

# **MITSUBISHI MARINE ENGINE S12A2-T2MPTK**

for Mitsubishi Heavy Industries(Shanghai)Co.,ltd

## **OPERATION & MAINTENANCE MANUAL**

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### **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.



**MITSUBISHI HEAVY INDUSTRIES  
ENGINE & TURBOCHARGER**

♦Company names or product names described in this Operation & Maintenance Manual are trademarks or registered trademarks of their respective owners in general.

# FOREWORD

This Operation & Maintenance Manual describes information and basic points required to use the Mitsubishi Diesel Engine (hereinafter called the "engine") correctly and effectively.

Please read this manual before using the engine.

In addition, operation, inspection and maintenance of the engine must be limited to the persons who understand the contents of this manual sufficiently.

Failure to follow instructions in this manual may result in serious accidents and increase in emission gas.

## ■ 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](http://www.P65warnings.ca.gov/diesel).

## Important Information

### Important Tips for Safety of Work

- ♦To avoid a potential risk, you must thoroughly understand the functions of this engine.
- ♦All involved personnel should actively participate, recognize their roles, and organize themselves and their work to ensure a safe environment.
- ♦To prevent injury, fatal accident or damage to this engine, you must obey the cautions, compliance rules and normal directions of use described in this manual while giving the highest priority to safety. If you do not obey them,
  - ♦it could result in death in the worst case.
  - ♦it could threaten your health.
  - ♦it may cause damage to this engine or the devices.
- ♦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, inspecting, and maintaining the engine.

- ♦Descriptions about devices and facilities outside the scope of our supply are included in this manual. For the devices and facilities outside the scope of our supply, refer to the corresponding manual of the generator and the supplier's operation manual and obey the descriptions.
- ♦Electrical instruments must be inspected or maintained by a person who has received education and training for handling and avoiding risks about the electrical instruments on the machine, in addition to general knowledge needed for electric construction work.

### General

- ♦This engine must be operated, inspected and maintained only by qualified persons who have thorough knowledge of engines and their dangers, and also have received risk avoidance training.
- ♦Be sure to read and understand this manual before operating, inspecting, and maintaining the engine. Working with insufficient understanding could cause personal injury or damage to the devices due to unexpected operation of them.
- ♦Inadequate operation or maintenance will cause unexpected damage to the device due to accumulated engine damage if not cause immediate failure. Carefully perform engine operation and maintenance.
- ♦Be sure to obey the applicable laws and regulations of the national government and other local municipalities.
- ♦When disposing this engine, follow the method defined by the national government or other local municipalities.
- ♦When discarding fuel, engine oil, or coolant, follow the method defined by the national government or other local municipalities.
- ♦The devices covered by the recycle law and those for which recycling requirements are stipulated shall be disposed in accordance with the corresponding laws and regulations.
- ♦Install an hour meter on the engine so that you can find the exact engine operating time, thereby performing the specified maintenance at the appropriate time in accordance the Scheduled Maintenance as described herein.
- ♦When modifying this engine, changing the specifications, and disassembling it, contact your Mitsubishi dealer. If the customer modifies the engine or changes the specifications, it could become impossible to ensure safety.

- ♦ Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET) cannot foresee all potential dangers of the engine, potential dangers resulting from human error and other causes, or a danger caused by a specific environment in which the engine is used.
- ♦ For the devices and facilities outside the scope of our supply, provide the corresponding manuals as "Usage Information" to the operators and let them obey the descriptions. MHIET will not bear a responsibility for damage or injury caused by the devices and facilities outside the scope of our supply.
- ♦ In some countries or regions, this engine cannot be used depending on the laws, regulations and installation environment. When transferring this engine to a third party, check the regional conditions of them and contact your Mitsubishi dealer.
- ♦ Make sure that all warning/caution/emission labels are legible. Clean or replace the labels when the description and/or illustration are not clear to read.
  - ♦ Illegible labels fail to alert people, which may cause personal injury, environmental pollution, and damage to the engine.
- ♦ For cleaning the labels, use a cloth and soapy water. DO NOT USE CLEANING SOLVENTS, GASOLINE, OR OTHER CHEMICALS THAT MAY ERASE THE PRINT OR CAUSE PEELING OFF OF THE LABEL. If the labels are damaged, replace them with new ones.
- ♦ When replacing a part that has a label attached, attach the new label to the new part so that it is in the same state as before replacement.
- ♦ New labels are available at your MHIET dealer, MHIET group company, or MHIET.

## Important Tips for Managing Safety of Work

- ♦ You must prepare a "Safety Manual", which describes your management criteria and operation rules. The supervisor must have the operators understand the "Safety Manual" preliminarily. In addition, keep the manual at hand so the operator can read it whenever necessary.
- ♦ In order to prevent a disaster, the accident prevention measures must be suitable for the functions and specifications of this engine.
- ♦ The accident prevention activities must be as the occupational safety and health management system planned and performed organizationally and continuously. This occupational safety and health management system must include the following points:
  - ♦ Proper location of this engine
  - ♦ Instructions concerning maintenance and usage of the operators' personal protective equipment
  - ♦ Organization of the operation management system such as preparation of operation standards, clarification of the operation command system, etc.
  - ♦ Education and training of the operators
- ♦ Important purposes of the safety measures are to prevent personal injuries, protect the environment, and protect the engine. Always consider environmental protection.
- ♦ Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET) shall accept no responsibility for loss or injury resulting from not observing instructions in this manual, or not paying attention to commonly required precautions when operating, inspecting or maintaining this engine.

## About This Manual

- ♦ This manual is intended for native speakers of the language in which the manual is written. If the operator of this engine is not a native speaker of the language used in this manual, the owner of the engine is requested to provide thorough safety guidance to the operator. Also prepare and affix warning labels written in the native language of the operators.
- ♦ MHIET possesses the copyright of this manual. All rights reserved. No part of this manual, including illustrations and technical descriptions, may be photocopied, translated, or reproduced, in whole or in part, in any electronic medium or machine readable form without prior written consent from MHIET.
- ♦ Illustrations in this manual may differ from the engine you have purchased. Covers can be omitted from illustrations to provide a better view of the inside.
- ♦ The contents of this manual are subject to change without any notice.
- ♦ When transferring this engine to a third party, make sure to attach this manual.
- ♦ Keep this manual in the usual place so that it can be used any time.
- ♦ If you need more information or if you have any questions, contact your Mitsubishi dealer.

## Warranty Provisions

1. Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (hereinafter referred to as MHIET) shall make a repair or replacement of a failure or damage at no charge, only when the said failure or damage occurs during the warranty period (refer to the individual contract) of this engine, and MHIET admits that its cause arises from the material, a problem of production, or a problem concerning our construction work within the scope of the contract specifications. The above-mentioned warranty period of this engine is not updated or prolonged by the said repair.
2. The above-mentioned warranty is the only one provided by MHIET concerning this engine.  
No new contracts or warranties arise from this manual.  
MHIET will not bear a responsibility for any loss (including, but not limited to direct loss, indirect loss, lost profits, operating losses, down time loss, etc.) caused by any reason, regardless of whether the warranty period is expired or not.
3. The warranty coverage is effective for the original purchaser only. Those to whom ownership is later transferred are not provided with the warranty.
4. We may deny the warranty coverage regardless of the warranty period if fault or damage has been caused to the engine by any reason mentioned below:
  - ♦ Fault or damage caused by operation or maintenance deviated from the instructions or cautions described in this manual
  - ♦ Fault or damage caused by being repaired or modified by other than us/Mitsubishi dealer, or by illegal act
  - ♦ Fault or damage caused by abuse, misuse, incorrect operation or misapplication
  - ♦ Fault or damage caused by operation or maintenance beyond the specification limit
  - ♦ Fault or damage caused by use of spare parts, optional parts or consumables (including engine oil, LLC and fuel) that MHIET do not recommend
  - ♦ Fault or damage caused by a natural disaster (earthquake, typhoon, flood, seismic sea waves, volcanic eruption, etc.) fire, war, terrorism, or other abnormal operational conditions which MHIET cannot bear responsibility
  - ♦ Fault or damage caused by the location of this engine (for example, electromagnetic environment stress)
  - ♦ Fault or damage caused by resale or relocation
  - ♦ Fault or damage caused by consumption or age deterioration
  - ♦ Fault or damage caused by other reasons which MHIET cannot bear responsibility

## Warning Indication

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

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

### Warning Statements

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

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

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



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



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



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



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

Note:

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

## Unit of Measurement

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

- ♦Pressure: 1 MPa = 10.197 kgf/cm<sup>2</sup>
- ♦Torque: 1 N•m = 0.10197 kgf•m
- ♦Force: 1 N = 0.10197 kgf
- ♦Power, output: 1 kW = 1.341 HP = 1.3596 PS
- ♦Rotational speed: 1 min<sup>-1</sup> = 1 rpm
- ♦Kinetic viscosity: 1 mm<sup>2</sup>/s = 1 cSt

## Abbreviations, Standards and Others

- ♦API = American Petroleum Institute
- ♦ASTM = ASTM International
- ♦CARB = California Air Resources Board
- ♦CCS = Cold Cranking Simulator
- ♦EPA = United States Environmental Protection Agency
- ♦FED = Federal Specifications and Standards
- ♦ISO = International Organization for Standardization
- ♦JIS = Japanese Industrial Standards
- ♦JPI = Japan Petroleum Institute
- ♦LLC = Long Life Coolant
- ♦MHIET = Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.
- ♦MRV = Mini - Rotary Viscometer
- ♦OSHA = Occupational Safety and Health Administration
- ♦SAE = Society of Automotive Engineers
- ♦SDS = Safety Data Sheet

# 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 on board 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 the engine or do maintenance work (part replacement, adjustment), you must follow the instructions described in the Technical File and perform the repair or maintenance work properly. Ship-owner, captain, and chief engineers have a responsibility to verify the work that has been done, and record every detail of work on "Maintenance Records for Parameters" in the Technical File with signatures.



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# Chapter 1 SAFETY CAUTIONS

## Fire and Explosion Protection



**WARNING**

### Keep Flames Away

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



Wipe off spilled fuel, engine oil, and LLC immediately and thoroughly. Spilled fuel, engine oil, and LLC may ignite and cause a fire. Store the 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 may cause a fire or explosion.

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

### Pay Attention to Engine Room Ventilation

Always keep the engine room well ventilated. Insufficient air in the room may cause an increase in the engine temperature and a decrease in the output power and performance. Prior to installation of the engine, it is recommended to provide an adequate ventilation system by calculating the proper amount of supply air needed for the engine.

### Do Not Open Side Covers Until Engine Cools

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

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

### Be Alert for Leaking Fuel, Oil, or Exhaust Gas

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

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

### Use Explosion-Proof Light

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

### Prevention of Electric Short Circuit

Do not inspect or repair the electrical system with the ground cable connected to the battery. Otherwise, a fire could result from short-circuit. Be sure to disconnect the battery cable from the negative (-) terminal before proceeding with any work.

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

### Keep Fire Extinguishers and First-Aid Kit Handy

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



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

# Stay Away From Rotating and Moving Parts



## WARNING

### Keep Rotating Parts Covered for Safety

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



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

Never remove the protective covers.

### Check Work Area for Safety Before Starting

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

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

### Stay Away From Moving Parts During Operation

Stay away from rotating parts of the engine while the engine is running. Do not place any objects which might be easily entangled near the rotating parts.



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

### Lockout and Tagout

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

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

To accomplish the lockout/tagout, remove the starter switch key, place the battery switch to the OFF position and attach a "DO NOT OPERATE" or similar caution sign to the starter switch.

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

### Be Sure to Stop Engine Before Inspection/Maintenance

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

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

### Always Put Turning Tool Back in Place After Use

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

Starting the engine with the turning tool inserted or with the turning gear engaged may lead to not only engine damage but also personal injuries.

## Prevention of Exhaust Gas Poisoning

### WARNING

### Pay Attention to Ventilation When Operating Engine

Check exhaust pipes and pipe joints for gas leaks.

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



### California, U.S.A-Proposition 65 Warning Statement

#### WARNING

The engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects or other reproductive harm.

## Prevention of Hearing Loss

### CAUTION

### Wear Ear Plugs

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



## Fall Prevention

### WARNING

### Lift Engine Carefully

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

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

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

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

Keep the angle formed by slings that are attached to hangers within 60 degrees. If the angle exceeds this limit, an 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 the Engine

Do not climb onto the engine, nor step on any engine parts, which located on the engine 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 could result in a personal injury.

### Always Use a Stable Foothold During Maintenance

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

Do not stand on an unstable stool or parts box. Otherwise, it could result in personal injury.

Do not put any unnecessary objects on a work platform.



## Burn Protection



**CAUTION**

### Do Not Touch Engine During or Immediately After Operation

Do not touch any part of the engine during or immediately after operation. A hot engine may cause burns.

Before conducting maintenance and inspection work, check the water temperature gauge to see if the engine has cooled sufficiently.



### Be Careful When Opening and Closing of Coolant Expansion Tank Pressure Cap

Never open the coolant expansion tank pressure pressure cap while the engine is running or immediately after stopping. Stop the engine, and then open the cap after the coolant temperature has dropped sufficiently. To open the coolant expansion tank pressure pressure cap, open slowly to release the pressure in the tank.

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

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

### Refill Coolant Only After the Coolant Temperature Dropped

Before adding coolant, check the coolant temperature with the gauge if it is lowered to the normal temperature. Adding coolant immediately after engine shutdown may result in burns.

### Do Not Remove Heat Shields

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

## Burn Prevention When Changing Oil

Before draining oil or changing oil filters, wear leather gloves or be sure to check the engine has cooled down. Hot oil or hot parts may cause burns if touched.

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



**CAUTION**

### Use Specified Fuel, Engine Oil, and LLC Only

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

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

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

### Handle LLC Carefully

When handling LLC, always wear rubber gloves, a protective face mask, and protective eyeglasses. If LLC or cooling water containing LLC comes into contact with your skin or eyes, or if it is ingested, you may suffer from damage of your skin or eyes, or poisoning. If coolant (LLC) is accidentally swallowed, induce vomiting immediately, and seek medical attention. If coolant (LLC) gets in your eyes, flush them immediately with plenty of water and seek medical attention. If coolant (LLC) splashes onto your skin or clothing, wash it away immediately with plenty of water.

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

### Proper Disposal of Waste Oil, LLC, and Coolant

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

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

## When a Problem Occurs

### CAUTION

### Stop Operation Immediately If You Notice Any Abnormality

Stop the operation immediately if you notice any unusual noise, odor, or vibration during operation.

When an emergency occurs, press the emergency stop button to stop the engine. If the cause of problem cannot be located after stopping, contact your MHIET dealer. Continuous operation neglecting an unusual symptom could cause serious or fatal accident.

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

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

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

### Be Careful When Starting After an Abnormal Stop

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

### Stop Engine Immediately When Engine Oil Pressure Has Dropped

When excessive engine oil pressure drop is observed, stop the engine immediately, and inspect the lubrication system to locate the cause. Continued engine operation may 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 may cause charging failure or cooling failure, and result in serious engine problems.

## Battery Safety Precautions

### CAUTION

### Be Careful When Handling Battery

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



## Other Precautions


**CAUTION**

### Do Not Tamper

Unauthorized modification of the engine will void your warranty.

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

### Always Use Mitsubishi Genuine Parts

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

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

### Observe Safety Rules at Work Site

Observe the safety rules established at your workplace.

Do not operate the engine if you are not feeling well. Inform your supervisor of your condition. Operation of the engine with reduced attentiveness may cause improper operation that could result in accidents. When working in a team of two or more people, use specified hand signals to communicate among workers.

### Wear Proper Work Clothing and Protective Gears

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

### Never Break the Seals

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

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

### Performance of Pre-operation Inspection and Periodic Inspections

Be sure to perform the everyday check-up (pre-operation inspections) and periodic inspections as instructed in this manual.

Failure to conduct the everyday check-up (pre-operation inspections) or periodic inspections and maintenance may result in many problems and damage to various parts of the engine, serious accidents, and deterioration of exhaust gas.

### Engine Break-in

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

Operating a new engine or an engine that has been overhauled under a severe condition during break-in will shorten the service life of the engine, because the engine parts are not well lubricated and warmed up yet.

## Warming Up Engine First

After starting the engine, run the engine at a low idling speed until the coolant temperature reaches approximately 50°C [122°F]. Start the actual engine operation after warming up operation is completed. (Except for the emergency generator which requires a rapid starting. Refer to the technical manual of auxiliary devices for rapid starting.)

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

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

## Cool Down the Engine Before Stopping

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

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

During cooling operation, check the engine for abnormalities.

## Do Not Operate the Engine in an Overloaded Condition

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

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

## Limitation of Continuous Under Light Load Operation

Allowable minimum load during continuous operation:

Operate with 30% or more of the rated output. Allowable continuous operation time with a load factor of 30% or less of the rated output: Limit the operation within one hour. Operate with a load factor of 50% or more for 30 minutes or more after continuous operation with 30% or less of the rated output is conducted. The following problems may occur when light load operation is conducted beyond the above allowable range:

- ♦Fuel and/or oil leak from the exhaust system
- ♦Carbon build-up on the cylinder head and exhaust pipe
- ♦Sulfuric acid corrosion
- ♦Dilution
- ♦Generation of blue-white smoke (mainly during low idle operation)

## Do Not Splash Water on Engine

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

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

If the water enters into the combustion chambers, the internal engine may be damaged due to water hammer, and result in a serious accident.

## Pre-cleaner Maintenance Precautions

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

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

## **Use Proper Tools for Maintenance Work**

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

## **Do Not Operate Starter for a Long Duration**

Do not operate 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 may 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 during operation, it will stop the engine and the activation of instruments, and may deteriorate alternator diode and transistor.

## **Engine Transportation Precautions**

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

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

## **Do Not Turn Engine to Reverse Direction**

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

## **Operate Clutch at Low Idling Speed**

When switching between forward and reverse (clutch operation), lower the engine speed and perform idling at either N (Neutral) ↔ F (Forward) or N (Neutral) ↔ R (Reverse). If the clutch operation is performed while rotating at high speed, the marine gear may be damaged.

## **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/Caution Labels



## Maintenance of Warning/Caution Labels

Make sure that all warning/caution labels are legible. Clean or replace the labels when the description and/or illustration are not clear to read.

- Illegible labels fail to alert people, which may cause personal injury, environmental pollution, and damage to the engine.
- For cleaning the labels, use a cloth and soapy water. DO NOT USE CLEANING SOLVENTS, GASOLINE, OR OTHER CHEMICALS THAT MAY ERASE THE PRINT OR CAUSE PEELING OFF OF THE LABEL. If the labels are damaged, replace them with new ones.
- When replacing a part that has a label attached, attach the new label to the new part so that it is in the same state as before replacement.
- New labels are available at your MHIET dealer, MHIET group company, or MHIET.

