

MITSUBISHI MARINE ENGINE

S16R-T2MPTK

for Mitsubishi Heavy Industries Engine System Asia Pte.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**

Contact Us for MHIET Engine Parts

According to the contents of the inquiry, we may share personal information including your name, address, telephone number, e-mail address and contents of the inquiry with our group companies. In this case, MHI take responsibility for managing personal information and will not use such information for purposes other than responding to your inquiry.

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FOREWORD

This operation and maintenance manual contains detailed operation, inspection and maintenance information for engines from Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.

Please be noticed that some contents are repeated among chapters for better understanding.

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

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

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



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

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

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

Limited Warranty

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

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.'s warranty is limited to the compensation work of repair or replacement of parts.

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

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

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

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

Important Information

- ♦To avoid the potential hazards, accident prevention activities must be planned methodically and conducted continually by considering all aspect of engine operation, maintenance and inspection. All related personnel, including managers and supervisors, should actively participate, recognize their roles and organize themselves and their work to ensure a safe environment.
- ♦The foremost safety objective is to prevent accidents which may result in injury or death, or equipment damage.
- ♦Always observe laws or regulations of the local or federal/national government.
- ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. cannot foresee all potential dangers of the engine, potential danger resulting from human error and other causes, or danger caused by a specific environment in which the engine is used.
Since there are many actions that cannot be performed or must not be performed, it is impossible to indicate every caution in this manual or on warning labels. As such, it is extremely important to follow instructions in this manual and also to take general safety measures when operating, maintaining and inspecting the engine.
- ♦This manual has been prepared for people whose native language is English. When the engine is used by individuals whose native language is not English, the customer is requested to provide thorough safety guidance to the operators. Also attach safety, caution and operating signs that describe the original warning label statements in the native language of the operators.
- ♦The engine must be operated, maintained and inspected only by qualified persons who have thorough knowledge of engines and their dangers and who also have received risk avoidance training.
- ♦To prevent an accident, do not attempt to carry out any operation other than those described in this manual, and do not use the engine for any unapproved purpose.
- ♦When the ownership of the engine is transferred, be sure to give this manual to the new owner though we do not warrant the engine. Also inform Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. of the name and address of the new owner of the engine.
- ♦This manual is copyrighted and all rights are reserved. This manual, including illustrations and technical references, in whole or in part, may not be photocopied, translated, or reproduced in any electronic medium or machine readable form without prior written consent from Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.
- ♦The contents in this manual are subject to change at any time without notice for improvement of the engine.
- ♦Pictures or illustrations in this manual may differ from the engine you have.
Please note that, depending on specifications, items described in this manual may differ from those on your engine in shape, or may not be installed on your engine.
- ♦Please contact a dealer of Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. if you need more information or if you have any questions.
- ♦If the manual is lost or damaged, please obtain a new copy at a dealer of Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. as soon as possible.

- ♦ 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.

Warning Indication

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

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

Warning Statements

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

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

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



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



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



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



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

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

Units of Measurement

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

- ♦Pressure: 1 MPa = 10.197 kgf/cm²
- ♦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⁻¹ = 1 rpm
- ♦Kinetic viscosity: 1 mm²/s = 1 cSt

Abbreviations, Standard 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 marine use engine you have purchased is provided with "Engine International Air Pollution Certificate" (EIAPP-certificate) which proves the NO_x 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 NO_x regulations. EIAPP-certificate and Technical File must be kept onboard all the time. If you fail to do so, you may receive penalties for violations.

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

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

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Chapter 1 BASIC SAFETY PRECAUTIONS

Fire and Explosions



WARNING

Keep Flames Away

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



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

Store fuel and engine oil in a well-ventilated area.

Make sure that the caps of fuel and engine oil containers are tightly closed.

Keep Engine Surrounding Area Tidy and Clean

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

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

Ventilation of Engine Room

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

Do Not Open Side Cover Until Engine Cools

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

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

Care for Fuel, Oil and Exhaust Gas Leaks

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

Such leaks, if not repaired, can cause fuel or engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable materials, possibly leading to personal injury and/or damage to equipment.

Use Explosion-Proof Lighting Apparatus

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

Prevent Electrical Wires From Short-Circuiting

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

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

Keep Fire Extinguishers and a First-Aid Kit Handy

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

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



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

Stay Clear of All Rotating and Moving Parts



Install Protective Covers Around Rotating Parts

Make sure the protective covers of the engine are correctly installed.

Repair any damaged or loose covers.

Never remove protective covers such as front cover, fuel injection pump coupling cover and alternator cover that enclose rotating parts during operation.

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

Never remove protective covers.



Check Work Area For Safety

Before starting the engine, make sure no one is near the engine and tools are not left on or near the engine.

Alert people in the area when starting the engine.

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

Stay Clear of Moving Parts During Operation

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

Put objects, which might be easily caught by rotating parts, away from rotating parts.

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



Lockout and Tagout

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

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

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

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

Stop the Engine Before Servicing

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

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

Always Restore Engine Turning Tools After Use

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

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

Be Careful of Exhaust Fume Poisoning

WARNING

Operate Engine in a Well-ventilated Area

Check the exhaust pipes and pipe joints for gas leaks.

Exhaust gas from the engine may contain harmful substances. Operating the engine in an poorly-ventilated area can cause gas poisoning.



Protect Ears From Noise

WARNING

Wear Ear Plugs

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

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



Be Careful of Falling Down

WARNING

Lift Engine Carefully

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

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

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

The hangers equipped on the engine are designed for lifting the engine only. When the marine gear is installed in the engine, give extra consideration to avoid overloading of the engine hangers.

Keep the angle formed by slings attached to hangers within 60°. If the angle exceeds this limit, excessive load could be imposed on the hangers and this could damage the hangers and result in a serious accident. Attach wire ropes to the hangers after removing the pipe near the hanger.

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



Do Not Climb Onto Engine

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

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

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

Always Prepare Stable Scaffold

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

Standing on a decrepit stool or parts box may result in personal injury.

Do not put any unnecessary objects on a work platform.



Be Careful Not Burn Yourself



Do Not Touch the Engine During or Immediately After Operation

To avoid burns, do not touch the engine during or immediately after operation.

A hot generator set can cause burns.

To conduct maintenance and inspection work, wait until the engine has cooled sufficiently by checking the temperature gauge.



Be Careful of Opening and Closing Coolant Expansion Tank Cap

Never open the coolant expansion tank cap while the engine is running or immediately after the generator set is stopped. Stop the engine and open the cap after the coolant temperature lowers sufficiently.

To open the coolant expansion tank cap, open slowly to discharge the pressure inside the tank.

The coolant is hot while engine is running and immediately after the engine stops. If the cap is opened when the coolant is at an operating temperature, steam and hot coolant may blow out and result in burns. To avoid a risk of getting scalded by steam, wear thick rubber gloves or wrap a cloth around the cap.

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

Refill Coolant Only After the Coolant Temperature Dropped

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

Never Remove Heat Shields

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

Be Careful of Burns When Changing Oil

When draining oil or changing a oil filter, wear leather gloves or be sure to check the engine temperature before work. If hot oil or parts touch your skin, it can cause burns.

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



Use Only Specified Fuel, Engine Oil and LLC

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

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

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

Handle LLC Carefully

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

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

Proper Disposal of Waste Oil, LLC and Coolant

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

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

If Problem Occurs

CAUTION

Stop Operation Immediately If You Notice Any Unusual Symptoms

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

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

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

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

Avoid Restart Immediately After Abnormal Stop

After abnormal stop, do not restart immediately. If the engine stops because of abnormality, check and remedy the cause of the problem before restarting. If you continue the operation without any remedy, it can result in serious problems.

Avoid Continuous Engine Operation at Low Oil Pressure

If an abnormal engine oil pressure drop is indicated, stop the engine immediately, and inspect the lubrication system to locate the cause. If you continue the operation, it may cause seizure of bearings, etc.

If Belt Breaks, Stop Engine Immediately

If the belt breaks, stop the engine immediately and replace the belt. If you continue the operation without any remedy, it could cause damage to battery and cooling system, and result in serious engine problems.

Battery

CAUTION

Handle Battery Correctly

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



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

Other Cautions



CAUTION

Never Modify Engine

Unauthorized modification of the engine will void our warranty.

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

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

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, and inform your supervisor of your condition. Operation of the engine with reduced awareness may cause improper operation that could result in accidents.

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

Work Clothing and Protective Gear

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

Never Break Seals

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

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

Perform All Specified Pre-operation Inspections and Periodic Inspections

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

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

Break-In Engine

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

Operating new engines or overhauled engines in a severe condition during the break-in period shortens the service life of the engine.

Warm-Up Engine Before Use

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

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

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

Conduct Cooling Operation Before Stopping the Engine

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

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

During cooling operation, check the engine for abnormalities.

Never Operate the Engine Under Over Load

If an overloaded condition such as black exhaust smoke is observed, reduce the load immediately and assure the proper output and load.

Overloading causes not only high fuel consumption but also excessive carbon deposits inside the generator set. Carbon deposits cause various problems and will shorten the service life of the generator set.

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)

Protection of Engine Against Water Entry

Do not allow rainwater, etc. to enter the engine through the air inlet or exhaust openings.

Do not wash the engine while it is running. Cleaning fluid (water) can be sucked into the engine.

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

Conduct Proper Maintenance of Pre-Cleaner

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

- ♦ Wash pre-cleaner periodically. If pre-cleaner is clogged, exhaust temperature will increase because sufficient intake air for combustion is not supplied, and as a result, a failure may occur.
- ♦ Never operate the engine without pre-cleaner. The turbocharger may suck particles of foreign materials into the engine and could result in serious accidents.
- ♦ When removing the pre-cleaner, take care so that foreign material accumulated on the pre-cleaner will not enter the inside the engine. When the pre-cleaner is removed, immediately cover the air inlet with a plastic sheet, etc. to prevent foreign material from entering the engine.

Use of Tools Ptimum for Each Work

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

Avoidance of Prolonged Time of Starter Operation

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

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

Do Not Turn Off the Battery Switch During Operation

Do not turn off the battery switch during operation. If the battery switch is turned OFF when the engine is running, it stops operation of meters and also may deteriorate alternator diode and transistor.

Precautions for Transporting the Engine

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

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

Do Not Turn Engine to Reverse Direction

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

Operate Clutch at Low Idling Speed

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

Shift Clutch Properly

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

Warning/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.

