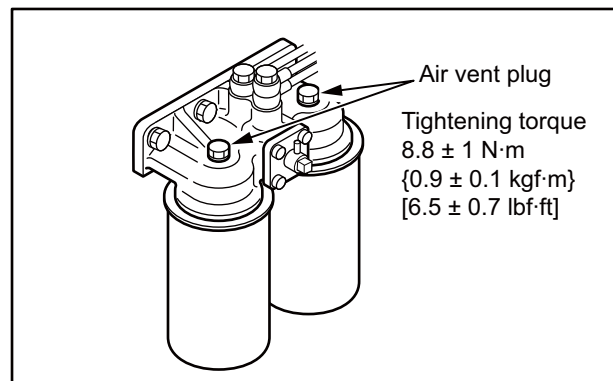


Fig. 3-4 Fuel Filter - Bleed Air

Fuel Injection Pump - Bleed Air

1. Loosen the air vent plug on the fuel injection pump by rotating 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 while pushing it to lock.
3. Tighten the air vent plug on the fuel injection pump.

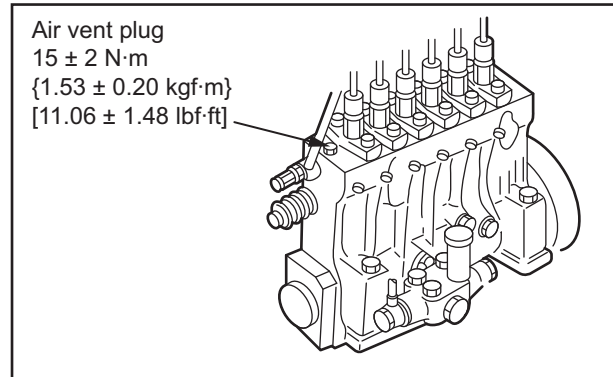


Fig. 3-5 Fuel Injection Pump - Bleed Air

Priming Pump Tightening Method

CAUTION

Securely tighten the priming pump. If the priming pump is not firmly tightened, internal thread will be worn due to engine vibration, resulting in sudden ejection of priming pump to cause fuel flow-out. Or if the priming pump is excessively tightened, the head of the priming pump can be damaged.

1. Gently tighten the priming pump by hand, and make a mark that shows the seating position.
2. Using a wrench or another appropriate tool, further tighten the priming pump by 90 ± 10 degrees.
3. Check the mounting position of head packing.

Note: If the head packing has abnormality such as deformation or scratches, the priming pump should be replaced. Consult a dealer of MHIET. for replacement of the priming pump.

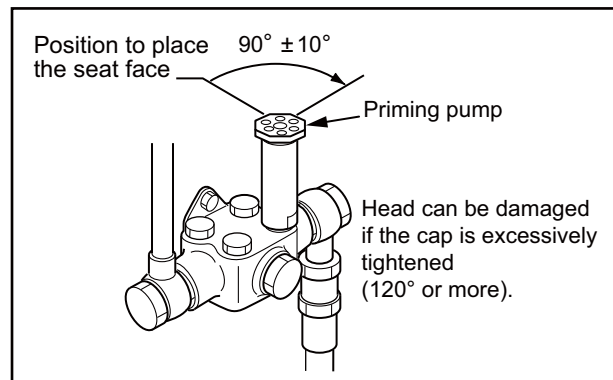


Fig. 3-6 Priming Pump Tightening Method

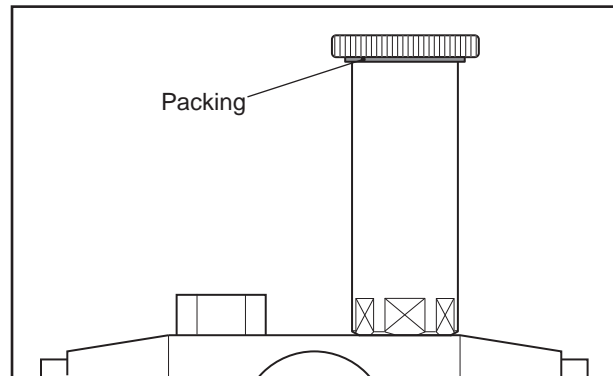


Fig. 3-7 Priming Pump Head Packing

Preparation of Lubrication System

Engine Oil - Filling

CAUTION

Refill 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 increase 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 as follows:
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 engine oil level is higher than the maximum mark on the oil level gauge, drain engine oil by opening the drain valve.
If the engine oil level is low, add the specified engine oil.
7. Check the oil pan, etc., for oil leaks. Repair if there is oil leak.
8. With the manual stop lever placed in pulled position, rotate the engine with starter for approx. 10 seconds to circulate oil to the engine thoroughly. Stop for 1 minute, then, repeat this operation two or three times to circulate oil to all parts of the engine.

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

9. Start the engine and run at no-load and low-idling condition for 5 to 10 minutes.
10. Stop the engine for 30 minutes or more, and then, check the oil level with the oil level gauge again and add oil to the specified level.
For details, refer to "[Test Operation](#)" (3-8).

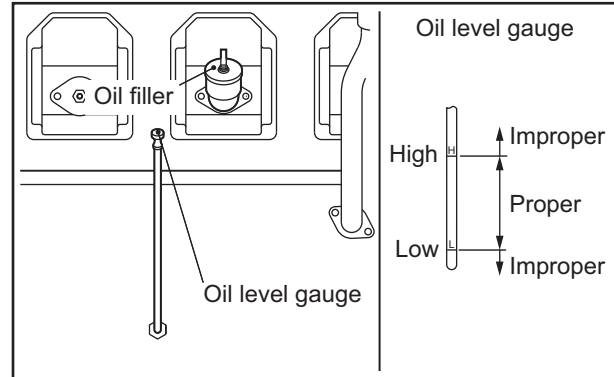


Fig. 3-8 Oil Filler and Oil Level Gauge

Preparation of Cooling System

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, hot coolant steam that can burn you will burst out. 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.

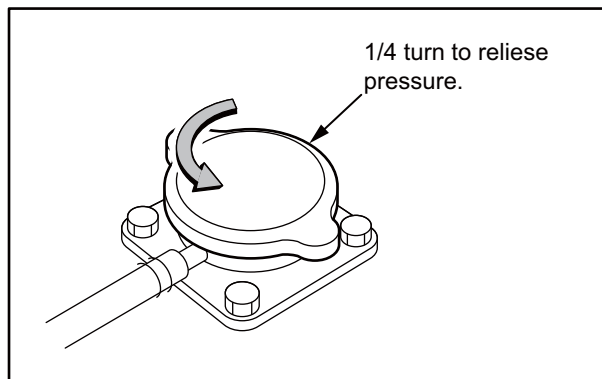


Fig. 3-9 Coolant Expansion Tank Cap

Coolant - Refill

CAUTION

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

1. Close the coolant drain cocks of engine and water pump securely.
2. Open the coolant filler port and add a mixture of water and coolant having the specified concentration.

Note: (a) 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).

(b) For complete air bleeding, loosen the air vent plug on the upper section of thermostat.

3. Check the heat exchange equipment and other parts for coolant leaks. Repair the leak if found.
4. When coolant reaches the specified level, close the coolant fill port securely.
5. With the manual stop lever placed in the pulled position, crank the engine for approx 10 seconds using the starter. Stop for approx. 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.

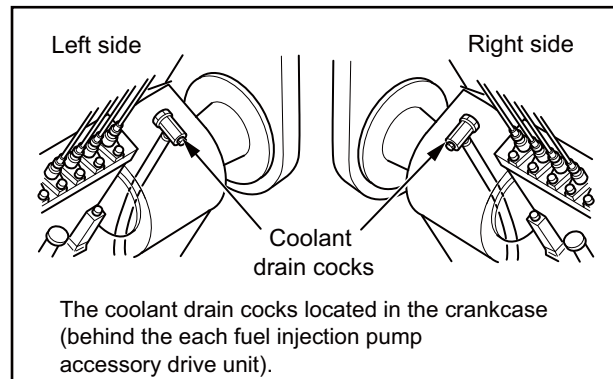


Fig. 3-10 Coolant Drain Cock (Engine Body)

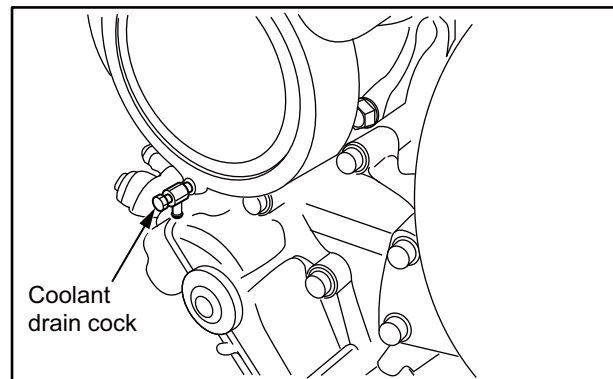


Fig. 3-11 Coolant Drain Cock (Water Pump)

Preparation of 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 electrolyte level is below the "LOWER LEVEL" mark. Continual use 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.

Remove all battery cables, then charge the battery in a well ventilated area.

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

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

Electrolyte (battery electrolyte) contains dilute sulfuric acid. Careless handling of the battery can lead to loss of sight and/or skin burns. Also, do not swallow the battery electrolyte.

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

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

The battery electrolyte can cause blindness if splashing into the 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 electrolyte, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.

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

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

Battery Electrolyte Level - Check

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

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

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

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

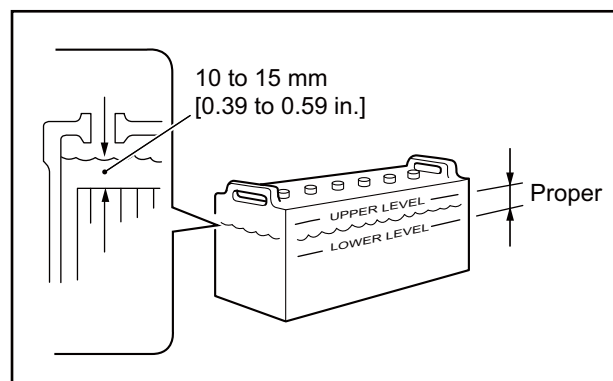


Fig. 3-12 Battery Electrolyte Level - Check

Test Operation

To conduct a test operation, follow the procedures below.

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

Starting and Stopping

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 could get burns 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, check the engine and surrounding area 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.

Normal Engine Operation

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

CAUTION

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

Preparations for Operation

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

Engine External - Inspect

CAUTION

Check external parts of the engine, particularly hot parts (exhaust manifold, etc.) and battery unit for any accumulation of flammable material. Also check for leaks of fluids such as 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 it or contact a dealer of MHIET.

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 a dealer of MHIET.
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.
 - Fuel supply valve: Open
 - Coolant drain cock (valve): Closed
 - Engine oil drain plug: Closed

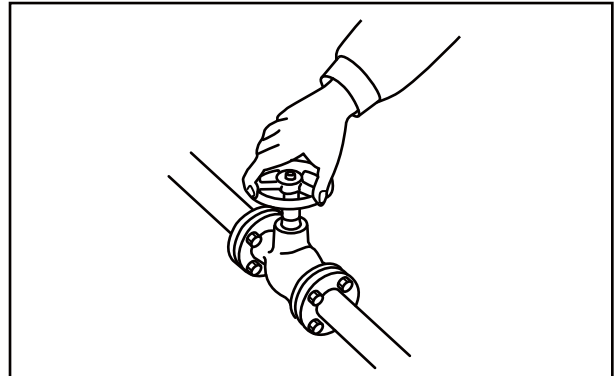


Fig. 3-13 Valves for Open/Closed Position - Check

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

WARNING

From water drain valve, fuel is discharged together with water. Wipe off any spilled fuel completely.

1. Turn the 3-way cock of oil-water separator to the "drain" position.
2. Loosen the air vent plug.
3. Open the water drain valve, and drain the water from oil-water separator.
4. Turn the 3-way cock of oil-water separator on the inlet side to the "operation" position.
5. Close the water drain valve.
6. Bleed air from the oil-water separator.
7. Turn the 3-way cock of oil-water separator on the outlet side to the "operation" position.

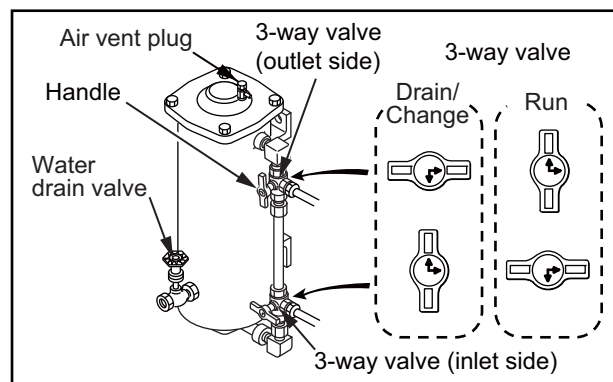


Fig. 3-14 Oil-Water Separator - Drain Water

Fuel Control Link - Check

Check the fuel control link for smooth movement. Push the manual stop lever to the fuel increase direction, check the movement of the rack cancel spring. Then loosen your grip on the lever little by little, making sure the manual stop lever returns to the no fuel injection position smoothly. Also check all ball joints for looseness and play.

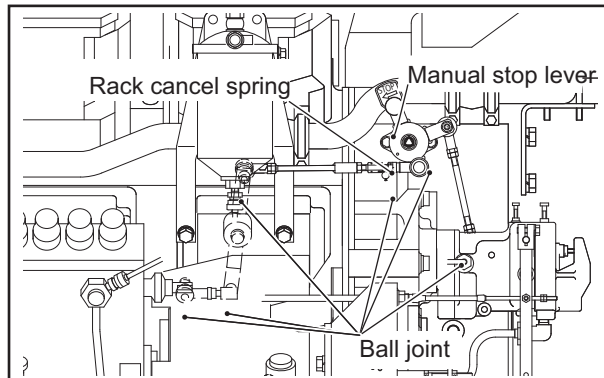


Fig. 3-15 Fuel Control Link - Check

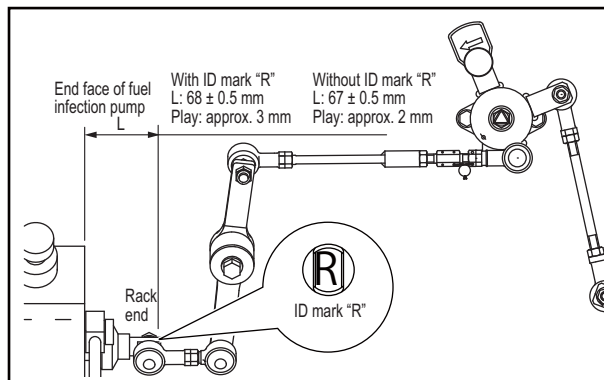


Fig. 3-16 No Fuel Injection Position

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 increase of oil temperature could adversely affect engine components.