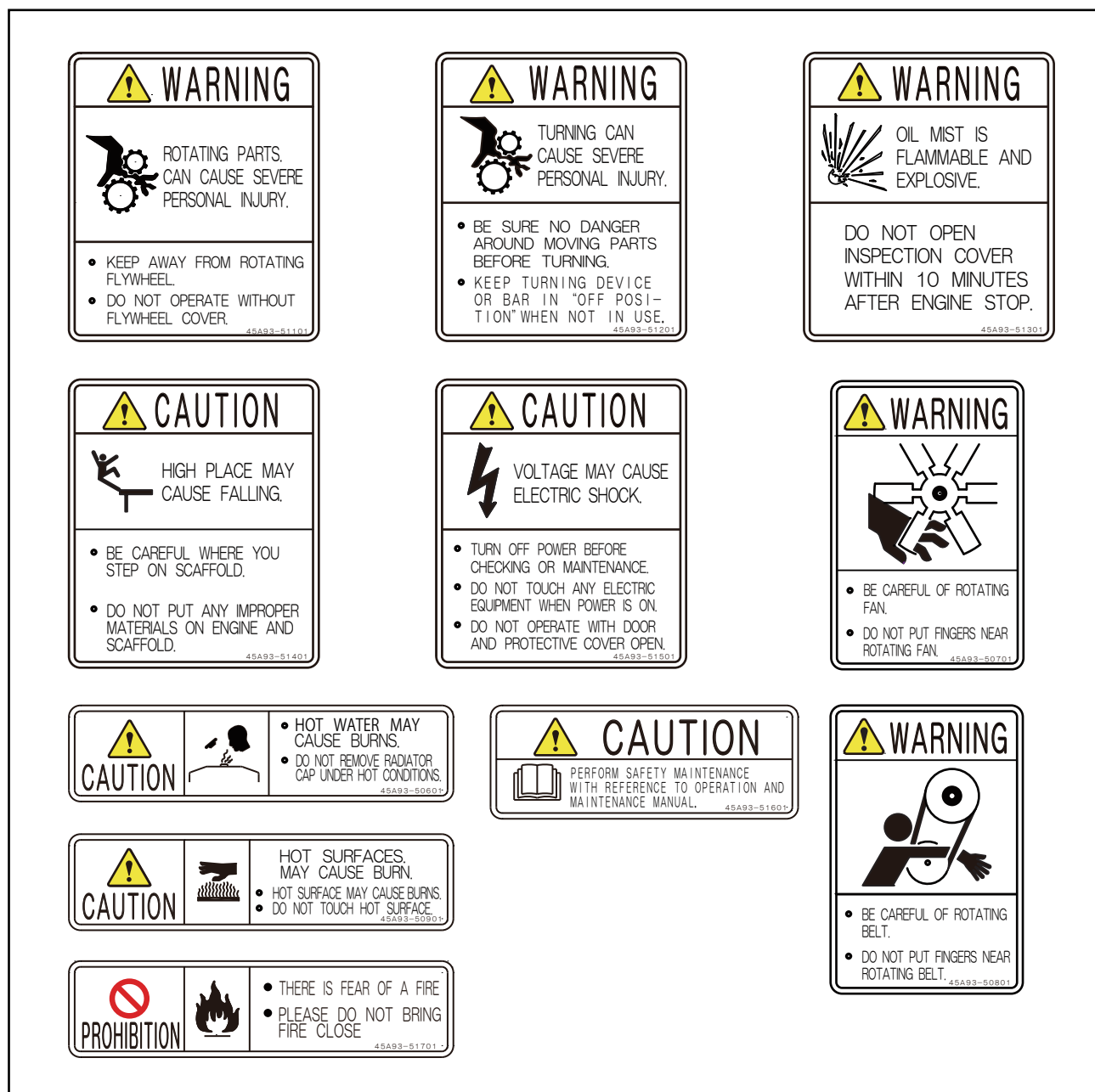


Fig. 1-1 Warning/Caution Labels



# Chapter 2 NAMES OF PARTS

## Engine External Views

### Front View

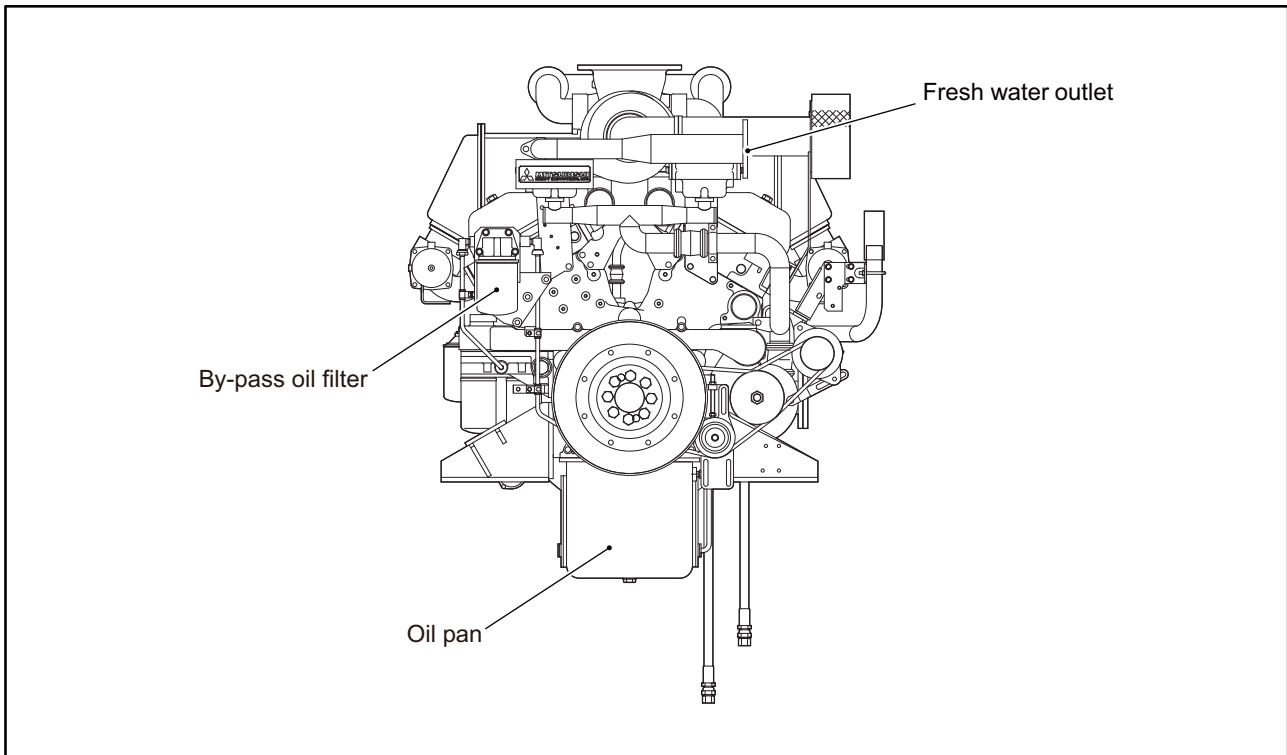


Fig. 2-1 Engine Front View

### Rear View

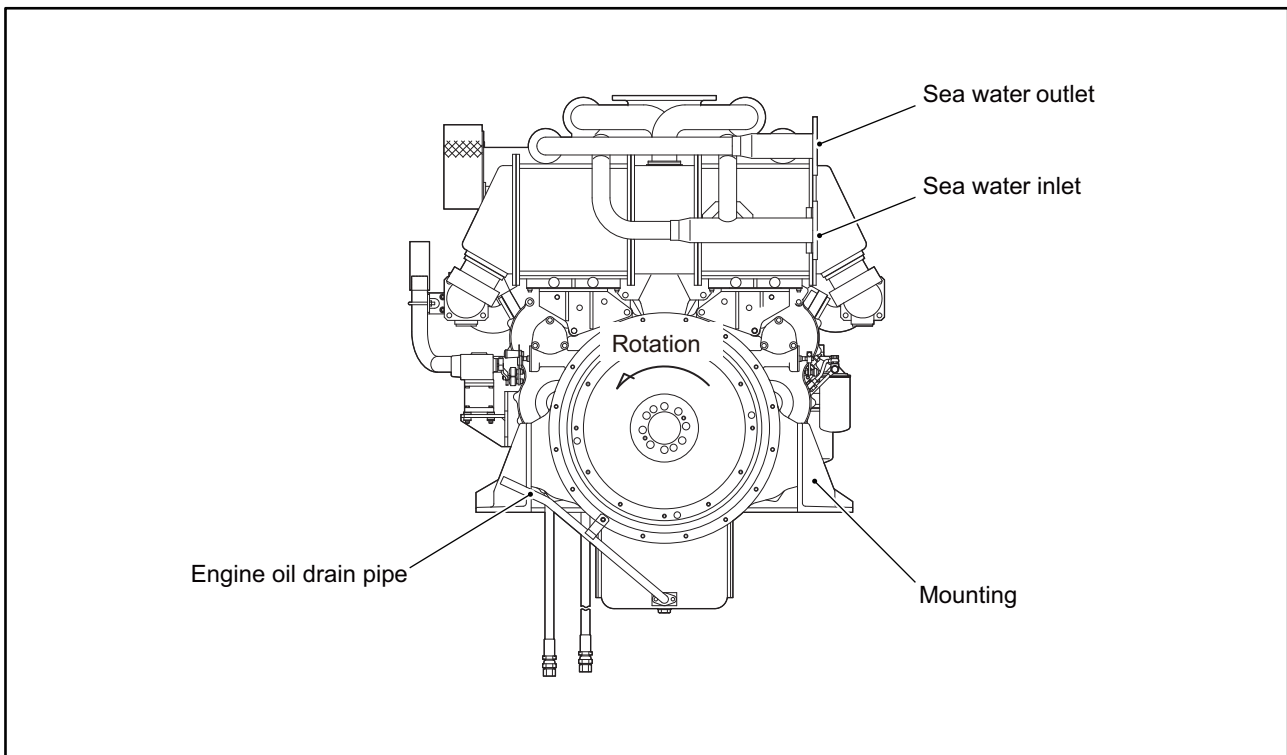


Fig. 2-2 Engine Rear View

## Left View

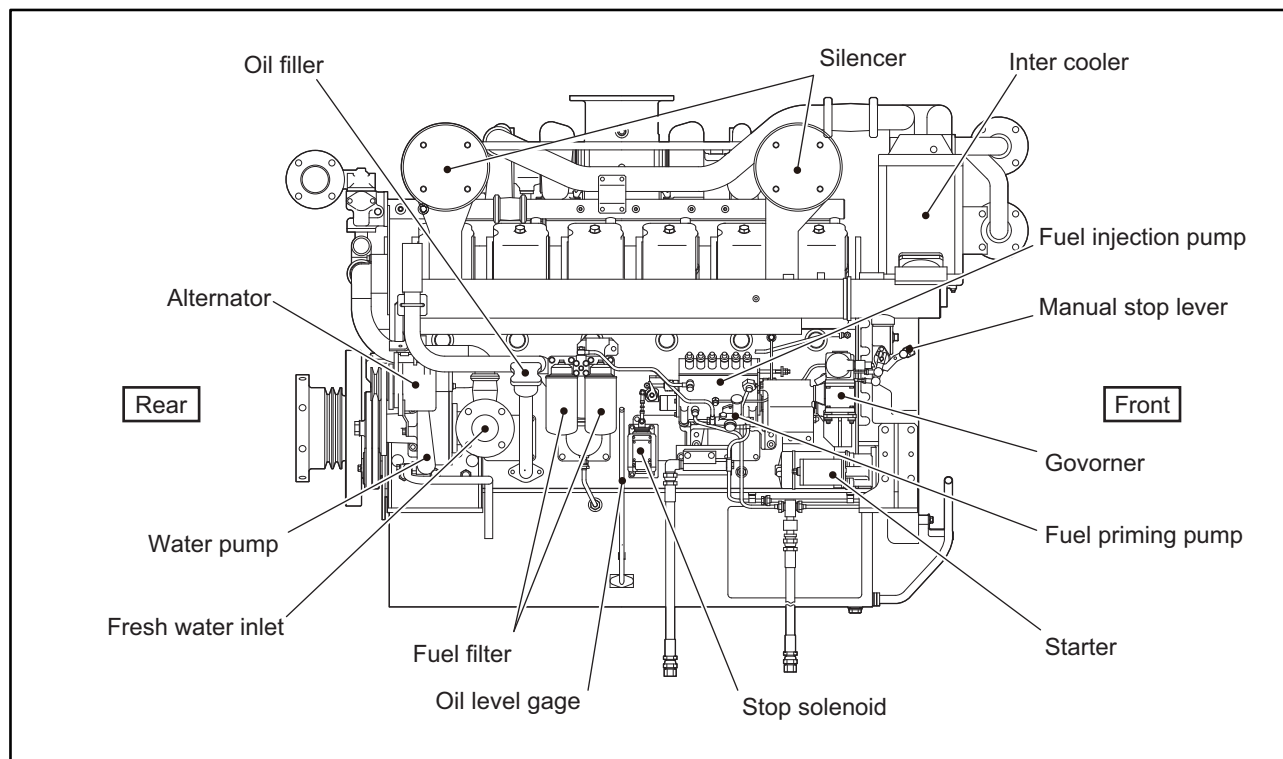


Fig. 2-3 Engine Left-Side View

## Right View

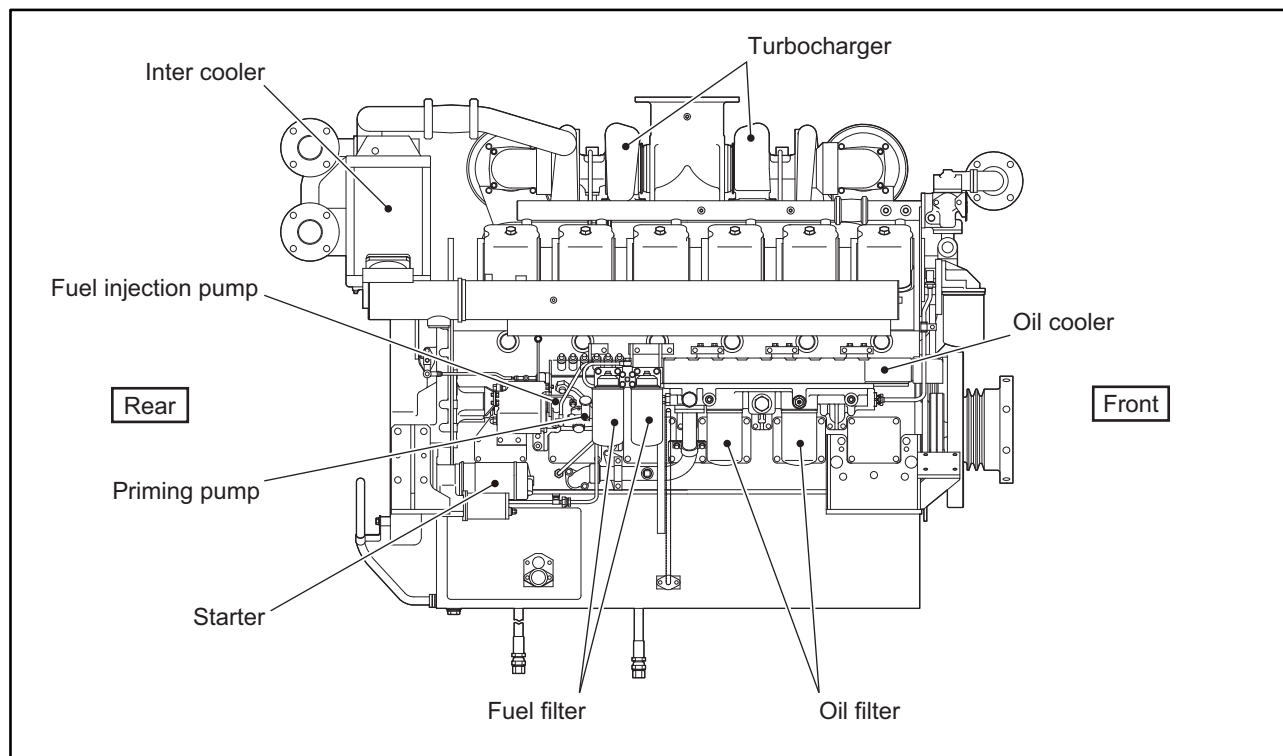


Fig. 2-4 Engine Right-Side View

## Operating Devices

### Manual Stop Lever

The manual stop lever is provided to stop the engine in the event of an emergency and also when the engine will not stop with the stop button.

The manual stop lever is mounted on the fuel control link unit. You can stop the engine by operating this lever in the "STOP" direction.

If the engine will not stop even after operating the lever in the "STOP" position, cut off the fuel supply to the engine.

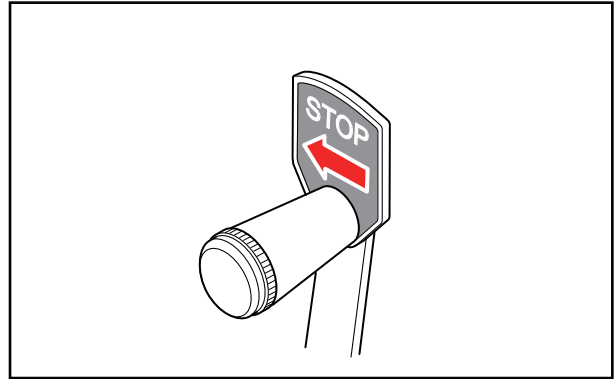


Fig. 2-5 Manual Stop Lever

### Stop Solenoid

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

The stop solenoid moves the rack of fuel injection pump to the no-fuel position to stop the engine.

This engine is equipped with the RUN OFF type stop solenoid. The stop solenoid is not energized while the engine is running. It is energized by a stop signal to stop the engine.

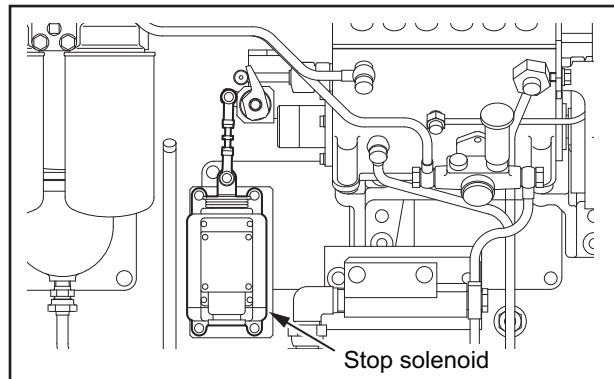


Fig. 2-6 Stop Solenoid



## Preparation for Operation of New or Overhauled Engine

For new engines or overhauled/reassembled engines, the operation is different from normal. As for a new engine, conduct the following checks before starting the first operation. As for a overhauled engine (when either main bearing, connecting rod bearing, piston ring, or cylinder liner has been replaced), conduct "[Preparation of Operation for Overhauled Engines](#)" (3-8). For second operation onward, follow the instructions described in the "[Normal Engine Operation](#)" (3-10).

## 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. It may 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 fuel supply pipes to the engine are thoroughly clean.
2. Fill the fuel tank with fuel.
3. Remove the fuel feed pipe, and check the discharged fuel for foreign materials such as dust.
4. Install the fuel feed pipe to the engine fuel inlet.

## Bleeding the Fuel System

### ⚠ WARNING

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

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

## Priming Pump Cap - Handling

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

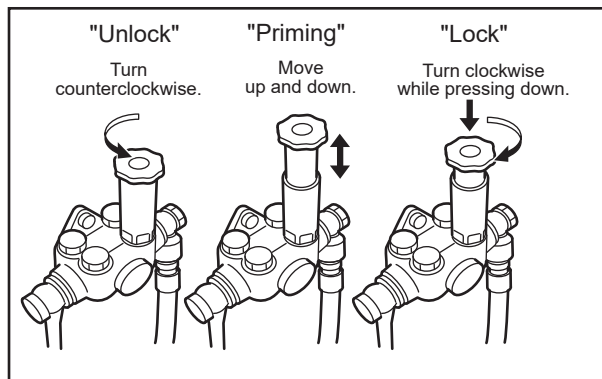


Fig. 3-1 Priming Pump Cap - Handling

## Fuel Filter - Bleed Air

### CAUTION

If the air vent plug, the threaded portion of the bracket and the sealing washer are damaged, replace with a new one.

1. Loosen the air vent plug of the fuel filter about one turn.
2. Move the priming pump up and down to pump fuel.
3. When bubble-free fuel comes out from the air vent plug, tighten the air vent plug to the specified torque.

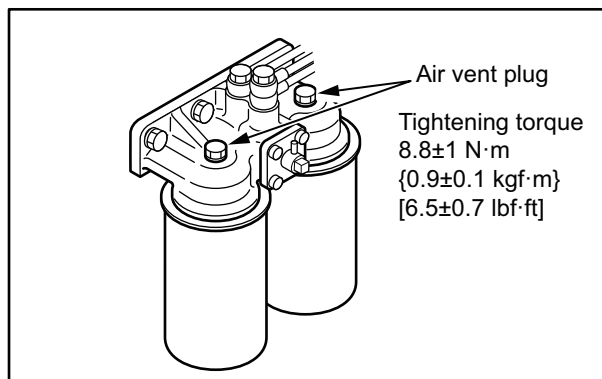


Fig. 3-2 Fuel Filter - Bleed Air

## Fuel Injection Pump - Bleed Air

1. Loosen the air vent plug on the fuel injection pump by rotating about 1 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.

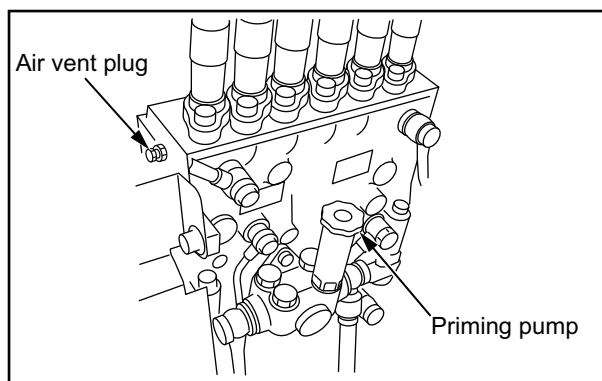


Fig. 3-3 Fuel Injection Pump - Bleed Air

## Priming Pump Tightening Method

### CAUTION

Securely tighten the priming pump. If the priming pump is not firmly tightened, the internal threads will be worn due to engine vibration, and the fuel may flow out by a sudden ejection of priming pump. Or if the priming pump is excessively tightened, the head of the priming pump can be damaged.

Be sure to tighten the pump at a correct angle.

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

Note: If the head packing has abnormality such as deformation or scratches, the priming pump must be replaced. Consult with your MHIET dealer.

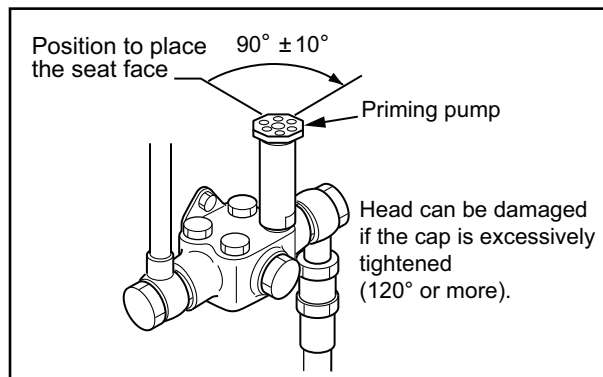


Fig. 3-4 Priming Pump Tightening Method

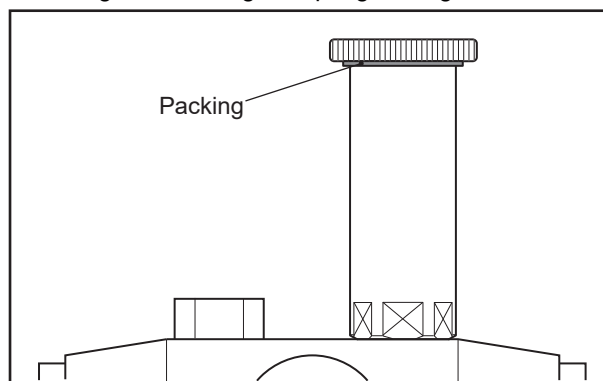


Fig. 3-5 Priming Pump Head Packing

## Preparation of Lubrication System

### Engine Oil - Refill

#### **CAUTION**

Always refill 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.

And also, the engine components are adversely affected by the increase of oil temperature.

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

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

3. Check the oil level in the oil pan as follows:
4. Pull out the oil level gauge and wipe it clean with a cloth.
5. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
6. The proper oil level is between the high and low marks on the oil level gauge. If the oil level is low, add the specified engine oil.
7. Inspect the oil pan and other area for oil leaks. Repair if there is oil leak.
8. Operate the engine oil priming pump and confirm that the engine oil pressure increases to approximately 0.2 MPa {2.04 kgf/cm<sup>2</sup>} [29.01 psi].