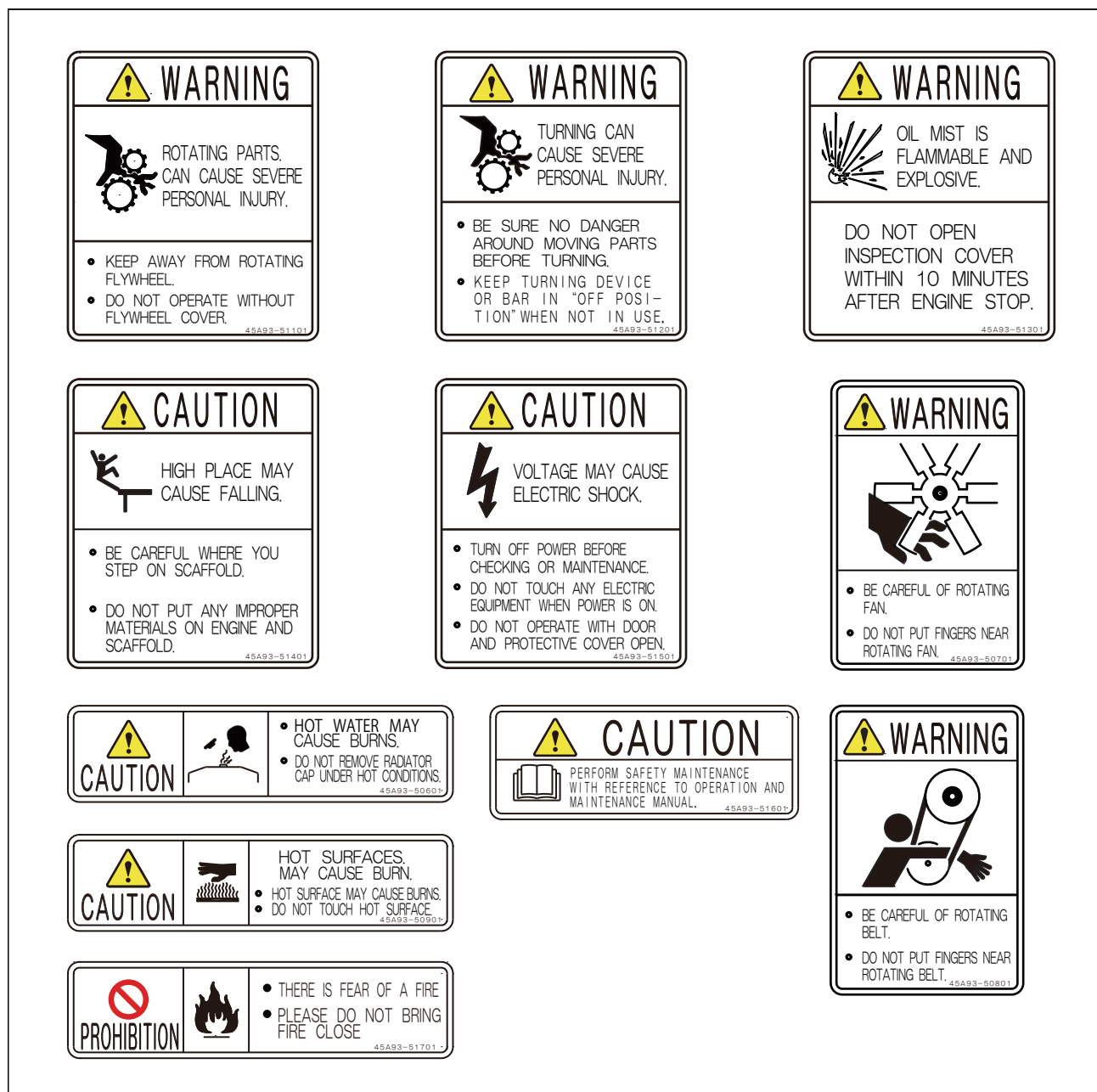


Fig. 1-1 Warning/Caution Labels

Chapter 2 NAME OF PARTS

Engine External Views

Front View

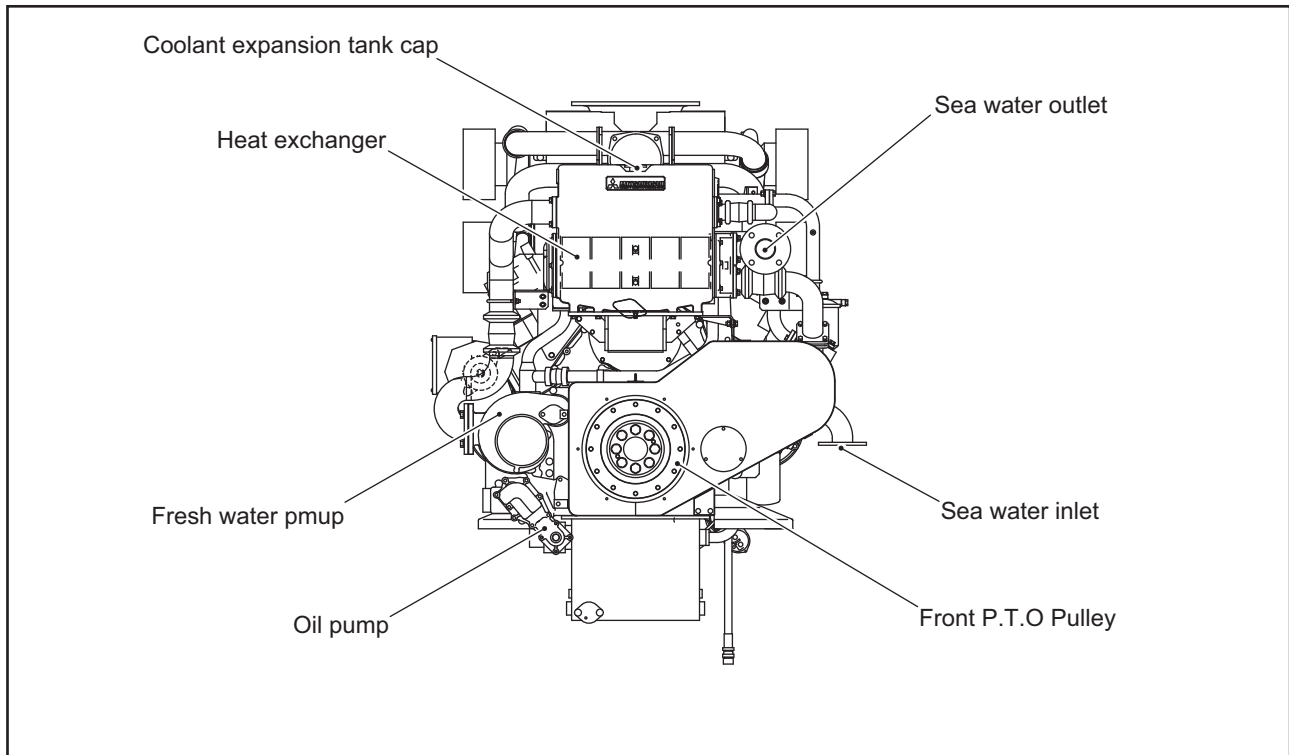


Fig. 2-1 Engine Front View

Rear View

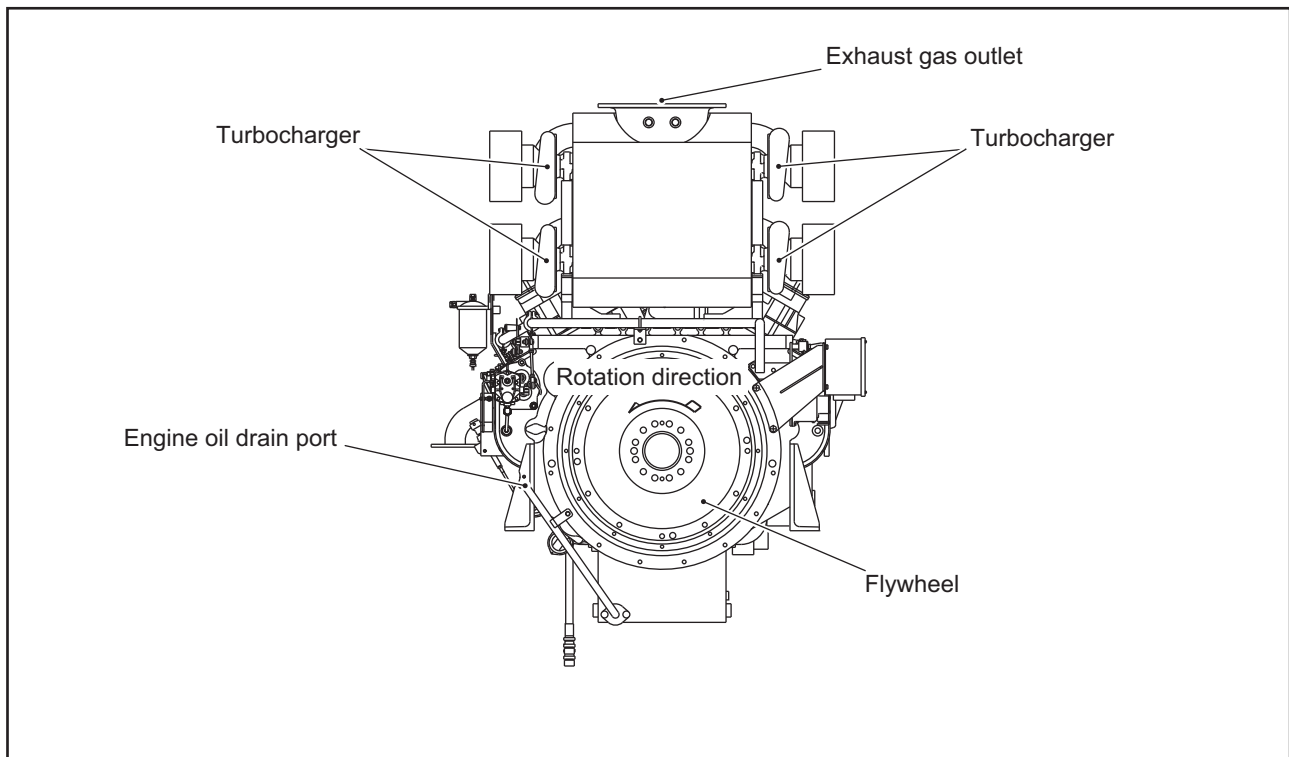


Fig. 2-2 Engine Rear View

Left View

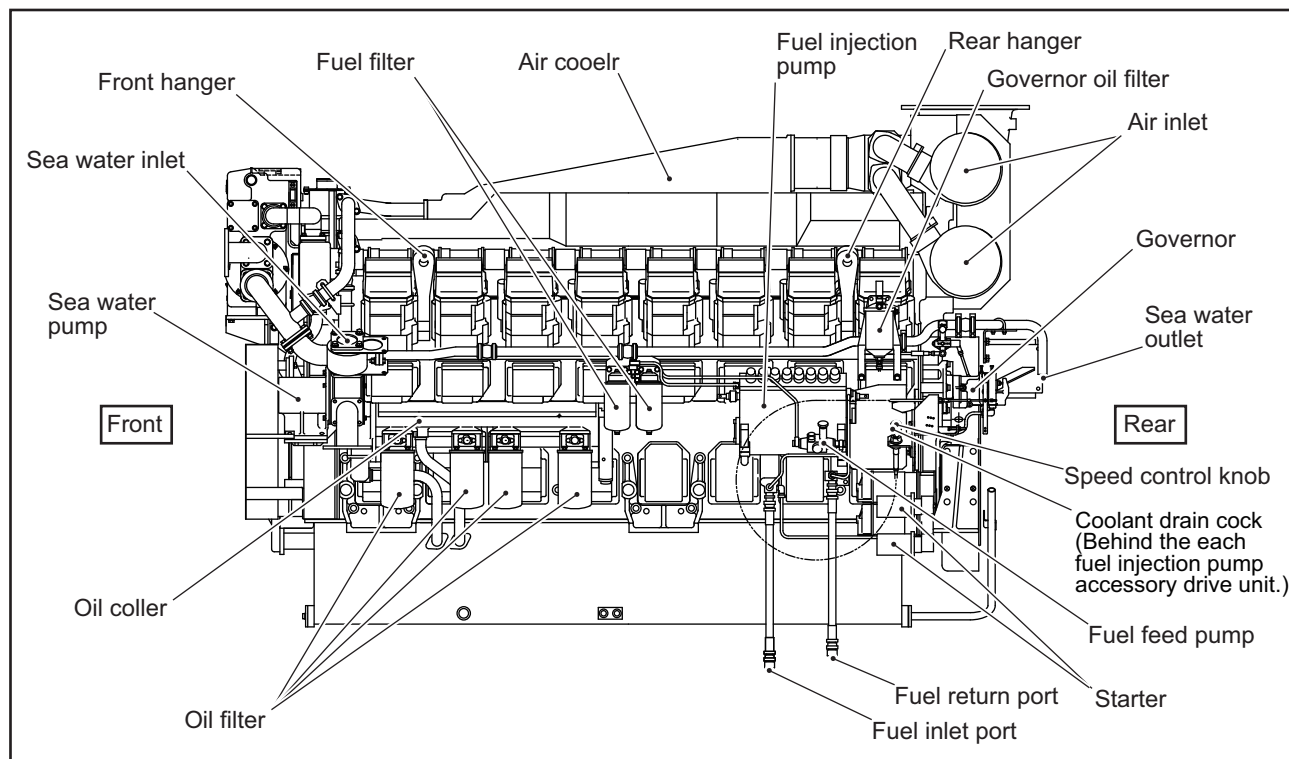


Fig. 2-3 Engine Left View

Right View

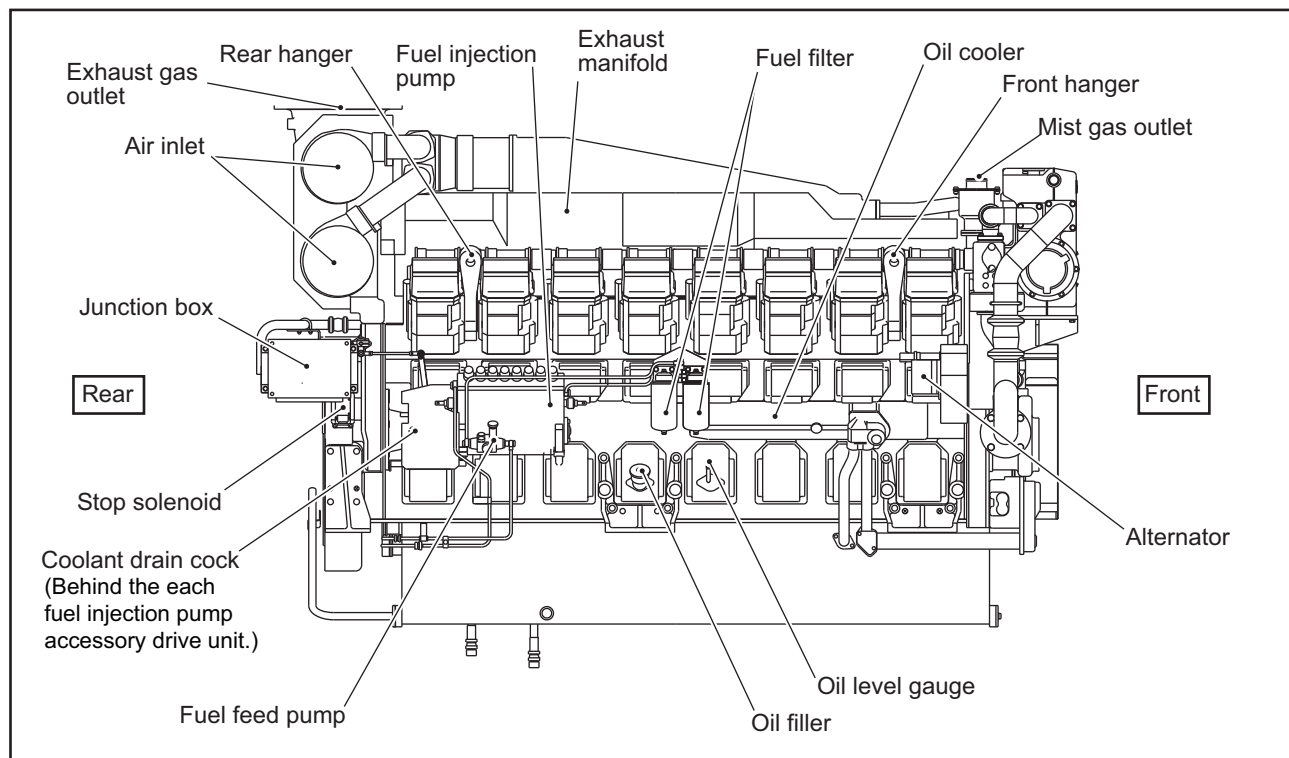


Fig. 2-4 Engine Right View

Equipment and Instrument

Speed Control Knob

You can adjust the engine speed in the engine room.

Speed fine turning is done by turning the knob.

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

Press the bottom to unlock the knob.

Speed of rotation can be adjusted by moving the knob. Pull the knob for high-speed rotation and press it for low-speed rotation.