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

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](#)" (8-12). For refilling engine oil, refer to "[Engine Oil - Filling](#)" (8-13).

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

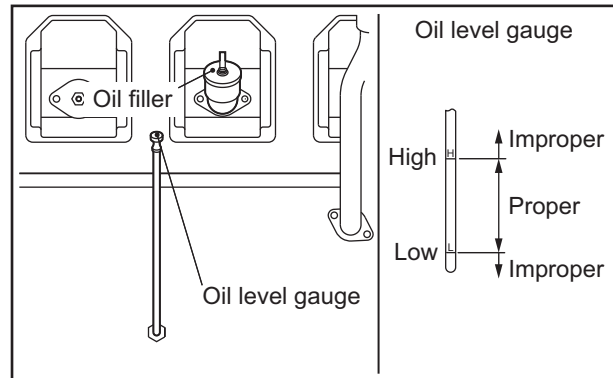


Fig. 3-17 Oil Filler and Oil Level Gauge

Coolant Level - Check

WARNING

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.

When opening the coolant expansion tank cap, raise the lever to the upright position to release internal pressure.

The coolant is hot while the engine is running and immediately after the engine stops. Do not open the cap when the coolant is hot to prevent accidental burns due to hot steam and boiling water. 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. Check the coolant level in the coolant expansion tank with the level gauge.
2. If the coolant level is low, add coolant to the specified level.

Note: (a) Determine the quantity of LLC based on the coolant capacity and the LLC concentration chart.

(b) For coolant, refer to ["COOLANT" \(6-1\)](#).

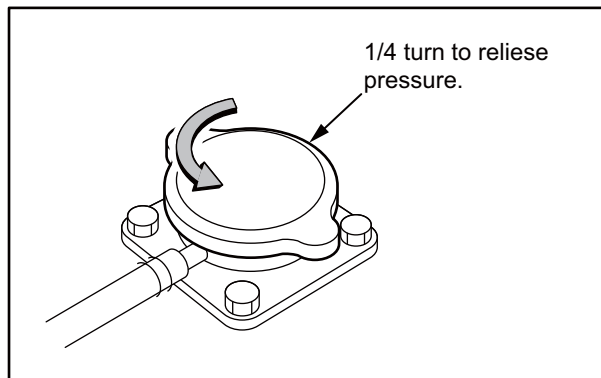


Fig. 3-18 Coolant Expansion Tank Cap

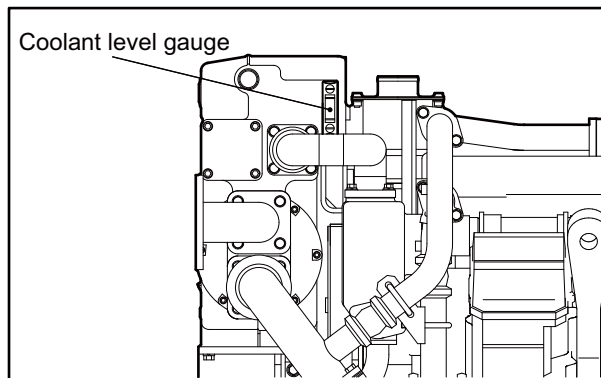


Fig. 3-19 Coolant Level - Check

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.

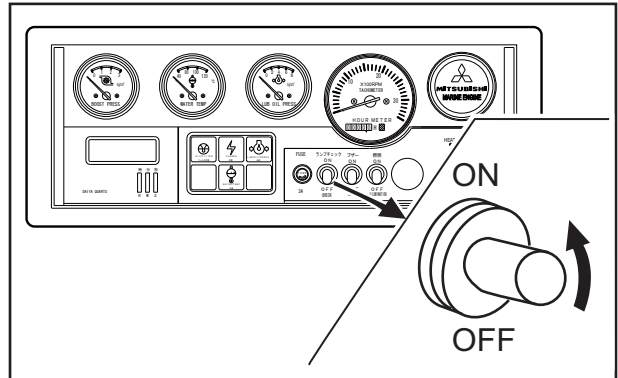


Fig. 3-20 Warning Indicator Light - Operation Check

Control Cable - Check

Check the visual appearance of control cable for flaw, 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 position of marine gear for "Forward", "Neutral," and "Reverse."

Starting-up

Cautions When Starting

⚠ WARNING

Before starting the engine, make sure no one is near the engine and that no tools are left on or near the engine. Alert people in the area when starting the engine.

CAUTION

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

Restart the engine after it stops completely.

Check the movement of governor actuator and fuel system if the engine will not start after repeating above steps 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 starter while pulling the manual stop lever to circulate oil in the engine. Repeat this three times with approx. 1 minute intervals between rotations.

If preheating time is longer than that, it could decrease battery capacity faster or shorten the life of air heater.

Starting Procedures

1. Open the Kingston valve.
2. Turn the battery switch to the "ON" position.
3. Place the speed control lever in the low idle position and place the direction lever in the neutral position.

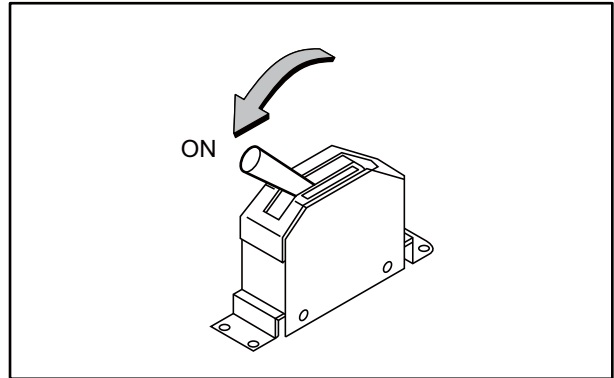


Fig. 3-21 Battery switch "ON"

4. Turn the starter switch key to the "START" position, and start the engine.

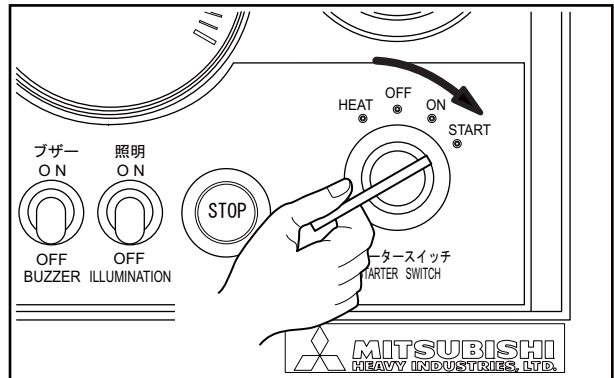


Fig. 3-22 Starter Switch "START"

5. Release your hand from the key when the engine has started. The key returns to "ON" position automatically.

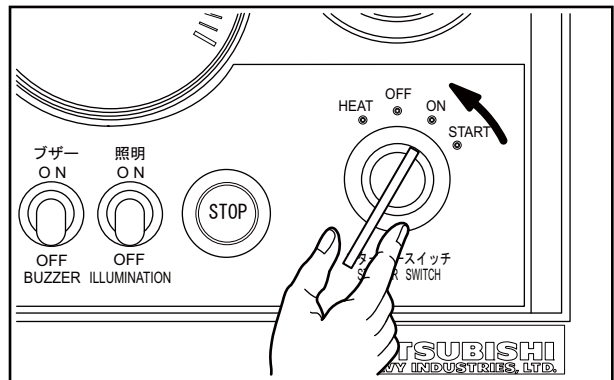


Fig. 3-23 Starter Switch "ON"

Warm-up Operation

⚠ WARNING

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

CAUTION

Do not conduct warm-up operation for a prolonged period of time. Carbon deposits form in the cylinder, which may result in incomplete 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 approx. 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 functions 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.

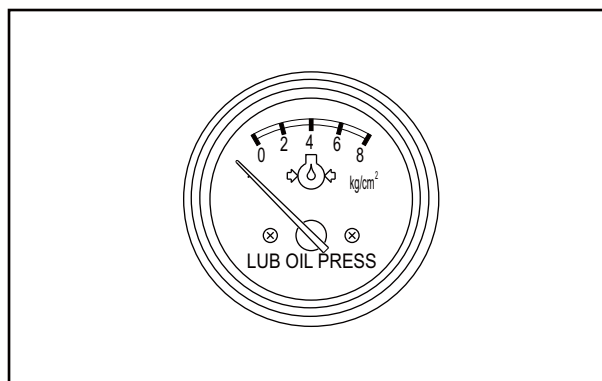


Fig. 3-24 Oil Pressure Gauge

Engine External Inspection During Warm-up

Visually inspect the engine for external damage, abnormal noise, odor, vibration and exhaust gas color, then inspect for fuel, engine oil and coolant or exhaust gas leaks from joints during warm-up operation.

Operation

Cautions During Operation Operate the Clutch Carefully

CAUTION

When shifting (operating clutch) between neutral and forward, and between neutral and reverse, make sure the engine speed is lower than 50 % of rated speed.

The marine clutch can be damaged if the gear (clutch) is shifted between forward and reverse while the engine is operating at high speed.

Do not leave the clutch in a half-engaged position.

CAUTION

When shifting the marine gear clutch, be sure to securely place the clutch in the correct 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.

Pay Attention to Gauges and Alarm Lamps

CAUTION

If a gauge shows an abnormal indication or an alarm lamp lights (buzzer is also activated), reduce the engine speed to no load minimum rated 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.

Observe 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 and other parts 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 in low idle for 5 to 6 minutes to cool the engine before stopping. And check the engine for abnormalities.

Do not race the engine immediately before shutdown.

Do not restart the engine immediately after abnormal stop. If the engine stops, setting off the alarm, be sure to locate the cause of the problem and correct the problem before starting the engine again. After restarting the operation, check the engine for abnormalities again. If an abnormality is found, repair it immediately.

When stopping the engine by pressing the stop button, you do not need to keep pressing the button.

Stopping Procedure

1. Place the direction lever in the neutral "N" position.
2. Before stopping, run the engine at low idle for 5 to 6 minutes to cool the engine.
3. Press the engine stop button on the instrument panel to stop the engine.

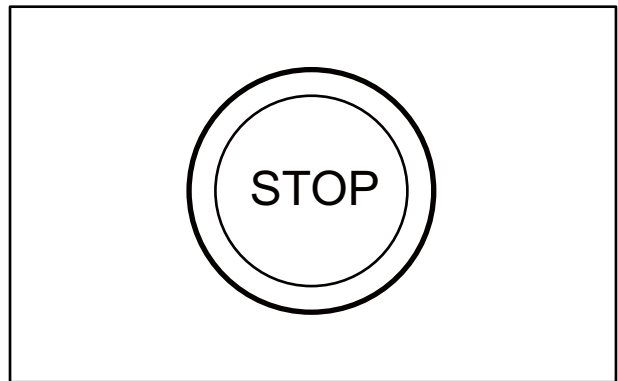


Fig. 3-25 Engine Stop Button

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

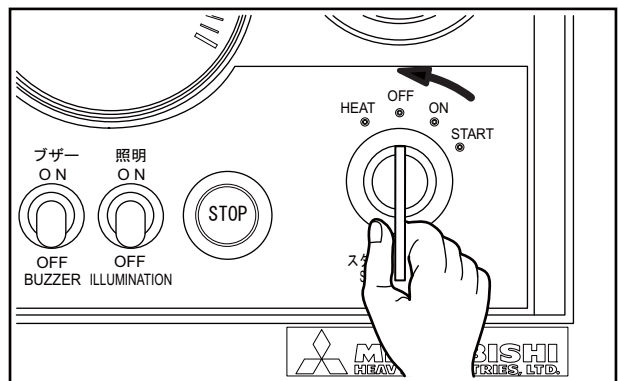


Fig. 3-26 Starter Switch "OFF"

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

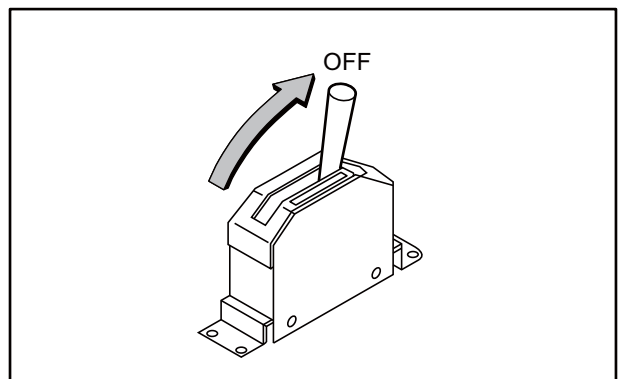


Fig. 3-27 Battery Switch "OFF"

Recommended Fuel

 **WARNING**

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

Use a fuel that meets the requirements in the following [Table 4-1 of "Parameter Entity References"](#) and [Table 4-2 of "Recommended limit and use limit of fuel property"](#)

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

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

Table 4-1 Recommended Fuel

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

Handling Fuel

When using fuel 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 fuel tank. For a complete filtration, it is recommended to use a clean lint-free cloth together with the strainer.

Fuel Specifications

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

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

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 [10.8°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 [5.4 °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 type)		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 The content should be as low as the diesel fuel. ISO 4260 ISO 8754
Water content and sediment		0.1 volume % or lower		JIS K 2275:1996 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]	0.80 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 [356 °F]	75 % carbonization or less	80 % carbonization or less	Fed 791B
	24 hrs at 230 °C [356 °F]	55 % carbonization or less	-	
	48 hrs at 180 °C [356 °F]	Tar-free	-	
Aromatics substances (by HPLC)		38 % by volume or less		JIS K 2536:2003 ISO 3837
Polycyclic aromatic content		8 volume % or lower		
Asphaltene		0.1 weight % or lower		-

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

Item	Recommended limit	Use limit	Test method
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.