Note: Perform this procedure after the preparation work for the lubrication and cooling systems have finished.

9. Start the engine and run the engine under no load for 5 to 10 minutes.
10. Stop the engine, and after 30 minutes or more has elapsed, check the oil level with the oil level gauge again and add oil to the specified level.

For details, refer to "Test Operation" (3-7).

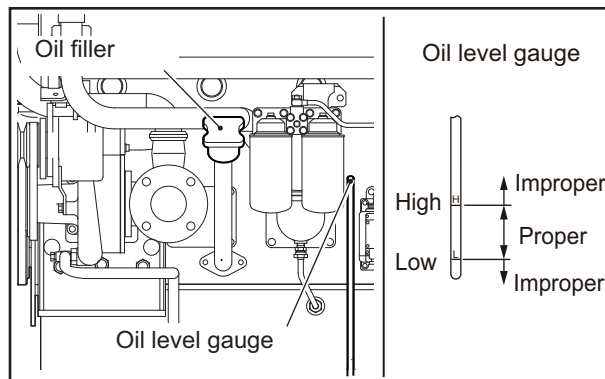


Fig. 3-6 Oil Filler and Oil Level Gauge

## Preparation of Cooling System

### Coolant - Refill

#### CAUTION

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

1. Close every coolant drain cock securely.
2. Open the coolant filler port and add a mixture of water and coolant (LLC) 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 SPECIFICATION](#)" (12-1).

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

3. Check for coolant leaks. Repair if a leak is found.
4. With the manual stop lever placed in the pulled position, crank the engine for approximately 10 seconds using the starter. Stop for approximately 1 minute, and then repeat the cranking 2 or 3 times to bleed air from the cooling system.

Note: This procedure should be performed together with the items described under the Preparation of Lubrication System.

5. Check the coolant level.

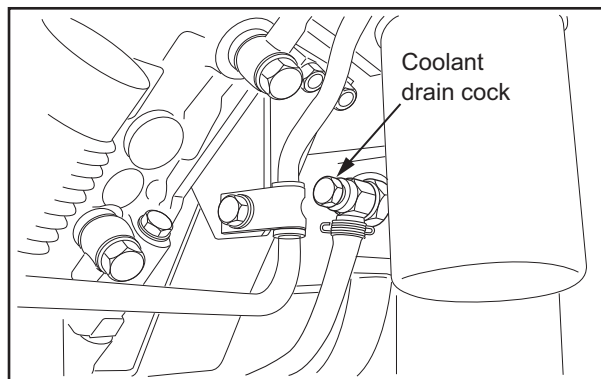


Fig. 3-7 Coolant Drain Cock (Engine Body)

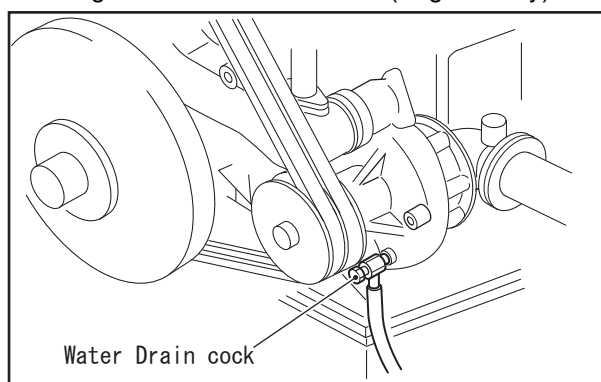


Fig. 3-8 Coolant Drain Cock (Fresh Water Pump)

## 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 near the battery may cause an explosion.
- ♦Do not use the battery when the battery fluid level is below the "LOWER LEVEL" mark. It may explode.
- ♦Do not short the battery terminals with a tool or other metal object.
- ♦When removing battery, always remove the plug from the negative (-) terminal first. When connecting battery, always connect the plug to the positive (+) terminal first.
- ♦Before charging the battery, remove all battery cables, and then charge the battery in a well-ventilated area.
- ♦Make sure the cable clamps are securely attached to the battery terminals. A loose cable clamp may cause sparks, and it may result in an explosion.
- ♦Before servicing electrical components or conducting electric welding, set the battery switch to the [OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.
- ♦Battery fluid contains dilute sulfuric acid. Careless handling of the battery may cause a sight loss and/or skin burns. Also, do not swallow the battery fluid.
- ♦Wear protective goggles and rubber gloves when working with the battery (e.g. when adding water or charging battery).
- ♦If battery fluid is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to clean thoroughly.
- ♦The battery fluid may cause sight loss if splashing into the your eyes. If it gets into your eyes, immediately flush it away with plenty of clean water, and seek immediate medical attention.
- ♦If you accidentally swallow battery fluid, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.
- ♦If the battery does not fully recover after charging for 24 hours or more, do not use the battery.

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

### Battery Fluid Level - Check

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

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

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

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

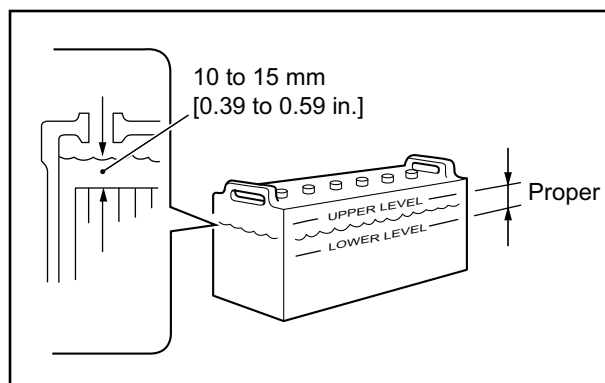


Fig. 3-9 Battery Fluid Level - Check

## Test Operation

To conduct the test operation, follow the procedures below:

Note: For engine operation, refer to "Normal Engine Operation" (3-10).

### Start and Stop

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

### Inspection

#### CAUTION

Never open the coolant expansion tank pressure 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 pressure cap, place a waste cloth over the cap, and loosen it about a quarter-turn to release the internal pressure.

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

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

#### CAUTION

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

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

## Preparation of Operation for Overhauled Engines

When either main bearing, connecting rod bearing, piston ring, or cylinder liner has been replaced, conduct the break-in operation as follows:

### Preparation Before Engine Starting

- ♦ Check the amount of fuel, engine oil, coolant, and then bleed the fuel system and cooling system.
- ♦ Remove the breather pipe at an arbitrary position.
- ♦ Inspect the link from governor output lever to the fuel injection pump rack. Make sure that the control rack is in the non-injection position when stopped and that the control rack is "0" by operating the stop lever.
- ♦ Check the wiring of electrical system (sensor, meter alarm panel, starter, alternator, stop solenoid, battery), turn on the main switch of the controller and confirm that there is no abnormality. Set the speed lever position of the governor so that the engine runs at a low idle speed after the start-up.
- ♦ Activate the stop solenoid and confirm that the fuel injection pump rack is in the predetermined non-injection position.
- ♦ Install the pressure gauge, thermometer, and flow meter as required.

### Engine Start-up

1. While pulling the stop lever to the non-injection position, turn the starter for about 10 seconds 2 or 3 times (pause for 1 minute or more) to rotate the crankshaft and circulate engine oil to each part of the engine. At this time, check that there is no abnormality such as abnormal noise and rotational fluctuation.
2. Start the engine with normal startup operation. Confirm that the engine runs at a low idle speed after start-up.
3. Make sure that hydraulic pressure rises immediately and coolant circulates.
4. Check that there is no leakage of lubricating oil, coolant, and fuel, leakage of gas (air), abnormal noise, abnormal vibration.
5. After making sure the engine is running at the low idle speed without any problem, stop the engine.

## Break-In Operation

### CAUTION

Be prepared for emergency stop operation in preparation for unexpected trouble during engine operation.

### Break-in Operation Load and Time

Since it is important to protect the generator, turn off the exciting circuit before operation. Turn on the exciting circuit when the rotation speed is close to 90% of the rated rotation. For the break-in operation, increase the load gradually as follows. Note that the time indicates the minimum time that stable operation can be confirmed.

Table 3-1 Break-In Operation

| Break-In Operation |                                                  |                          |             |            |
|--------------------|--------------------------------------------------|--------------------------|-------------|------------|
|                    | Rotational speed (min <sup>-1</sup> )            |                          | Load factor | Time (min) |
| 1                  | Low rotating speed                               | 600 to 900               | No-load     | 20         |
| 2                  | Medium rotating speed                            | 1000 to 1200             | No-load     | 10         |
| 3                  | High rotating speed                              | 1400 to rated speed      | No-load     | 10         |
| 4                  | Marine auxiliary engine speed under partial load | Equivalent to 25% output | 25%         | 20         |
| 5                  |                                                  | Equivalent to 50% output | 50%         | 20         |
| 6                  |                                                  | Equivalent to 75% output | 75%         | 30         |
| 7                  | Rated speed                                      |                          | 100%        | 20         |

### Engine - Inspection during Operation

During the break-in operation, pay attention to the followings and make sure that there is no abnormality.

- ♦Oil pressure and oil temperature
- ♦Coolant temperature and fluid level
- ♦Oil, coolant, and fuel leaks, especially oil leaks from turbocharger lubricant pipe fittings
- ♦Sound and vibration
- ♦Intake air pressure and intake air temperature
- ♦Exhaust color and odor
- ♦Exhaust gas temperature
- ♦Variations between right and left banks
- ♦Blow-by gas (amount and color)
- ♦Rotational fluctuation
- ♦Face and radial runouts of rotating parts
- ♦Display and operation of meter and warming

### After Break-in Operation - Inspection and Adjustment

- ♦Valve clearance (when cold)
- ♦Fuel injection timing
- ♦External bolts and nuts - retighten
- ♦Belt tension
- ♦Investigation and correction of abnormal parts such as oil leak

## Normal Engine Operation

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

### CAUTION

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

## Pre-operation Inspection

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

## Engine Exterior - Inspection

### CAUTION

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

Inspect the engine exterior as instructed below:

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

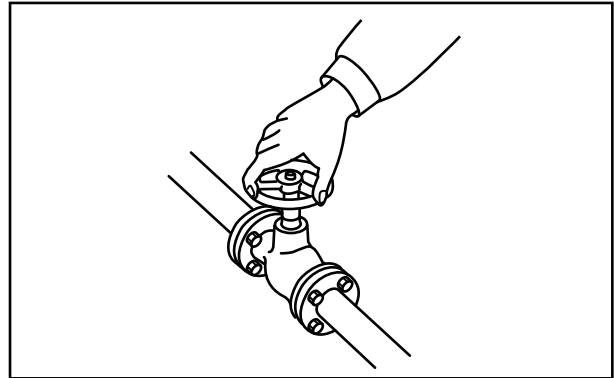


Fig. 3-10 Valve Open/Closed Position - Check

## Fuel Tank Oil Level - Check

### WARNING

Make sure that there is no open flame in the vicinity before handling fuel.

Wipe off any spilled fuel completely. It can 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 "High" level.

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

## Engine Oil Level - Check

### CAUTION

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

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

1. Stop the engine and leave it for 30 minutes or more.
2. Pull out the oil level gauge and wipe oil off from the oil level gauge using a clean waste cloth.
3. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
4. The oil level should be between the H and L 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" \(8-8\)](#). For refilling engine oil, refer to ["Engine Oil - Refill" \(8-9\)](#).

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

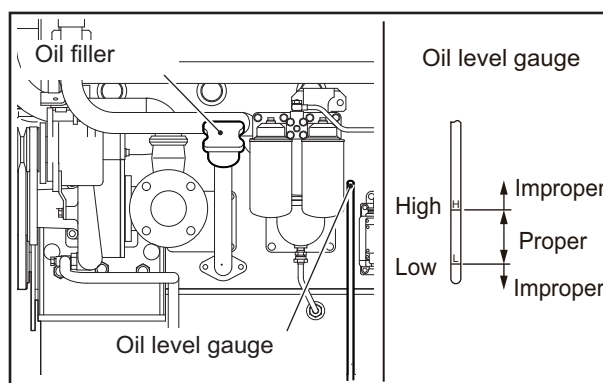


Fig. 3-11 Oil Filler and Oil Level Gauge

## Start-up

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



### WARNING

Before starting the engine, make sure no one is near the engine and that no tools are left on or near the engine. Also, in a loud voice, notify people in the area before starting the engine.

### CAUTION

Do not apply load to the engine at startup.

Do not use the starter continuously. The continuous use 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 will not start, return the key to the "OFF" position and wait for more than 1 minute before cranking again.

## Warm-up Operation



### WARNING

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

### CAUTION

Do not conduct warm-up operation for extended periods of time. Carbon deposits accumulate in the cylinder and may cause faulty combustion.

During warm-up operation, avoid an overload operation (if overloaded, black smoke is exhausted). Overload operation 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.

## Engine Oil Pressure - Check

During warm-up operation, make sure the oil pressure is normal.

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

For the normal value, refer to ["Inspection During Operation" \(3-13\)](#).

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

## Engine - Walk Around Check

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

# Operation

## Precautions in Engine Operation

### WARNING

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

### CAUTION

During operation, do not touch hot parts such as exhaust pipes. You can get burned.

### CAUTION

Always keep the engine room well ventilated. The room temperature rises if air ventilation in the engine room is not sufficient, which may reduce engine output and performance.

For break-in of a new or overhauled engine, operate the engine at a light load for first 50 hours of operation. The new engine components are not well lubricated and fitted in each other. Thus, if operated under heavy load or severe conditions during the break-in period, it will shorten the service life of the engine.

Do not turn the battery switch OFF during operation. If the battery switch is turned off during operation, it will not only stop the operation of instruments but also deteriorate the alternator diode and transistor. Never turn the key to the "START" position during operation. Otherwise, the starter may be damaged. Allowable minimum load during continuous operation: Operate with 30% or more of the rated output. Allowable continuous operation time with a load factor of 30% or less of the rated output: Limit the operation within one hour. Operate with a load factor of 50% or more for 30 minutes or more after continuous operation with 30% or less of the rated output is conducted.

The following problems may occur when light load operation is conducted beyond the above allowable range:

- ♦Fuel and/or oil leak from the exhaust system
- ♦Carbon build-up on the cylinder head and exhaust pipe
- ♦Sulfuric acid corrosion
- ♦Dilution
- ♦Generation of blue-white smoke (mainly during low idle operation)

Pay attention to the generated voltage of generator set.

## Inspection During Operation

Carefully check the exterior of engine such as pipe joints for leaks during operation.

Check the engine for abnormal noise, odor, or vibration.

Check exhaust gas color from the exhaust muffler.

Check instruments and gauges, and make sure they show normal readings.

Table 3-2 Standard Values at Rated Speed

| Item                | Standard value                                                    |
|---------------------|-------------------------------------------------------------------|
| Engine oil pressure | 0.2 to 0.4 MPa<br>{2 to 4 kgf/cm <sup>2</sup> }<br>[28 to 57 psi] |
| Coolant temperature | 70 to 110°C<br>[158 to 230°F]                                     |

Note: (a) When the oil pressure drops below 0.15 MPa {1.5 kgf/cm<sup>2</sup>} [21 psi] in normal operation, or below 0.05 MPa {0.5 kgf/cm<sup>2</sup>} [7 psi] at low idling, stop the engine immediately. Be sure to find the cause and repair the problem before starting the engine again.

(b) When the thermo switch is activated during normal operation, run the engine at a low idle speed for 5 to 6 minutes to cool down the engine, and then stop the engine. Be sure to find the cause and repair the problem before starting the engine again.

## Stopping

---

 **CAUTION**

---

Do not stop the engine abruptly during high-speed operation or while engine is hot. Otherwise, the engine life will be shortened. Except in a case of emergency, operate the engine at a low idle speed 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 start the engine immediately after an abnormal stop. If the engine stops with a warning buzzer, be sure to find the cause and correct the problem before starting the engine again. After the operation has been resumed, check the engine for abnormalities again. If an abnormality is found, repair promptly.

---

To stop, follow the instructions specified for the engine.

## Inspection After Stopping

Inspect the engine for fluid leaks such as fuel, oil, or coolant after the engine is stopped. If any leak is found, repair the leak, or contact your MHIET dealer if the repair is not easy.

## Recommended Fuel



### WARNING

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

Use a fuel that meets the requirements in the following [Table 4-1 "Recommended Fuel"](#) and [Table 4-2 "Recommended Limit and Service Limit for Fuel Properties"](#).

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

Note: Please use the fuel that meets the laws and regulations of the country or region where the engine is used, if the laws and regulations are applied.

Table 4-1 Recommended Fuel

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

## Handling Fuel

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

Fill up the fuel tank or service tank at the end of each operation.

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

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

Be sure to use a strainer when filling the fuel tank. Use clean cloth to filtrate the fuel to reduce the contaminants such as dust.

# Fuel Quality Standard

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

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

| Item                                                       |                              | Recommended limit                                                                                   | Service limit                                                         | Test method                                                                                                  |
|------------------------------------------------------------|------------------------------|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| Flash point                                                |                              | 50°C [122°F] or more (Base on fuel handling regulations.)                                           |                                                                       | JIS K 2265<br>ISO 3679<br>ISO 2719                                                                           |
| Distillation properties                                    | Initial boiling point        | 170°C [338°F] or more                                                                               |                                                                       | JIS K 2254<br>ISO 3405                                                                                       |
|                                                            | 90% distillation 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<br>ISO 3016                                                                                       |
| Cloud point (CP)                                           |                              | Ambient temperature or below                                                                        |                                                                       | JIS K 2269<br>ISO 3015                                                                                       |
| Cold filter plugging point (CFPP)                          |                              | Lower than ambient temperature by 3°C [5.4°F] or more                                               |                                                                       | JIS K 2288<br>IP 309/96                                                                                      |
| Carbon residue (10% residual oil)                          |                              | 0.4 mass% or less                                                                                   | 1.0 mass% or less                                                     | JIS K 2270<br>ISO 6615<br>ISO 10370                                                                          |
| Cetane number                                              |                              | 45 or more *1                                                                                       | 45 or more *2                                                         | JIS K 2280<br>ISO 5165                                                                                       |
| Cetane index (new method)                                  |                              | 45 or more                                                                                          |                                                                       | JIS K 2280<br>ISO/DIS 4264                                                                                   |
| Kinetic viscosity                                          |                              | 2.0 mm <sup>2</sup> /s or more at (30°C [86°F])<br>8.0 mm <sup>2</sup> /s or less at (50°C [122°F]) |                                                                       | JIS K 2283<br>ISO 3104                                                                                       |
| Sulfur content                                             |                              | 0.2 mass% or less                                                                                   | 1.0 mass% or less *2 *3<br>(Shorten the engine oil change intervals.) | JIS K 2541<br>(The content amount as low as that of regular light oil is desirable)<br>ISO 4260<br>ISO 8754. |
| Water content and sediments                                |                              | 0.1 volume% or less                                                                                 |                                                                       | JIS K 2275<br>ISO 3733                                                                                       |
| Ash content                                                |                              | 0.01 mass% or less                                                                                  | 0.03 mass% or less                                                    | JIS K 2272<br>ISO 6245                                                                                       |
| Copper corrosion (50°C [122°F], 3Hr)                       |                              | Discoloration = Copper plate No. 3 or less (deep discoloration)                                     |                                                                       | JIS K 2513<br>ISO 2160                                                                                       |
| Density 15°C [59°F]                                        |                              | 0.83 to 0.87 g/cm <sup>3</sup><br>[51.8 to 54.3 lb/ft <sup>3</sup> ]                                | 0.80 to 0.87 g/cm <sup>3</sup><br>[49.94 to 54.3 lb/ft <sup>3</sup> ] | JIS K 2249<br>ISO 3675                                                                                       |
| Coking                                                     | 250°C [482°F], 24 Hr         | Carbonization 75% or less                                                                           | Carbonization 80% or less                                             | Fed 791B                                                                                                     |
|                                                            | 230°C [446°F], 24 Hr         | Carbonization 55% or less                                                                           | -                                                                     |                                                                                                              |
|                                                            | 180°C [356°F], 48 Hr         | Tar-free                                                                                            | -                                                                     |                                                                                                              |
| Aromatics substances (by HPLC)                             |                              | 38 volume% or less (total of aroma contents)                                                        |                                                                       | JIS K 2536<br>ISO 3837                                                                                       |
| Polycyclic aromatic content                                |                              | 8 volume% or less                                                                                   |                                                                       |                                                                                                              |
| Asphaltene                                                 |                              | 0.1 mass% or less                                                                                   |                                                                       | -                                                                                                            |
| Fine foreign substances (foreign substances at fuel inlet) |                              | 10 mg/L or less                                                                                     |                                                                       | JIS B 9931<br>ISO 4405                                                                                       |

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

| Item                                                                                                  | Recommended limit                                                                                                                        | Service limit | Test method                                                 |
|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------|-------------------------------------------------------------|
| 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 standard vapor pressure 1.4 kPa{0.01 kgf/cm <sup>2</sup> } [0.20 psi])       | -             | ISO 12156-1                                                 |
| BDF: Biodiesel fuel (FAME: Fatty Acid Methyl Ester)                                                   | The quality of the fuel for blending shall meet JIS K 2390, ASTM D 6751, EN14214.<br>Mixing ratio of fuel blending: 7 volume% or less *4 |               | JIS K 2390(FAME for blended fuel)<br>ASTM D6751<br>EN 14214 |

\*1: Cetane index (JIS K 2280) substitutes. When the fuel which satisfies the service limit of cetane number is not available with some inevitable reasons, the use of cetane booster is allowed. However, this is allowed only for the period before getting the fuel which satisfies the service limit after consulting with the fuel supplier and the manufacturer of cetane booster, and at the customer's own risk. The additive rate of 0.5% or less of cetane booster, and the lube oil analysis at every 125 hours are recommended. High concentration of additive may cause metal erosion, rubber material infiltration, increased load in high-load operation, and acceleration of lube oil deterioration.