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

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

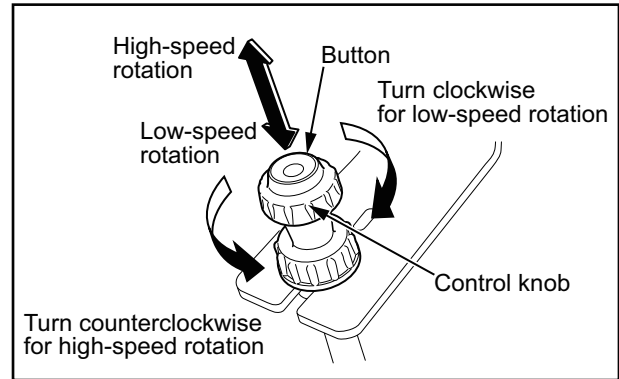


Fig. 2-5 Speed Control Knob

Manual Manual Stop Lever

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

When the manual stop lever, which is located in the fuel control link, is moved in the "STOP" direction, the engine stops.

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

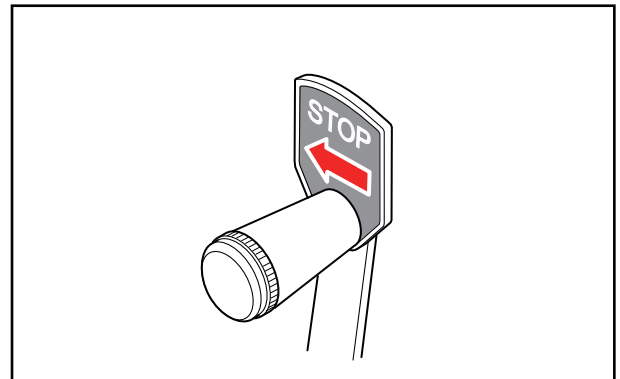


Fig. 2-6 Manual Stop Lever

Stop Solenoid

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

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

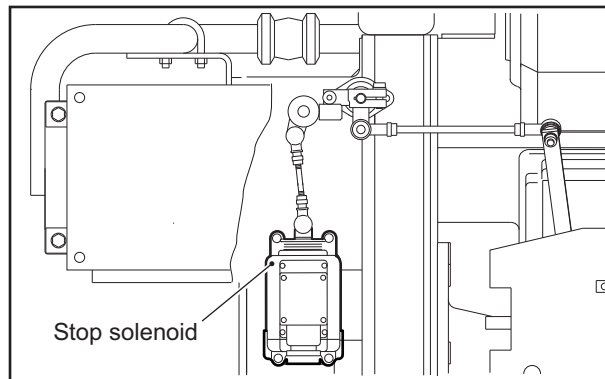


Fig. 2-7 Stop Solenoid

Instruments

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

Oil Pressure Unit

Indicate the oil pressure.

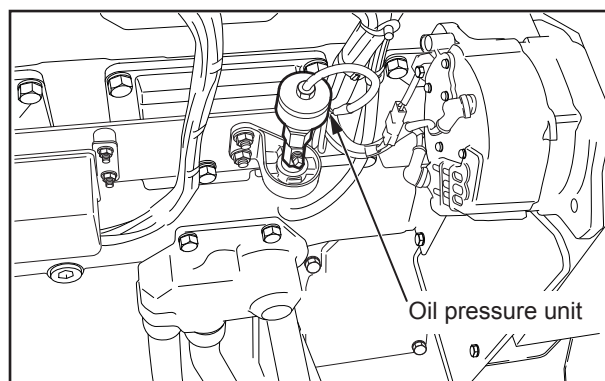


Fig. 2-8 Oil Pressure Unit

Revolution Detection Pickup

It is installed in the timing gear case, and detects engine speed at all times.

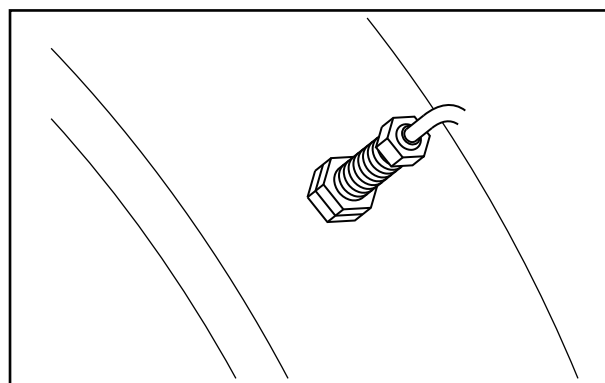


Fig. 2-9 Revolution Detection Pickup

Engine Protection Devices

Thermo Switch

A thermo switch that stops the engine when the coolant temperature has increased and reached a present temperature is equipped.

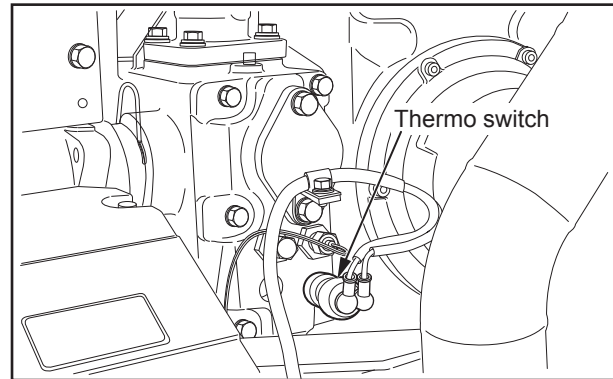


Fig. 2-10 Thermo Switch

Water Temperature Sensor

A water temperature sensor (resistance-temperature detector), which gives an alert when the cooling fresh-water temperature is raised to the specified value, is installed.

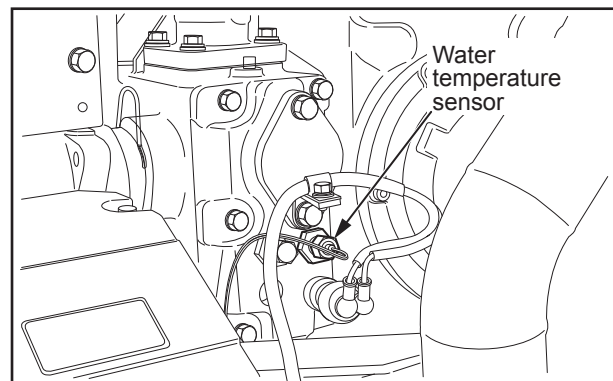
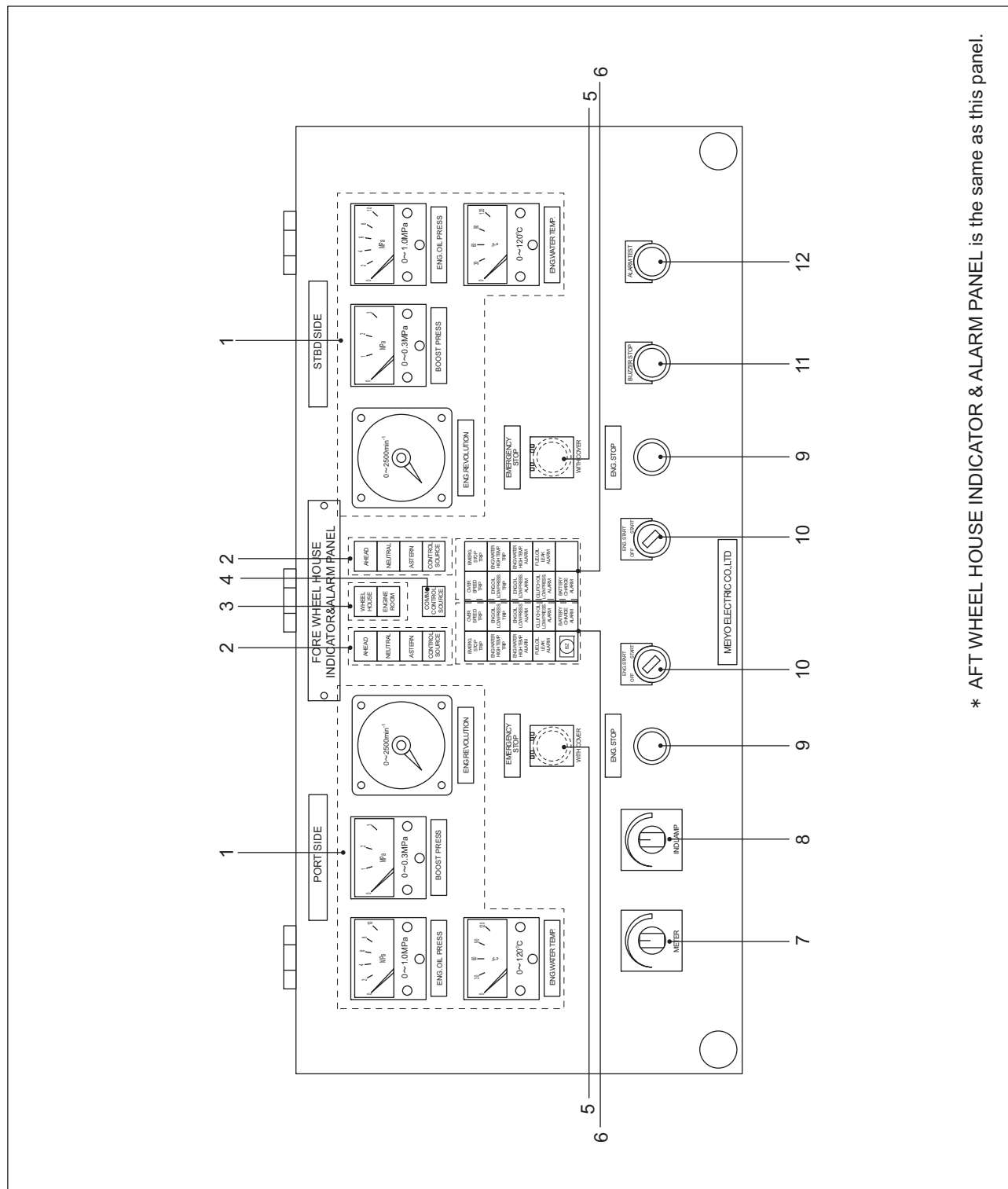


Fig. 2-11 Water Temperature Sensor

About WHEEL HOUSE INDICATOR & ALARM PANEL



* AFT WHEEL HOUSE INDICATOR & ALARM PANEL is the same as this panel.

Fig. 2-12 WHEEL HOUSE INDICATOR & ALARM PANEL

Table 2-1 About WHEEL HOUSE INDICATOR & ALARM PANEL

No.	Name		Function
1	METER	ENG. REVOLUTION	Indicates the rotational speed of engine in revolutions per minute
		BOOST PRESS.	Indicates the pressure in the intake manifold.
		ENG. OIL PRESS.	Indicates engine oil pressure.
		ENG. WATER TEMP.	Indicates the fresh-water temperature of engine.
2	CLUTCH POSITION		Indicates the clutch position (AHEAD, NEUTRAL, ASTEN).
	CONTROL SOURCE		Glow when CONT. SOURCE of ENGINE ROOM INDICATOR & ALARM PANEL is ON.
3	ENGINE START POSITION		Indicates the engine starting place (WHEEL HOUSE or ENGINE ROOM). The engine can be started only at the operating location in which the lamp lights.
4	COMM CONTROL SOURCE		Glow when COMM. CONTROL SOURCE switch of WHEEL HOUSE INDICATOR & ALARM PANEL is turned ON.
5	EMERGENCY STOP (WITH COVER)		The main engine stops when this button is pressed. The cover is installed to the button so that it is not operated by accident.
6	ALARM LAMP	EMERG. STOP TRIP	This lamp glows when the EMERGENCY STOP button is pressed.
		OVER SPEED TRIP	Glow when the engine is stopped by engine over-speeding (1947 min^{-1} or higher).
		ENG. WATER HIGH TEMP. TRIP	Glow when the engine is stopped by the high temperature of cooling fresh-water of 95°C [203°F] or higher. Take appropriate measures if the lamp glows.
		ENG. OIL LOW PRESS. TRIP	This lamp glows when the engine stops urgently due to low engine oil pressure of 0.15 MPa [1.5 kgf/cm^2] [21 psi] or less. Take appropriate measures if the lamp glows.
		ENG. WATER HIGH TEMP. ALARM	This lamp glows when the coolant fresh-water temperature rises abnormally to 90°C [194°F] or higher. If the lamp glows, stop the engine after operating the engine at the low idling, then take appropriate measures.
		ENG. OIL LOW PRESS. ALARM	This lamp glows when the engine stops urgently due to low engine oil pressure of 0.20 MPa [2 kgf/cm^2] [29 psi] or less. Take appropriate measures if the lamp glows.
		FUEL OIL LEAK ALARM	This lamp glows when fuel leak occurs. Take appropriate measures if the lamp glows.
		CLUTCH OIL LOW PRESS ALARM	This lamp glows when clutch oil pressure is abnormally low. Take appropriate measures if the lamp glows.
		BATTERY CHARGE ALARM	This lamp glows when the battery charging is not enough.
		BZ	This lamp glows when an alarm is given.
6	METER		Adjusts brightness of indicators.
7	IND LAMP		Adjusts brightness of indicator lamp.
8	ENG. STOP		You can stop the engine by pressing the button.
9	ENG. START (WITH KEY)		The engine can be started when the key is turned to the "START" position. It automatically returns to OFF position when you take your hand off the key.
10	BUZZER STOP		You can stop the alarm buzzer by pressing the button after the alarm.
11	ALARM TEST		Push the button to verify the operation of alarm lamp and buzzer. Check this during prestart inspections.