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 or CH-4 oil which is suitable to turbo/supercharged and high-load engines.

When using grade CF engine oil, the certified year must be the year of 2009 or before and the oil must meet the requirements listed in the [Table 5-1 of "Table of Recommended Limit of Engine Oil Properties"](#).

If 0.2% or less sulfur contact fuel is used in the engine, CF or CH-4 grade oil can be used. However, the oil must be CH-4 grade lubricating oil that has base value of 8.0 mgKOH/g or higher by Hydrochloric acid method.

If measured by the perchloric acid method, the total base value must be 11.0 mgKOH/g or more.

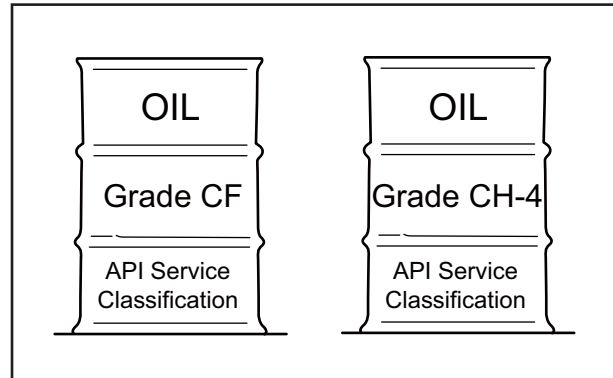


Fig. 5-1 Engine Oil Grade

Engine Oil Specifications

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

Table 5-1 Table of Recommended Limit of Engine Oil Properties

Item		Unit	Recommended limit	Test method	
API/JASO			Grade CF *1	-	
SAE viscosity		-	15W-40	-	
Color ASTM		-	L4.0	JIS K 2580 ISO 2049	
Density	15°C [59 °F]	g/cm ³	0.87 to 0.90	JIS K 2249 ISO 3675 ISO3838 ISO 649-4 ISO 91-1	
Kinetic viscosity	40°C [104 °F]	mm ² /s	100 to 110	JIS K 2283 ISO 3107 ISO 2904	
	100°C [212 °F]		13.5 to 15.5		
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 contents of fuel	1.0 weight % or less	JIS K 2501 ISO 3771 ISO 6618 ISO 6619 ISO 7537	
			0.2 weight % or less		10 or higher (up to 13)
	Perchloric acid method	Sulfur contents of fuel	1.0 weight % or less		8 or higher (up to 13)
			0.2 weight % or less		13 or higher (up to 16)
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 higher	JPI-5S-36-91	
Pour point		°C [°F]	-25 [-13] or lower	JIS K 2269 ISO 3015 ISO 3016	

Table 5-1 Table of Recommended Limit of Engine Oil Properties

Item		Unit	Recommended limit	Test method
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 lower	FED791-3462
	325°C [617 °F]		300 or lower	

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

*2 Temperature of test I (24°C [75.2°F]), Temperature of test II (93.5°C [200.3°F]), Temperature of test III (24°C [75.2°F] after 93.5°C [200.3°F])

*3 Temperature of aluminum panel: 300°C [572°F] and 325°C [617°F], Temperature of engine oil: 100°C [212°F], Splatter time: 15 seconds,

? Downtime: 45 seconds, Test time: 8 hours. The properties are the weight of solid product.

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 of oil temperature, while excessively low oil viscosity accelerates wear due to inadequate lubrication, and also causes a decrease in engine output.

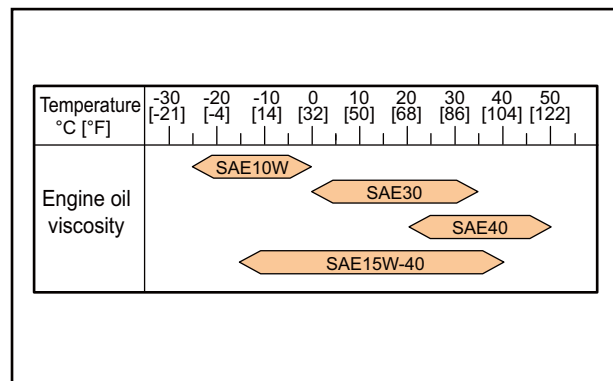


Fig. 5-2 Selection of Oil Viscosity

Handling Engine Oil

WARNING

Before filling the engine with engine oil, stop the engine and make sure there are no open flames and other fire hazards near the engine. Leaked or spilled oil on hot surfaces or electrical components can cause a fire. Wipe off any spilled oil immediately and thoroughly. After filling 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 by a service station operated under the provision of the law. When removing 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 of Engine Oil

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

The quality of engine oil and the operating condition of the engine have influence on deterioration of the engine oil. Change the engine oil in accordance with Chapter 7 MAINTENANCE SCHEDULE. However, only if engine oil analyze result allows, oil replacement interval may be changed.

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

Table 5-2 Table of Engine Oil Properties

Properties		Standard		Test method
Kinetic viscosity	mm ² /s @100°C [212 °F]	For main engine/ main generator	+30 % or less rate of change from new oil 10 mm ² /s [0.155 in ² /s] or more	JIS K 2283:2007 ISO 3107 ISO 2909
		For emergency generator	+30 % or less rate of change from new oil -20 % or less rate of change from new oil	
Base number	mgKOH/g	2.0 or more by hydrochloric acid (HCL) method 1/2 of new oil or more by 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 higher		JIS K 2265:2007 ISO 3769 ISO 2719
Pentane insolu- bles	Wt %	0.5 or less		Compliant to ASTM D 893
Pentane Insoluble Coagulated	Wt %	3.0 or less		Compliant to ASTM D 893

Definition of Properties of Engine Oil

Kinetic viscosity

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

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

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 base number indicates the amount of dispersant detergent in oil, it can be used to estimate consumption of basic dispersant detergent. The ability to disperse sludge declines as dispersant detergent is consumed. So, 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 in sliding parts.

Flash point

The flash point is lowered by contamination with fuels. 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 understand 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 get 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 the use.

The followings are found by the engine oil analysis service.

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

The engine oil analysis service can diagnose the internal condition of the engine 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.

Chapter 6 COOLANT

Note: In this operation manual, the word "coolant" represents 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 recommended value, however, up to the limit value is acceptable.

Table 6-1 Water quality standards

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

Note: Other than the requirements above, turbidity must be below 15 mg/liter.

Long Life Coolant (LLC)

⚠ CAUTION

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

Be sure to use Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. genuine long life coolant (LLC), "GLASSY long life coolant (ethyl-ene glycol type)" or "PG GLASSY long life coolant (propylene glycol type)." When using an LLC other than Mitsubishi Heavy Industries Engine & Turbocharger' genuine long life coolant by necessity, be sure to use the non-amine type LLC that meets our specification. Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. disclaims the warranty claim about malfunctions due to the use of LLC that does not meet our specification.

Genuine LLC

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

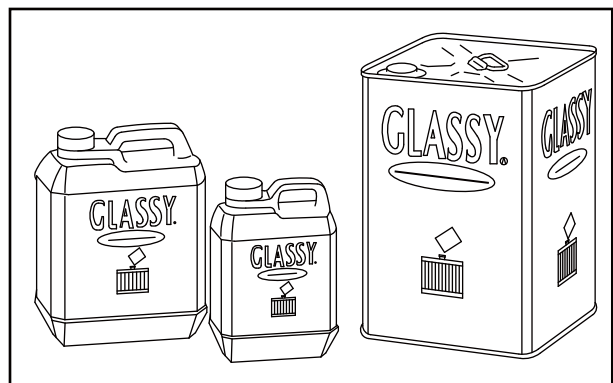


Fig. 6-1 GLASSY - LLC

Other Commercial LLCs

CAUTION

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

When using an LLC other than genuine MHIET 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 of LLCs, be sure to use the LLC that meets the requirements below.

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. disclaims the warranty claim for defects 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 stored 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 Requirements

LLC shall be tested according to JIS K2234, Section 7 "Test method", and satisfy the requirements. General matters and specimen sampling method shall comply with JIS K2234.

Table 6-2 LLC Quality Requirements

Property		Standard	
Appearance		No precipitation	
Density		Minimum 1.112 g [0.039225 oz.]/cm ³ [69.4199 lb/ft ³] (20/20 °C) [68/68 °F] (Stock solution)	
Water content		Maximum 5.0 weight % (Stock solution)	
Frozen temperature	30 vol %	Maximum -14.5 °C [6 °F]	
	50 vol %	Maximum -34.0 °C [-29 °F]	
Boiling temperature		155 °C [311 °F] or higher (Stock solution)	
pH		7.0 to 11.0 (30 vol %)	
Bubbling character (ASTM D3306-01)	30 vol %	4.0 ml or less	
	33 ¹ / ₃ vol %	150 ml [0.032 gal] or less, disappearance of bubble within 5 seconds.	
Hard water adaptability		1.0 or less (50 vol %)	
Metallic causticity (88±2°C [190±3.60°F], 336±2 Hr, 30 vol % (E.G), 50 vol % (P.G))	Metal specimen	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
		Appearance of the specimen after testing	No visible signs of corrosion on the surface excluding the area in contact with the spacer. However, discoloration is accept- able.
	Bubbling during the test		No bubbles overflowing
	Properties of liquid after test- ing	pH	6.5 to 11.0
		pH change	±1.0
Precipitation		0.5 vol % or less	
Appearance of liquid		No remarkable discoloration, separation and gel generation.	

Table 6-2 LLC Quality Requirements

Property			Standard	
Circulation metallic causticity (98±2°C [208±3.60°F], 1000 Hr, 30 vol % (E.G), 50 vol % (P.G)	Metal specimen	Mass change	Aluminum, Cast iron, Steel, Brass, Solder, Copper ±0.30 mg/cm ²	
		Appearance of the specimen after testing		No visible signs of corrosion on the surface excluding the area in contact with the spacer. However, discoloration is acceptable.
	Properties of liquid after testing	pH		7.0 to 9.0
		pH change		±1.0
		Pre-alkalinity change		±15 %
		Precipitation		1.0 vol % or less
		Appearance of liquid		No remarkable discoloration, separation and gel generation.
Density of ion	Fe, Cu, Al, Zn, Pb, NH ₄ ⁺	10 ppm or less		
Circulation metallic causticity (88±3°C [190±5.40°F], 1000±2 Hr, 30 vol % (E.G)	Metal specimen	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
	Appearance of the specimen after testing		No visible signs of corrosion on the surface excluding the area in contact with the spacer. However, discoloration is acceptable.	
	Properties of liquid after testing	pH		6.5 to 11.0
		pH change		Maximum ±1.0
		Appearance of liquid		No remarkable discoloration, 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 Requirements

Property		Standard	
Rubber adapt-ability (30 vol % water solution, 115 °C [239 °F], 360 Hr)	Silicon	Tensile strength change	-60 to 0 %
		Elongation change	-40 to +20 %
		Volume change	0 to +40 %
		Hardness change	-20 to +10 %
	Acrylonitrile butadiene rub- ber	Tensile strength change	0 to +10 %
		Elongation change	-15 to +15 %
		Volume change	0 to +40 %
		Hardness change	-10 to 0 %
	Ethylene pro- pylene diene monomer	Tensile strength change	0 to +10 %
		Elongation change	-30 to 0 %
		Volume change	0 to +10 %
		Hardness change	-10 to 0 %
Storage stability vol % (30 vol %, room temperature, 6 Hr)		0.3 or less	

Maintenance of LLC

 **CAUTION**

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

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

Replacement Intervals of LLC

CAUTION

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

Failure to renew LLC may cause malfunctions due to rust prevention performance degradation 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, 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. Be sure to observe the coolant anti-freeze concentration range given in the table below.

Table 6-3 Recommended LLC Concentration

Ambient temperature		to -10°C [14°F]	to -20°C [-4°F]	to -30°C [-22°F]	to -45°C [-49°F]
LLC Con- centration	GLASSY (ethylene glycol)	30%	40%	50%	60%
	PG GLASSY (propylene glycol)	40%	55%	70%	85%

- Concentration must be 60% at a maximum for GLASSY (ethylene glycol) and 85% for PG GLASSY (propylene glycol). If concentration is higher than that, it can lead to a risk of adverse effects. For example, anti-freeze performance will decrease. Or coolant temperature will rise due to the decrease in specific heat.
- Coolant temperature will increase by approx. 1.5°C [34.7°F] for 60% concentration of GLASSY (ethylene glycol) and approx 3°C [37.4°F] for 85% concentration of PG GLASSY (propylene glycol). Check heat exchanger capacity of the cooling system to avoid overheating.

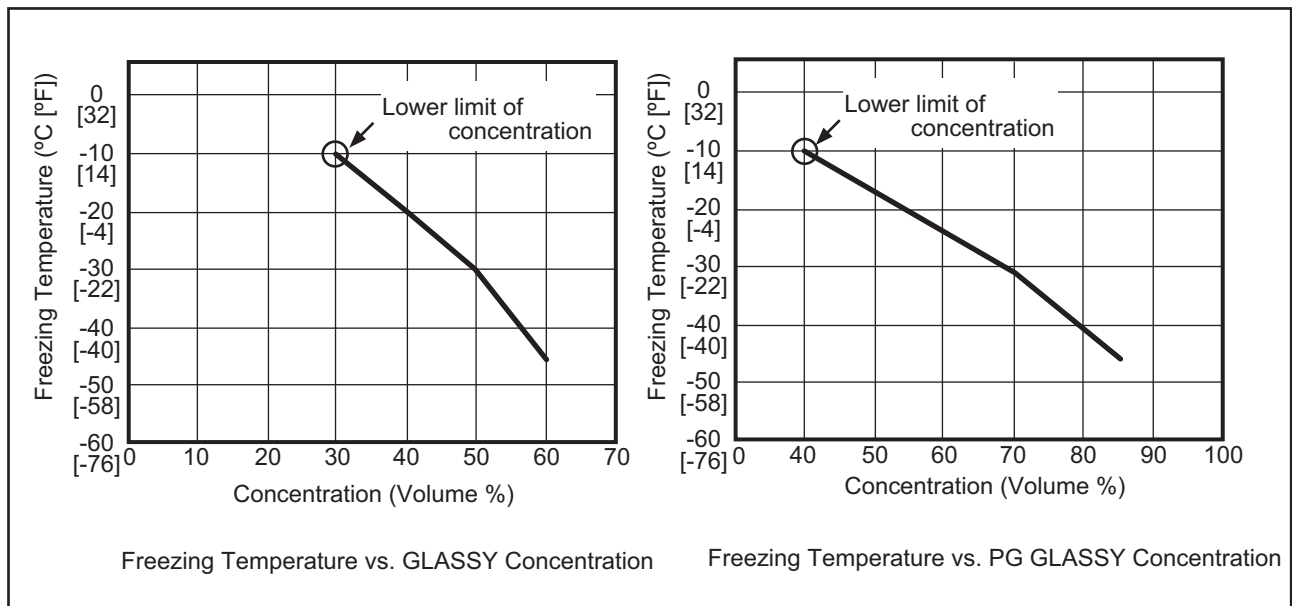


Fig. 6-2 Coolant Freezing Temperature (GLASSY, PG GLASSY)

Importance 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 subjected to the severe conditions described above. Those materials have different ionization characteristics, and this difference accelerates corrosion through the medium of engine coolant. To prevent such a problem, it is necessary to use the LLC having the additive that prevents rust.