•Brand examples of cetane number improver:

HITEC 4105K (Made by Afton Chemical)

\*2: Only the emergency generator operated at an ambient temperature of 5°C [41°F] or more, a fuel of cetane number 40 to 45 and sulfur content 0.2% or less can be used, if the below requirements are satisfied:

•Install a water heater.

•Time from startup to load input is to be 40 seconds.

•Operating the engine at no load or low load (load factor 30% or less) for a prolonged period of time is avoided.

\*3: If the sulfur content of using fuel is higher than 0.2 mass%, use the specified engine oil [Chapter 5 ENGINE OIL](#).

\*4: In case of using BDF, consult with the fuel supplier, and consider and take necessary treatment such as;

•Antioxidation at high temperature

•Prevention from fuel solidification at low temperature

•Prevention from growth of microbe

•Removal of moisture'

For details, refer to "Technical Information".

For Engine warranty coverage, refer to "[Warranty Provisions](#)" (page - iv) conditions in this manual.



## Use Recommended Engine Oil Only

### 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 shorten the service life of the engine.

Use only MHIET genuine engine oil for the engine. If you have to use an oil other than MHIET genuine oil, check the engine oil grade, and use only the oil that meets our quality standard. Furthermore, conduct the analysis of oil to review the oil replacement intervals. MHIET disclaims the warranty claim for malfunctions due to the use of engine oil that does not meet our quality standard.

## Genuine MHIET Engine Oil

MHIET have developed from the various test results to offer "MITSUBISHI DIESEL ENGINE OIL CH-4 15W-40" as the most suitable engine oil for our marine engine.

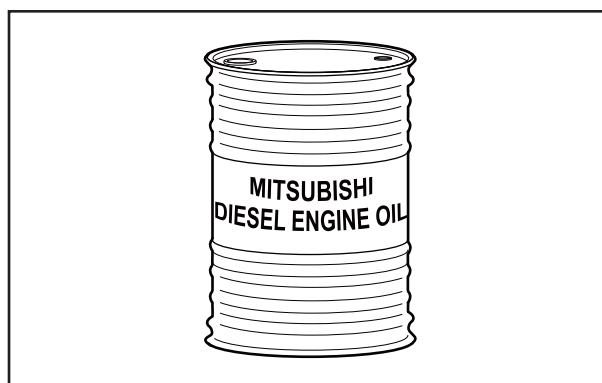


Fig. 5-1 MITSUBISHI DIESEL ENGINE OIL

## Other Commercial Engine Oils

### CAUTION

Never mix different brands of engine oil with genuine MHIET oil. When engine oils of different brands are mixed and used, the additives in the engine oils may chemically change and the performance of the engine oil may deteriorate. Several types of diesel engine oil are specified, but among them, use CF or CH-4 category for our engine, which is suitable for high supercharging and heavy load. When using the CF grade engine oil, the certified year must be the year of 2009 or before and the oil must meet the requirements listed in the "[Engine Oil Quality Standard](#)" (5-2). If the fuel with 0.2% or less sulfur content is used in the engine, CF or CH-4 grade oil can be used. However, the oil must have 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.

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.

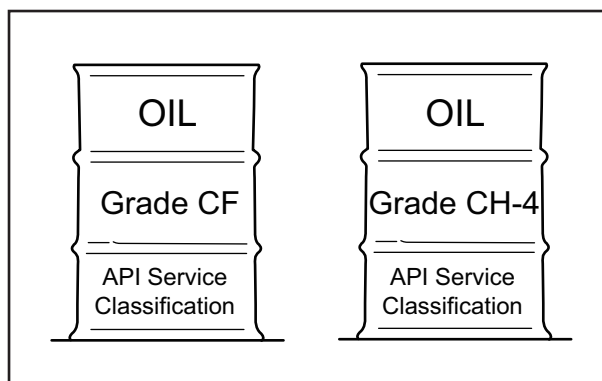


Fig. 5-2 Engine Oil Grade

## Engine Oil Quality Standard

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

Table 5-1 Engine Oil Quality Standards (Grade CF SAE 30)

| Item                             |                          |                        |                   | Unit          | Recommended property value | Test method  |
|----------------------------------|--------------------------|------------------------|-------------------|---------------|----------------------------|--------------|
| ASTM Color                       |                          |                        |                   | -             | L3.0                       | JIS K 2580   |
| Density                          |                          | 15°C [59°F]            |                   | g/cm³         | 0.87 to 0.90               | JIS K 2249   |
| Kinetic viscosity                |                          | 40°C [104°F]           |                   | mm²/s         | 95.0 to 110                | JIS K 2283   |
|                                  |                          | 100°C [212°F]          |                   |               | 11.0 to 12.5               |              |
| Flash point                      |                          |                        |                   | °C [°F]       | 200 [392] or more          | JIS K 2265   |
| Base number                      | Hydrochloric acid method | Sulfur content in fuel | 1.0 mass% or less | mgKOH/g       | 10 or more (up to 13)      | JIS K 2501   |
|                                  |                          |                        | 0.2 mass% or less |               | 8.0 or more (up to 13)     |              |
|                                  | Perchloric acid method   |                        | 1.0 mass% or less |               | 13 or more (up to 16)      |              |
|                                  |                          |                        | 0.2 mass% or less |               | 11 or more (up to 16)      |              |
| Acid number                      |                          |                        |                   | mgKOH/g       | 1.8 or less                | JIS K 2501   |
| Sulfur content                   |                          |                        |                   | %             | 0.7 or less                | JIS K 2541   |
| Sulfuric acid ash                |                          |                        |                   | mass%         | 2.0 or less                | JIS K 2272   |
| Carbon residue content           |                          |                        |                   | %             | 2.0 or less                | JIS K 2270   |
| High temperature shear viscosity |                          | 150°C [302°F]          |                   | mPa·S         | 2.9 or more                | JPI-5S-36-91 |
| Pour point                       |                          |                        |                   | °C [°F]       | -12.5 [9.5] or less        | JIS K 2269   |
| Additives                        |                          | Ca                     |                   | mass%         | 0.40 to 0.48               | JIS K 0116   |
|                                  |                          | P                      |                   |               | 0.037 to 0.050             |              |
|                                  |                          | Zn                     |                   |               | 0.042 to 0.055             |              |
|                                  |                          | B                      |                   |               | 0.010 or less              |              |
|                                  |                          | Si                     |                   |               | 0.005 or less              |              |
|                                  |                          | N                      |                   | 0.060 or less | JIS K 2609                 |              |
| Bubbling test                    |                          | I                      |                   | mL            | 10/0 or less               | JIS K 2518   |
|                                  |                          | II                     |                   |               | 30/0 or less               |              |
|                                  |                          | III                    |                   |               | 10/0 or less               |              |
| Panel coking test*               |                          | 300°C [572°F]          |                   | -             | 40 or less                 | FED791-3462  |
|                                  |                          | 325°C [617°F]          |                   |               | 300 or less                |              |

\*: 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 accumulated on the panel.

Table 5-2 Engine Oil Quality Standards (Grade CF SAE 15W-40)

| Item                             |                          |                        |                   | Unit           | Recommended property value | Test method  |
|----------------------------------|--------------------------|------------------------|-------------------|----------------|----------------------------|--------------|
| ASTM Color                       |                          |                        |                   | -              | L4.0                       | JIS K 2580   |
| Density                          |                          | 15°C [59°F]            |                   | g/cm³          | 0.87 to 0.90               | JIS K 2249   |
| Kinetic viscosity                |                          | 40°C [104°F]           |                   | mm²/s          | 100 to 110                 | JIS K 2283   |
|                                  |                          | 100°C [212°F]          |                   |                | 13.5 to 15.5               |              |
| Flash point                      |                          |                        |                   | °C [°F]        | 225 to 250 [437 to 482]    | JIS K 2265   |
| Base number                      | Hydrochloric acid method | Sulfur content in fuel | 1.0 mass% or less | mgKOH/g        | 10 or more (up to 13)      | JIS K 2501   |
|                                  |                          |                        | 0.2 mass% or less |                | 8.0 or more (up to 13)     |              |
|                                  | Perchloric acid method   |                        | 1.0 mass% or less |                | 13 or more (up to 16)      |              |
|                                  |                          |                        | 0.2 mass% or less |                | 11 or more (up to 16)      |              |
| Acid number                      |                          |                        |                   | mgKOH/g        | 15 to 2.0                  | JIS K 2501   |
| Sulfur content                   |                          |                        |                   | %              | 0.5 or less                | JIS K 2541   |
| Sulfuric acid ash                |                          |                        |                   | mass%          | 2.0 or less                | JIS K 2272   |
| Carbon residue content           |                          |                        |                   | %              | 2.0 or less                | JIS K 2270   |
| High temperature shear viscosity |                          | 150°C [302°F]          |                   | mPa·S          | 3.7 or more                | JPI-5S-36-91 |
| Pour point                       |                          |                        |                   | °C [°F]        | -25 [-13] or less          | JIS K 2269   |
| Additives                        |                          | Ca                     |                   | mass%          | 0.480 to 0.570             | JIS K 0116   |
|                                  |                          | P                      |                   |                | 0.050 to 0.070             |              |
|                                  |                          | Zn                     |                   |                | 0.060 to 0.080             |              |
|                                  |                          | B                      |                   |                | 0.010 or less              |              |
|                                  |                          | Si                     |                   |                | 0.001 or less              |              |
|                                  |                          | N                      |                   | 0.030 to 0.060 | JIS K 2609                 |              |
| Bubbling test                    |                          | I                      |                   | mL             | 10/0 or less               | JIS K 2518   |
|                                  |                          | II                     |                   |                | 30/0 or less               |              |
|                                  |                          | III                    |                   |                | 10/0 or less               |              |
| Panel coking test*               |                          | 300°C [572°F]          |                   | -              | 140 or less                | FED791-3462  |
|                                  |                          | 325°C [617°F]          |                   |                | 300 or less                |              |

\*: 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 accumulated on the panel.

Table 5-3 Engine Oil Quality Standards (Grade CH-4 SAE 15W-40)

| Item                             |                          | Unit               | Recommended property value | Test method                               |
|----------------------------------|--------------------------|--------------------|----------------------------|-------------------------------------------|
| ASTM Color                       |                          | -                  | L4.0                       | ASTM D 1500                               |
| Flash point                      |                          | °C [°F]            | 200 [392] or more          | ASTM D 92                                 |
| Kinetic viscosity                | 40°C [104°F]             | mm <sup>2</sup> /s | 100 to 120                 | ASTM D 445<br>ASTM D 7042                 |
|                                  | 100°C [212°F]            |                    | 13.00 to 15.00             |                                           |
| CCS Viscosity                    | -20°C [-4°F]             | mPa·S              | 7000 or less               | ASTM D 5293                               |
| MRV Viscosity                    | -25°C [-13°F]            | mPa·S              | 60000 or less              | ASTM D 4684                               |
| Sulfuric acid ash                |                          | mass%              | 2.0 or less                | ASTM D 874                                |
| Acid number                      |                          | mgKOH/g            | 4.0 or less                | ASTM D 664                                |
| Base number                      | Hydrochloric acid method | mgKOH/g            | 8.0 or more                | ASTM D 2896                               |
|                                  | Perchloric acid method   | mgKOH/g            | 11 or more                 |                                           |
| Pour point                       |                          | °C [°F]            | -25 [-13] or less          | ASTM D 7346<br>ASTM D 6749/97             |
| Bubbling test                    | I                        | mL                 | 10/0 or less               | ASTM D 892                                |
|                                  | II                       |                    | 20/0 or less               |                                           |
|                                  | III                      |                    | 10/0 or less               |                                           |
| Additives                        | Ca                       | mass%              | 0.38 to 0.48               | ASTM D 5185<br>ASTM D 4951<br>ASTM D 6481 |
|                                  | P                        |                    | 0.11 to 0.15               |                                           |
|                                  | Zn                       |                    | 0.12 to 0.17               |                                           |
|                                  | S                        |                    | 0.5 or less                |                                           |
| NOACK (evaporability)            |                          | mass%              | 18 or less                 | ASTM D 5800                               |
| High temperature shear viscosity | 150°C [302°F]            | mPa·S              | 3.7 or more                | ASTM D 4741                               |
| Carbon residue content           |                          | -                  | 2.0 or less                |                                           |
| Hot tube test *                  |                          | -                  | 4.0 or more                |                                           |

\*300°C [572°F], 16 hours

## 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 and causes gas leak from the cylinder due to inadequate lubrication, and also causes a decrease in engine output.

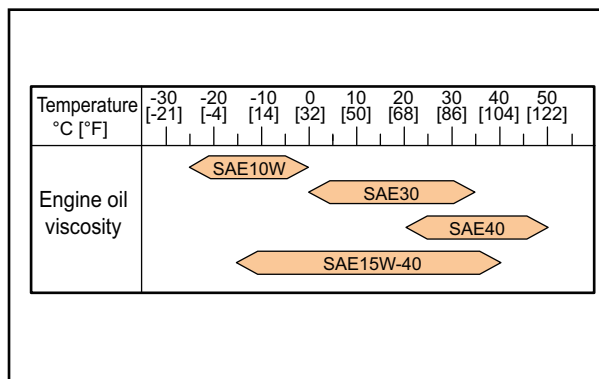


Fig. 5-3 Selection of Oil Viscosity

# Handling Engine Oil

## WARNING

Before filling the engine with engine oil, stop the engine and make sure there is no open flame nearby. If oil is spilled or leaked on hot surfaces or electrical components, it may 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 perform the work in a service station operated under the provision of the law. When draining oil from the engine or oil can, be sure to use an oil pump.

Tighten the oil can cap securely.

Store the oil can in a well-ventilated place and out of direct sunlight.

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

## Service Limits for Engine Oil

Engine oil degrades through the use and by the lapse of time. The quality of engine oil and the operating condition of the engine have influence on deterioration of the engine oil. Change the engine oil in accordance with [Chapter 7 PERIODIC MAINTENANCE SCHEDULE](#). However, only when the engine oil analysis result allows, the oil change intervals can be extended. The limit of extended oil change interval is 500 hours. For the determination of engine oil properties degradation, see the table below. If any of oil properties exceeds the limit, change the engine oil with new oil.

Table 5-4 Engine Oil Properties

| Properties                    |                                         | Standard value                                                                                            |                                                                                      | Test standard                      |
|-------------------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------------------------------------|
| Kinetic viscosity             | mm <sup>2</sup> /s<br>@100°C<br>[212°F] | For main engine/<br>main generator                                                                        | +30% or less rate of change from new oil<br>10 mm <sup>2</sup> /s or more            | JIS K 2283<br>ISO 3107<br>ISO 2909 |
|                               |                                         | For emergency generator                                                                                   | +30% or less rate of change from new oil<br>-20% or more rate of change from new oil |                                    |
| Base number                   | mgKOH/g                                 | 2.0 or more with hydrochloric acid (HCL) method<br>1/2 of new oil or more by perchloric acid (PCA) method |                                                                                      | JIS K 2501<br>ISO 3771             |
| Acid number                   | mgKOH/g                                 | +3.0 or less of new oil                                                                                   |                                                                                      | JIS K 2501<br>ISO 3771             |
| Water content                 | volume%                                 | 0.2 or less                                                                                               |                                                                                      | JIS K 2275<br>ISO 9029             |
| Flash point (open cup)        | °C [°F]                                 | 180 [356] or more                                                                                         |                                                                                      | JIS K 2265<br>ISO 3679<br>ISO 2719 |
| Pentane insolubles            | mass%                                   | 0.5 or less                                                                                               |                                                                                      | ASTM D 893                         |
| Coagulated pentane insolubles | mass%                                   | 3.0 or less                                                                                               |                                                                                      | ASTM D 893                         |

## Definition of Property Limit of Engine Oil

### Kinetic Viscosity

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

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

### Base Number

The total base number represents the ability to neutralize organic acids generated by the oxidation of engine oil and sulfurous acid and sulfuric acid by burning sulfur compounds in fuel. Because the base number indicates the amount of dispersant detergent in oil, it can be used to estimate the consumption of basic dispersant detergent. The ability to disperse sludge declines as the dispersant detergent is consumed. Thus, the base number is often used as an indication of cleaning capability decline.

### Acid Number

The total acid number in the oil increases due to the formation of organic acids by the oxidation of engine oil, the formation of sulfurous acid and sulfuric acid by the combustion of sulfur compounds in the fuel, and the incomplete combustion products.

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

### Water Content

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

### Flash Point

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

### Insolubles

Insolubles include acid products of engine oil, imperfect combustion products, sludge or soot, worn metal particles and dust. Insolubles value 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 dispersant detergent and collect the sludge dispersed in oil) to identify the engine oil contamination level, and thereby, the insoluble value can be a marker to prevent the piston ring from seizure or premature wear.

## Engine Oil Analysis Service

For a long productive service life of engine, the use of engine oil analysis service is recommended.

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

The following information is obtained by the engine oil analysis service:

- ♦The amount of fine metal powder in engine oil due to abrasion is measured, by which, worn parts of the engine can be located.
- ♦Water, LLC, or salt that should not be in engine oil can be detected if presented.
- ♦Deteriorated condition of engine oil is shown. These will allow the planning of operational and maintenance counter-measures, and show the proper engine oil replacement intervals.

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

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



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

## Recommended Water for Coolant

Use soft water (such as tap water) for the engine cooling system. The water quality must meet the requirements in the table below. Basically, the water quality should be within the range of the recommended values, however, up to the limit value is acceptable.

Table 6-1 Water Quality Standard

| Item                                  | Chemical symbol               | Unit | Recommend value | Limit value | Main harm                     |
|---------------------------------------|-------------------------------|------|-----------------|-------------|-------------------------------|
| pH (25°C [77°F])                      | -                             | -    | 6.5 to 8.0      | 6.5 to 8.5  | Corrosion and scale formation |
| Electrical conductivity (25°C [77°F]) | -                             | mS/m | ≤ 25            | ≤ 40        | Corrosion and scale formation |
| Total hardness                        | CaCO <sub>3</sub>             | mg/L | ≤ 95            | ≤ 100       | Scale formation               |
| M alkalinity                          | CaCO <sub>3</sub>             | mg/L | ≤ 70            | ≤ 150       | Scale formation               |
| Chlorine ion                          | Cl <sup>-</sup>               | mg/L | ≤ 100           | ≤ 100       | Corrosion                     |
| Sulphate ion                          | SO <sub>4</sub> <sup>2-</sup> | mg/L | ≤ 50            | ≤ 100       | Corrosion                     |
| Total iron                            | Fe                            | mg/L | ≤ 1.0           | ≤ 1.0       | Scale formation               |
| Silica                                | SiO <sub>2</sub>              | mg/L | ≤ 30            | ≤ 50        | Scale formation               |
| Residue by evaporation                | -                             | mg/L | ≤ 250           | ≤ 400       | Scale formation               |

## Long Life Coolant (LLC)

### CAUTION

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

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

## Genuine MHIET LLC

MHIET recommends the use of our genuine long life coolant "GLASSY long life coolant (ethylene glycol type)" and eco-friendly product "PG GLASSY long life coolant (propylene glycol type)," which are most appropriate coolant for Mitsubishi diesel engines.

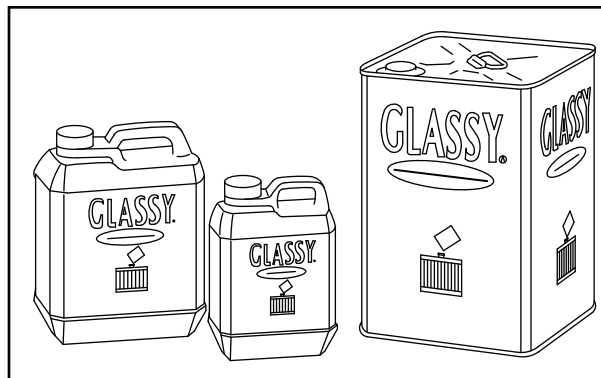


Fig. 6-1 GLASSY Long Life Coolant

## 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. MHIET 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 must not cause any problems such as corrosion and precipitation deposits in the engine cooling system.
- LLC must be mixed well with other non-amine type LLC that meets this requirements and must not separate elements included in the each product, and must not decrease the performance of both products.
- LLC must not corrode the container and must not produce a precipitate when LLC is stored in the container for 6 months.
- LLC must 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 must be 2 years after the delivery, provided that they are stored under indoor normal temperature.

## LLC Quality Standard

LLC must be tested in accordance with JIS K 2234, Section 7 "Test method," and satisfy the requirements. General matters and specimen sampling method must comply with JIS K 2234.