About ENGINE ROOM INDICATOR & ALARM PANEL

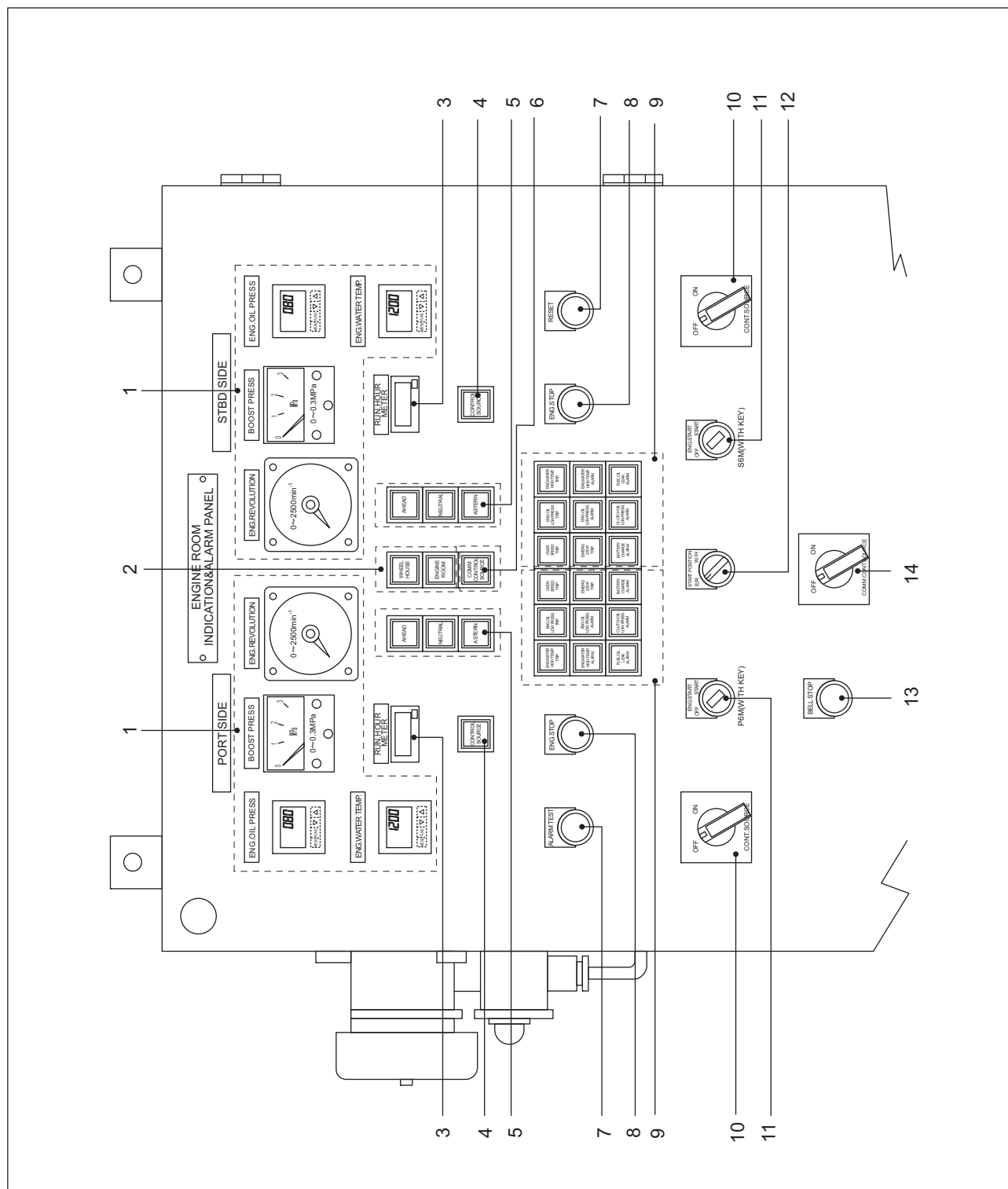


Fig. 2-13 ENGINE ROOM INDICATOR & ALARM PANEL

Table 2-2 About ENGINE ROOM INDICATOR & ALARM PANEL

No.	Name		Function
1	METER	ENG. REVOLUTION	Indicates the rotational speed of engine in revolutions per minute
		BOOST PRESS.	Indicates the pressure in the intake manifold.
		ENG. OIL PRESS.	Indicates engine oil pressure.
		ENG. WATER TEMP.	Indicates the fresh-water temperature of engine.
2	ENGINE START POSITION		Indicates the engine starting place (WHEEL HOUSE or ENGINE ROOM). The engine can be started only at the operating location in which the lamp lights.
3	RUN. HOUR METER		Indicates the operating time of engine.
4	CONTROL SOURCE		Glow when CONT. SOURCE on ENGINE ROOM INDICATION & ALARM PANEL is ON.
5	CLUTCH POSITION		Indicates the clutch position (AHEAD, NEUTRAL, ASTERN).
6	COMM. CONTROL SOURCE		Glow when CONT. SOURCE of WHEEL HOUSE INDICATOR & ALARM PANEL is ON.
7	RESET button		Press the button to clear alarm display.
8	ENG. STOP button		The engine stops when this button is pressed.
9	ALARM LAMP	ENG. WATER HIGH TEMP. TRIP	Glow when the engine is stopped by the high temperature of cooling fresh-water of 95°C [203°F] or higher. Take appropriate measures if the lamp glows.
		ENG. OIL LOW PRESS. TRIP	This lamp glows when the engine stops urgently due to low engine oil pressure of 0.15 MPa {1.5 kgf/cm ² } [21 psi] or less. Take appropriate measures if the lamp glows.
		OVER SPEED TRIP	Glow when the engine is stopped by engine over-speeding (1947 min ⁻¹ or higher). Take appropriate measures if the lamp glows.
		ENG. WATER HIGH TEMP. ALARM	This lamp glows when the coolant fresh-water temperature rises abnormally to 90°C [194°F] or higher. If the lamp glows, stop the engine after operating the engine at the low idling, then take appropriate measures.
		ENG. OIL LOW PRESS. ALARM	This lamp glows when the engine stops urgently because of low engine oil pressure of 0.20 MPa {2 kgf/cm ² } [29 psi] or less. Take appropriate measures if the lamp glows.
		EMERG. STOP TRIP	This lamp glows when the engines stopped by manual emergency stop.
		CLUTCH OIL LOW PRESS. ALARM	This lamp glows when clutch oil pressure is abnormally low. Take appropriate measures if the lamp glows.
		BATTERY CHARGE ALARM	This lamp glows when the battery charging is not enough.
10	CONT. SOURCE		This switch turns ON the power of WHEEL HOUSE and ENGINE ROOM INDICATOR & ALARM PANEL.
11	ENG. START (WITH KEY)		The engine can be started when the key is turned to the "START" position. It automatically returns to OFF position when you take your hand off the key.
12	START POSITION		Indicates the engine starting place (WHEEL HOUSE or ENGINE ROOM). The engine can be started only at the operating location in which the lamp lights.
13	BELL STOP		The alarm buzzer is stopped when pressing the button after the alarm. However, the alarming display will not be cleared.
14	COMM CONT. SOURCE		Turn the switch to the "ON" position to turn on the power.

Using Manual Turning Gear

WARNING

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

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

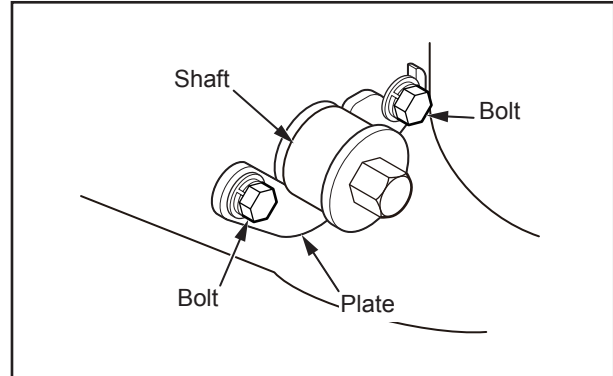


Fig. 2-14 Manual Turning Gear Position
(While Engine is Running)

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

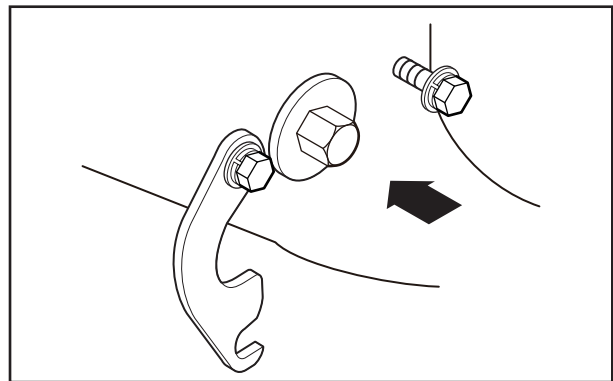


Fig. 2-15 Manual Turning Gear Position
(When Pushing Shaft in)

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

CAUTION

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

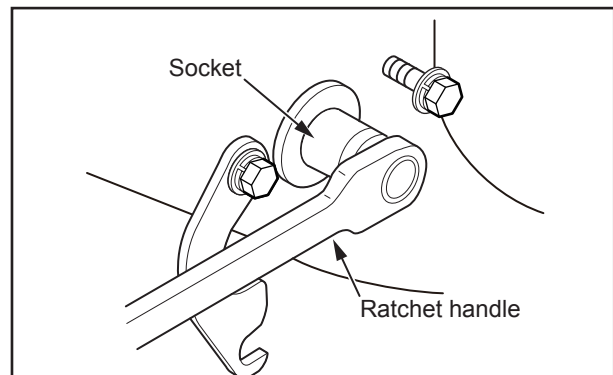


Fig. 2-16 Turning Gear Position
(When Turning Shaft)

Preparation for Operating New or Overhauled Engine

Before proceeding with operation of a new overhauled engine, conduct the inspections described in this section. 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. Spilled fuel can ignite and cause a fire.

CAUTION

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

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

Fuel System - Bleed Air

WARNING

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

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

Priming Pump Cap - Handling

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

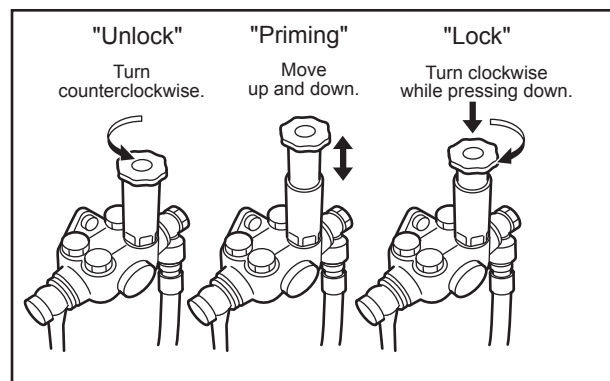


Fig. 3-1 Priming Pump Cap - Handling

Oil-Water Separator - Bleed Air

For Suction Type

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

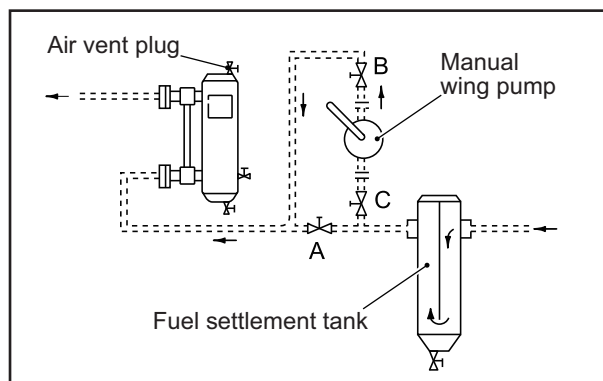


Fig. 3-2 Air Bleeding From Oil-Water Separator
(Suction Type)

For Gravity Type

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

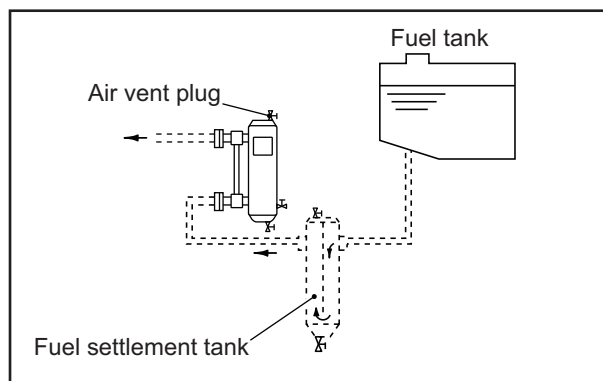


Fig. 3-3 Bleeding Air From Oil-Water Separator
(Gravity Type)

Fuel Filter - Bleed Air

CAUTION

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

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

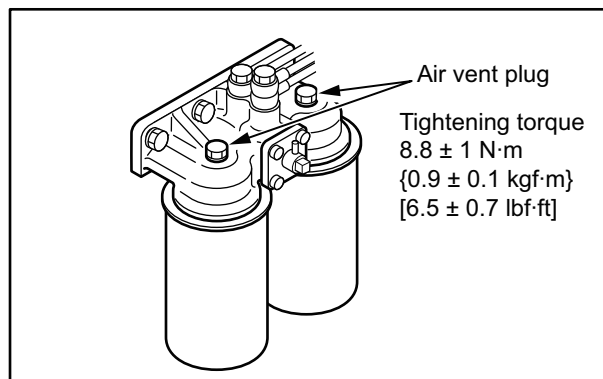


Fig. 3-4 Fuel Filter - Bleed Air

Fuel Injection Pump - Bleed Air

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

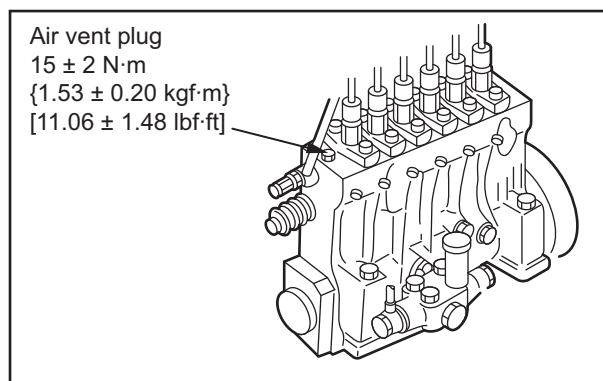


Fig. 3-5 Fuel Injection Pump - Bleed Air

Priming Pump Tightening Method

CAUTION

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

1. Gently tighten the priming pump by hand, and make a mark indicating the position to place the seat face.
2. Using a wrench or another appropriate tool, further tighten the priming pump by $90 \pm 10^\circ$.
3. Check the mounting position of head packing.