Characteristics of LLC Additive and Points to Remember

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 result in dissolution of metals instead of protecting metals from corrosion. Consequently, other corrosion preventing chemicals react with dissolving metals and accelerate corrosion. This condition generates more severe corrosion than when plain soft water is used. This is a typical problem caused by the use of inappropriate LLC.

Examples of Abnormalities Caused by LLC (Amine Type)

Pitting of Iron Parts

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

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

Corrosion of Aluminum Parts

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

This means, after silicate is used up, the high alkalinity causes chemical attacks on aluminum. To prevent this problem, proper maintenance of the coolant is required. Examples: rapid wear of mechanical seals of the water pump due to secondary effects of silicate gel formation, corrosion of aluminum parts after silicate used-up.

Pitting and Clogging of the 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 Maintenance Schedule

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

Observe the standard service intervals given in the maintenance schedule. 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 "Maintenance schedule."

Note: Appropriate service intervals vary depending on the usage and operating conditions as well as consumption of fuel, oil and coolant. Check the operating record of the engine to determine the most appropriate service intervals. (Feel free to consult a dealer of MHIET regarding service intervals.) Service the items at multiples of the original requirement. For example, at 1000 service hours, also service those items listed under every 250 service hours and every 500 service hours.

MAINTENANCE SCHEDULE

Table 7-1 MAINTENANCE SCHEDULE

Inspection and Maintenance Intervals	Service items	Page
First 100 hours of operation (Only once)	Engine Oil and Oil Filter - Replace	8-12
	Fuel Filter - Replace	8-8
	Valve Clearance - Inspect and Adjust	*
	Engine External - Inspect (Bolts, Nuts, Common Bed Bolts - Retightening)	8-1
Every 100 service hours	Oil-Water Separator - Drain Water	8-6
Every 250 service hours	Engine Oil and Oil Filter - Replace	8-12
	Belt and Belt Tension - Inspect and Adjust	8-2
	Pre-cleaner - Clean, Inspect and Replace	8-23
Every 500 service hours	Includes service items for every 100 and 250 service hours.	-
	Gauze Filter - Clean	8-7
Every 1000 service hours	Includes service items for every 100, 250 and 500 service hours.	-
	Fuel Filter - Replace	8-8
	Oil-Water Separator Element - Replace	8-6
	Seawater Pump Impeller - Inspect	8-21
	Turbocharger Rotor Movement and Looseness - Inspect	*
	Valve Clearance - Inspect and Adjust	*
	Fuel Injection Nozzle - Inspect and Adjust	*
Every 2000 service hours or every 1 year	Includes service items for every 100, 250, 500 and 1000 service hours.	-
	High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace	8-11
	Low Pressure Fuel Pipe, Oil Pipe and Clip - Inspect and Replace	8-11
	Fuel Injection Nozzle Tips - Replace	*
	Fuel Control Link Ball Joint - Inspect	8-10
	Seawater Pump Impeller - Replace	*
	Bolts and Nuts on Exhaust and Air Inlet Pipes - Retighten	*
	Harness Damage and Terminal Looseness - Inspect	*

Table 7-1 MAINTENANCE SCHEDULE

Inspection and Maintenance Intervals	Service items	Page	
Every 4000 service hours or 2.5 years	Includes service items for every 100, 250, 500, 1000 and 2000 service hours.	-	
	Engine Overhaul	Cylinder Head - Disassembly and Inspect Valve Mechanism - Inspect Cylinder Liner Inside Surface - Inspect	*
	Belt - Replace	*	
	Damper - Inspect	8-3	
	Fuel Injection Timing - Inspect and Adjust	*	
	Fuel Injection Pump Coupling Bolt and Laminated Plate - Inspect	*	
	Fuel Control Link Ball Joint - Replace (Stop Solenoid and Governor)	*	
	Heat Exchanger - Clean	*	
	Thermostat Operation - Check	*	
	Air Cleaner Element - Clean	*	
	Starter - Inspect	8-26	
	Alternator - Inspect	8-26	
	Protection System Operation - Inspect	*	
	Coolant (Fresh Water) - Change (Every 2 Years)	8-18	

Table 7-1 MAINTENANCE SCHEDULE

Inspection and Maintenance Intervals	Service items	Page	
Every 8000 service hours or every 5 years	Includes service items for every 100, 250, 500, 1000, 2000 and 4000 service hours.	-	
	Engine Overhaul	Piston - Inspect Crankshaft - Inspect Main Bearing - Replace Thrust Plate - Replace Connecting Rod Bearing - Replace Camshaft Bushing - Inspect Cylinder Liners - Replace Piston Ring - Replace Inlet and Exhaust Valves - Replace Inlet and Exhaust Valve Seats - Replace Valve Rotator - Replace Damper - Replace	*
	Fuel Flexible Hose - Replace	*	
	Fuel Injection Pump - Inspect and Adjust (Replace parts as needed)	*	
	Governor - Inspect and Adjust (Replace parts as needed)	*	
	Clamp Seat for High-Pressure Fuel Injection Pipe - Replace	*	
	Oil Cooler - Clean	*	
	Fresh Water Pump Unit Seal and Ball Bearing - Replace	*	
	Seawater Pump Unit Seal and Ball Bearing - Replace	*	
	Tension Pulley Bearing - Replace	*	
	Thermostat - Replace	*	
	Coolant Hose - Replace	*	
	Replace coolant expansion tank cap	*	
	Turbocharger - Overhaul	*	
	Every 16000 service hours or every 10 years	Includes service items for every 100, 250, 500, 1000, 2000, 4000 and 8000 service hours.	-
Replace the following parts with new ones: Piston, connecting rod bushing, piston pin, rocker bush, gear bushing, tappet, 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		*	
As required	Seawater Strainer Mesh Filter - Clean and Replace	8-22	

Note: (a) The table above also includes the parts not supplied by MHIET For the parts that are not supplied by MHIET inspect and maintain them in accordance with the instructions in the manufacturer's (supplier) manual.

(b) Items marked with * in the maintenance schedule require special tools or professional maintenance service. For the servicing of those items, contact a dealer of MHIET.

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

Chapter 8 PERIODIC INSPECTION AND MAINTENANCE PROCEDURES

Engine Proper

Engine External - Inspect

CAUTION

Check external parts of the engine, particularly hot parts (exhaust manifold, etc.) and battery unit for any accumulation of flammable material. Also check for leaks of fluids such as 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 it or contact a dealer of MHIET.

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 a dealer of MHIET.
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.
 - ♦Fuel supply valve: Open
 - ♦Coolant drain cock (valve): Closed
 - ♦Engine oil drain plug: Closed

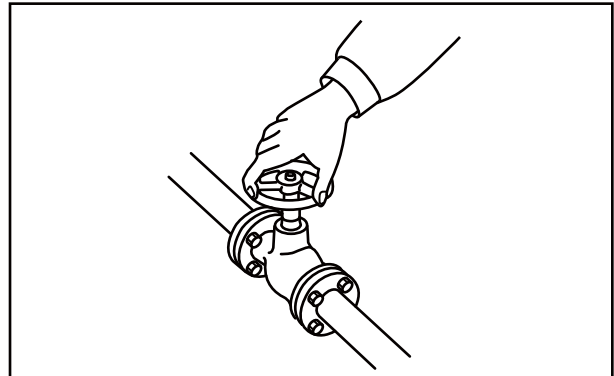


Fig. 8-1 Valves for Open/Closed Position - Check

Belt and Belt Tension - Inspect and Adjust

CAUTION

If defects such as cuts or surface separations are found during 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 correctly 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 10 to 15 mm [0.39 to 0.59 in.], the tension is correct.
Belt pushing force: approx. 98 to 147 N {10 to 15 kgf} [22 to 32.4 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 the adjusting rod.
3. Loosen the lock nut of adjusting rod.
Note: The crankcase side screw at the end of adjusting rod is a left-hand threads.
4. Turn the adjusting rod to adjust the belt tension.
5. After adjusting deflection, fix lock nuts of adjusting rod.
6. Tighten all retaining bolts of the alternator and the adjusting rod.
7. Install the belt cover.

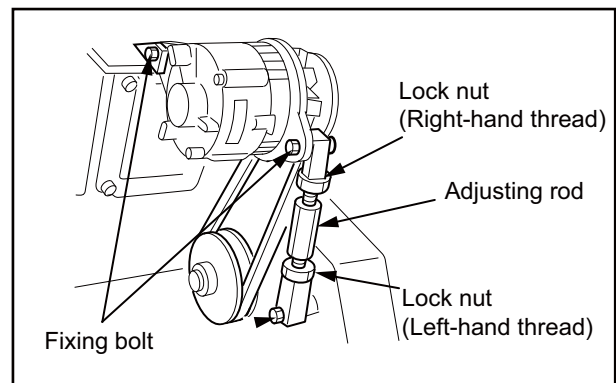


Fig. 8-2 Belt Tension (Alternator Side) - Adjust

Belt Tension (Sea-Water Pump Side) - Adjust

1. Remove the belt cover.
2. Loosen all the bolts that hold the tension bracket.
3. Loosen the lock nuts of the adjusting bolt. Turn the adjusting bolts to adjust the belt tension.
4. Tighten the bolts that hold the tension bracket.
5. Install the belt cover.

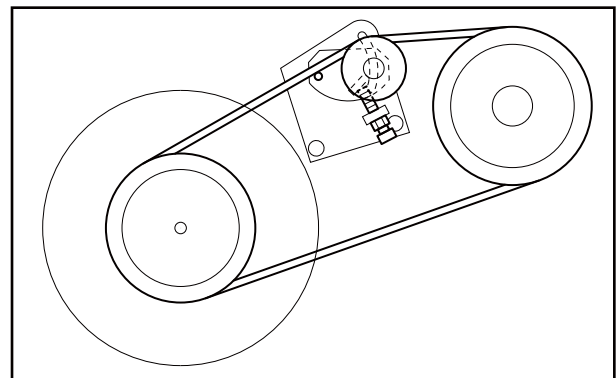


Fig. 8-3 Belt Tension (Sea-Water Pump Side) - Adjust

Damper - Inspect

Damper - Check Visually

CAUTION

The protective cover for the damper should not be air-tight.

Installation of a closed cover can cause damage to the damper due to heat.

Visually check the damper for scratches, silicon oil leaks, and paint discoloration or peeling.

Note: If any defects are found in the damper, contact a dealer of MHIET.

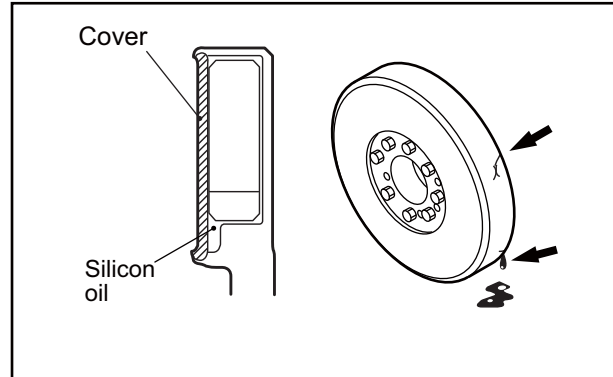


Fig. 8-4 Damper - Check Visually

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.

Change oil to oil having a lower viscosity.

It is necessary to 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, hot coolant steam that can burn you will burst out. 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 could 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.

Draining Sea Water

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 "Draining Sea Water" (8-4).

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

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

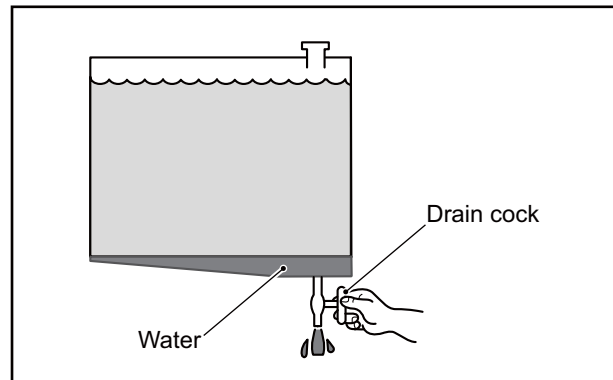


Fig. 8-5 Fuel Tank - Drain Water

Oil-Water Separator - Drain Water

WARNING

From water drain valve, fuel is discharged together with water. Wipe off any spilled fuel completely.

1. Turn the 3-way cock of oil-water separator to the "drain" position with the handle attached to it.
2. Loosen the air vent plug.
3. Open the water drain valve, and drain the water from oil-water separator.
4. Turn the 3-way cock of oil-water separator on the inlet side to the "operation" position.
5. Close the water drain valve.
6. Bleed air from the oil-water separator.
7. Turn the 3-way cock of oil-water separator on the outlet side to the "operation" position.