Table 6-2 LLC Quality Standard

| Test items                                                                                                                                                                                |                                     |                                                                 |           | Standard value                                                                                                                           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-----------------------------------------------------------------|-----------|------------------------------------------------------------------------------------------------------------------------------------------|
| Visual inspection                                                                                                                                                                         |                                     |                                                                 |           | No precipitation                                                                                                                         |
| Specific gravity                                                                                                                                                                          |                                     |                                                                 |           | Minimum 1.112 g/cm <sup>3</sup> [69.4199 lb/ft <sup>3</sup> ]<br>(20/20°C) [20/68°F]<br>(undiluted solution)                             |
| Water content                                                                                                                                                                             |                                     |                                                                 |           | 5.0 weight or less (undiluted solution)                                                                                                  |
| Freezing temperature                                                                                                                                                                      |                                     | 30% by volume in aqueous solutions                              |           | -14.5°C [5.9°F] or less                                                                                                                  |
|                                                                                                                                                                                           |                                     | 50% by volume in aqueous solutions                              |           | -34.0°C [-29.2°F] or less                                                                                                                |
| Equilibrium reflex boiling point                                                                                                                                                          |                                     |                                                                 |           | 155°C [311°F] or more<br>(undiluted solution)                                                                                            |
| pH                                                                                                                                                                                        |                                     |                                                                 |           | 7.0 to 11.0<br>(30% by volume in aqueous solution)                                                                                       |
| Bubbling character<br>(ASTM D3306-01)                                                                                                                                                     |                                     | 30% by volume in aqueous solutions                              |           | 4.0 mL [0.0008 gal] or less                                                                                                              |
|                                                                                                                                                                                           |                                     | 33 <sup>1</sup> / <sub>3</sub> % by volume in aqueous solutions |           | 150 mL [0.032 gal] or less, deforming<br>time 5 sec. or less                                                                             |
| Hard water compatibility                                                                                                                                                                  |                                     |                                                                 |           | 1.0 or less<br>(50% by volume in aqueous solution)                                                                                       |
| Metallic causticity<br>(88±2°C<br>[190.4±4°F],<br>336±2 Hrs,<br>30% by volume in<br>aqueous solution<br>(ethylene glycol),<br>50% by volume in<br>aqueous solution<br>(propylene glycol)) | Metallic test<br>piece              | Mass change                                                     | Aluminum  | ±0.30 mg/cm <sup>2</sup>                                                                                                                 |
|                                                                                                                                                                                           |                                     |                                                                 | Cast iron | ±0.15 mg/cm <sup>2</sup>                                                                                                                 |
|                                                                                                                                                                                           |                                     |                                                                 | Steel     | ±0.15 mg/cm <sup>2</sup>                                                                                                                 |
|                                                                                                                                                                                           |                                     |                                                                 | Brass     | ±0.15 mg/cm <sup>2</sup>                                                                                                                 |
|                                                                                                                                                                                           |                                     |                                                                 | Solder    | ±0.30 mg/cm <sup>2</sup>                                                                                                                 |
|                                                                                                                                                                                           |                                     |                                                                 | Copper    | ±0.15 mg/cm <sup>2</sup>                                                                                                                 |
|                                                                                                                                                                                           |                                     | Visual inspection of test piece after<br>testing                |           | Any corrosion should not be observed<br>except for the contacting position of the<br>test piece and spacer. Discoloration is<br>allowed. |
|                                                                                                                                                                                           | Bubble formation during test        |                                                                 |           | Bubble must not overflow.                                                                                                                |
|                                                                                                                                                                                           | Property of<br>liquid after<br>test | pH                                                              |           | 6.5 to 11.0                                                                                                                              |
|                                                                                                                                                                                           |                                     | pH change                                                       |           | ±1.0                                                                                                                                     |
|                                                                                                                                                                                           |                                     | Precipitation                                                   |           | 0.5% by volume in aqueous solution or<br>less                                                                                            |
|                                                                                                                                                                                           |                                     | Visual inspection of liquid                                     |           | No significant discoloration. No signifi-<br>cant changes such as separation and<br>gel generation.                                      |

Table 6-2 LLC Quality Standard

| Test items                                                                                                                                                                                 |                               |                                               |                                                       | Standard value                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Circulating corrosion<br>(98±2°C<br>[208.4±4°F],<br>1000 Hrs,<br>30% by volume in<br>aqueous solution<br>(ethylene glycol),<br>50% by volume in<br>aqueous solution<br>(propylene glycol)) | Metallic test piece           | Mass change                                   | Aluminum, cast iron, steel, brass, solder, and copper | ±0.30 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               | Visual inspection of test piece after testing |                                                       | Any corrosion should not be observed except for the contacting position of the test piece and spacer. Discoloration is allowed. |
|                                                                                                                                                                                            | Property of liquid after test | pH                                            |                                                       | 7.0 to 9.0                                                                                                                      |
|                                                                                                                                                                                            |                               | pH change                                     |                                                       | ±1.0                                                                                                                            |
|                                                                                                                                                                                            |                               | Reserve alkalinity change                     |                                                       | ±15%                                                                                                                            |
|                                                                                                                                                                                            |                               | Precipitation                                 |                                                       | 1.0% by volume in aqueous solutions or less                                                                                     |
|                                                                                                                                                                                            |                               | Visual inspection of liquid                   |                                                       | No significant discoloration. No significant changes such as separation and gel generation.                                     |
|                                                                                                                                                                                            |                               | Ion concentration                             | Iron, copper, aluminum, zinc, lead, and ammonium ion  | 10 ppm or less                                                                                                                  |
| Circulating corrosion<br>(88±3°C<br>[190.4±6°F],<br>1000±2 Hrs,<br>30% by volume in<br>aqueous solution<br>(ethylene glycol))                                                              | Metallic test piece           | Mass change                                   | Aluminum                                              | ±0.60 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               |                                               | Cast iron                                             | ±0.30 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               |                                               | Steel                                                 | ±0.30 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               |                                               | Brass                                                 | ±0.30 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               |                                               | Solder                                                | ±0.60 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               |                                               | Copper                                                | ±0.30 mg/cm <sup>2</sup>                                                                                                        |
|                                                                                                                                                                                            |                               | Visual inspection of test piece after testing |                                                       | Any corrosion must not be observed except for the contacting position of the test piece and spacer. Discoloration is allowed.   |
|                                                                                                                                                                                            | Property of liquid after test | pH                                            |                                                       | 6.5 to 11.0                                                                                                                     |
|                                                                                                                                                                                            |                               | pH change                                     |                                                       | ±1.0 or less                                                                                                                    |
|                                                                                                                                                                                            |                               | Visual inspection of liquid                   |                                                       | No significant discoloration. No significant changes such as 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 significant corrosion.                                                                                                |

Table 6-2 LLC Quality Standard

| Test items                                                                                                          |                                          |                              | Standard value |
|---------------------------------------------------------------------------------------------------------------------|------------------------------------------|------------------------------|----------------|
| Rubber adaptability<br>(30% by volume in aqueous solution, 115°C [239°F], 360 Hrs)                                  | Silicone                                 | Tensile strength change rate | -60 to 0%      |
|                                                                                                                     |                                          | Elongation change rate       | -40 to +20%    |
|                                                                                                                     |                                          | Volume change rate           | 0 to +40%      |
|                                                                                                                     |                                          | Hardness change rate         | -20 to +10%    |
|                                                                                                                     | Nitrile rubber                           | Tensile strength change rate | 0 to +10%      |
|                                                                                                                     |                                          | Elongation change rate       | -15 to +15%    |
|                                                                                                                     |                                          | Volume change rate           | 0 to +40%      |
|                                                                                                                     |                                          | Hardness change rate         | -10 to 0%      |
|                                                                                                                     | Ethylene pro-<br>pylene diene<br>monomer | Tensile strength change rate | 0 to +10%      |
|                                                                                                                     |                                          | Elongation change rate       | -30 to 0%      |
|                                                                                                                     |                                          | Volume change rate           | 0 to +10%      |
|                                                                                                                     |                                          | Hardness change rate         | -10 to 0%      |
| Storage stability (% by volume in aqueous solution)<br>(30% by volume in aqueous solutions, room temperature 6 Hrs) |                                          |                              | 0.3 or less    |

## Maintenance of LLC

### CAUTION

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

LLC is toxic. Do not dump coolant containing LLC drained from the engine casually into sewage. For disposal of used coolant, consult the LLC distributor.

## Replacement Intervals of LLC

### CAUTION

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

Failure to replace LLC may cause malfunctions due to rust prevention performance degradation and cavitations.

## LLC Concentration (GLASSY and PG GLASSY)

1. 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.
2. Coolant anti-freeze concentration for the engine is determined by the ambient minimum temperature of the year. Maintain the coolant concentration in the range shown in the table below:

Table 6-3 Recommended LLC Concentration

| Ambient temperature |                              | Up to -10°C<br>[14°F] | Up to -20°C<br>[-4°F] | Up to -30°C<br>[-22°F] | Up to -45°C<br>[-49°F] |
|---------------------|------------------------------|-----------------------|-----------------------|------------------------|------------------------|
| LLC concentration   | GLASSY (ethylene glycol)     | 30%                   | 40%                   | 50%                    | 60%                    |
|                     | PG GLASSY (propylene glycol) | 40%                   | 55%                   | 70%                    | 90%                    |

3. Concentration must be 60% at a maximum for GLASSY (ethylene glycol) and 90% for PG GLASSY (propylene glycol). If the concentration is higher than that, the antifreeze effect will decrease, or the cooling water temperature will increase due to the lowered specific heat.
4. Coolant temperature will increase by approximately 1.5°C [2.7°F] for 60% concentration of GLASSY (ethylene glycol) and approximately 3°C [5.4°F] for 90% concentration of PG GLASSY (propylene glycol). Check heat exchanger capacity of the cooling system to avoid overheating.

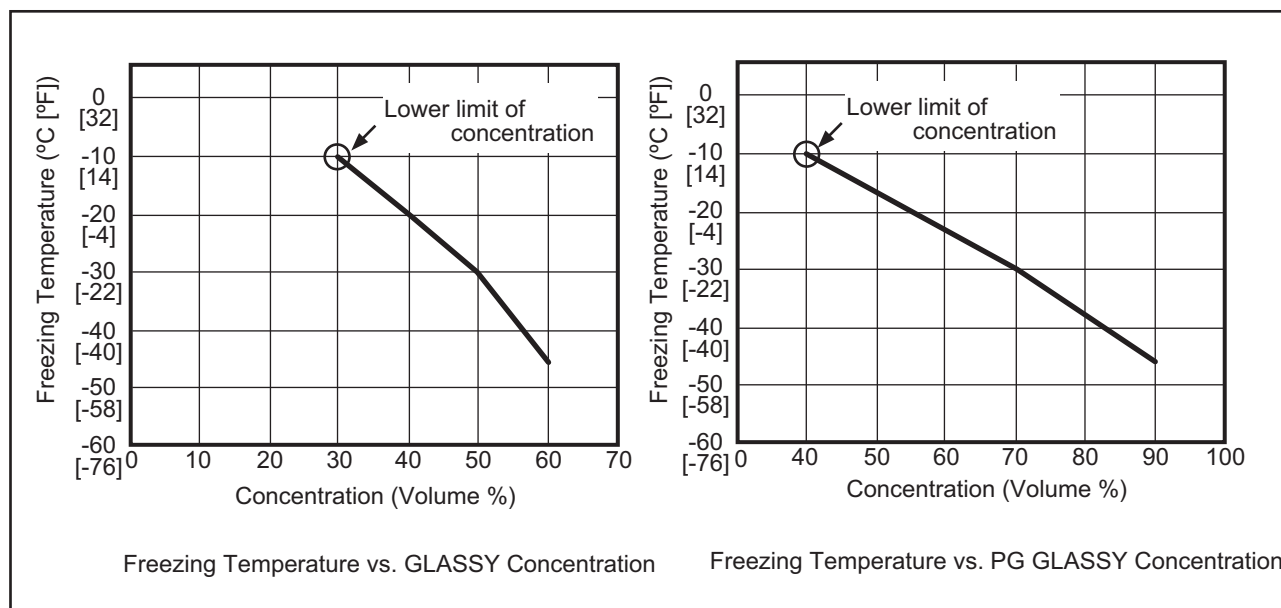


Fig. 6-2 Coolant Freezing Temperature (GLASSY and PG GLASSY)

## LLC Concentration Measuring Method

### Tool

Coolant tester

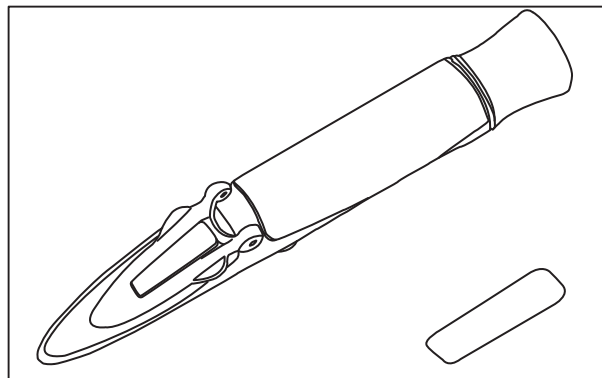


Fig. 6-3 Coolant Tester

### Calibration

1. Place one or two drops of distilled or tap water on the prism.

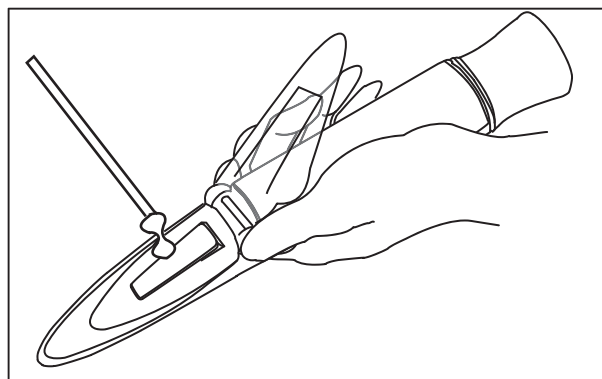


Fig. 6-4 Measuring Procedure 1

2. Close the daylight plate gently.

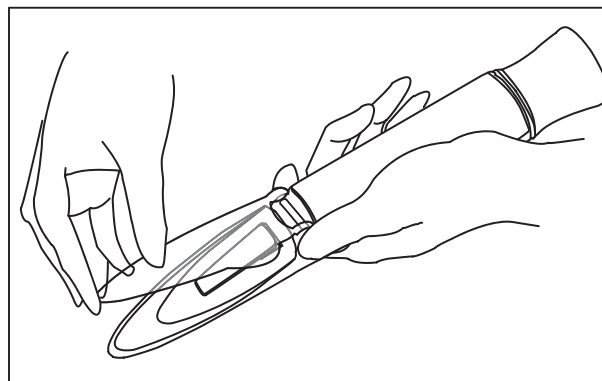


Fig. 6-5 Measuring Procedure 2

3. Spread the drop evenly on the prism surface. Do not allow bubbles staying on the surface.

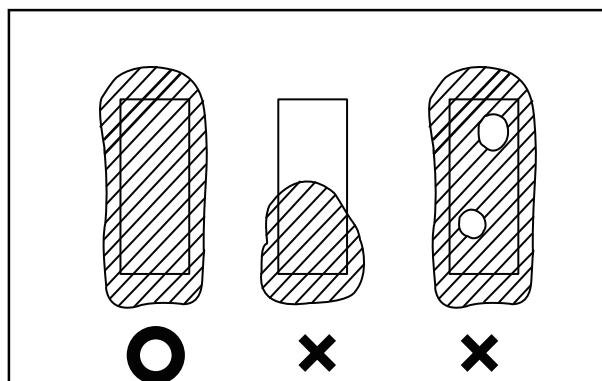


Fig. 6-6 Measuring Procedure 3

4. Read the scale through the eye piece. Turn the eye piece until the scale is clearly visible.

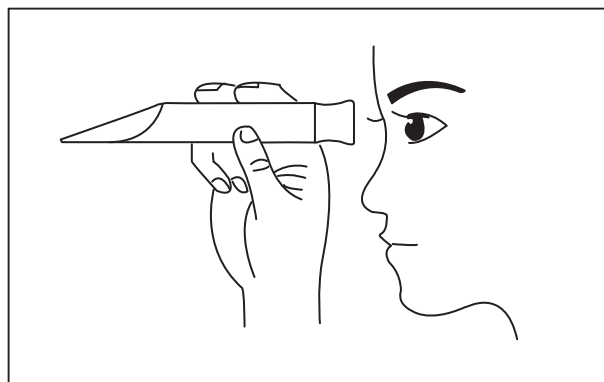


Fig. 6-7 Measuring Procedure 4

5. Verify the boundary line of blue color aligns with the 0% on the scale.

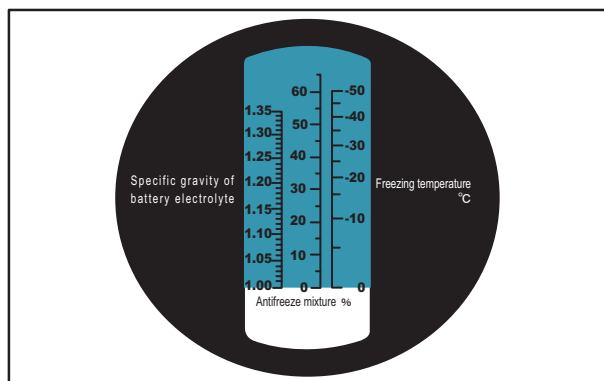


Fig. 6-8 Measuring Procedure 5

6. Adjust the scale calibration screw with the tool to align the boundary line and the 0% line if they are not aligned.

### CAUTION

Do not rotate the calibration screw excessively. The refractometer may be damaged.

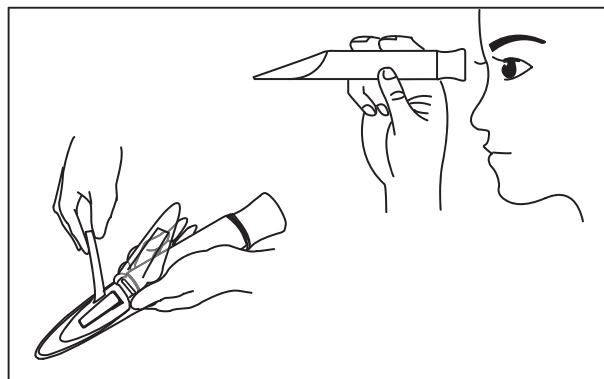


Fig. 6-9 Measuring Procedure 6

## Measurement

1. Place one or two drops of specimen on the prism.  
(Fig. 6-4)
2. Close the daylight plate gently. (Fig. 6-5)
3. Spread the specimen evenly on the prism surface.  
Do not allow bubbles staying on the surface.  
(Fig. 6-6)
4. Read the scale through the eye piece. Turn the eye piece until the scale is clearly visible. (Fig. 6-7)
5. Read the measured value where the boundary line crosses the scale line.

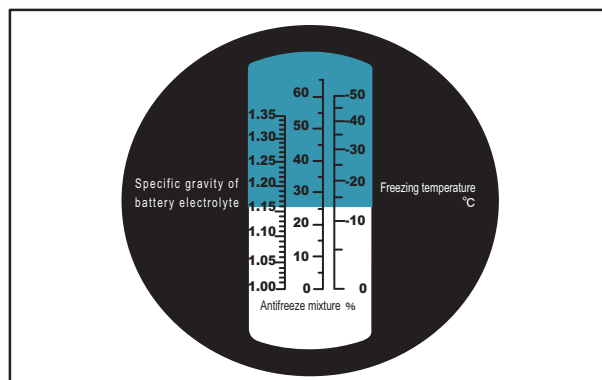


Fig. 6-10 Measuring Procedure 7

6. Wipe off the specimen with water-soaked soft facial tissue.

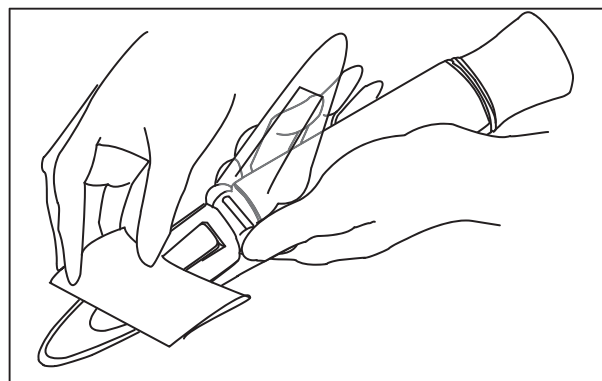


Fig. 6-11 Measuring Procedure 8

## Necessity of LLC

Smaller and lighter engines are today's trend as they can offer greater output, lower fuel consumption, and lower exhaust emission levels.

Conditions to which engine coolant is subjected, therefore, are becoming severer due to longer operating hours, higher coolant temperature, and higher coolant circulating speed.

Furthermore, many different materials such as steel, aluminum, copper, solder, and rubber are used in the cooling system, and they are also subject to the severe conditions described above. Those materials have different ionization characteristics, and this difference accelerates corrosion through the medium of engine coolant. To prevent such a problem, it is necessary to use the LLC containing additives that prevent rust.

## Characteristics of LLC Additives

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

Furthermore, if the chemicals are not well proportioned to match the metals used in the cooling system, certain chemicals in the LLC become rapidly used up, and it results in corrosion of metals to be protected. Consequently, other corrosion preventing chemicals react with dissolving metals, by which corrosion is accelerated. This condition generates more severe corrosion than when plain soft water is used. This is a typical problem caused by the use of inappropriate LLC.

## Examples of Abnormalities Caused by Amine Type LLC

### Pitting of Iron Parts

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

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

### Corrosion of Aluminum Parts

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

This means, after silicate is used up, the high alkalinity causes chemical attacks on aluminum. To prevent this problem, proper maintenance of the coolant is required. For example, rapid wear of fresh water pump mechanical seal due to gelification of silicate salt has been observed.

# Chapter 7 PERIODIC MAINTENANCE SCHEDULE

## How to Use the Periodic Maintenance Schedule

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

Obeys the standard service intervals specified in the "Periodic Maintenance Schedule". However, when you think the engine should need the inspection and maintenance earlier than the specified intervals in the "Periodic Maintenance Schedule", change the intervals accordingly.

Note: Appropriate service intervals vary with usage and operating conditions as well as conditions of fuel, oil, and coolant.

Be sure to check the items which are included in the applicable interval and shorter intervals. Be sure to conduct periodic inspection at specified intervals, either hours or calendar days, whichever comes first.

(Example) During the inspection conducted at "Every 4000 Service Hours," also inspect the items listed under "Every 2000 Service Hours" and "Every 1000 Service Hours."

Items marked with \* in the "Periodic Maintenance Schedule" require special tools or large-scale maintenance. For those items, contact your MHIET dealer.

### <Engine top overhaul>

On the top overhaul, remove the cylinder head, inspect and replace as required the cylinder head, combustion chamber and other main components. For details of top overhaul, contact your MHIET dealer.

### <Engine major overhaul>

On the major overhaul, disassemble the whole engine, conduct inspection, maintenance, and replacement of main components. For details of major overhaul, contact your MHIET dealer.