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

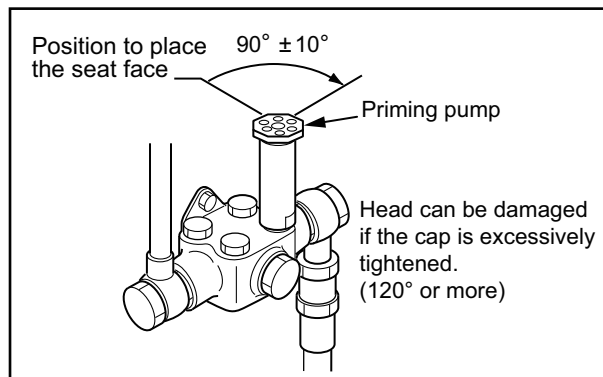


Fig. 3-6 Priming Pump Tightening Method

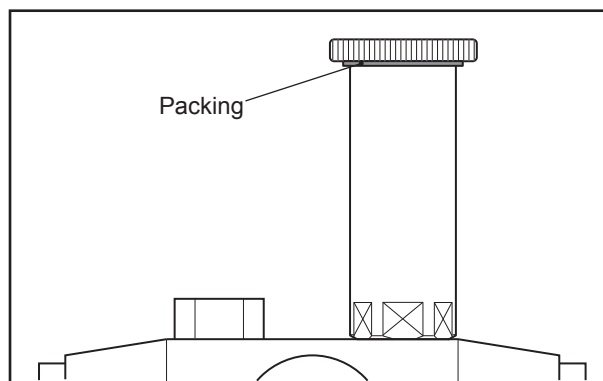


Fig. 3-7 Priming Pump Head Packing

Preparation of Lubrication System

Engine Oil - 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 component parts 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 SPECIFICATIONS" (12-1).

3. Check the oil level in the oil pan as follows:
4. Pull out the oil level gauge and wipe it clean with a 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 check the engine oil pressure to be raised to approximately 0.2 MPa {2.04 kgf/cm²} [29.01 psi].

Note: This procedure should be performed together with that of cooling system.

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" (3-9).

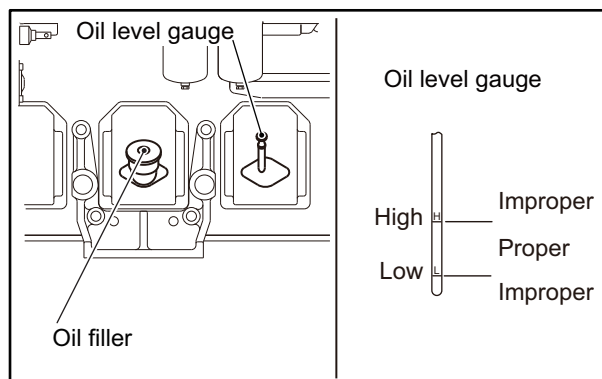


Fig. 3-8 Oil Filler and Oil Level Gauge

Preparation for Cooling System

Coolant Expansion Tank Cap - Open/Close



CAUTION

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

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

Coolant is hot while engine is running and immediately after stopping. If the cap is opened when the coolant is hot, hot coolant steam will burst out and you could suffer serious burns. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

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

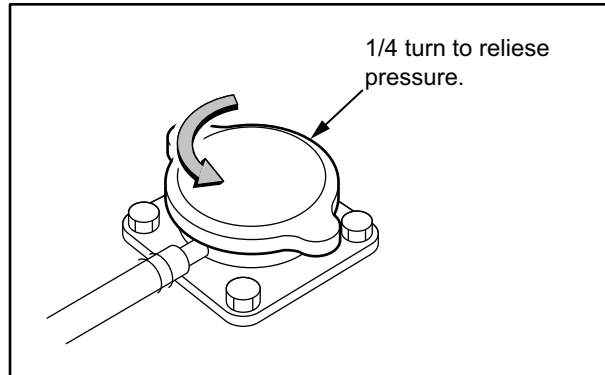


Fig. 3-9 Coolant Expansion Tank Cap

Coolant - Refill

CAUTION

Too add the coolant, use the coolant of the same LLC concentration to the original coolant in the engine.

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

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

For the coolant, refer to "COOLANT" (6-1).

For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

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

3. Check the radiator and other parts for coolant leaks. Repair if a leak is found.
4. When coolant reaches the specified level, close the coolant expansion tank cap securely.
5. 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 to bleed the cooling system.

Note: This procedure should be performed together with that of the engine oil system.

6. Check the coolant level.

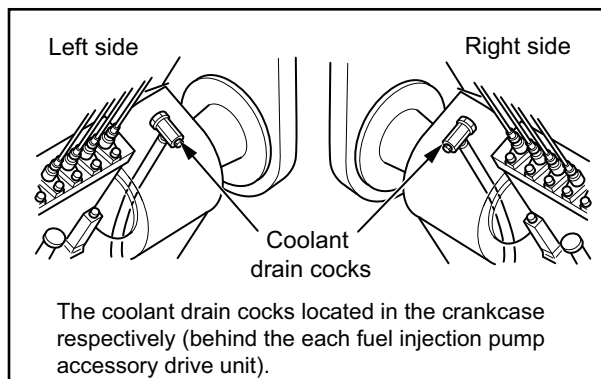


Fig. 3-10 Coolant Drain Cock (Engine)

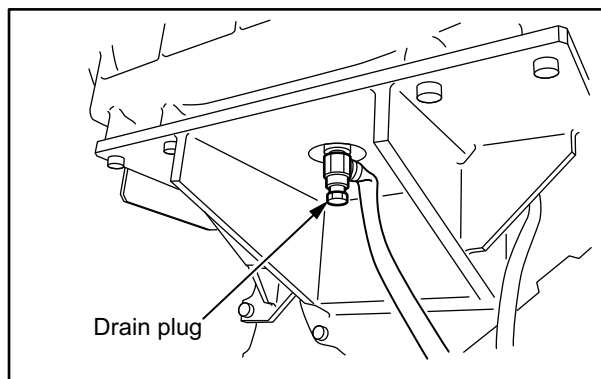


Fig. 3-11 Coolant Drain Cock (Coolant Expansion Tank)

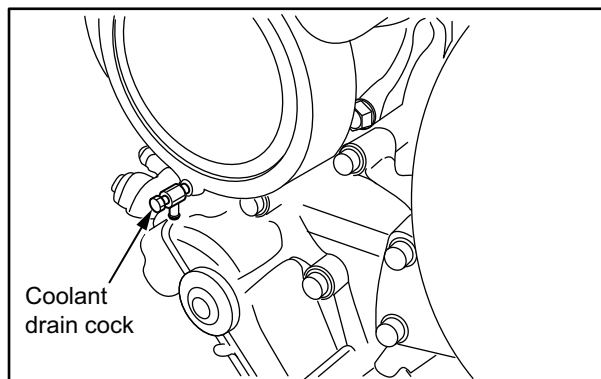


Fig. 3-12 Coolant Drain Cock (Fresh Water Pump)

Preparation of Electrical System

Battery - Check

CAUTION

If battery electrolyte is spilled on your skin or clothes, flush immediately with plenty of water. If battery electrolyte gets into your eyes, flush them immediately with plenty of water and then get medical attention.

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

If the battery is not able to be fully recovered after charging for 24 hours more, do not use the battery.

If the engine is started with a low-level electrolyte battery, it may cause an explosion.

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

Battery Electrolyte Level - Inspect

The battery electrolyte evaporates in the use, and the electrolyte level gradually decreases. The proper electrolyte surface level is between the LOWER LEVEL and UPPER LEVEL marks.

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

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

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

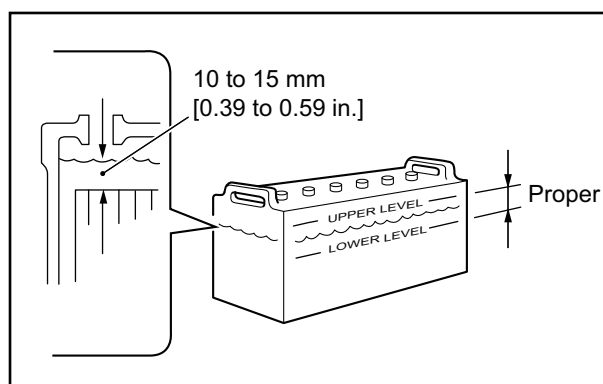


Fig. 3-13 Battery Electrolyte Level - Inspect

Test Operation

To conduct a test operation, follow the procedures below.

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

Starting and Stopping

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

Inspection

⚠ CAUTION

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

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

The coolant is hot while engine is running and immediately after the engine stops. If the cap is opened when the coolant is at an operating temperature, steam and hot coolant may blow out and result in burns. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

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

CAUTION

Too add the coolant, use the coolant of the same LLC concentration to the original coolant in the engine.

1. Leave the engine be stopped for about 30 minutes.
2. During this period, check the engine and surrounding area for leaks of fuel, engine oil or coolant.
3. At 30 minutes after the engine stop, check the oil level with the oil level gauge.
4. If the oil level is low, add engine oil from the oil filler port. Be sure to use the engine oil of the same brand and type.
5. Open the coolant expansion tank cap and check the coolant level.
6. If the coolant level is low, add coolant to the specified level.
7. If a reserve tank is equipped, fill the reserve tank with coolant up to the "FULL" level line.

Normal Engine Operation

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

CAUTION

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

Preparations for Operation

Always conduct the following inspection before starting the engine.

Engine External - Inspect

CAUTION

Check around the engine, particularly around its hot part (exhaust manifold, etc.) and battery unit for any accumulation of flammables, fuel leaks, and engine oil leaks, and so on. Remove dust from the top surface of the battery. A fire can be caused by combustible materials placed near hot engine parts. If any abnormality is found, be sure to repair it or contact your local dealer.

Inspect the engine exterior as described below.

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Check the whole engine for leaks of fuel, engine oil or coolant. If a leak is found, repair the leak, or contact a dealer of MHIET.
3. Walk around and check bolts and nuts for looseness.
4. Check electric wiring for disconnection, looseness, cuts, or rubbing.
5. Ensure the following valves, plugs or cocks are properly positioned.
 - Fuel feed valve: Open
 - Coolant drain cock (valve): Closed
 - Engine oil drain plug: Closed

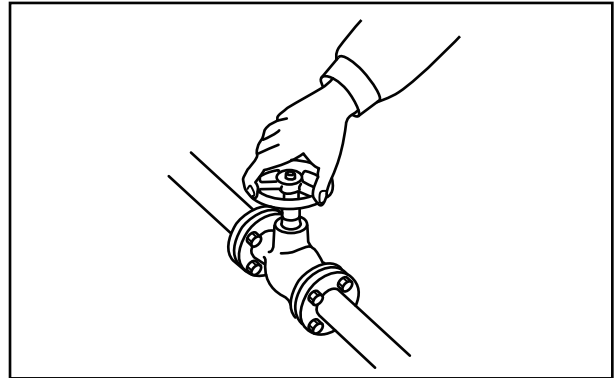


Fig. 3-14 Valves for Open/Closed Position - Check

Fuel Tank Oil Level - Check

WARNING

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

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

CAUTION

Do not remove the strainer during fuel tank filling.

For 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, refill the tank to the "FULL" level mark.

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

Oil-Water Separator - Drain Water

WARNING

Fuel is also discharged from the drain cock. Wipe off any spilled fuel completely. Spilled fuel can ignite and cause a fire.

Make sure there is no open fires around the engine before proceeding with the job.

Open the inlet valve slowly to prevent overflowing fuel. Wrap a cloth around the water separator just in case, as fuel may spill.

1. Close the inlet cock and outlet cock.
2. Turn the T-handle, and remove the upper lid.
3. Open the drain cock, and drain water in the water separator.
4. Close the all drain cocks after draining.
5. Fill the water separator with fuel.
6. Attach the upper lid, and tighten the T-handle.
7. Open the inlet cock and outlet cock.

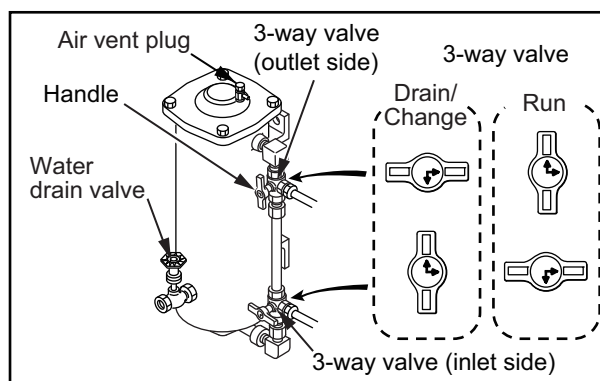


Fig. 3-15 Oil-Water Separator - Drain Water

Engine Oil Level - Check

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 component parts are adversely affected by the increase of oil temperature.

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

1. Stop the engine and leave it for 30 minutes or more.
2. Pull out the oil level gauge and wipe oil off 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 proper oil level is between the high and low marks on the oil level gauge. If the engine oil goes over the high marks on the oil level gauge, drain the oil. If the oil level is low, add engine oil of the specified grade.

For draining engine oil, refer to "[Engine Oil - Drain](#)" (8-11). For refilling engine oil, refer to "[Engine Oil - Refill](#)" (3-5).

5. Install the oil filler cap after adding engine oil.

Note: (a) Before installing the oil filler cap, wipe off engine oil on the oil filler cap and pipe.

(b) Overtightening the oil filler cap may cause damage.

Tighten the oil filler cap for two and a half to three turns after the rubber part contacts the inner surface of the pipe.