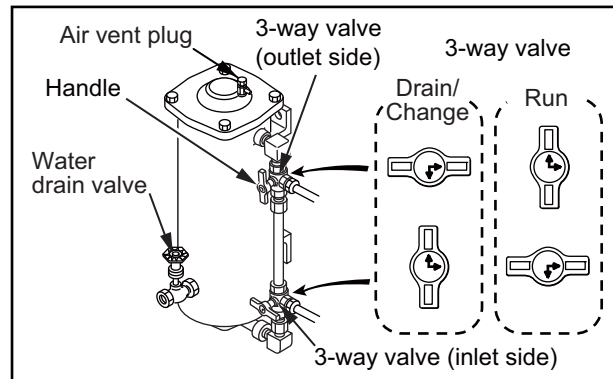


Fig. 8-6 Oil-Water Separator - Drain Water

Oil-Water Separator Element - Replace

1. Place a tray under the oil-water separator to catch fuel.
2. Turn the 3-way cock of oil-water separator to the "Replacement" position with the handle.
3. Loosen the air vent plug.
4. Open the water drain valve, and drain fuel from oil-water separator.
5. Remove the cover mounting bolts and remove the cover.
6. Replace the element with a new one.
7. After confirming that O-ring and spring are attached to the cover, install the cover.

Note: Be sure to use a new O-ring.

8. Close the water drain valve.
9. Bleed air from the oil-water separator.
10. Turn the 3-way cock to "Operation" position.
11. Be sure to bleed air from fuel system after replacement of element.

Note: (a) For bleeding air from fuel system, refer to ["Fuel Filter - Bleed Air" \(3-2\)](#).

- (b) During subsequent engine operation, check for fuel leaks from the cover mounting portion. If fuel leaks, retighten the cover mounting bolts.

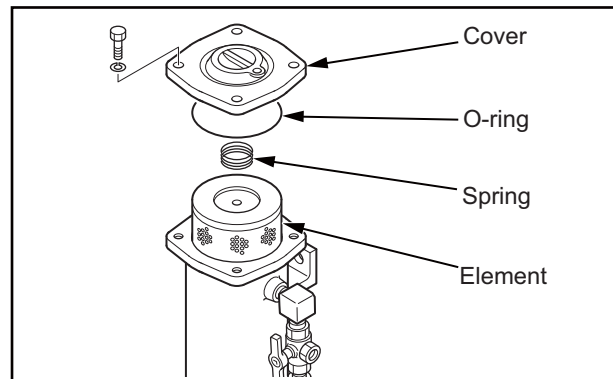


Fig. 8-7 Oil-Water Separator Element - Replace

Gauze Filter - Clean

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

1. Remove the 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. After cleaning, install the gauze filter into the union bolt using a screw driver.
5. Install the union bolt to the fuel feed pump.
6. Bleed air from the fuel filter.

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

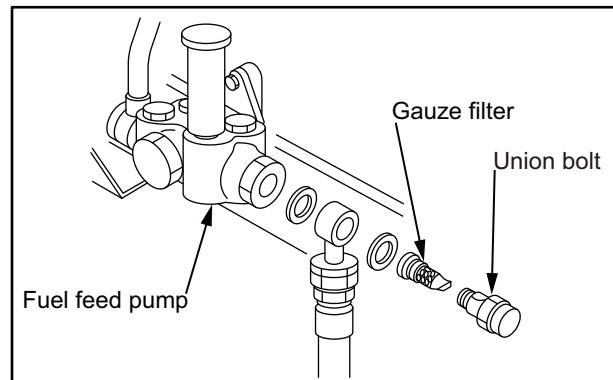


Fig. 8-8 Gauze Filter - Clean

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 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 to a full turn.

CAUTION

Hand tighten fuel filters. 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.

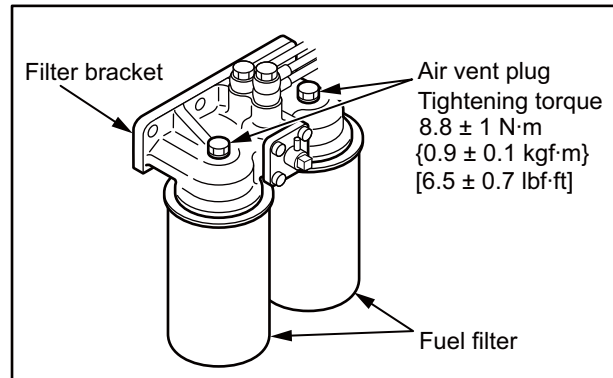


Fig. 8-9 Fuel Filter - Replace

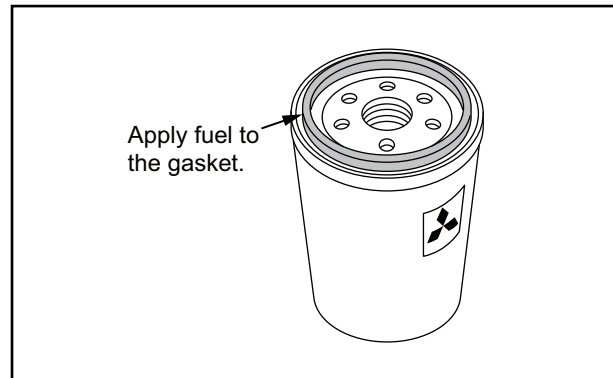


Fig. 8-10 Fuel Filter

Fuel Filter - Replace While Engine is Running

If the engine has to be operated continuously, you can replace fuel filters while the engine is running by turning the switchover cock located between the fuel filters.

Note: (a) In general, the engine must be stopped when replacing fuel filters.

Only if you cannot stop the engine at any cost, replace fuel filters by following the instructions below.

(b) During fuel filter replacement, fuel may flow out from the stop side filter mounting surface. Be sure to place a tray under the fuel filter.

CAUTION

When replacing fuel filters during operation, be sure to decrease engine speed to low idle.

1. Remove the switchover cock cover.
2. Turn the switchover cock and align the pin with the mark.
3. After the fuel filter is replaced, bleed the fuel filter.

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

4. Place the switchover cock in the operating position.
5. Install the switchover cock cover.

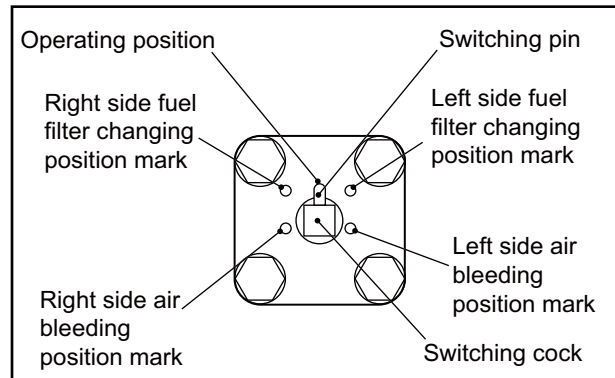


Fig. 8-11 Fuel Filter Switchover Cock

Fuel Control Link Ball Joint - Inspect

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

CAUTION

If the sealed ball joints are found loosened, contact a dealer of MHIET. If the seal on the ball joint is broken, the engine is no longer covered under warranty.

If the ball joints are integrated with the control link, replace the control link assembly. When installing ball joints, be sure to tighten the nuts firmly.

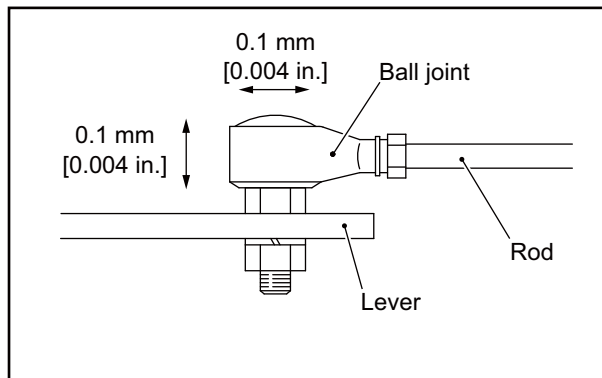


Fig. 8-12 Ball Joints Looseness - Inspect

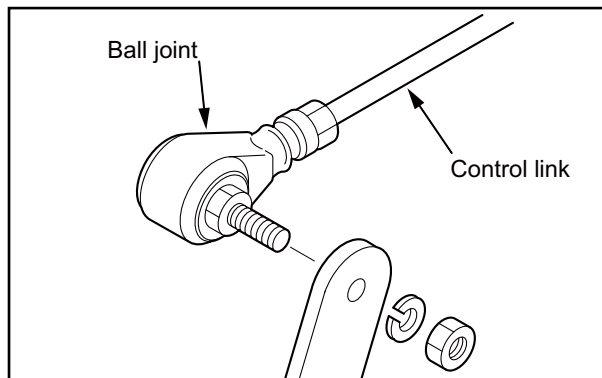


Fig. 8-13 Fuel Control Link - Remove

Fuel Pipe - Inspect

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

Visual Inspection

Check clamp seat for cracks and wear. Check 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 clamp seat with a new one. Also, check 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 (complete replacement).

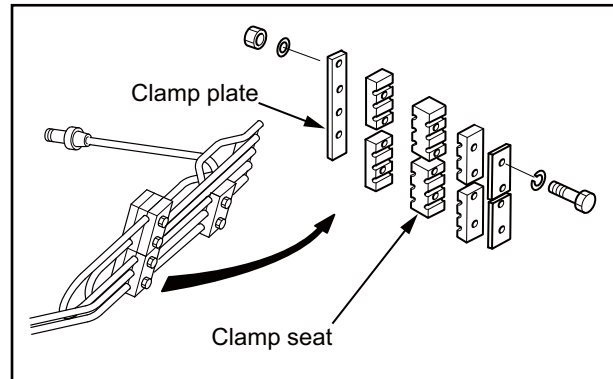


Fig. 8-14 High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

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

Visual Inspection

Loosen 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.

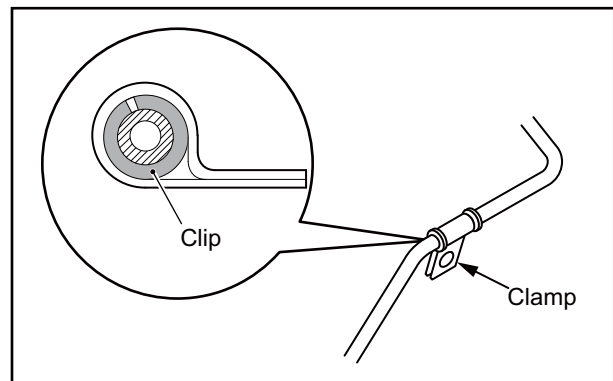


Fig. 8-15 Low Pressure Fuel Pipe, Oil Pipe and Clip - Inspect and Replace

Lubrication System

Engine Oil and Oil Filter - Replace

CAUTION

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

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

CAUTION

Do not dump waste oil. It is forbidden by law. For the disposal of waste oil, consult a dealer of MHIET.

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

Also engine oil analysis is recommended when changing 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 port and drain pump with a vinyl hose.
2. Operate the drain pump to drain engine oil.

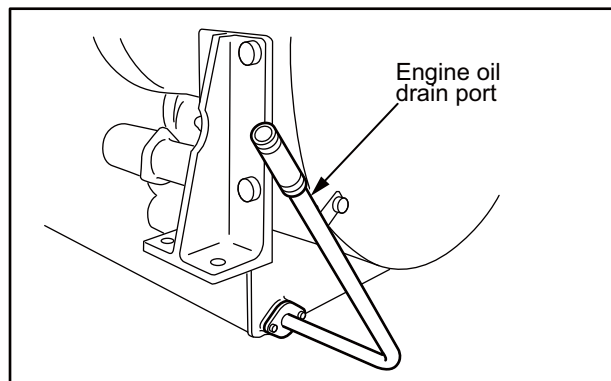


Fig. 8-16 Engine Oil - Drain Port

Engine Oil - Filling

CAUTION

Refill 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 increase 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 oil leak.
9. With the stop lever placed in pulled position, rotate the engine with 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.

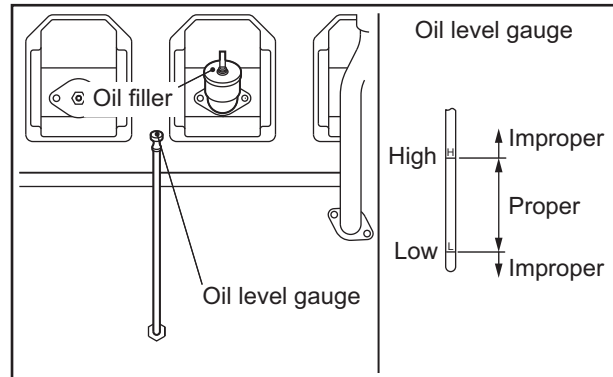


Fig. 8-17 Oil Filler and Oil Level Gauge

Oil Filter - Change

WARNING

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

CAUTION

Hand tighten oil filters. Do not use a filter wrench. Be careful not to dent or scratch oil filter surfaces.

1. Clean the area around oil filters.
2. Place a tray under the oil filter.
3. Using a filter wrench, remove the oil filter.
4. Thoroughly wipe off oil on the oil filter mounting surface of the filter bracket with a cloth.
5. Check the new oil filter to make sure that the gasket is properly seated in the groove.
6. Apply clean engine oil to gasket.
7. Install the oil filter to the filter bracket. When the gasket comes in contact with the mounting surface of the filter bracket, further rotate 3/4 to a full turn.

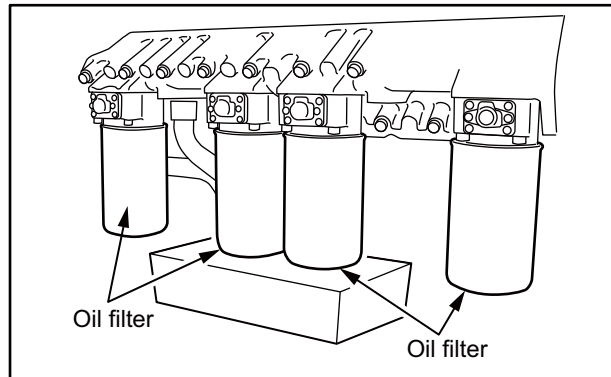


Fig. 8-18 Oil Filter - Change

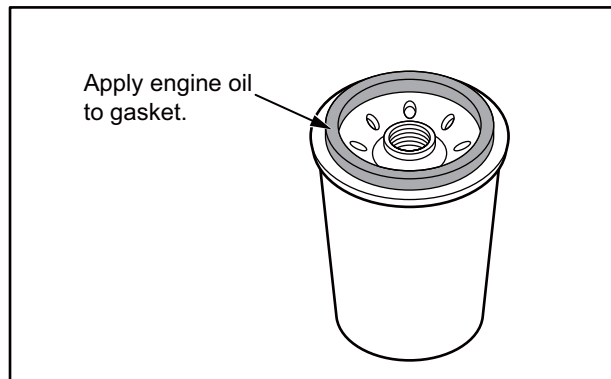


Fig. 8-19 Oil Filter

Oil Filter - Replace While Engine is Running

If the engine cannot be stopped when oil filter change interval has been reached, the oil filter can be replaced while the engine is running by turning the switchover cock located between the oil filters.