Table 7-1 Rating Definition for Diesel Engine for Industrial Applications

| Name of rating                              | Definition                                                                                                                                                                                                                                                                                             | Required conditions for warranty (*1)                                                         |                                                                   |                                                                    | Operating Hr/year (Recommendation) |
|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-------------------------------------------------------------------|--------------------------------------------------------------------|------------------------------------|
|                                             |                                                                                                                                                                                                                                                                                                        | Load/operating time (*2)                                                                      | Overhaul interval after delivery <Maximum>                        |                                                                    |                                    |
|                                             |                                                                                                                                                                                                                                                                                                        | Ave. load factor/yr                                                                           | Top                                                               | Major                                                              |                                    |
| A-rating<br>Maximum<br>Fuel Stop Power      | Maximum rating used for general applications except gen-set.<br>Used for applications with cyclic load and speed.                                                                                                                                                                                      | 50% or lower<br><br>Continuous operation with over 90% load shall be limited to 30 min.       | 4000Hr or 4yr<br>whichever comes earlier                          | 8000Hr or 8yr<br>whichever comes earlier                           | (3000Hr)                           |
| B-rating<br>Intermittent<br>Irrigation Pump | Load and speed are constant in principle.<br>In some cases, this may be used for applications with cyclic load.                                                                                                                                                                                        | 80% or lower<br><br>Continuous operation of over 90% load is limited up to 1Hr (per 24Hr).    | 4000Hr or 4yr<br>whichever comes earlier                          | 8000Hr or 8yr<br>whichever comes earlier                           | (4000Hr)                           |
| C-rating<br>Continuous                      | Used for applications with constant load and speed.<br>Continuous operation for long time is acceptable as long as required conditions for warranty in this document is observed.<br>However, the average load factor per year shall not exceed 90%, as specified in required conditions for warranty. | 80% or lower<br><br>Continuous operation of overload (≤110%) is limited up to 1Hr (per 24Hr). | 6000Hr or 4yr<br>whichever comes earlier<br>(Recommended :4000Hr) | 12000Hr or 8yr<br>whichever comes earlier<br>(Recommended :8000Hr) | None                               |

(\*1) Atmospheric condition as per ISO 15550:2005 (JIS B 8003:2005) (Barometric pressure: 100 kPa {1.02 kgf/cm<sup>2</sup>} [14.5 psi], ambient temperature: 298 K, relative humidity: 30%).

(\*2) Average load factor shall be calculated as per the formula in ISO 8528:2005 'average power output (Ppp)'.

# Periodic Maintenance Schedule

Table 7-2 Periodic Maintenance Schedule for Marine Engine

| Inspection and Maintenance Period |                            | Service Items                                                  | Terms                             |
|-----------------------------------|----------------------------|----------------------------------------------------------------|-----------------------------------|
| Service Period                    | Service hours              |                                                                |                                   |
| Daily                             | -                          | Walk around check<br>(Check leakage of fuel, oil and coolant.) | Check                             |
|                                   |                            | Fuel Tank Oil Level                                            | Check                             |
|                                   |                            | Engine Oil Level                                               | Check                             |
|                                   |                            | Coolant Level                                                  | Check                             |
|                                   |                            | Fuel Control Link                                              | Check                             |
|                                   |                            | Damper Temperature                                             | Check                             |
|                                   |                            | Battery Electrolyte Level                                      | Check                             |
|                                   |                            | Water separator                                                | Drain Water                       |
|                                   |                            | Fuel Filter<br>(Wire Element Type)                             | Clean                             |
| -                                 | First 100<br>service hours | Engine Oil                                                     | Replace, Analyze<br>(Recommended) |
|                                   |                            | Oil Filters                                                    | Replace                           |
|                                   |                            | Bypass Oil Filters                                             | Replace                           |
|                                   |                            | Fuel Filters                                                   | Replace                           |
|                                   |                            | Valve Clearance<br>(Check Valve mechanism at the same time)    | Check and Adjustment              |
|                                   |                            | Bolts and Nuts on the engine                                   | Re-tighten                        |
| Every year                        | Every 250<br>service hours | Bypass Oil Filters                                             | Replace                           |
|                                   |                            | Belts                                                          | Check and Tension<br>adjustment   |
|                                   |                            | Pre-cleaners                                                   | Clean and Check                   |
|                                   |                            | Battery                                                        | Check                             |
|                                   |                            | Wiring Cable Connection                                        | Check                             |
|                                   |                            | Engine Oil *1                                                  | Replace, Analyze<br>(Recommended) |
|                                   |                            | Oil Filters *1                                                 | Replace                           |
|                                   | Every 500<br>service hours | Gauze Filters                                                  | Clean                             |
|                                   |                            | Governor Oil Filters                                           | Replace                           |

Table 7-2 Periodic Maintenance Schedule for Marine Engine

| Inspection and Maintenance Period |                          | Service Items                                               | Terms                                                                                               |
|-----------------------------------|--------------------------|-------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Service Period                    | Service hours            |                                                             |                                                                                                     |
| Every year                        | Every 1000 service hours | Fuel Filters                                                | Replace                                                                                             |
|                                   |                          | Fuel Filter (Wire Element Type)                             | Clean                                                                                               |
|                                   |                          | Water Separator Element                                     | Replace                                                                                             |
|                                   |                          | Seawater Pump Impeller                                      | Check                                                                                               |
|                                   |                          | Turbocharger Rotors                                         | Check                                                                                               |
|                                   |                          | Bolts and Nuts on the engine                                | Re-tighten                                                                                          |
|                                   |                          | Valve Clearance<br>(Check Valve mechanism at the same time) | Check and Adjustment                                                                                |
|                                   |                          | Fuel Injection Timing                                       | Check and Adjustment                                                                                |
|                                   |                          | LLC concentration level of coolant                          | Check                                                                                               |
| Every 2 years                     | Every 2000 service hours | Dampers                                                     | Check                                                                                               |
|                                   |                          | Starters                                                    | Check                                                                                               |
|                                   |                          | Alternator                                                  | Check                                                                                               |
|                                   |                          | Air Coolers                                                 | Clean and Check                                                                                     |
|                                   |                          | Fuel Injection Pump Laminate Plate                          | Check                                                                                               |
|                                   |                          | Belts                                                       | Replace                                                                                             |
|                                   |                          | Pre-cleaners                                                | Replace                                                                                             |
|                                   |                          | Fuel Injection Pump Control Rack Operation                  | Check (Movement)                                                                                    |
|                                   |                          | High Pressure Fuel Injection Pipes and Clamp Seats          | Check                                                                                               |
|                                   |                          | Low Pressure Fuel Pipes and Clips                           | Check                                                                                               |
|                                   |                          | Oil Pipes and Clips                                         | check                                                                                               |
|                                   |                          | Fuel Injection Nozzle Tips, Springs and Specers             | Replace<br>*After replacement, check spray condition and opening pressure, and adjust if necessary. |
|                                   |                          | Fuel Control Linkage Ball Joints                            | Check                                                                                               |
|                                   |                          | Seawater Pump Impeller                                      | Replace                                                                                             |
|                                   |                          | Harnesses and Terminals                                     | Check<br>(Damage or Looseness)                                                                      |
|                                   |                          | Bolts and Nuts on Exhaust and Air Inlet Pipes               | Re-tighten                                                                                          |
| -                                 | Every 4000 service hours | Heat Exchangers                                             | Clean and Check                                                                                     |
|                                   |                          | Pipe Clamps                                                 | Check                                                                                               |
|                                   |                          | Exhaust Pipe Joints (Bellows)                               | Check                                                                                               |
|                                   |                          | Thermostats                                                 | Check (for Actuation)                                                                               |
|                                   |                          | Protective Devices                                          | Check (for Actuation)                                                                               |
|                                   |                          | Turbochargers                                               | Overhaul                                                                                            |
|                                   |                          | Unit Seal and Ball Bearings of Water Pumps                  | Replace                                                                                             |
|                                   |                          | Unit Seal and Ball Bearings of Seawater Pumps               | Replace                                                                                             |

Table 7-2 Periodic Maintenance Schedule for Marine Engine

| Inspection and Maintenance Period                                                                                        |                          | Service Items                                                                                                                         | Terms                                  |
|--------------------------------------------------------------------------------------------------------------------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|
| Service Period                                                                                                           | Service hours            |                                                                                                                                       |                                        |
| <b>TOP Overhaul</b><br>Service intervals vary depends on the use condition. For details, refer to the rating definition. |                          | Cylinder Heads                                                                                                                        | Disassemble and Check                  |
|                                                                                                                          |                          | Valve Mechanism                                                                                                                       | Disassemble and Check                  |
|                                                                                                                          |                          | Inlet and Exhaust Valves, and its valve seats                                                                                         | Clean and Check                        |
|                                                                                                                          |                          | Top surface of Pistons                                                                                                                | Clean and Check                        |
|                                                                                                                          |                          | Cylinder Liner Surface                                                                                                                | Check                                  |
| -                                                                                                                        | Every 8000 service hours | Fuel Flexible Hoses                                                                                                                   | Replace                                |
|                                                                                                                          |                          | Fuel Injection Pump                                                                                                                   | Check and Test                         |
|                                                                                                                          |                          | Governor                                                                                                                              | Check and Test                         |
|                                                                                                                          |                          | High Pressure Fuel Injection Pipes and Clamp Seats                                                                                    | Replace                                |
|                                                                                                                          |                          | Oil Coolers                                                                                                                           | Clean and Check                        |
|                                                                                                                          |                          | Tension Pulley Bearing                                                                                                                | Replace                                |
|                                                                                                                          |                          | Thermostats                                                                                                                           | Replace                                |
|                                                                                                                          |                          | Cooling Fresh Water and Seawater Hoses                                                                                                | Replace                                |
|                                                                                                                          |                          | Water Tank Cap                                                                                                                        | Replace                                |
|                                                                                                                          |                          | Electrical Components (Instruments, Sensor and etc)                                                                                   | Check                                  |
|                                                                                                                          |                          | Relays (Including Relays for Governor and Panel)                                                                                      | Replace                                |
|                                                                                                                          |                          | <b>MAJOR Overhaul (1st time)</b><br>Service intervals vary depends on the use condition. For details, refer to the rating definition. | Includes the TOP overhaul maintenance. |
| Inlet and Exhaust Valves, and its valve seats                                                                            | Replace                  |                                                                                                                                       |                                        |
| Valve Rotators and Cotters                                                                                               | Replace                  |                                                                                                                                       |                                        |
| Rocker Arm Adjusting Screws                                                                                              | Replace                  |                                                                                                                                       |                                        |
| Bridge Caps                                                                                                              | Replace                  |                                                                                                                                       |                                        |
| Camshaft Bushings                                                                                                        | Replace                  |                                                                                                                                       |                                        |
| Camshaft Thrust Plates                                                                                                   | Replace                  |                                                                                                                                       |                                        |
| Camshaft Expansion Plugs                                                                                                 | Replace                  |                                                                                                                                       |                                        |
| Main Bearings                                                                                                            | Replace                  |                                                                                                                                       |                                        |
| Thrust Plates                                                                                                            | Replace                  |                                                                                                                                       |                                        |
| Cylinder Liners                                                                                                          | Replace                  |                                                                                                                                       |                                        |
| Piston Rings                                                                                                             | Replace                  |                                                                                                                                       |                                        |
| Connecting Rod Bearings                                                                                                  | Replace                  |                                                                                                                                       |                                        |
| Dampers                                                                                                                  | Replace                  |                                                                                                                                       |                                        |
| Air-Duct Rubber Hoses                                                                                                    | Replace                  |                                                                                                                                       |                                        |
| Consumable Items (Gaskets, Oil seals, O-rings, etc.)                                                                     | Replace                  |                                                                                                                                       |                                        |

Table 7-2 Periodic Maintenance Schedule for Marine Engine

| Inspection and Maintenance Period                                                                                                    |                          | Service Items                                  | Terms             |
|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------------------------------------|-------------------|
| Service Period                                                                                                                       | Service hours            |                                                |                   |
| <b>MAJOR Overhaul(2nd time)</b><br>Service intervals vary depends on the use condition. For details, refer to the rating definition. |                          | Includes the MAJOR overhaul (1st) maintenance. | -                 |
|                                                                                                                                      |                          | Cylinder Head Bolts                            | Check             |
|                                                                                                                                      |                          | Valve Guides                                   | Replace           |
|                                                                                                                                      |                          | Valve Springs                                  | Replace           |
|                                                                                                                                      |                          | Tappets                                        | Replace           |
|                                                                                                                                      |                          | Push Rods                                      | Replace           |
|                                                                                                                                      |                          | Pistons                                        | Replace           |
|                                                                                                                                      |                          | Connecting Rod ASSYs                           | Replace           |
|                                                                                                                                      |                          | Rocker Bushings                                | Replace           |
|                                                                                                                                      |                          | Main Cap Bolts and Washers                     | Replace           |
|                                                                                                                                      |                          | Fuel Injection Pumps                           | Check and Test    |
|                                                                                                                                      |                          | Governor                                       | Check and Test    |
|                                                                                                                                      |                          | Protective Devices                             | Repair or Replace |
| Every 2years                                                                                                                         | Every 8000 service hours | Coolant                                        | Replace           |
| As required                                                                                                                          |                          | Fuel System                                    | Bleed Air         |

Note: (a) Conduct the scheduled maintenance at specified intervals, either service hours or service period, whichever comes first.

(b) If the part is not supplied from Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET), service the part following the supplier's operation manual.

(c) Meaning of "Check" and "Replace" are as below.

Check : In case that abnormal points found as a result of visual check or some measurement, repair the failure condition by replacing parts and adjustment.

Replace : When the engine reach each service hours, unconditionally replace the parts and adjust them.

(d) Service intervals vary depending on the use conditions. For details, see the rating definition.

(e) **\*1 Period of oil replacement should be maximum 500 hours (250 hours as recommended). However, in case of oil pan of shallow type, period of oil replacement shall be 250 hours unconditionally.**



## Engine

### Engine Exterior - Inspect

#### CAUTION

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

Inspect the engine exterior as instructed below:

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

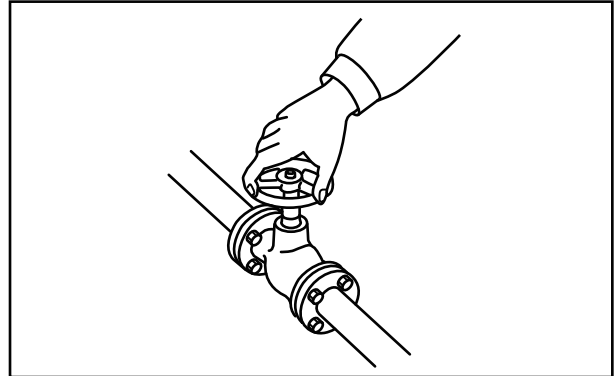


Fig. 8-1 Valve Open/Closed Position - Check

## Belt and Belt Tension - Inspect and Adjust

### CAUTION

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

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

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

Adjust the belt tension properly by following the procedures below:

### Belt - Inspect

1. Inspect the belt visually for peeling or breaks. If any abnormality is found, replace the belt with a new one.
2. Inspect the belt tension (deflection).  
Push the belt strongly at the midway between pulleys. If the deflection is 10 to 15 mm [0.4 to 0.6 in.], the tension is correct.  
Belt pushing force: approximately 98 to 147 N {10 to 15 kgf} [22 to 33 lbf]  
If the belt deflection is not within the specified range, adjust the belt tension.

### Belt Tension (Alternator Side) - Adjust

1. Remove the belt cover.
2. Loosen all retaining bolts of the alternator and adjusting plate.
3. Insert a bar between the alternator and crankcase and use leverage to move the alternator to have proper belt tension.
4. After tension adjustment, tighten all retaining bolts of the alternator and adjusting plate.
5. Install the belt cover.

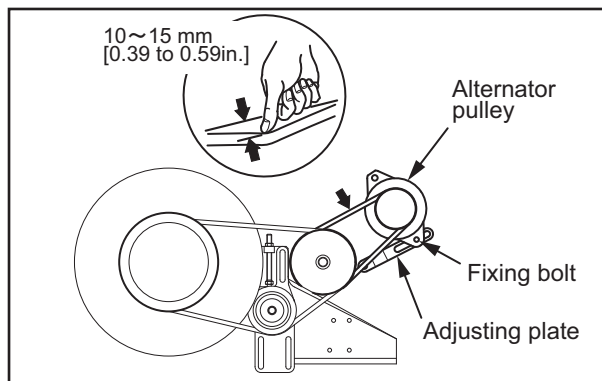


Fig. 8-2 Belt Tension - Adjust

## Damper - Inspect

### Damper - Check visually

#### CAUTION

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

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

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

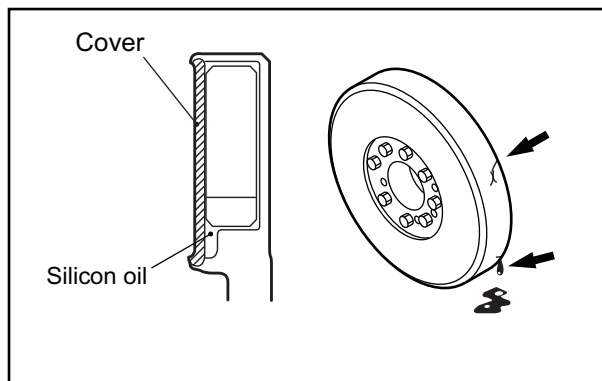


Fig. 8-3 Damper - Check Visually

# 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. It may 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 drip 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 specifications of fuel tank differs from the contents in this operation manual, obey the tank manufacturer's operation manual.

## Fuel Tank - Drain Water

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

1. Place a drip pan (capacity of 2 L [0.53 U.S. gal.] or more) under the drain cock of fuel tank.
2. Open the drain cock of fuel tank and drain fuel at least 1 to 2 L [0.26 to 0.53 U.S. gal.].
3. After making sure water and foreign material particles has been discharged together with fuel, close the drain cock.

Note: If the specifications of fuel tank differs from the contents in this operation manual, obey the tank manufacturer's operation manual.

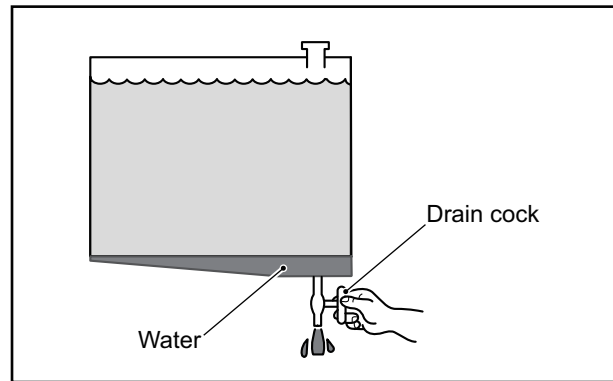


Fig. 8-4 Fuel Tank - Drain Water

## 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. Check the gauze filter for damage.
5. After cleaning, install the gauze filter into the union bolt using a screw driver.
6. Install the union bolt to the fuel feed pump.
7. Bleed air from the fuel filter.

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

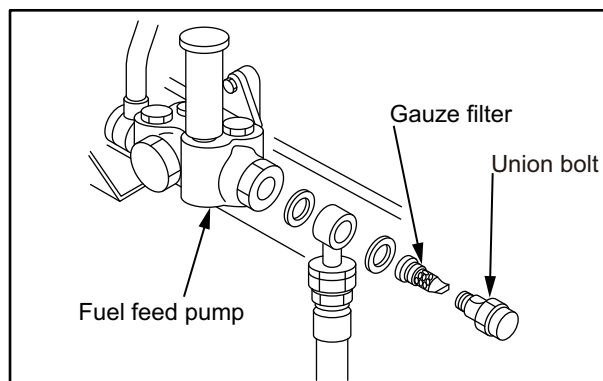


Fig. 8-5 Gauze Filter - Clean

## Fuel Filter - Replace

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



### WARNING

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

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

### CAUTION

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

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

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

Note: To bleed air from 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, tighten the fuel filter.

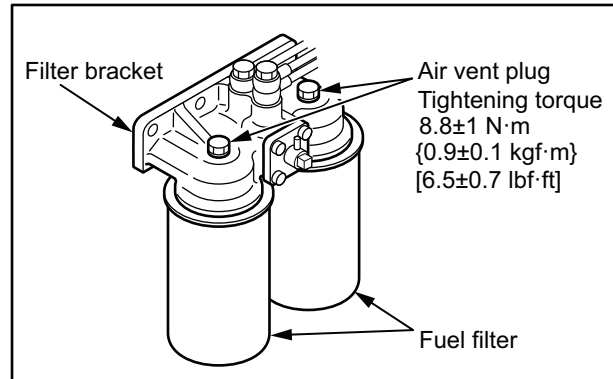


Fig. 8-6 Fuel Filter - Replace

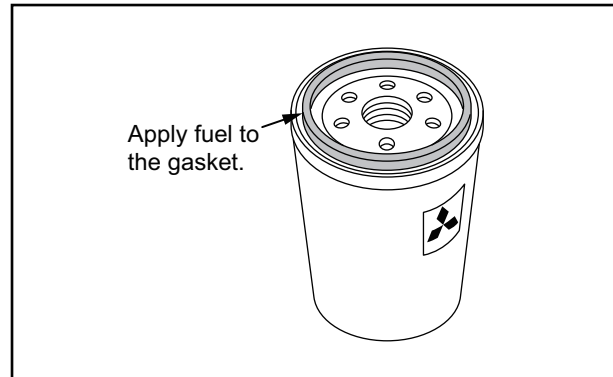


Fig. 8-7 Fuel Filter

## 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 stopped 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.

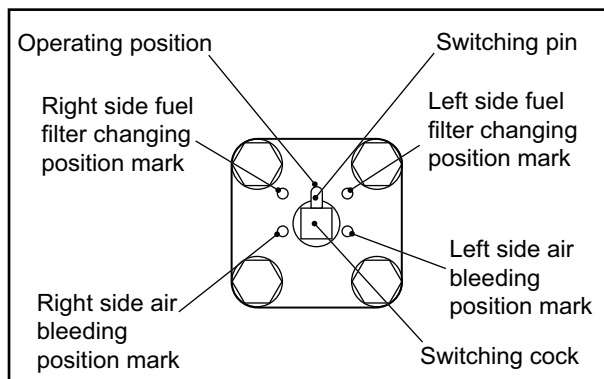


Fig. 8-8 Fuel Filter Switchover Cock

## Fuel Control Link Ball Joint - Inspect

Check the 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 a new one.