6. Check the oil pan and other area for oil leaks.

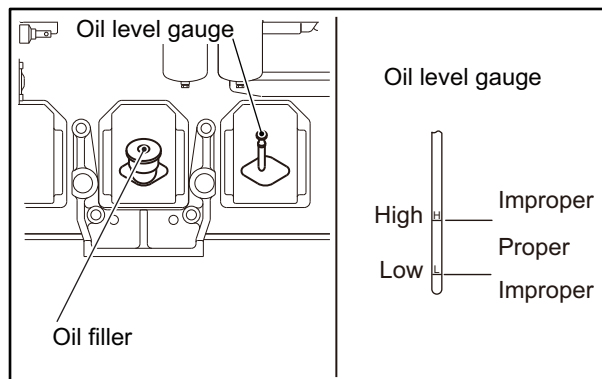


Fig. 3-16 Oil Filler and Oil Level Gauge

Coolant Level - Check

CAUTION

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

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

The coolant is hot while engine is running and immediately after the engine stops. If the cap is opened when the coolant is hot, hot coolant steam will burst out and you could suffer serious burns. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

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

CAUTION

Too add the coolant, use the coolant of the same LLC concentration to the original coolant in the engine.

1. Check the coolant level in the coolant expansion tank with the glass water gauge.
2. If the coolant level is low, add coolant to the specified level.

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

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

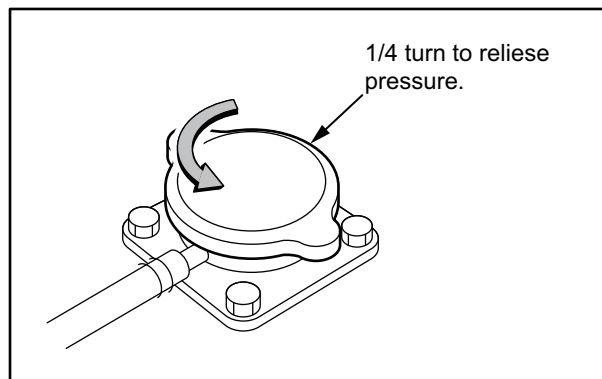


Fig. 3-17 Coolant Expansion Tank Cap

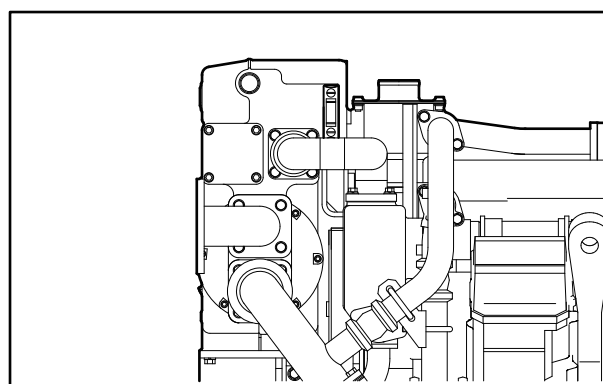


Fig. 3-18 Coolant Level - Check

Warning Indicator Lamp Operation - Check

1. Turn the starter switch to the "ON" position.
2. Press the "ALARM TEST" button.
3. Check if each lamp glows. If the lamp is not turned on, check the bulb of each lamp.

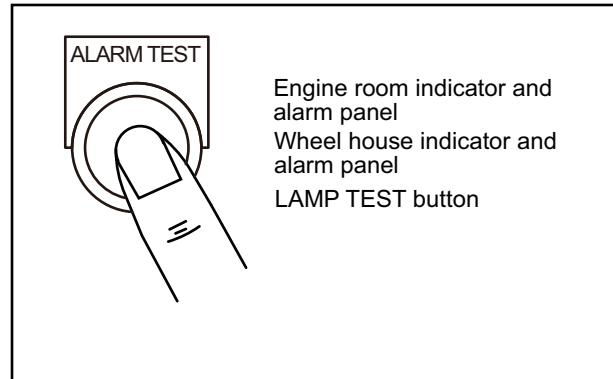


Fig. 3-19 Warning Indicator Lamp Operation Check

Control Cable - Check

Check the visual appearance of control cable between the actuator and governor in the engine room for flaw, deformation, discoloration, abnormal rust, etc.

Start

Cautions When Starting

WARNING

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

CAUTION

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

Restart the engine after it stops completely.

Check the movement of governor actuator and fuel system if the engine will not start after repeating above step three to five times.

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

When the engine is not operated for a long time (one week or more), rotate the crankshaft for 10 seconds with starter while pulling the manual stop lever to circulate oil in the engine. Repeat this three times with approx. one minute intervals between rotations.

Pre-heating during cold weather should be performed between 80 to 12 seconds.

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

Start Procedures

1. Turn the starter switch to the "ON" position.

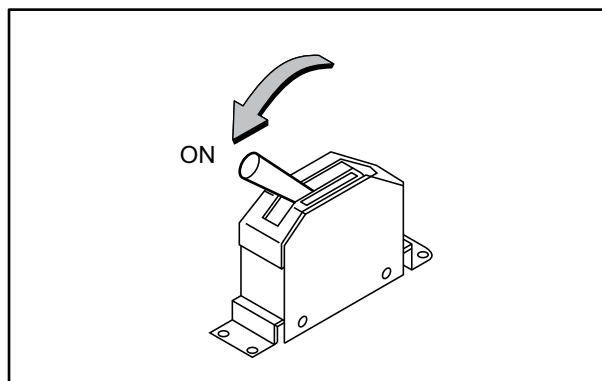


Fig. 3-20 Battery Switch "ON"

2. Turn the COMM CONT. SOURCE switch on ENGINE ROOM INDICATOR & ALARM PANEL to "ON."

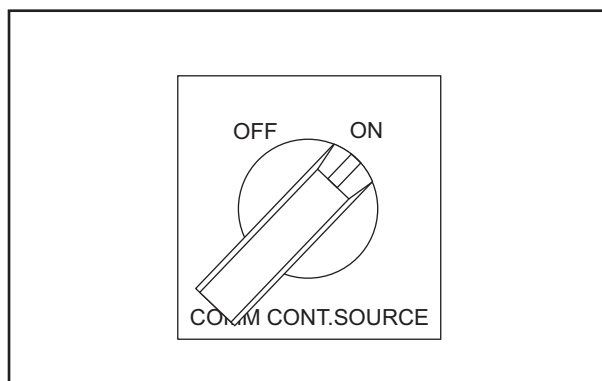


Fig. 3-21 COMM CONT. SOURCE Switch "ON"

3. Place the START POSITION switch on ENGINE ROOM INDICATOR & ALARM PANEL to a desired starting place.

Note: The engine can be started at the selected starting place.

4. Place the speed control lever to the "L" position and place the direction lever to the "N" position.

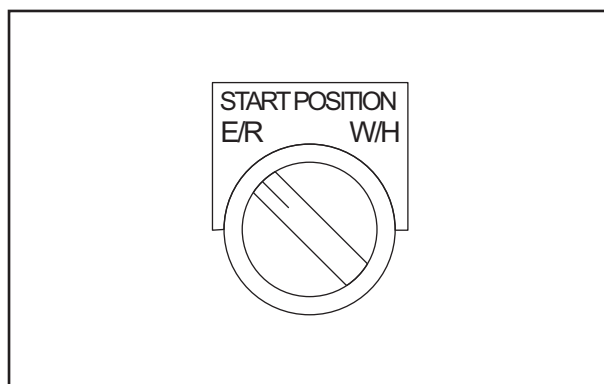


Fig. 3-22 START POSITION Switch

5. Turn on the CONT. SOURCE switch of selected starting location on PORT SIDE and STBD SIDE of INDICATION & ALARM PANEL

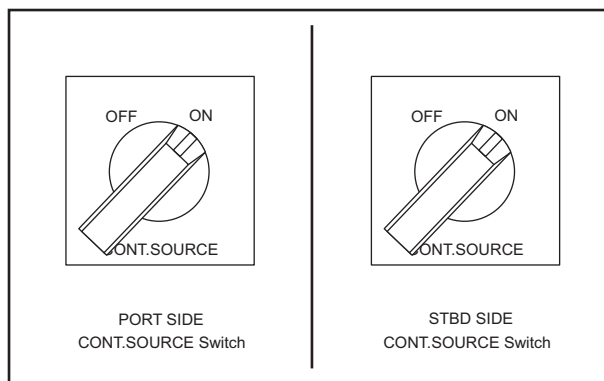


Fig. 3-23 CONT. SOURCE Switch "ON"

6. Turn the ENG. START key to the "START" position, and start the engine.

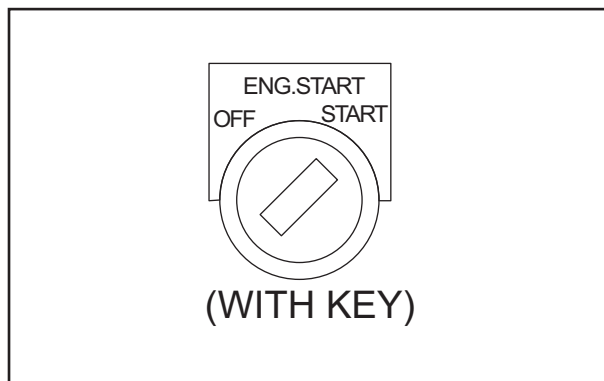


Fig. 3-24 ENG. START Switch "START"

Warm-Up Operation

WARNING

Stay away from rotating parts during operation. If your cloth gets tangled in moving parts, it can result in serious injury or death.

CAUTION

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

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

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

Engine Oil Pressure - Check

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

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

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

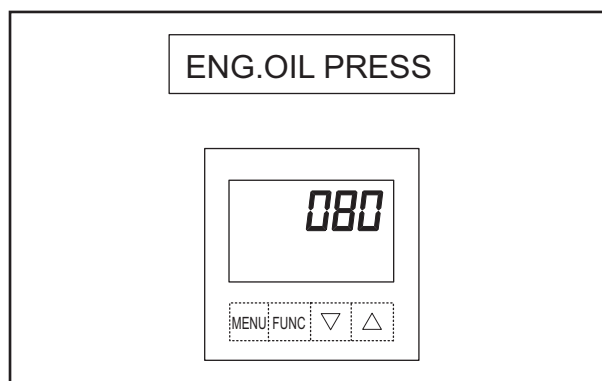


Fig. 3-25 Engine Oil Pressure Gauge in Engine Room

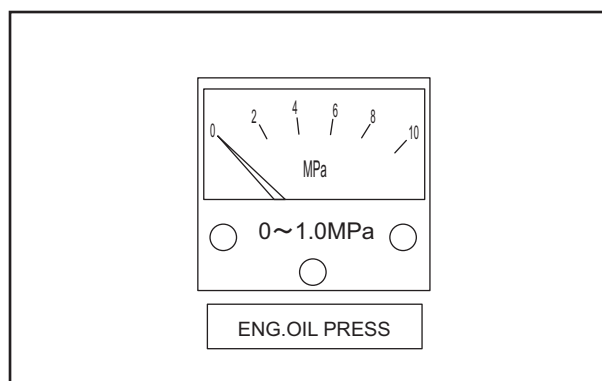


Fig. 3-26 Engine Oil Pressure Gauge in Wheel House

External Inspection During Warm-Up

Visually check the external view of the engine for abnormal noise, odor, vibration and exhaust gas color, then check the leakage of fuel, engine oil and coolant or exhaust gas from joints during warm-up operation.

Run

Cautions During Operation

Pay Attention to Gauges and Alarm Lamps

CAUTION

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

Pay Attention to Abnormal Noise

CAUTION

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

Pay Attention to Exhaust Color

CAUTION

If the exhaust gas shows an abnormal color, there is a problem in the engine. Stop the engine and inspect the engine by referring to the ["TROUBLESHOOTING" \(11-1\)](#) to locate and correct the problem.

Avoid Operating the Engine at a Speed Which Causes Resonance

CAUTION

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

Observe Sea Water Discharging Volume

CAUTION

If sea water does not circulate properly, overheating and other malfunctions can result. Note the amount of sea water discharged in normal operation, and regularly check the amount of discharged sea water to judge if it is normal.

Check to see if the kingston valve, sea water strainer and other parts are clogged with dust or plastic particles.

Check to see if the brine pump impeller is damaged.

Limitation of Continuous Under Light Load Operation

CAUTION

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)
-

Stop

Cautions When Stopping

CAUTION

Stopping the engine abruptly while engine parts are hot due to high-speed operation can be a cause for heat up of the engine parts and shorten the engine life. Before stopping the engine, run the engine with the idle speed at low Rpm's for 5 or 6 minutes to cool the engine, and check the engine for abnormalities.

Do not race the engine immediately before shutting it down.

If the engine stops abnormally, do not restart the engine immediately. When the engine stops with alarms, be sure to locate the cause of the problem and correct the problem before restarting the engine. After restarting the operation, check the engine for abnormalities again. If the engine has an abnormality, repair it immediately.

When stopping the engine by pushing the stop button, keep pushing the button until the engine stops completely. If not, the engine may start again.

Stopping Procedure

1. Place the speed control lever to the "L" position and place the direction lever to the "N" position.
 2. Before stopping, run the engine at low idle for 5 to 6 minutes to cool the engine.
 3. Push the "ENG. STOP" button on WHEEL HOUSE INDICATOR & ALARM PANEL to stop the engine.
- Note: To stop the engine from ENGINE ROOM, use "ENG. STOP" button on ENGINE ROOM INDICATOR & ALARM PANEL.