Note: (a) Normally, the engine must be stopped when replacing oil filters.

Only if the engine cannot be stopped at any cost, replace the oil filter by following the instructions below.

- (b) Place a tray to catch oil flowing out during filter replacement, as a small amount of oil may leak from filter mounting portion on the stopped side.

CAUTION

When replacing oil filters during operation, be sure to decrease engine speed to low idle.

Do not replace two or more filters at the same time.

1. Remove the switchover cock cover.
2. Turn the switchover cock so that the switchover cock pin faces to the filter replacement position (right side).
This stops the engine oil supply to the filter.
3. Replace the oil filter.
4. Place the switchover cock in the operating position.
5. Install the switchover cock cover.

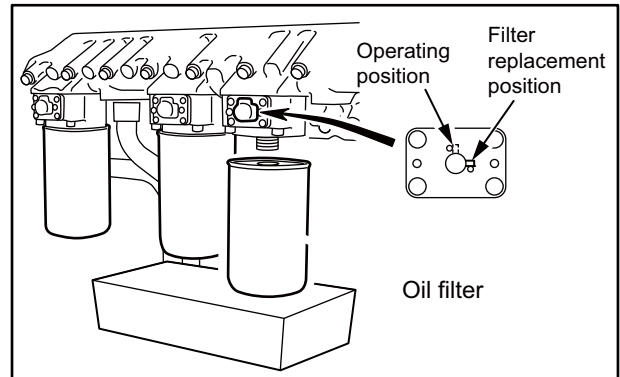


Fig. 8-20 Oil Filter - Replace While Engine is Running

Fuel and Water Ingress 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 L [0.26 to 0.53 U.S. gal.] of engine oil, and check for abnormal odor and discoloration to determine if the oil is mixed 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 you cannot repair, contact a dealer of Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.

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.

Governor Oil Filter - Change

⚠ WARNING

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

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

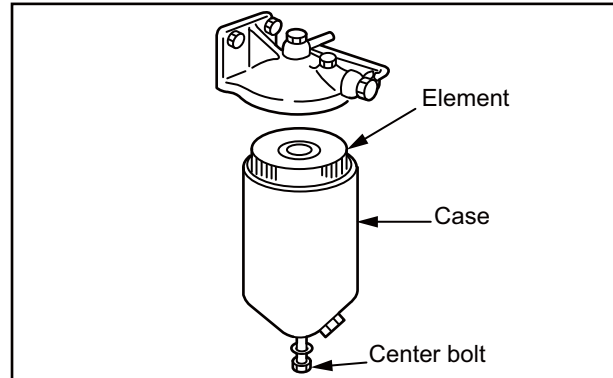


Fig. 8-21 Governor Oil Filter - Change

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, hot coolant steam that can burn you will burst out. 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.

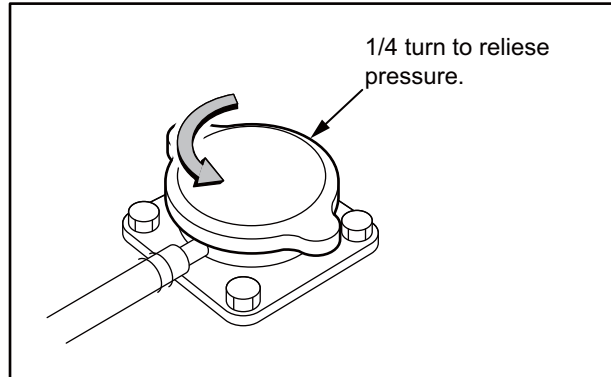


Fig. 8-22 Coolant Expansion Tank Cap

Coolant - Drain

1. After making sure the engine has cooled, open the coolant expansion tank cap.
2. Prepare a can that catches coolant, and open the drain cocks and plugs to drain the coolant.

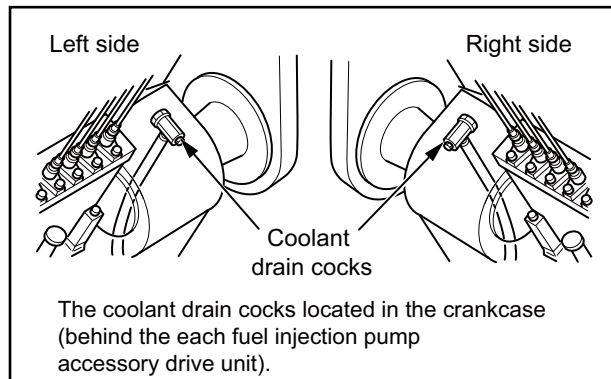


Fig. 8-23 Coolant Drain Cock (Engine Body)

Cooling System - Clean

CAUTION

Wash the cooling system before operating the engine for the first time, or 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.

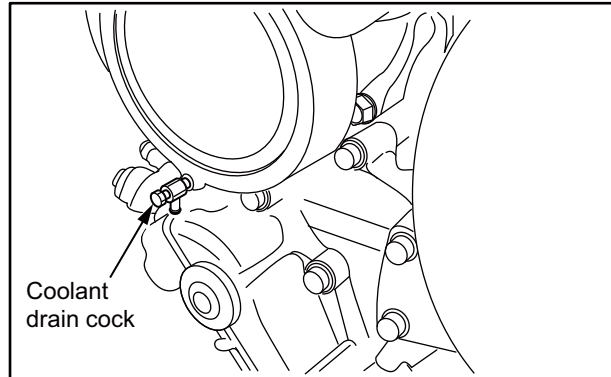


Fig. 8-24 Coolant Drain Cock (Water Pump)

Coolant - Refill

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, hot coolant steam that can burn you will burst out. 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.

CAUTION

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

1. Tighten the drain cocks and plugs firmly.
2. Remove the coolant expansion tank cap, and add a mixture of water and LLC of the specified concentration to the specified level.
Note: Determine the quantity of LLC using 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 coolant expansion tank, etc. for coolant leaks. If a leak is found, repair it.
4. When coolant reaches the specified level, tighten the coolant expansion tank cap firmly.
5. With the manual stop lever placed in the pulled position, crank the engine for approx 10 seconds using the starter. Stop cranking for 1 minute, then, repeat the cranking two or three times to bleed the cooling system.
6. Check the coolant level in the coolant expansion tank.

Draining Sea Water

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 the seawater drain cock or remove the plug to drain seawater.
3. Remove the seawater pump cover, and drain seawater from the seawater pump.

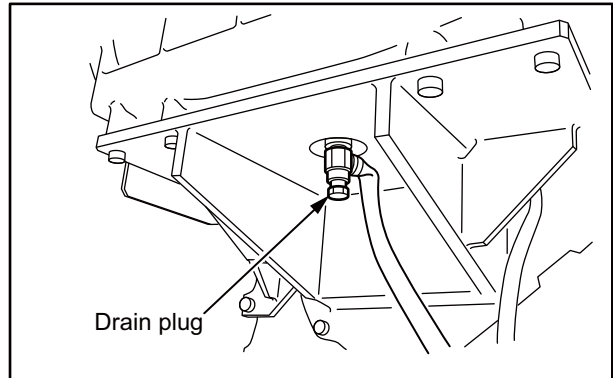


Fig. 8-25 Seawater Drain Cock (Heat Exchanger)

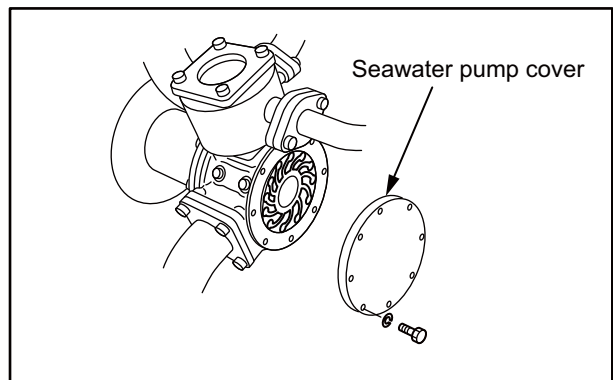


Fig. 8-26 Seawater Pump Cover

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.

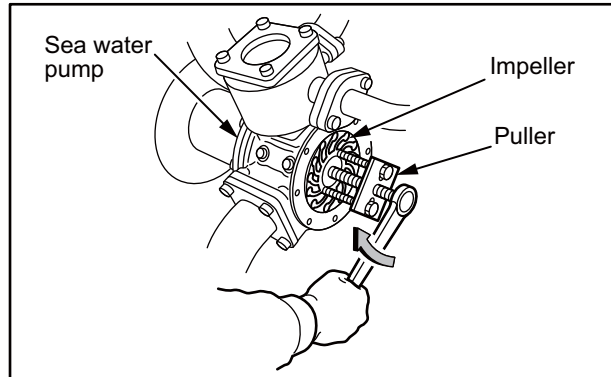


Fig. 8-27 Seawater Pump Impeller - Inspect

Seawater Strainer Mesh Filter - Clean and Replace

CAUTION

Pay attention to the orientation of strainer mesh filter when installing.

Piping shall be free from deformation and stress.

Do not drop or lay any objects on the seawater strainer. Do not use it as a foothold.

When installing O-rings, be careful so that O-ring does not protrude from the groove.

Do not tighten the hexagon cap nut excessively. The outer acrylic casing may be damaged. However, if the tightening torque is too weak, the hexagon cap nut may loosen, causing water leaks, which may result in accidents.

Be sure to tighten to the proper tightening torque.

1. Stop the engine and close the Kingston valve.
2. Drain seawater that remains by loosening the drain plug.
3. Loosen the hexagon cap nut and remove the top cover and O-ring.
4. Remove the strainer and remove trash.
Replace O-ring, strainer, and anti-corrosive zinc as required.
5. Install the strainer mesh filter against the seawater flow.
6. Set the top cover so that the mesh filter is engaged with two filter fixing ribs.
7. Install O-ring and top cover, and tighten the hexagon cap nut. Tightening torque for the nut is 1100 N.m {112.17 kgf.m} [811.32 lbf.ft].
8. Open the Kingston valve.
9. Loosen the air vent plug to bleed air.

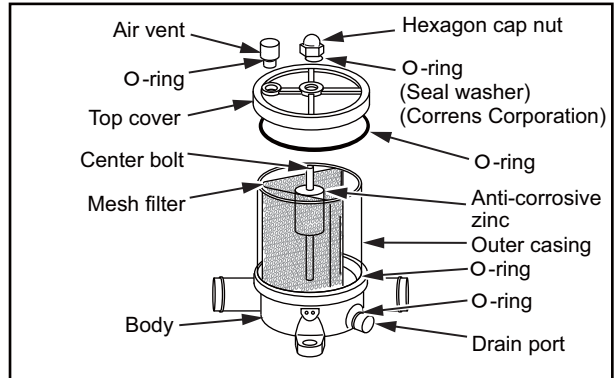


Fig. 8-28 Seawater Strainer Mesh Filter - Clean and Replace

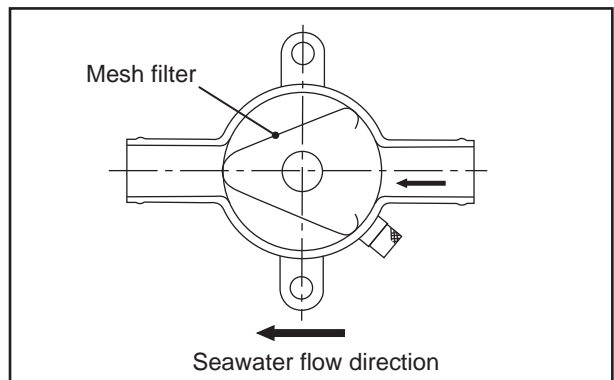


Fig. 8-29 Mounting Orientation of Strainer Mesh Filter

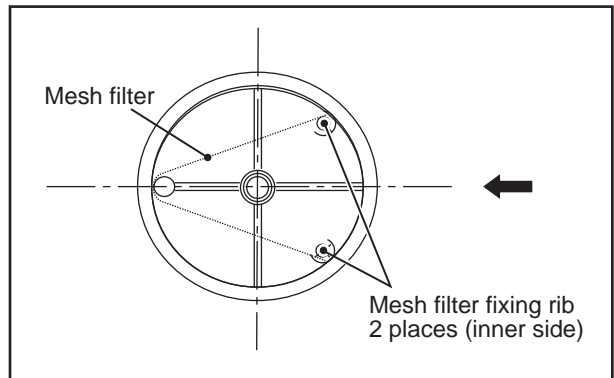


Fig. 8-30 Arrangement to Top Cover

Inlet and Exhaust Systems

Turbocharger - Inspect

CAUTION

Inspect the turbocharger when the engine is cold. Also, 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.

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 looseness. Turn the wheel to check if it rotates smoothly. Replace if there is looseness or the wheel does not rotate smoothly.

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

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

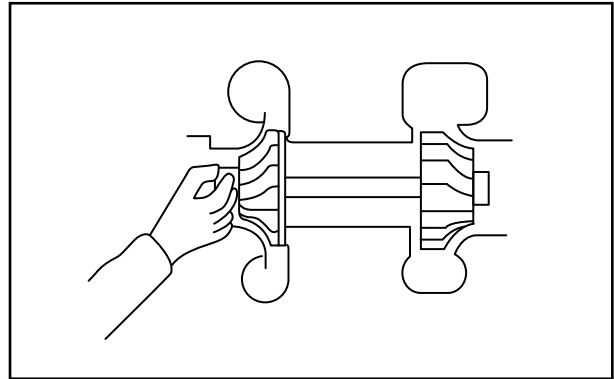


Fig. 8-31 Turbocharger - Inspect

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 removes foreign particles of 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 cleaning, inspection or replacement, install the pre-cleaner to the silencer.