### CAUTION

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

If the ball joint is integrated with the control link, replace the control link assembly. When installing the ball joint, be sure to tighten the nut firmly.

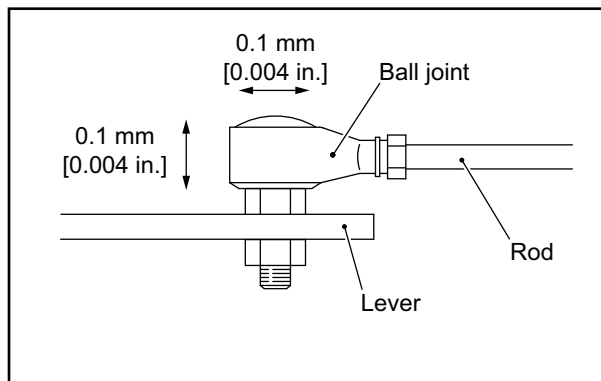


Fig. 8-9 Ball Joint - Check for Looseness

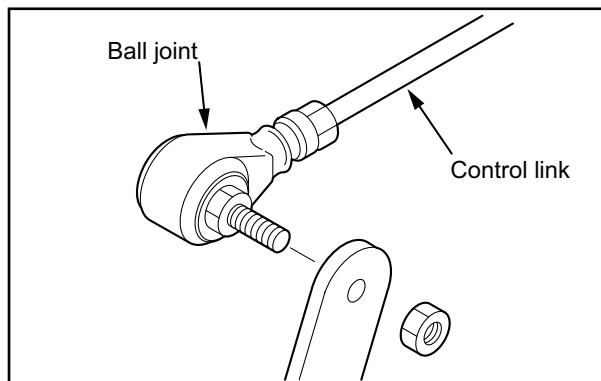


Fig. 8-10 Fuel Control Link - Remove

## Fuel Pipe - Inspect

### WARNING

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

Also make sure the fuel pipe does not contact with other pipe and object.

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

## High-pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

### Visual Inspection

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

### Every Major Overhaul

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

### Every Other Major Overhaul

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

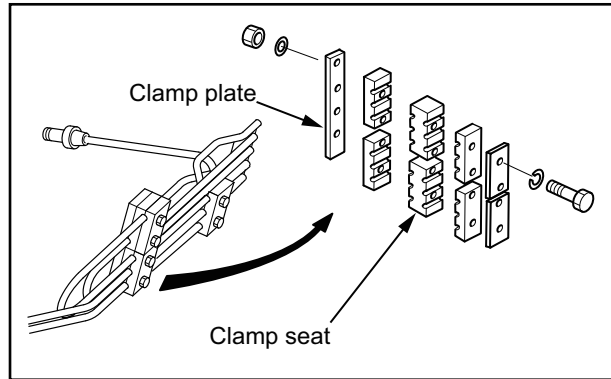


Fig. 8-11 High-pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

## 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.

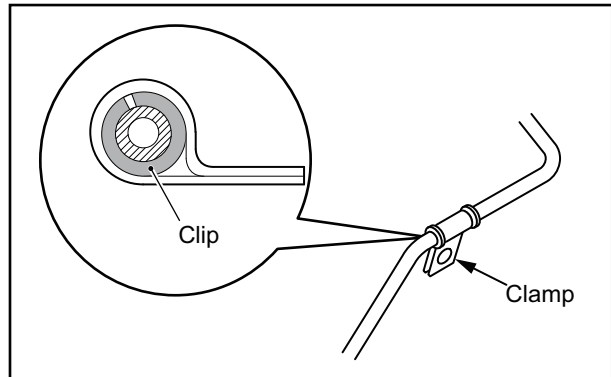


Fig. 8-12 Low-pressure Fuel Pipe, Oil Pipe, and Clip - Inspect and Replace

## Lubrication System

### Engine Oil and Oil Filter - Replace

#### CAUTION

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

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

#### CAUTION

Do not dump drain oil down the drain. It is forbidden by law. For the disposal of drain oil, contact your MHIET dealer.

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

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

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

### Engine Oil - Drain

1. Connect the engine oil drain port and drain pump with a vinyl hose.
2. Operate the drain pump to drain engine oil.

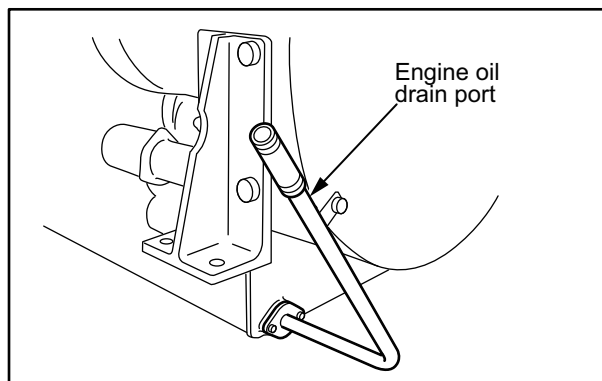


Fig. 8-13 Engine Oil - Drain Port

## Engine Oil - Refill

### **CAUTION**

Always refill 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 and leave it for 30 minutes or more.
2. Remove the oil filler cap.
3. Fill the engine oil pan with the specified engine oil to the specified level.

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

4. Pull out the oil level gauge and wipe oil off the oil level gauge using a clean waste cloth.
5. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
6. The proper oil level is between the high and low marks on the oil level gauge.  
If the oil level is low, add the specified engine oil.
7. Check the oil pan and other area for oil leaks. Repair if there is oil leak.
8. Operate the engine oil priming pump and check the engine oil pressure to be raised to approximately 0.2 MPa {2.04 kgf/cm<sup>2</sup>} [29 psi].

Note: Perform this procedure after the work for the lubrication and cooling systems have finished.

9. Start the engine and run the engine under no load for 5 to 10 minutes.
10. Stop the engine, and after 30 minutes or more has elapsed, check the oil level with the oil level gauge again and add oil to the specified level.

For details, refer to "Test Operation" (3-7).

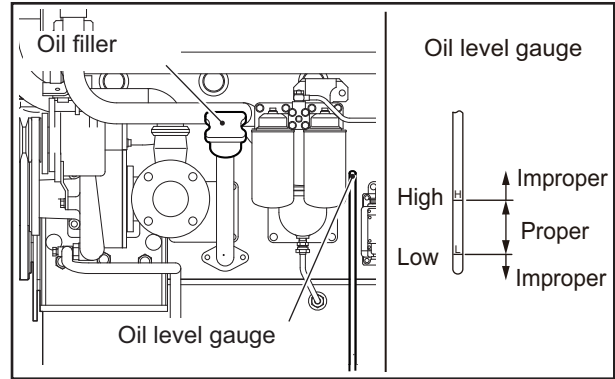


Fig. 8-14 Oil Filler and Oil Level Gauge

## Oil Filter - Change



### WARNING

If filter case is dented, do not use the filter. Dented 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.

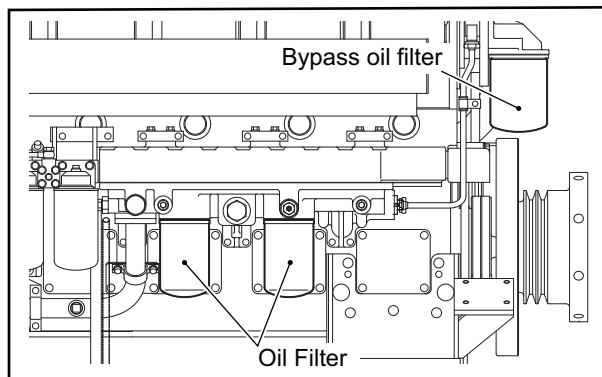


Fig. 8-15 Oil Filter - Change

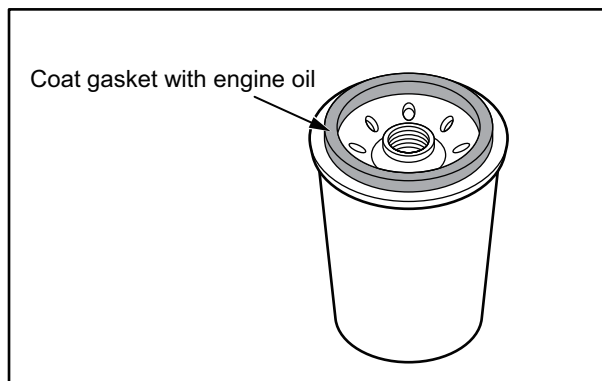


Fig. 8-16 Oil Filter

## Oil Filter - Replace While Engine is Running

### 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.

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.

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.

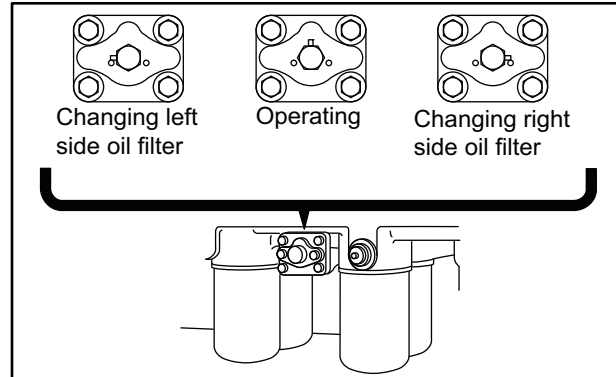


Fig. 8-17 Oil Filter - Replace While Engine is Running

## Ingress of Fuel and Water In Engine Oil - Inspect

### CAUTION

Continuous operation with water or fuel mixed in the engine oil will decrease the engine oil viscosity, which can lead to 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 see if the oil is contaminated with fuel and water.

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

If water is mixed, oil may turn milky white.

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

If fuel or water is mixed with the engine oil, find the cause and repair. If the repair is not easy, consult with your MHIET dealer.

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

## Cooling System

### Coolant (Fresh Water) - Change

#### CAUTION

The coolant mixed with the recommended LLC must be changed every 2 years.

#### Coolant - Drain

1. After making sure the engine has cooled, open the coolant expansion tank pressure cap.
2. Place coolant receiving cans under drain cocks. Open the drain cocks to drain coolant.

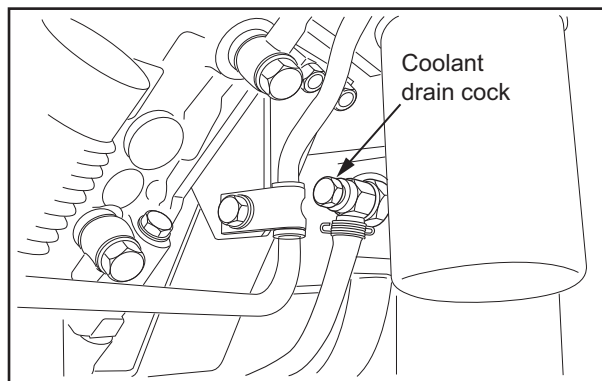


Fig. 8-18 Coolant Drain Cock (Engine Body)

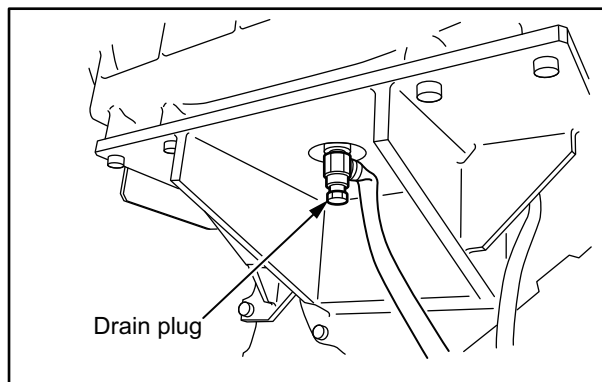


Fig. 8-19 Coolant Drain Cock (Water-Cooled Exhaust Pipe)

## Cooling System - Clean

### CAUTION

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

1. Close coolant drain cocks and plugs.
2. Pour a cleaning solution (a solution that is non-corrosive to rubber and metals) into the cooling system, and operate the engine at 800 to 900 min<sup>-1</sup> 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<sup>-1</sup> for about 10 minutes.  
Repeat the above rinsing steps until the draining water becomes clear and clean.

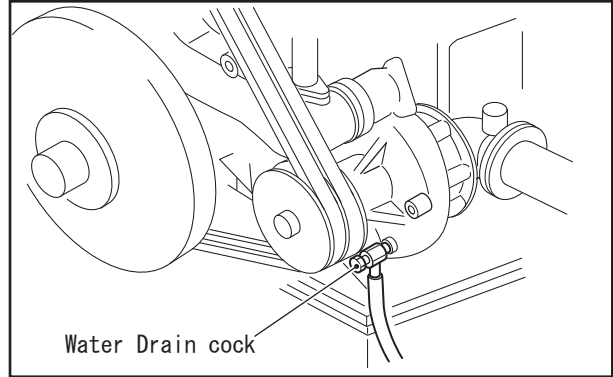


Fig. 8-20 Coolant Drain Cock (Fresh Water Pump)

## Coolant - Refill

### CAUTION

Never open the coolant expansion tank pressure 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 pressure cap, place a waste cloth over the cap, and loosen it about a quarter-turn to release the internal pressure.

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

When tightening the coolant expansion tank pressure 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 pressure cap, and add a mixture of water and LLC of the specified concentration to the specified level.  
Note: Determine the amount of LLC using the LLC concentration chart. For the coolant, refer to **"COOLANT" (6-1)**.  
For the coolant capacity, refer to **"MAIN SPECIFICATION" (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 pressure cap firmly.
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.
6. Check the coolant level in the coolant expansion tank.

## Inlet and Exhaust Systems

### Turbocharger - Inspect

**CAUTION**

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

**CAUTION**

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

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

Note: When the inspection requires the removal of turbocharger, contact your MHIET dealer. Also, check the compressor wheel fins for discoloration and breaks, and check for rubbing between compressor wheel and housing.

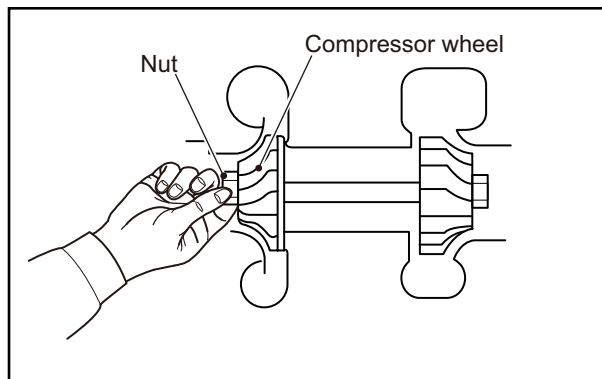


Fig. 8-21 Turbocharger - Inspect

## Pre-cleaner - Clean, Inspect, and Replace



### CAUTION

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

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

1. Remove the pre-cleaner from the silencer, and hand-wash the pre-cleaner with a mild detergent.
2. Rinse the pre-cleaner with fresh water.
3. After drying thoroughly, inspect the pre-cleaner for damage such as breaks. If breaks 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, getting thinner or stretched due to cleaning, replace it with a new one.

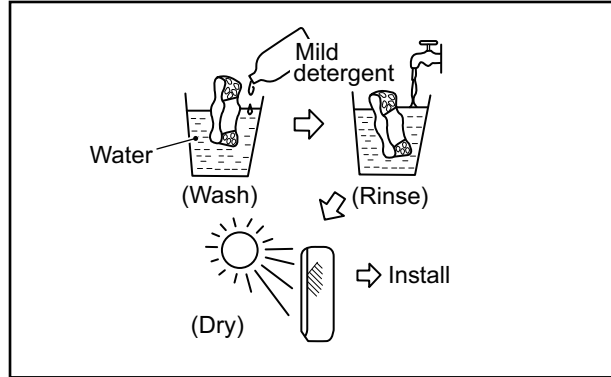


Fig. 8-22 Pre-cleaner - Wash

# 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 near the battery may cause an explosion.
- ♦Do not use the battery when the battery fluid level is below the "LOWER LEVEL" mark. It may explode.
- ♦Do not short the battery terminals with a tool or other metal object.
- ♦When removing battery, always remove the plug from the negative (-) terminal first. When connecting battery, always connect the plug to the positive (+) terminal first.
- ♦Before charging the battery, remove all battery cables, and then charge the battery in a well-ventilated area.
- ♦Make sure the cable clamps are securely attached to the battery terminals. A loose cable clamp may cause sparks, and it may result in an explosion.
- ♦Before servicing electrical components or conducting electric welding, set the battery switch to the [OFF] position or remove the plug from the negative (-) terminal to cut off the electrical current.
- ♦Battery fluid contains dilute sulfuric acid. Careless handling of the battery may cause a sight loss and/or skin burns. Also, do not swallow the battery fluid.
- ♦Wear protective goggles and rubber gloves when working with the battery (e.g. when adding water or charging battery).
- ♦If battery fluid is spilled onto the skin or clothing, immediately wash it away with lots of water. Use soap to clean thoroughly.
- ♦The battery fluid may cause sight loss if splashing into the your eyes. If it gets into your eyes, immediately flush it away with plenty of clean water, and seek immediate medical attention.
- ♦If you accidentally swallow battery fluid, gargle with plenty of water and then drink lots of water, and seek immediate medical attention.
- ♦If the battery does not fully recover after charging for 24 hours or more, do not use the battery.

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

## Battery Fluid Level - Check

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

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

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

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

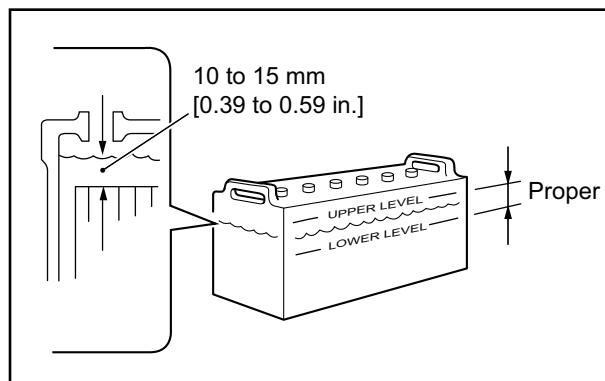


Fig. 8-23 Battery Fluid Level - Check

## Specific Gravity of Battery Electrolyte - Check

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

Table 8-1 Specific Gravity of Battery Electrolyte

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

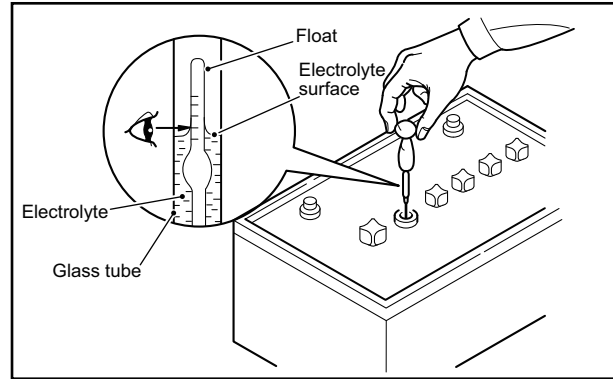


Fig. 8-24 Specific Gravity of Battery Electrolyte - Check

## Starter - Inspect

Visually inspect the starter and ring gear for damage.

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

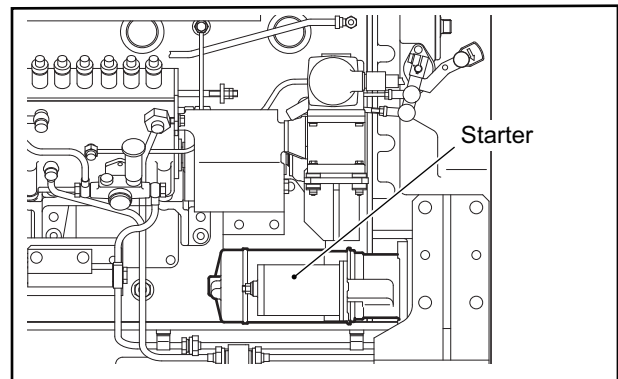


Fig. 8-25 Starter - Inspect

## Alternator - Inspect

Visually inspect the alternator for damage.

Remove the belt and turn the pulley by hand to check the smooth rotation. 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, contact your MHIET dealer.

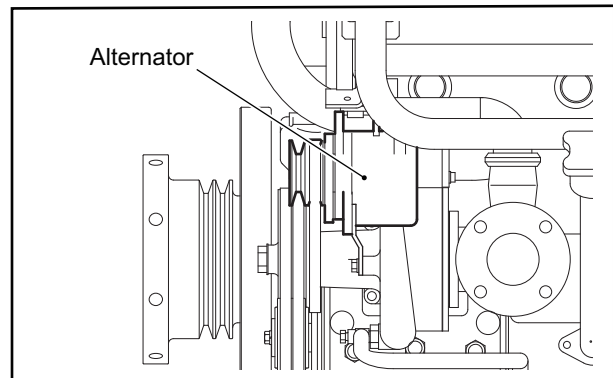


Fig. 8-26 Alternator - Inspect



# 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. Make a fuel mixture containing 50% rust-proof fuel (NP-9) and run it as quickly as possible at the rated speed.
3. After stopping the engine, suck a vaporizing rust inhibitor (VCI) into the air supply system (approximately 5 g [0.18 oz] for the direct model and approximately 10 g [0.35 oz] for the V model) and crank the engine twice or more.
4. Fill the fuel tank with fuel to protect the fuel tank from rusting. However, it is not necessary for FRP tanks.
5. Apply a sufficient quantity of anti-rust oil (NP-3-2) on the exposed machined surfaces.
6. Cover the air inlet, exhaust outlet, breather, etc. with adhesive cloth tape or plastic film.
7. Loosen the belt.
8. Apply a thin coat of grease on the starter and alternator terminals, and cover the openings. Also place desiccants inside the openings, and cover the openings with polyethylene sheet or processed polyethylene paper.
9. Disconnect the cables from the battery terminals, and charge the battery. Clean the terminals, apply a thin coat of grease on the terminals, and store in a cool and dry room.
10. Cover the entire engine.