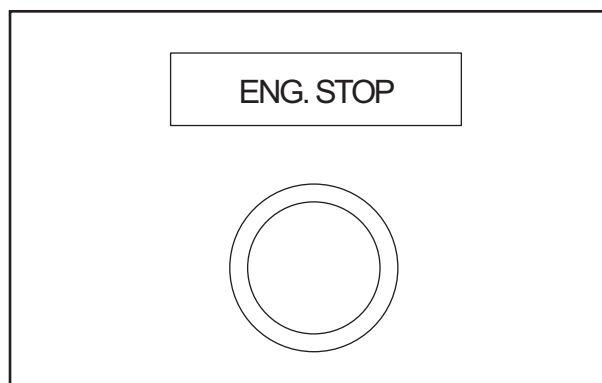


Fig. 3-27 ENG. STOP Button

4. Turn OFF the CONT. SOURCE switch of PORT SIDE and STBD SIDE of ENGINE ROOM INDICATOR & ALARM PANEL

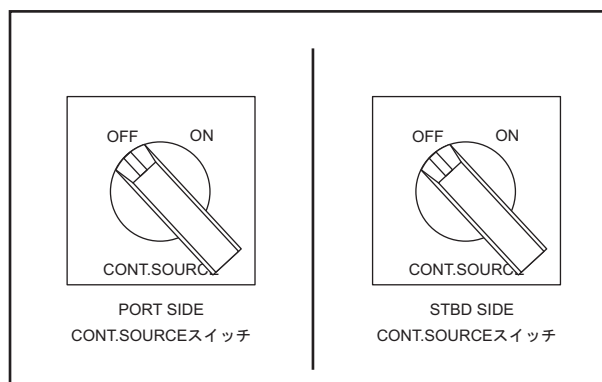


Fig. 3-28 CONT. SOURCE Switch "OFF"

5. Turn OFF the COMM CONT. SOURCE switch on ENGINE ROOM INDICATOR & ALARM PANEL.

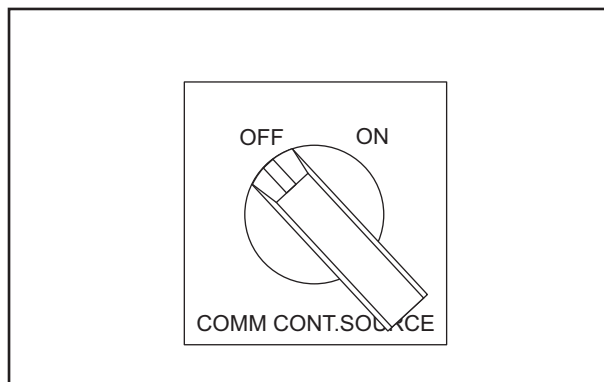


Fig. 3-29 COMM CONT. SOURCE Switch "OFF"

6. Turn the battery switch to the "OFF" position.

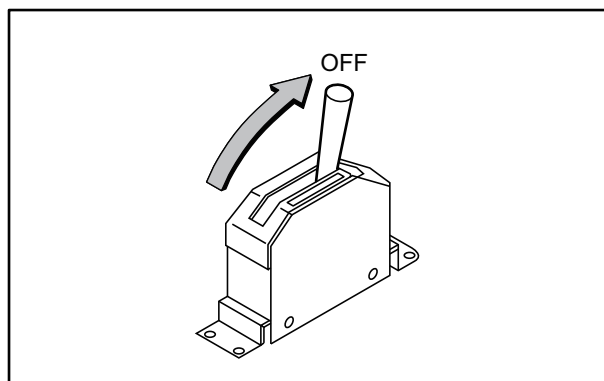


Fig. 3-30 Battery Switch "OFF"

Emergency Stop

To stop the engine urgently from WHEEL HOUSE, push "EMERGENCY STOP" button.

To stop the engine urgently in ENGINE ROOM, use the manual stop lever on the engine.

Note: When recover the engine to the operation after the emergency stop, press the "RESET" button on the engine room indicator and alarm panel.

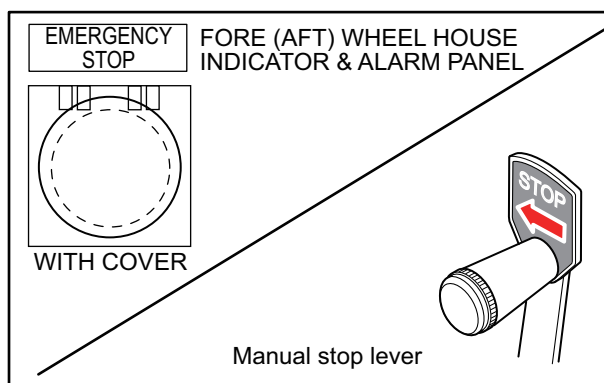


Fig. 3-31 "EMERGENCY STOP" Button and Manual Stop Lever

Recommended Fuel



WARNING

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

Use fuel that meets the values specified in the following [Table 4-1 Recommended Fuel](#) and [Table 4-2 Recommended Limit and Use Limit of Fuel Property](#).

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

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

Table 4-1 Recommended Fuel

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

Fuel Quality Standard

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

Table 4-2 Recommended Limit and Use Limit of Fuel Property

Item		Recommended limit	Use limit	Test method
Flash Point		50°C [122°F] or higher (In accordance with the regulation)		JIS K 2265 ISO 3769 ISO 2719
Distillation	Initial boiling point	170°C [338°F] or higher		JIS K 2254 ISO 3405
	90% distillate temperature	330 to 380°C [626 to 716°F]		
Pour point (PP)		Lower than ambient temperature by 6°C [10.8°F] or more		JIS K 2269 ISO 3016
Cloud point (CP)		Ambient temperature or below		JIS K 2269 ISO 3015
Cold filter plugging point (CFPP)		Lower than ambient temperature by 3°C [5.4°F] or more		JIS K 2288 IP 309/96
Carbon residue (10 % residual oil)		0.4 mass% or less	1.0 mass% or less	JIS K 2270 ISO 6615 ISO 10370
Cetane number		45 or more		JIS K 2280 ISO 5165
Cetane index (new type)		45 or more		JIS K 2280 ISO/DIS 4264
Kinetic Viscosity		2.0 mm ² /s or more at (30°C) [86°F] 8.0 mm ² /s or less at (50°C) [122°F]		JIS K 2283 ISO 3104
Sulfur content		0.2 mass% or less	1.0 mass% or less (Shorten the engine oil change intervals.)	JIS K 2541 (The content should be as low as the diesel fuel.) ISO 4260 ISO 8754
Water content and sediment		0.1% or less by volume		JIS K 2275 ISO 3733
Ash content		0.01 mass% or less	0.03 mass% or less	JIS K 2272 ISO 6245
Copper corrosion (50°C [122°F], 3Hr)		Discoloration = Copper plate No.3 or less (deep discoloration)		JIS K 2513 ISO 2160
Density (15°C [59°F])		0.83 to 0.87 g/cm ³ [51.8 to 54.3 lb/ft ³]	0.80 to 0.87 g/cm ³ [49.94 to 54.3 lb/ft ³]	JIS K 2249 ISO 3675
Caulking	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 aromatic content)		JIS K 2536 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/liter or less		JIS B 9931 ISO 4405

Table 4-2 Recommended Limit and Use Limit of Fuel Property

Item	Recommended limit	Use 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 WS 1.4 kPa {0.01 kgf/cm ² } [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 3751, EN14214. Allowable mixing ratio of fuel blending: 7 volume% or less.		JIS K2390 (FAME standard for mixing) ASTM D 6751 EN 14214

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.

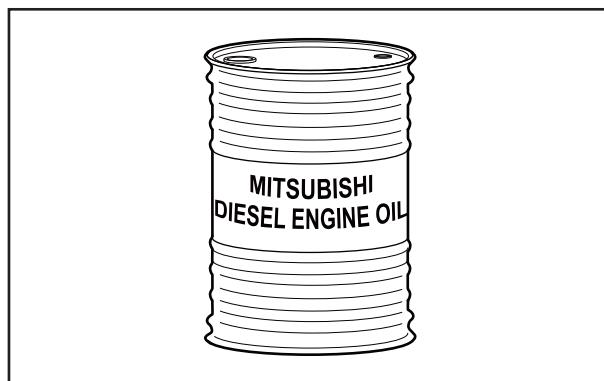


Fig. 5-1 MITSUBISHI DIESEL ENGINE OIL

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.

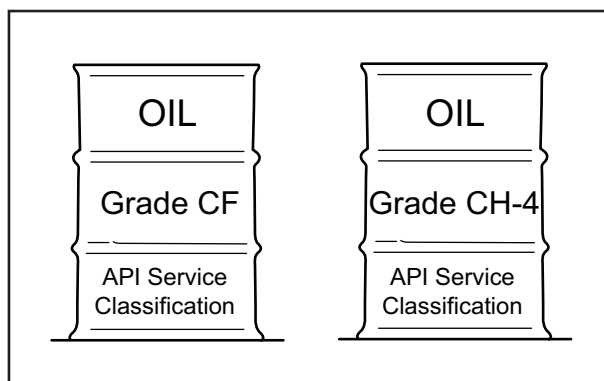


Fig. 5-2 Engine Oil Grade

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 ² /s	100 to 120	ASTM D 445 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 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 ASTM D 4951 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.

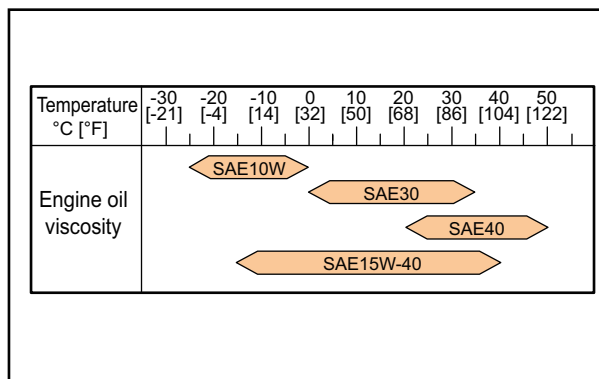


Fig. 5-3 Selection of Oil Viscosity

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 of Engine Oil

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

The quality of engine oil and fuel, and the operating condition of the engine affect the deterioration of the engine oil. Replace the engine oil in accordance with [Chapter 7 MAINTENANCE SCHEDULE](#). However, only if engine oil analyze result allows, oil replacement interval may be changed.

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

Table 5-4 Table of Engine Oil Properties

Properties		Standard	Test method
Kinetic viscosity	mm ² /s @100°C [212 °F]	+30 % or less rate of change from new oil 10 mm ² /s [0.155 in ² /s] or more	JIS K 2283:2007 ISO 3107 ISO 2909
		+30 % or less rate of change from new oil -20 % or more rate of change from new oil	
Base number	mgKOH/g	2.0 or more with hydrochloric acid (HCL) method 1/2 of new oil or more with perchloric acid (PCA) method	JIS K 2501:2003 ISO 3771
Acid number	mgKOH/g	+3.0 of new oil or less	JIS K 2501:2003 ISO 3771
Water content	Vol %	0.2 or less	JIS K 2275:1996 ISO 9029
Flash point (Open cup)	°C [°F]	180 [356] or higher	JIS K 2265:2007 ISO 3769 ISO 2719
Pentane insoluble	Wt %	0.5 or less	Compliant to ASTM D 893
Pentane insoluble coagulated	Wt %	3.0 or less	Compliant to ASTM D 893

Definition of 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.

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

Recommended Water for Coolant

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

Table 6-1 Water Quality Standards

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

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

Long Life Coolant (LLC)

CAUTION

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

Be sure to use Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.genuine long life coolant (LLC) "GLASSY long life coolant (Ethylene glycol type)" or "PG GLASSY long life coolant (Non-amine type)" as coolant. When using other brand LLCs by necessity, be sure to use the non-amine type LLC that meets the specification in Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. disclaims the warranty claims about malfunctions due to the use of LLC that does not meet the following specification.

Genuine LLC

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

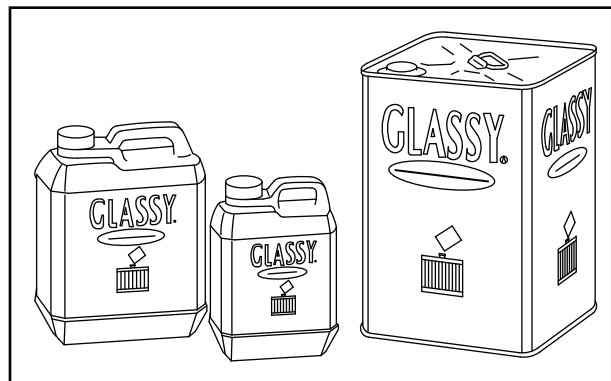


Fig. 6-1 GLASSY - LLC

Other Commercial LLCs

CAUTION

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

When using LLC other than MHIET genuine long life coolant (LLC) "GLASSY long life coolant (Ethylene glycol type)" or "PG GLASSY long life coolant (propylene glycol type)", be sure to use the LLC which meets specification in MHIET

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

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

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

Requirements for Other Commercial LLCs

If you must use other brand of LLCs, be sure to use the LLC that meets the requirements below.

Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. disclaims the warranty claim for malfunctions caused by the use of LLC that does not meet our requirements.

General Quality Requirements for LLC

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

LLC Specifications

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

Table 6-2 LLC Specifications

Property				Standard	
Appearance				No precipitation	
Density				Minimum 1.112 g/cm ³ [69.4199 lb/ft ³] (20/20 °C) [20/68 °F] (Stock solution)	
Water Content				Maximum 5.0 weight % (Stock solution)	
Frozen temperature	30 vol %			Maximum -14.5 °C [6 °F]	
	50 vol %			Maximum -34.0 °C [-29 °F]	
Boiling temperature				155 °C [311 °F] or higher (Stock solution)	
pH				7.0 to 11.0 (30 vol %)	
Bubbling character (ASTM D3306-01)	30 vol %			4.0 ml or less	
	33 ¹ / ₃ vol %			150 ml [0.032 gal] or less, Disappearance of bubble within 5 seconds.	
Hard water adaptability				1.0 or less (50 vol %)	
Metallic causticity (88±2°C [190.4±4°F], 336±2 Hr, 30 vol % (E.G), 50 vol % (P.G))	Metal specimen	Mass change	Aluminum	±0.30 mg/cm ²	
			Cast iron	±0.15 mg/cm ²	
			Steel	±0.15 mg/cm ²	
			Brass	±0.15 mg/cm ²	
			Solder	±0.30 mg/cm ²	
			Copper	±0.15 mg/cm ²	
	Appearance of the specimen after testing			No visible signs of corrosion on the surface excluding the area contacting to spacer.However, discoloration is acceptable.	
	Bubbling during the test			Not bubbling overflow	
	Properties of liquid after the test	pH			6.5 to 11.0
		pH change			±1.0
Precipitation			0.5 vol % or less		
Appearance of liquid			No remarkable discoloration, separation and gel generation.		