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

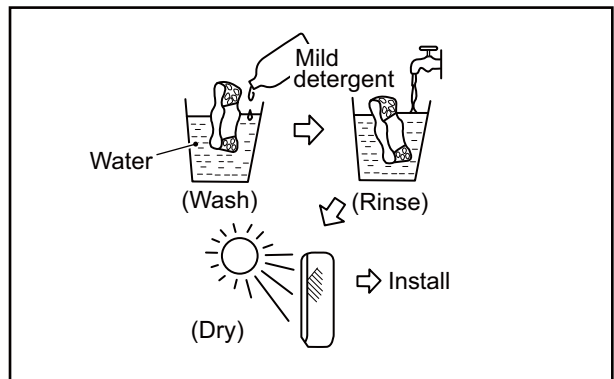


Fig. 8-32 Pre-cleaner - Wash

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 electrolyte level is below the "LOWER LEVEL" mark. Continual use 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.

Remove all battery cables, then charge the battery in a well ventilated area.

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

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

Electrolyte (battery electrolyte) contains dilute sulfuric acid. Careless handling of the battery can lead to loss of sight and/or skin burns. Also, do not swallow the battery electrolyte.

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

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

The battery electrolyte can cause blindness if splashing into the 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 electrolyte, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.

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

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

Battery Electrolyte Level - Check

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

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

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

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

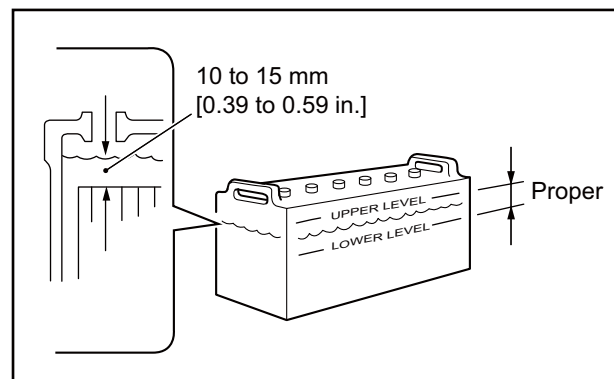


Fig. 8-33 Battery Electrolyte Level - Check

Specific Gravity of Battery Electrolyte - Check

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

Table 8-1 Specific Gravity of Electrolyte

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

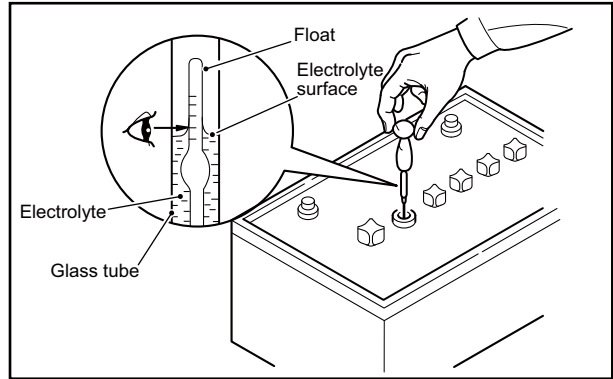


Fig. 8-34 Specific Gravity of Battery Electrolyte - Check

Starter - Inspect

Visually inspect the starter and ring gear for damage.

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

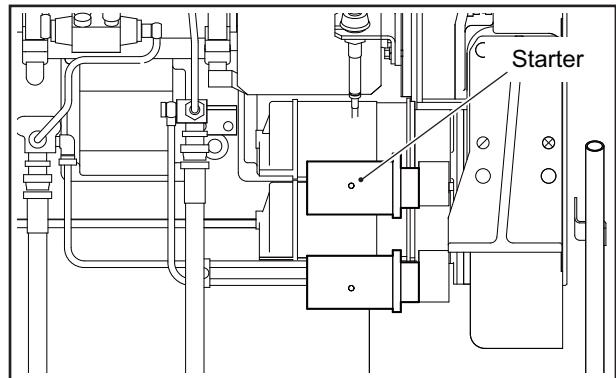


Fig. 8-35 Starter - Inspect

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 since the alternator is an air cooling type.

Note: If the alternator is defective, consult a dealer of MHIET.

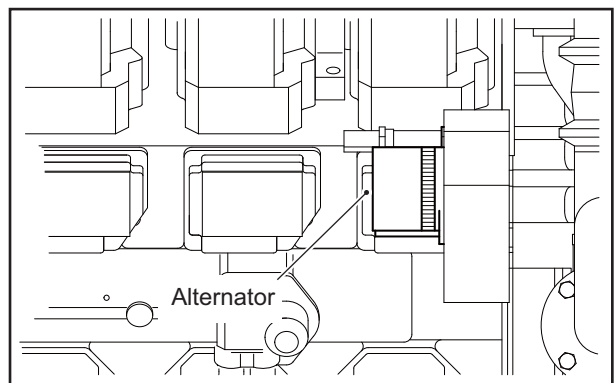


Fig. 8-36 Alternator - Inspect

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) (approx. 1g for example) 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 keep the fuel tank from rusting.
However, FRP tanks do not require any kind of corrosion protection.
7. Apply a sufficient quantity of anti-rust oil (NP-3-2) to the machined exposed 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. Cover the openings with polyethylene sheet or processed polyethylene paper, and place desiccants inside.
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 whole engine.

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

(b) You do not have to drain coolant since it contains LLC. (LLC must be the specified concentration. For LLC concentration, refer to "[LLC concentration \(GLASSY, PG GLASSY\)](#)" (6-7).)

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

Recommended Rust-Preventive Oil and Corrosion Inhibitor

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

JIS No.	Recommended product	Usage
K2246	NP-3-2 Nippon Oil Corporation Anti Rust P-1600	Prevention of rust on 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
Z1519	- 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 electrolyte 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 belt tension adjustment.

5. Remove sealing tapes from 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 "[Fuel Filter - Bleed Air](#)" (3-2).

8. Check the engine oil and coolant level.
9. Inspect each part.
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 approx 10 seconds using the starter.
Stop the operation for approx 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 starting the engine, refer to "[Starting-up](#)" (3-15).

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 can seize when it is started. To prevent such risks, the engine must be operated periodically.

Operating Engine for Maintenance

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 approx 10 seconds using the starter.
Stop the operation for approx 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 starting the engine, refer to "[Starting-up](#)" (3-15).

Lifting Engine

⚠ WARNING

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

Hitch 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 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.

Hitch 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.

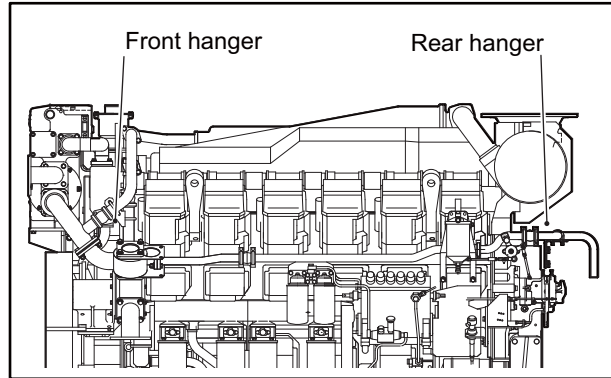


Fig. 10-1 Lifting Hangers

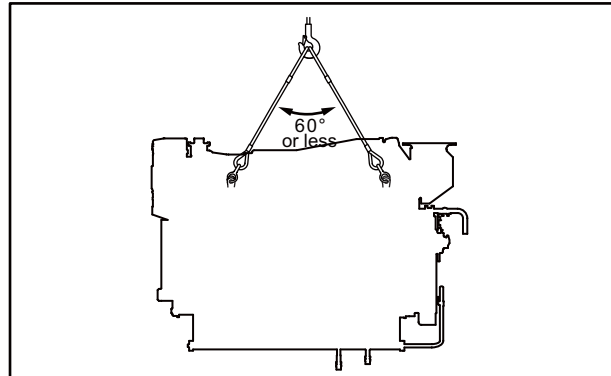


Fig. 10-2 Hitching Wire Ropes

General Precautions

Contact a Dealer of MHIET 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 your engine has failed and needs to be repaired, contact a dealer of MHIET.

Considerations Before Proceeding with Corrective Action

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

Check the parts that may be causing the problem in the most efficient 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 a component, take measures to prevent dust and foreign materials from entering the component being disassembled.

Cautions Regarding Parts Handling

Handle parts carefully.

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

Safety Work

Be sure to use wrenches of the correct size. Using a wrench of the wrong size can cause damage to nuts and also may result in injury.

Use correct 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 a long 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 will also be activated) 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 fresh water capacity
 - Leaks from cooling system
 - Belt tension and damage
 - Seawater pump impeller damage

If you have not found any problems after checking above, contact a dealer of MHIET.

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

Item to be inspected	Remedy	Reference page
Engine oil level decrease	Refill.	3-12
Oil viscosity is too low.	Use engine oil of appropriate viscosity suitable to ambient temperature.	5-3
Clogged oil filter	Replace oil filter.	8-12
Engine oil leaks	Contact your MHIET dealer.	
Lubricating oil pressure warning light failure		

Note: Immediately after starting the engine, oil pressure gauge reads higher the normal pressure as 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

Causes		Solutions
Electrical system	Faulty wire connection	<ul style="list-style-type: none"> ♦Check fuse. ♦Check wiring connection of each relay between battery, starter and starter switch.
	Battery charge failure	<ul style="list-style-type: none"> ♦Check alternator. (Refer to P8-26) ♦Check and adjust belt. (Refer to P8-2)
	Weak battery	<ul style="list-style-type: none"> ♦Check specific gravity of battery electrolyte. (Refer to P8-25) ♦Charge the battery. ♦Change the battery.
	Faulty starter or starter relay	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.
Lubricating system	Oil viscosity too high	<ul style="list-style-type: none"> ♦Use appropriate engine oil. (Refer to P5-1)
	Excessive oil level	<ul style="list-style-type: none"> ♦Check amount of engine oil. (Refer to P3-12)
Engine proper	Sliding parts rapid wear or lock	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Starter Cranks, but Engine Does Not Start

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

Causes		Solutions
Fuel system	Run out of fuel, blocked pipe	<ul style="list-style-type: none"> ♦Inspect fuel tank, refill fuel, bleed air. (Refer to P3-2) ♦Check fuel pipes and valves.
	Improper fuel properties	<ul style="list-style-type: none"> ♦Use appropriate fuel. (Refer to P4-1) ♦Remove dust, water or impurities. (Refer to P3-1)
	Fuel leaks from fuel line or injection pipe	<ul style="list-style-type: none"> ♦Check fuel lines and injection pipes for damage, and retighten if necessary. ♦Contact your MHIET dealer.
	Clogged fuel filter	<ul style="list-style-type: none"> ♦Inspect and replace fuel filter. (Refer to P8-8) ♦Inspect and replace oil-water separator element. (Refer to P8-6) ♦Clean gauze filter. (Refer to P8-7)
	Fuel feed pump malfunction	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.
	Fuel injection pump malfunction	<ul style="list-style-type: none"> ♦Check fuel injection pump rack stroke. ♦Contact your MHIET dealer.
	Fuel injection nozzle malfunction	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.
Air intake system	Insufficient amount of intake air	<ul style="list-style-type: none"> ♦Clean and inspect inlet system. ♦Contact your MHIET dealer.
Control system	Governor malfunction	<ul style="list-style-type: none"> ♦Check fuel control link operation. ♦Contact your MHIET dealer.
Engine proper	Compression pressure drop	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Insufficient Output

Table 11-4 Insufficient Output

Causes		Solutions
Fuel system	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1)
	Clogged fuel filter	•Inspect and replace fuel filter. (Refer to P8-8) •Clean gauze filter. (Refer to P8-7)
	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	•Check fuel injection pump couplings. •Contact your MHIET dealer.
	Improper maximum injection volume	•Check fuel injection pump rack stroke. •Contact your MHIET dealer.
Cooling system	Overheating, overcooling	•Check belt and adjust its tension. (Refer to P8-2) •Check seawater pump impeller and drive shaft. •Check heat exchanger. •Check control system. •Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	•Check turbocharger. (Refer to P8-23) •Clean, inspect and replace pre-cleaner. (Refer to P8-23) •Check intake air pressure and check for intake air leaks. •Check intake air temperature. •Contact your MHIET dealer.
	Increased resistance of exhaust air	•Check exhaust pipe. •Contact your MHIET dealer.
Engine proper	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	•Check propeller and propeller shaft. •Remove deposits.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Exhaust Smoke is White or Blue

Table 11-5 Exhaust Smoke is White or Blue

Causes		Solutions
Fuel system	Improper fuel properties	•Check cetane index, and use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Contact your MHIET dealer.
	Fuel injection nozzle malfunction	•Contact your MHIET dealer.
	Uneven volume of fuel injection	•Check ignition noise and exhaust smoke temperature. •Contact your MHIET dealer.
	Incorrect fuel injection timing	•Contact your MHIET dealer.
Lubricating system	Combustion of engine oil	•Check amount of engine oil. (Refer to P3-12) •Contact your MHIET dealer.
Cooling system	Overcooling	•Check control system. •Thermostat - Inspect •Contact your MHIET dealer.
Engine proper	Faulty valve timing	•Contact your MHIET dealer.
	Compression pressure drop	•Contact your MHIET dealer.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Exhaust Smoke is Black or Charcoal

Table 11-6 Exhaust Smoke is Black or Charcoal

Causes		Solutions
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	♦Check fuel injection pump couplings. ♦Contact your MHIET dealer.
	Uneven volume of fuel injection	♦Check exhaust gas temperature. ♦Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	♦Turbocharger - Inspect ♦Air Cleaner - Clean, Inspect and Replace ♦Check intake air pressure and check for intake air leaks. ♦Check intake air temperature and ventilation system. ♦Contact your MHIET dealer.
	Increase of exhaust resistance	♦Turbocharger - Inspect ♦Check exhaust pipe. ♦Contact your MHIET dealer.
Engine proper	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	♦Check load system. ♦Contact your MHIET dealer.
Rig	Excessive load	♦Adjust propeller matching.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Excessive Fuel Consumption