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

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

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

### Recommended Rust-Preventive Oil and Corrosion Inhibitor

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

| JIS    |         | Recommended product                                                                | Intended use                             |
|--------|---------|------------------------------------------------------------------------------------|------------------------------------------|
| K 2246 | NP-3-2  | ANTIRUST TERAMI SC by ENEOS Corporation                                            | Exposed machined surfaces                |
|        | NP-9    | ANTIRUST TERAMI LN by ENEOS Corporation                                            | Prevention of rust in fuel system        |
|        | NP-10-2 | ANTIRUST P-230 by ENEOS Corporation                                                | Prevention of rust in lubricating system |
| Z 1519 | -       | VCI Diana ND volatile corrosion inhibitor by Mitsubishi Gas Chemical Trading, Inc. | Prevention of rust in air intake system  |

### Maintenance During Storage

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

## When Using Engine After Storage

1. Remove the cover that has been placed over the entire engine.
2. Remove the covers from the starter and alternator.
3. Tension the belt.

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

4. Remove the sealing tapes that have been covered the openings of the engine.
5. Connect pipes and hoses.

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

6. Refuel it.
7. Inspect every part of the engine.
8. Remove the rocker covers, and lubricate the valve mechanism.
9. Connect a fully charged battery.
10. Make sure the engine oil pressure rises.
11. Warm up the engine until the engine oil fully lubricates each part of the engine.

Note: For engine starting procedure, refer to ["Start-up" \(3-12\)](#).

12. Operate the engine under load.

## Storing Engine in an Operable Condition

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

### Operation for Maintenance Purpose

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

1. With the manual stop lever placed in the pulled position, crank the engine for 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 at no load.

Note: For engine starting procedure, refer to ["Start-up" \(3-12\)](#).

## Lifting Engine

When using the crane to lift the engine, only those who have the crane operator license and also have a certificate of the crane operating skill training can operate the crane.

When a mobile crane is used, only those who has the mobile crane operating license can operate the crane.

However, for the mobile crane which lifting weight is more than 1 ton and less than 5 tons, those who have completed the small mobile crane operation skill training can operate such crane.



### **WARNING**

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

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

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

The hangers provided on the engine are designed for lifting the engine body only. For the engine coupled with a generator, use the hangers provided on the common bed.

Do not use hangers on the engine.

When lifting the engine equipped with a marine gear or others take care so that the load is not imposed only on the hanger on the engine.

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

Remove pipe covers and insulators located near the hangers, and then attach wire ropes to the hangers.

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.

---



## General Precautions

### Contact Your MHIET Dealer for Repair Service

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

### Considerations Before Proceeding with Corrective Action

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

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

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

### Cautions Against Contamination

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

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

### Cautions for Parts Handling

Handle parts carefully.

When replacing the part with a new one, order only the genuine MHIET part by referring to the parts catalogue.

### Safety Working Practices

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

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

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

If the coolant (fresh water) temperature exceeds 98°C [208°F] or if the coolant temperature warning lamp glows (also warning buzzer sounds), the engine is overheating. 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 is overheating.

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 base of the filler neck of expansion tank.
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 Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.

## When Engine Oil Pressure is Abnormal

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

Table 11-1 When Engine Oil Pressure is Abnormal

| Item to be inspected                              | Remedy                                                                   | Page |
|---------------------------------------------------|--------------------------------------------------------------------------|------|
| Decrease in amount of engine oil                  | Refill                                                                   | 8-9  |
| Oil viscosity is too low                          | Use engine oil of appropriate viscosity according to ambient temperature | 5-4  |
| Clogged oil filter                                | Replace oil filter                                                       | 8-10 |
| Engine oil leak                                   | Contact your MHIET dealer.                                               |      |
| Lubricating oil pressure warning lamp malfunction |                                                                          |      |

Note: Immediately after starting the engine, oil pressure gauge indicates a higher value than the normal 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

| Cause              |                                       | Remedy                                                                                                                                                                                      |
|--------------------|---------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Electrical system  | Faulty wire connection                | <ul style="list-style-type: none"> <li>♦Fuse - Inspect</li> <li>♦Wiring connection of each relay between battery, starter, and starter switch - Inspect</li> </ul>                          |
|                    | Battery charge failure                | <ul style="list-style-type: none"> <li>♦Alternator - Inspect (<a href="#">Refer to P8-17.</a>)</li> <li>♦Belt - Inspect and Adjust (<a href="#">Refer to P8-2.</a>)</li> </ul>              |
|                    | Weak battery                          | <ul style="list-style-type: none"> <li>♦Specific gravity of battery electrolyte - Check (<a href="#">Refer to P8-17.</a>)</li> <li>♦Battery - Charge</li> <li>♦Battery - Replace</li> </ul> |
|                    | Faulty starter or faulty safety relay | <ul style="list-style-type: none"> <li>♦Contact your MHIET dealer.</li> </ul>                                                                                                               |
| Lubricating system | Oil viscosity too high                | <ul style="list-style-type: none"> <li>♦Use appropriate engine oil. (<a href="#">Refer to P5-1.</a>)</li> </ul>                                                                             |
|                    | Excessive oil level                   | <ul style="list-style-type: none"> <li>♦Engine oil level - Check (<a href="#">Refer to P3-11.</a>)</li> </ul>                                                                               |
| Engine body        | Sliding parts rapid wear or lock      | <ul style="list-style-type: none"> <li>♦Contact your MHIET dealer.</li> </ul>                                                                                                               |

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

## Starter Cranks, but Engine Does Not Start

Table 11-3 Starter Turns, but Engine Will Not Start

| Cause             |                                             | Remedy                                                                                                                                                                                                                                        |
|-------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fuel system       | Run out of fuel, blocked pipe               | <ul style="list-style-type: none"> <li>•Fuel Tank - Inspect, Refill, and Bleed Air (<a href="#">Refer to P8-3.</a>)</li> <li>•Fuel Pipes and Valves - Inspect</li> </ul>                                                                      |
|                   | Improper fuel properties                    | <ul style="list-style-type: none"> <li>•Use appropriate fuel. (<a href="#">Refer to P4-1.</a>)</li> <li>•Dust, water, or impurities - Remove (<a href="#">Refer to P8-3.</a>)</li> </ul>                                                      |
|                   | Fuel leaks from fuel line or injection pipe | <ul style="list-style-type: none"> <li>•Fuel lines and injection pipes - Check and Tighten</li> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                    |
|                   | Clogged fuel filter                         | <ul style="list-style-type: none"> <li>•Fuel filter - Inspect and Replace (<a href="#">Refer to P8-5.</a>)</li> <li>•Water separator element - Inspect and Replace</li> <li>•Gauze filter - Clean (<a href="#">Refer to P8-4.</a>)</li> </ul> |
|                   | Fuel feed pump malfunction                  | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                                                                                 |
|                   | Fuel injection pump malfunction             | <ul style="list-style-type: none"> <li>•Fuel injection pump rack stroke - Inspect</li> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                             |
|                   | Fuel injection nozzle malfunction           | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                                                                                 |
| Air intake system | Insufficient amount of intake air           | <ul style="list-style-type: none"> <li>•Inlet system - Clean and Inspect</li> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                                      |
| Control system    | Governor malfunction                        | <ul style="list-style-type: none"> <li>•Fuel control link - Check</li> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                                             |
| Engine body       | Compression pressure drop                   | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                                                                                 |

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

## Insufficient Output

Table 11-4 Insufficient Output

| Cause                     |                                   | Remedy                                                                                                                                                                                                                                                                  |
|---------------------------|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fuel system               | Improper fuel properties          | •Use appropriate fuel. ( <a href="#">Refer to P4-1.</a> )                                                                                                                                                                                                               |
|                           | Clogged fuel filter               | •Fuel filter - Inspect and Replace ( <a href="#">Refer to P8-5.</a> )<br>•Gauze filter - Clean ( <a href="#">Refer to P8-4.</a> )                                                                                                                                       |
|                           | Fuel feed pump malfunction        | •Contact your MHIET dealer.                                                                                                                                                                                                                                             |
|                           | Fuel injection pump malfunction   | •Contact your MHIET dealer.                                                                                                                                                                                                                                             |
|                           | Fuel injection nozzle malfunction | •Contact your MHIET dealer.                                                                                                                                                                                                                                             |
|                           | Faulty fuel injection timing      | •Fuel injection pump drive coupling - Inspect<br>•Contact your MHIET dealer.                                                                                                                                                                                            |
|                           | Improper maximum injection volume | •Fuel injection pump rack stroke - Inspect<br>•Contact your MHIET dealer.                                                                                                                                                                                               |
| Cooling system            | Overheating or overcooling        | •Belt - Inspect and Adjust Tension ( <a href="#">Refer to P8-2.</a> )<br>•Control system - Inspect<br>•Contact your MHIET dealer.                                                                                                                                       |
| Inlet and exhaust systems | Insufficient amount of intake air | •Turbocharger - Inspect ( <a href="#">Refer to P8-14.</a> )<br>•Pre-cleaner - Clean, Inspect and Replace ( <a href="#">Refer to P8-15.</a> )<br>•Intake air pressure and intake air leaks - Inspect<br>•Intake air temperature - Inspect<br>•Contact your MHIET dealer. |
|                           | Increase of exhaust resistance    | •Exhaust pipe - Inspect<br>•Contact your MHIET dealer.                                                                                                                                                                                                                  |
| Engine                    | 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.                                                                                                                                                                                                                                             |

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

## Exhaust Smoke is White or Blue

Table 11-5 Exhaust Smoke is White or Blue

| Cause              |                                   | Remedy                                                                                                                                          |
|--------------------|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Fuel system        | Improper fuel properties          | <ul style="list-style-type: none"> <li>•Check cetane index, and use appropriate fuel.<br/>(Refer to P4-2.)</li> </ul>                           |
|                    | Faulty fuel injection timing      | <ul style="list-style-type: none"> <li>•Fuel injection pump drive coupling - Inspect</li> <li>•Contact your MHIET dealer.</li> </ul>            |
|                    | Fuel injection nozzle malfunction | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                   |
|                    | Uneven volume of fuel injection   | <ul style="list-style-type: none"> <li>•Ignition noise and exhaust smoke temperature - Inspect</li> <li>•Contact your MHIET dealer.</li> </ul>  |
|                    | Incorrect fuel injection timing   | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                   |
| Lubrication system | Combustion of engine oil          | <ul style="list-style-type: none"> <li>•Engine oil level - Check (Refer to P3-11.)</li> <li>•Contact your MHIET dealer.</li> </ul>              |
| Cooling system     | Overcooling                       | <ul style="list-style-type: none"> <li>•Control system - Inspect</li> <li>•Thermostat - Inspect</li> <li>•Contact your MHIET dealer.</li> </ul> |
| Engine body        | Faulty valve timing               | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                   |
|                    | Compression pressure drop         | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                   |

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

## Exhaust Smoke is Black or Gray

Table 11-6 Exhaust Smoke is Black or Gray

| Cause                    |                                   | Remedy                                                                                                                                |
|--------------------------|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Fuel system              | Improper fuel properties          | •Use appropriate fuel. ( <a href="#">Refer to P4-1.</a> )                                                                             |
|                          | Fuel feed pump malfunction        | •Contact your MHIET dealer.                                                                                                           |
|                          | Fuel injection pump malfunction   | •Contact your MHIET dealer.                                                                                                           |
|                          | Fuel injection nozzle malfunction | •Contact your MHIET dealer.                                                                                                           |
|                          | Faulty fuel injection timing      | •Fuel injection pump drive coupling - Inspect<br>•Contact your MHIET dealer.                                                          |
|                          | Irregular fuel injection quantity | •Exhaust gas temperature - Check<br>•Contact your MHIET dealer.                                                                       |
| Inlet and exhaust system | Insufficient amount of intake air | •Intake air pressure, intake air leaks - Check<br>•Intake air temperature and ventilation unit - Check<br>•Contact your MHIET dealer. |
|                          | Increase of exhaust resistance    | •Exhaust pipe - Check<br>•Contact your MHIET dealer.                                                                                  |
| Engine body              | Compression pressure drop         | •Contact your MHIET dealer.                                                                                                           |
|                          | Faulty valve timing               | •Contact your MHIET dealer.                                                                                                           |
|                          | Increase of sliding friction      | •Contact your MHIET dealer.                                                                                                           |
| Control system           | Excessive load                    | •Control system - Check<br>•Contact your MHIET dealer.                                                                                |

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

## Excessive Fuel Consumption

Table 11-7 Excessive Fuel Consumption

| Cause                    |                                             | Remedy                                                                                                                                |
|--------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Fuel system              | Fuel injection nozzle malfunction           | •Contact your MHIET dealer.                                                                                                           |
|                          | Faulty fuel injection timing                | •Fuel injection pump drive coupling - Check<br>•Contact your MHIET dealer.                                                            |
|                          | Improper fuel properties                    | •Use appropriate fuel. ( <a href="#">Refer to P4-1.</a> )                                                                             |
|                          | Fuel leaks from fuel line or injection pipe | •Fuel Line and Injection Pipes - Check and Tighten<br>•Contact your MHIET dealer.                                                     |
| Cooling system           | Overcooling                                 | •Control system - Check<br>•Thermostat - Check<br>•Contact your MHIET dealer.                                                         |
| Inlet and exhaust system | Insufficient amount of intake air           | •Intake air pressure, intake air leaks - Check<br>•Intake air temperature and ventilation unit - Check<br>•Contact your MHIET dealer. |
|                          | Increase of exhaust resistance              | •Exhaust pipe - Check<br>•Contact your MHIET dealer.                                                                                  |
| Engine body              | Compression pressure drop                   | •Contact your MHIET dealer.                                                                                                           |
|                          | Faulty valve timing                         | •Contact your MHIET dealer.                                                                                                           |
|                          | Increase of sliding friction                | •Contact your MHIET dealer.                                                                                                           |
| Load                     | Excessive load                              | •Readjustment of fire pump load                                                                                                       |

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

## Excessive Engine Oil Consumption

Table 11-8 Excessive Engine Oil Consumption

| Cause                    |                                          | Remedy                                                                                                                                                                             |
|--------------------------|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fuel system              | Faulty fuel injection timing             | <ul style="list-style-type: none"> <li>•Fuel injection pump drive coupling - Check</li> <li>•Contact your MHIET dealer.</li> </ul>                                                 |
| Lubricating system       | Oil leakage to the outside of the engine | <ul style="list-style-type: none"> <li>•Oil leaks - Check</li> <li>•Contact your MHIET dealer.</li> </ul>                                                                          |
|                          | Engine oil viscosity is low              | <ul style="list-style-type: none"> <li>•Use the oil having appropriate viscosity. (Refer to P5-4.)</li> </ul>                                                                      |
|                          | Excessive engine oil temperature         | <ul style="list-style-type: none"> <li>•Engine oil level - Check (Refer to P3-11.)</li> <li>•Oil cooler and oil thermostat - Check</li> <li>•Contact your MHIET dealer.</li> </ul> |
| Cooling system           | Overheating                              | <ul style="list-style-type: none"> <li>•Control system - Check</li> <li>•Thermostat - Check</li> <li>•Contact your MHIET dealer.</li> </ul>                                        |
| Inlet and exhaust system | Oil intrusion into air supply chamber    | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                      |
|                          | Friction of valve train parts            | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                      |
| Engine body              | Friction of sliding part                 | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                                                                                      |
| Load system              | Excessive load                           | <ul style="list-style-type: none"> <li>•Load system - Check</li> <li>•Contact your MHIET dealer.</li> </ul>                                                                        |

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

## Overheating

Table 11-9 Overheating

| Cause          |                                   | Remedy                                                                                                        |
|----------------|-----------------------------------|---------------------------------------------------------------------------------------------------------------|
| Cooling system | Insufficient coolant level        | <ul style="list-style-type: none"> <li>•Coolant leaks - Inspect</li> <li>•Coolant level - Check</li> </ul>    |
|                | Fresh water pump faulty operation | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                 |
|                | Thermostat malfunction            | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                 |
| Load system    | Excessive load                    | <ul style="list-style-type: none"> <li>•Load system - Inspect</li> <li>•Contact your MHIET dealer.</li> </ul> |
| Engine body    | Rapid wear of sliding parts       | <ul style="list-style-type: none"> <li>•Contact your MHIET dealer.</li> </ul>                                 |

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

## Engine Oil Pressure Drop

Table 11-10 Engine Oil Pressure Drop

| Cause              |                                        | Remedy                                                                                      |
|--------------------|----------------------------------------|---------------------------------------------------------------------------------------------|
| Lubrication system | Low engine oil level                   | •Engine oil level - Check ( <a href="#">Refer to P3-11.</a> )                               |
|                    | Faulty engine oil property (viscosity) | •Oil property analysis. Use appropriate engine oil. ( <a href="#">Refer to P5-4.</a> )      |
|                    | Oil temperature too high               | •Cooling system - Check<br>•Contact your MHIET dealer.                                      |
|                    | Clogged oil filter                     | •Oil filter and bypass oil filter - Inspect and replace ( <a href="#">Refer to P8-10.</a> ) |
|                    | Faulty oil pump operation              | •Contact your MHIET dealer.                                                                 |
|                    | Faulty relief valve operation          | •Contact your MHIET dealer.                                                                 |
| Control system     | Faulty pressure unit operation         | •Control system and wiring - Inspect<br>•Contact your MHIET dealer.                         |
| Engine body        | Rapid wear of sliding parts            | •Contact your MHIET dealer.                                                                 |
|                    | Increased clearance of sliding part    | •Contact your MHIET dealer.                                                                 |
| Load system        | Excessive load                         | •Load system - Inspect<br>•Contact your MHIET dealer.                                       |

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

## When Fuel has Run Out

When the engine stops due to fuel runout while engine is running, 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" \(3-11\)](#).
3. Bleed air from the fuel system.  
To bleed air from the fuel system, refer to ["Bleeding the Fuel System" \(3-1\)](#).
4. Start the engine.  
For engine starting procedure, refer to ["Start-up" \(3-12\)](#).

# Chapter 12 MAIN SPECIFICATION

Table 12-1 Main Specifications

| Item                             | Specifications                                                      |
|----------------------------------|---------------------------------------------------------------------|
| Engine model                     | S12A2-T2MPTK                                                        |
| Type                             | V type, water-cooled, 4-stroke cycle, turbocharged with intercooler |
| No. of cylinders - Arrangement   | 12-V type                                                           |
| Bore × Stroke                    | φ150 × 160 mm [5.91 × 6.30 in.]                                     |
| Displacement (declared value)    | 33.9 L [2069.02 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 and others                     |
| Direction of rotation            | Counterclockwise as viewed from the stern                           |
| Dimensions (L x W x H)           | 2285.4 × 1464 × 1967.5 mm [89.98 × 57.64 × 77.46 in.]               |
| Dry weight                       | 3890 kg [8576 lb]                                                   |
| Fuel                             | Diesel fuel                                                         |
| Fuel injection pump              | S7S type                                                            |
| Fuel filter                      | Cartridge type paper-element                                        |
| Fuel injection nozzle            | Hole type                                                           |
| Fuel injection starting pressure | 29.4 MPa {300 kgf/cm <sup>2</sup> } [4264 psi]                      |
| Governor                         | Electric motor starting                                             |
| Lubricating method               | Forced circulation (pressure fed by oil pump)                       |
| Lubrication oil                  | Grade CF or CH-4 oil (API service classification)                   |
| Engine oil capacity              | on level ground 120 L [31.7 U.S. gal.]                              |
| Oil filter                       | Cartridge type paper-element                                        |
| Oil cooler                       | Fresh water cooler, multi-plate type                                |
| Cooling method                   | Direct sea water cooling                                            |
| Cooling fresh water capacity     | Approx. 100 L [26.42 U.S. gal.]                                     |
| Starting system                  | Electric start                                                      |
| Starter                          | DC24 V - 7.5 kW x 2                                                 |
| Alternator                       | DC24 V - 35 A                                                       |
| Turbocharger                     | Mitsubishi TD10L type                                               |

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

| Revision | Revision date | Description                                                                                                                                                                                                                            |
|----------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -        | May 2019      | First edition issued.                                                                                                                                                                                                                  |
| 1        | July 2020     | Added precautionary text of "Limitation of Continuous Under Light Load Operation".                                                                                                                                                     |
| 2        | March 2021    | Changed the recommended limit/Service limit value of Fine foreign substances (foreign substances at fuel inlet) in the Fuel Properties Table to "10 mg/L or less".                                                                     |
| 3        | February 2022 | Changed the permissible mixing ratio of biodiesel fuel in the fuel properties table from "5 mass% or less" to "7 volume% or less in Chapter 4 FUEL.                                                                                    |
| 4        | April 2024    | <ul style="list-style-type: none"> <li>• Important Information<br/>Added a precaution regarding labels.</li> <li>• Chapter 5<br/>Revised the recommended engine oil.<br/>Updated the table of engine oil quality standards.</li> </ul> |
|          |               |                                                                                                                                                                                                                                        |
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## **Mitsubishi Marine Engine S12A2-T2MPTK OPERATION & MAINTENANCE MANUAL**

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