Table 11-7 Excessive Fuel Consumption

Causes		Solutions
Fuel system	Fuel injection nozzle malfunction	♦Contact your MHIET dealer.
	Faulty fuel injection timing	♦Check fuel injection pump couplings. ♦Contact your MHIET dealer.
	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1)
	Fuel leaks from fuel line or injection pipe	♦Check fuel lines and injection pipes for damage, and retighten if necessary. ♦Contact your MHIET dealer.
Cooling system	Overcooling	♦Check control system. ♦Thermostat - Inspect ♦Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	♦Turbocharger - Inspect ♦Air Cleaner - Clean, Inspect and Replace ♦Check intake air pressure and check for intake air leaks. ♦Check intake air temperature and ventilation system. ♦Contact your MHIET dealer.
	Increase of exhaust resistance	♦Turbocharger - Inspect ♦Check exhaust pipe. ♦Contact your MHIET dealer.
Engine proper	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	♦Adjust propeller matching.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Excessive Engine Oil Consumption

Table 11-8 Excessive Engine Oil Consumption

Causes		Solutions
Fuel system	Faulty fuel injection timing	<ul style="list-style-type: none"> •Check fuel injection pump couplings. •Contact your MHIET dealer.
Lubricating system	Oil leaking on outside engine	<ul style="list-style-type: none"> •Check oil leaks. •Contact your MHIET dealer.
	Engine oil viscosity too low	<ul style="list-style-type: none"> •Use appropriate oil viscosity. (Refer to P5-3)
	Excessive engine oil temperature	<ul style="list-style-type: none"> •Check amount of engine oil. (Refer to P3-12) •Check oil cooler and oil thermostat •Contact your MHIET dealer.
Cooling system	Overheating	<ul style="list-style-type: none"> •Check control system. •Thermostat - Inspect •Contact your MHIET dealer.
Inlet and exhaust systems	Oil entry to the air chamber	<ul style="list-style-type: none"> •Contact your MHIET dealer.
	Worn parts in valve operating system	<ul style="list-style-type: none"> •Contact your MHIET dealer.
Engine proper	Wear of sliding parts	<ul style="list-style-type: none"> •Contact your MHIET dealer.
Load system	Excessive load	<ul style="list-style-type: none"> •Check load system. •Contact your MHIET dealer.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Overheating

Table 11-9 Overheating

Causes		Solutions
Cooling system	Insufficient coolant level	<ul style="list-style-type: none"> •Check coolant leakage. •Check Coolant Level. (Refer to P3-13)
	Faulty water pump operation	<ul style="list-style-type: none"> •Contact your MHIET dealer.
	Faulty thermostat operation	<ul style="list-style-type: none"> •Contact your MHIET dealer.
Load system	Excessive load	<ul style="list-style-type: none"> •Check load system. •Contact your MHIET dealer.
Engine proper	Rapid wear of sliding parts	<ul style="list-style-type: none"> •Contact your MHIET dealer.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

Engine Oil Pressure Drop

Table 11-10 Engine Oil Pressure Drop

Causes		Solutions
Lubricating system	Low engine oil level	♦Check engine oil level. (Refer to P3-12)
	Faulty engine oil property (viscosity)	♦Analyze oil property. Use appropriate engine oil. (Refer to P5-3)
	Oil temperature too high	♦Cooling System - Check ♦Contact your MHIET dealer.
	Clogged oil filter	♦Inspect and replace oil filter. (Refer to P8-12)
	Faulty oil pump operation	♦Contact your MHIET dealer.
	Faulty relief valve operation	♦Contact your MHIET dealer.
Control system	Faulty pressure unit operation	♦Check control system and wiring. ♦Contact your MHIET dealer.
Engine proper	Rapid wear of sliding parts	♦Contact your MHIET dealer.
	Increased clearance of sliding part.	♦Contact your MHIET dealer.
Load system	Excessive load	♦Check load system. ♦Contact your MHIET dealer.

Note: The table above also includes the parts not supplied by MHIET For the parts not supplied by MHIET inspect and maintain them by following the manufacturer's operation manual.

When Fuel has Run Out

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

1. Turn the starter switch to the "OFF" position.
2. Add fuel to 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 "[Fuel Filter - Bleed Air](#)" (3-2).
4. Start the engine.
For starting the engine, refer to "[Starting-up](#)" (3-15).

Chapter 12 MAIN SPECIFICATIONS

Main Specifications

Table 12-1 Main Specifications

Item	Specifications
Engine model	S12R-T2MPTK
Rated output	1210 kW {1645 PS} / 1800 min ⁻¹ (Light Duty) 1040 kW {1414 PS} / 1650 min ⁻¹ (Midium Duty) 940 kW {1278 PS} / 1600 min ⁻¹ (Heavy Duty)
Type	Vertical, water-cooled, 4-stroke cycle, turbocharged with intercooler
No. of cylinders, arrangement	12-V
Cylinder bore x stroke	ø170 × 180 mm [6.69 x 7.09 in.]
Displacement (declared value)	49.0 L [2990 cu. in.]
Combustion system	Direct injection system
Compression ratio	14.5 : 1
Firing order	1-12-5-8-3-10-6-7-2-11-4-9
Rotational direction	Counterclockwise as viewed from the stern.
Dimensions (L × W × H)	2556.5 × 1622 × 1727.5 mm [100.65 × 63.86 × 68.01 in.]
Dry weight	Approx. 5500 kg [12125 lb.]
Fuel	Diesel fuel "Representative engine test fuel oil: fuel composition DMX (diesel fuel)"
Fuel injection pump	PS6 type × 2
Fuel filter	Cartridge type paper-element
Fuel injection nozzle	Hole type
Fuel injection starting pressure	34.3 MPa {350 kgf/cm ² } [4978 psi]
Governor	Hydraulic type (all-speed control)
Lubrication method	Forced circulation (pressure feed by oil pump)
Lubrication oil	Grade CF or CH-4 oil (API service classification)
Engine oil capacity	Oil pan: approx. 200 L [52 U.S. gal.], Whole engine: approx. 230 L [60 U.S. gal.]
Oil filter	Cartridge type paper-element
Oil cooler	Water cooled multi-plate
Cooling method	Freshwater cooler directly connected to engine
Cooling fresh water capacity	Approx. 227 L [59 U.S. gal.] (engine body)
Starting system	Electric start
Starter	DC24 V - 7.5 kW x 2
Alternator	DC24 V - 35 A
Turbocharger	Mitsubishi TF15/TD13

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

Chapter 13 ELECTRICAL WIRING DIAGRAM

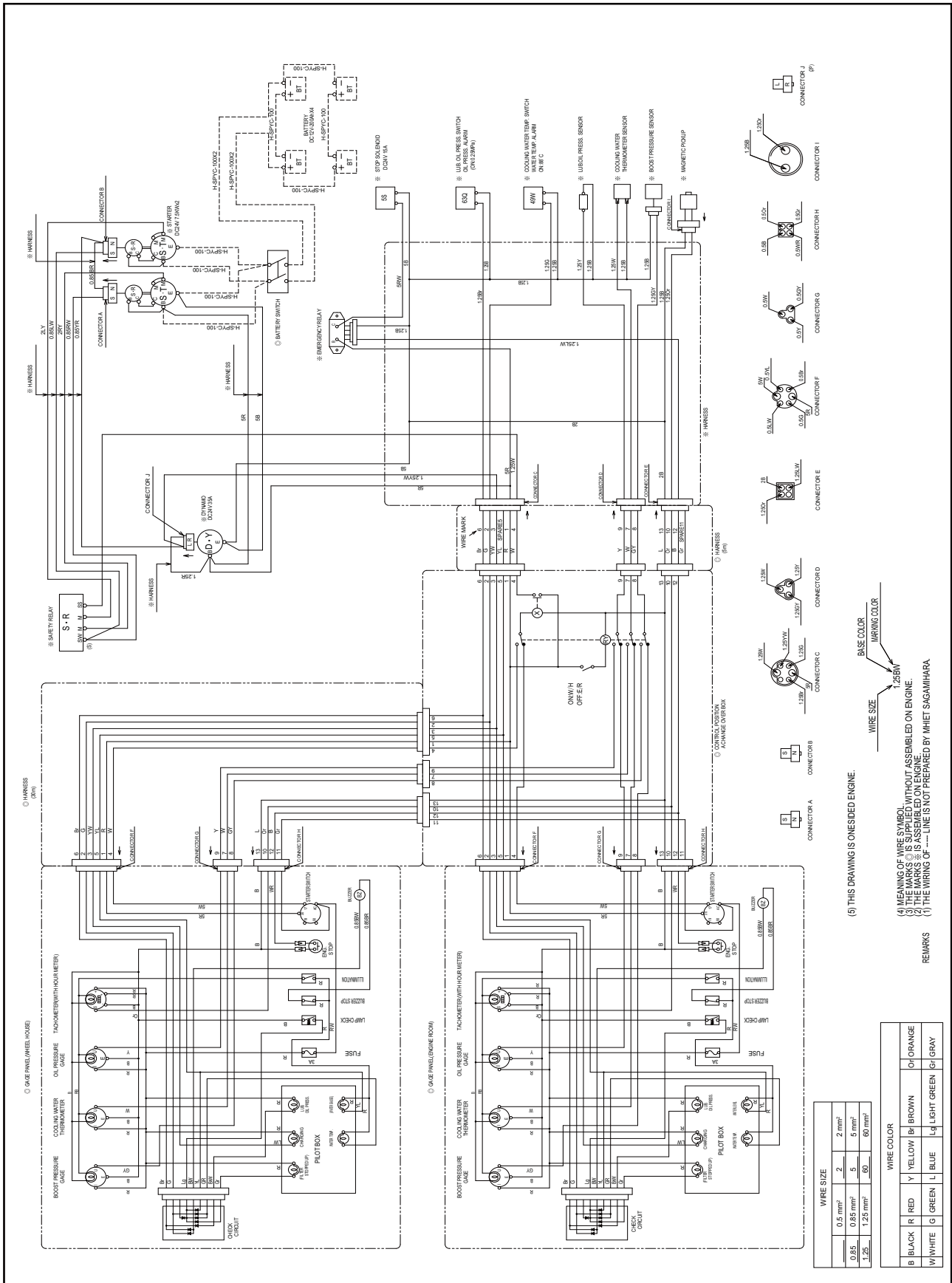


Fig. 13-1 Electrical Wiring Diagram

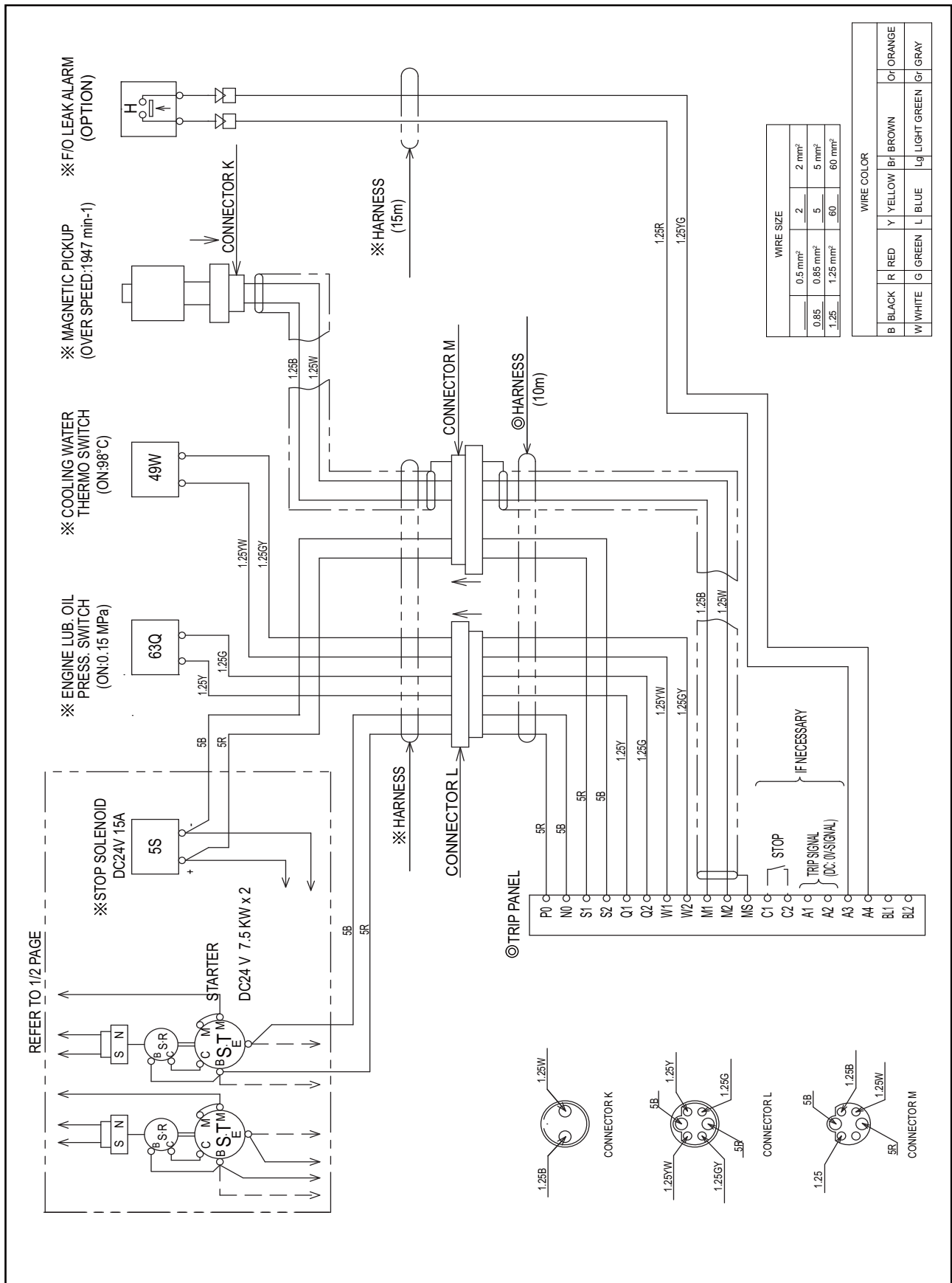


Fig. 13-2 Electrical Wiring Diagram

Mitsubishi Marine Engine S12R-T2MPTK OPERATION & MAINTENANCE MANUAL

Issued in September 2012

Pub. No. 291T1-00120

Issued by Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.
3000, Tana, Chuo-ku, Sagamihara, Kanagawa, 252-5293, Japan

Edited by MHI Sagami High-tech LTD.

Printed and bound by Fuji Xerox Service Link Co., Ltd.

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September 2012

OPERATION & MAINTENANCE MANUAL

SI2R-T2MPTK

Pub. No. 291T1-00120