Table 6-2 LLC Specifications

Property				Standard
Circulation metallic causticity (98±2°C [208.4±4°F], 1000 Hr, 30 vol % (E.G) 50 vol % (P.G)	Metal specimen	Mass change	Aluminum, Cast iron, Steel, Brass, Solder, Copper	±0.30 mg/cm ²
		Appearance of the specimen after testing		No visible signs of corrosion on the surface excluding the area contacting to spacer. However, discoloration is acceptable.
	Properties of liquid after the test	pH		7.0 to 9.0
		pH change		±1.0
		Pre-alkalinity change		±15 %
		Precipitation		1.0 vol % or less
		Appearance of liquid		No remarkable discoloration, separation and gel generation.
Circulation metallic causticity (88±3°C [190.4±6°F], 1000±2 Hr, 30 vol % (E.G)	Metal specimen	Mass change	Fe, Cu, Al, Zn, Pb, NH ₄ ⁺	10 ppm or less
			Aluminum	±0.60 mg/cm ²
			Cast iron	±0.30 mg/cm ²
			Steel	±0.30 mg/cm ²
			Brass	±0.30 mg/cm ²
			Solder	±0.60 mg/cm ²
			Copper	±0.30 mg/cm ²
		Appearance of the specimen after testing		No visible signs of corrosion on the surface excluding the area contacting to spacer. However, discoloration is acceptable.
	Properties of liquid after the test	pH		6.5 to 11.0
		pH change		Maximum ±1.0
		Appearance of liquid		No remarkable discoloration, separation and gel generation.
	Condition of parts	Pump seal		Free from any malfunction, liquid leak and abnormal noise during operation.
		Inside of pump case and blade		Free from remarkable corrosion

Table 6-2 LLC Specifications

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

Maintenance of LLC

CAUTION

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

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

Replacement Intervals of LLC

CAUTION

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

Failure to renew LLC may cause malfunctions due to performance degradation of preventing rust and cavitations.

LLC Concentration (GLASSY, 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. Be sure to maintain the coolant concentration in the range shown in the table below.

Table 6-3 Recommended LLC Concentration

Environmental temperature		to -10°C [14°F]	to -20°C [-4°F]	to -30°C [-22°F]	to -45°C [-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 be lowered, or the cooling water temperature will be increased 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). Confirm the heat exchanger capacity of the cooling system to avoid overheating.

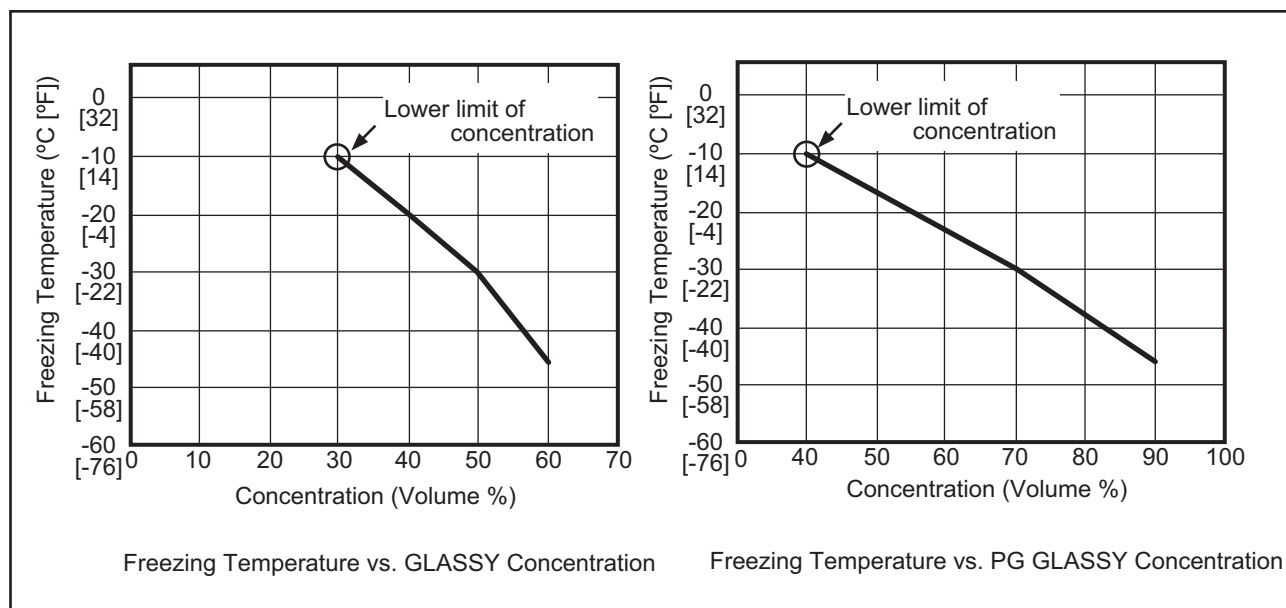


Fig. 6-2 Coolant Freezing Temperature (GLASSY and PG GLASSY)

Importance of LLC

Today's trend is toward smaller and lighter engines offering greater output, lower fuel consumption and lower exhaust emission levels.

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

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

Characteristics of LLC Additive and Important Notes

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

Moreover, if the chemicals are not well proportioned to match the metals used in the cooling system, certain chemicals in the LLC become rapidly used up and result in dissolution of metals instead of protecting metals from corrosion. Consequently, other corrosion preventing chemicals react with dissolving metals and accelerate corrosion. This condition generates more severe corrosion than when plain soft water is used. This is a typical problem caused by the use of inappropriate LLC.

Examples of Abnormalities Caused by LLC (Amine Type)

Pitting of Iron Parts

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

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

Corrosion of Aluminum Parts

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

This means, after silicate is used up, the high alkalinity causes chemical attacks on aluminum. To prevent this problem, proper maintenance of the coolant is required. For case example, rapid wear of mechanical seals in the fresh water pump due to secondary effects of silicate gel formed. Corrosion of aluminum parts after silicate is consumed.

Pitting and Clogging of the Heat Exchanger

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

Chapter 7 MAINTENANCE SCHEDULE

How to Use Maintenance Schedule

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

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

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

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

Maintenance Schedule

Table 7-1 Maintenance Schedule

Maintenance intervals	Service item	Page
First 100 service hours (only once)	Engine Oil and Oil Filter - Replace	8-11
	Fuel Filter - Replace	8-7
	Valve Clearance - Inspect and Adjust	*
	Engine External - Inspect	8-1
Every 100 service hours	Oil-Water Separator - Drain Water	8-5
Every 250 service hours	Engine Oil and Oil Filter - Replace	8-11
	Belt and Belt Tension - Inspect and Adjust	8-2
	Pre-Cleaner - Clean, Inspect and Replace	8-20
Every 500 service hours	Also service contents for every 100 and 250 service hours	-
	Gauze Filter - Clean	8-6
Every 1000 service hours	Also service contents for every 100, 250 and 500 service hours	-
	Fuel Filter - Replace	8-7
	Oil-Water Separator Element - Replace	8-5
	Sea Water Pump Impeller - Inspect	8-18
	Turbocharger - Inspect	8-19
	Valve Clearance - Inspect and Adjust	*
	Fuel Injection Nozzle - Inspect and Adjust	*
Every 2000 service hours or every 1 year	Also service contents for every 100, 250, 500 and 1000 service hours	-
	High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace	8-10
	Low Pressure Fuel Pipe, Oil Pipe and Clip - Inspect and Replace	8-10
	Fuel Injection Nozzle Tips - Replace	*
	Fuel Control Link Ball Joint - Inspect	*
	Sea Water Pump Impeller - Replace	*
	Bolts and Nuts on Exhaust and Air Inlet Pipes - Retighten	*
	Harness Damage and Terminal Llooseness - Inspect	*

Table 7-1 Maintenance Schedule

Maintenance intervals	Service item		Page
Every 4000 service hours or 2.5 years	Also service contents for every 100, 250, 500, 1000 and 2000 service hours		-
	Engine Body Overhaul	Cylinder Head - Disassembly and Inspect Valve Mechanism - Inspect Cylinder Liner Inside Surface - Inspect	*
	Belt - Repalce		*
	Damper - Inspect		*
	Fuel Injection Timing - Inspect and Adjust		*
	Fuel Injection Pump Coupling Bolt and Laminated Plate - Inspect		*
	Fuel Control Link Ball Joint - Replace (Including Stop Solenoid and Parts Relating to Gavernor)		*
	Heat Exchanger - Clean		*
	Thermostat Operation - Check		*
	Intercooler Element - Clean		*
	Starter - Inspect		8-22
	Alternator - Inspect		8-22
	Protection System Operation - Inspect		*
	Coolant - Change (Fresh water) (Every 2 Years)		8-16

Table 7-1 Maintenance Schedule

Maintenance intervals	Service item		Page
8000 hours or every 5 years	Also service contents for every 100, 250, 500, 1000, 2000 and 4000 service hours		-
	Engine Body Overhaul	Piston - Inspect Piston Ring - Replace Crankshaft - Inspect Main Bearing - Replace Thrust Plate - Replace Connecting Rod Bearing - Replace Camshaft Bushing - Inspect Cylinder Liners - Replace Inlet and Exhaust Valve - Replace Inlet and Exhaust Valve Seat Ring - Replace Valve Rotator - Replace Damper - Replace	*
	Fuel Flexible Hose - Replace		*
	Fuel Injection Pump - Inspect and Adjust (Replace Parts as Necessary)		*
	Governor - Inspect and Adjust (Replace Parts as Necessary)		*
	Clamp Seat of High-Pressure Fuel Injection Pipe - Replace		*
	Oil Cooler - Clean		*
	Fresh Water Pump Unit Seal and Ball Bearing - Replace		*
	Sea Waterer Pump Unit Seal and Ball Bearing - Replace		*
	Tension Pulley Bearing - Replace		*
	Thermostat - Replace		*
	Hoses of Fresh and Sea Cooling Water - Replace		*
	Radiator Cap - Replace		*
	Turbocharger - Overhaul		*
	Electrical Components - Inspect		*
	Relays - Replace (Including Relays for Governor and Panel)		*
	Rubber Blocks - Replace		*
16000 hours or every 10 years	Also service contents for every 100, 250, 500, 1000, 2000, 4000 and 8000 service hours		-
	Replace following parts with new ones. Piston, connecting rod bushing, piston pin, rocker bush, gear bushing, tappet, valve guide, valve spring, connection rod bolt, main bearing cap bolt, high pressure fuel injection pipe, low pressure fuel pipe, and oil pipe		*
	Cylinder Head Bolt - Inspect		*

Note: (a) The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them by following the instructions in the manufacturer's operation manual.

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

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

Basic Engine

Engine External - Inspect

CAUTION

Check around the engine, particularly around its hot part (exhaust manifold, etc.) and battery unit for any accumulation of flammables, fuel leaks, and engine oil leaks, and so on. Remove dust from the top surface of the battery. A fire can be caused by combustible materials placed near hot engine parts. If any abnormality is found, be sure to repair it or contact your local dealer.

Inspect the engine exterior as described below.

1. Make sure there is no combustible material near the engine or battery. Also, check to make sure that the engine and battery are clean. If combustible materials or dust are found near the engine or battery, remove them.
2. Check the whole engine for leaks of fuel, engine oil or coolant. If a leak is found, repair the leak, or contact a dealer of MHIET.
3. Walk around and check bolts and nuts for looseness.
4. Check electric wiring for disconnection, looseness, cuts, or rubbing.
5. Ensure the following valves, plugs or cocks are properly positioned.
 - Fuel feed valve: Open
 - Coolant drain cock (valve): Closed
 - Engine oil drain plug: Closed

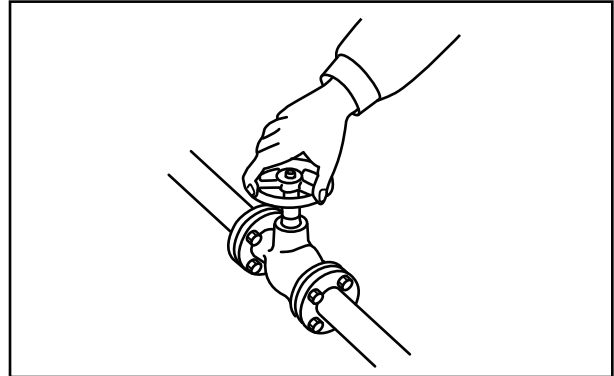


Fig. 8-1 Valves for Open/Closed Position - Check

Belt and Belt Tension - Inspect and Adjust

CAUTION

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

Keep oil and grease away from the belt. They may cause the belt to slip and shorten the service life.

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

Adjust the belt tension accurately by following the procedures below.

Belt - Inspect

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

Push the belt downward at the midway between pulleys. If the deflection is 10 to 15 mm [0.39 to 0.59 in.], the tension is correct.

Belt pushing force: Approx. 98 to 147 N•m {10 to 15 kgf•m} [22 to 32.4 lbf•ft]

If the deflection of belt is not within the standard, adjust the belt tension.

Belt Tension (Alternator Side) - Adjust

1. Remove the belt cover.
2. Loosen all retaining bolts of the alternator and adjusting rod.
3. Loosen the lock nut of adjusting rod.

Note: The crankcase side screw at the end of adjusting rod is a left-hand threads.

4. Turn the adjusting rod to adjust the belt tension.
5. After adjusting deflection, fix lock nuts of adjusting rod.
6. Tighten all retaining bolts of the alternator and adjusting rod.
7. Install the belt cover.

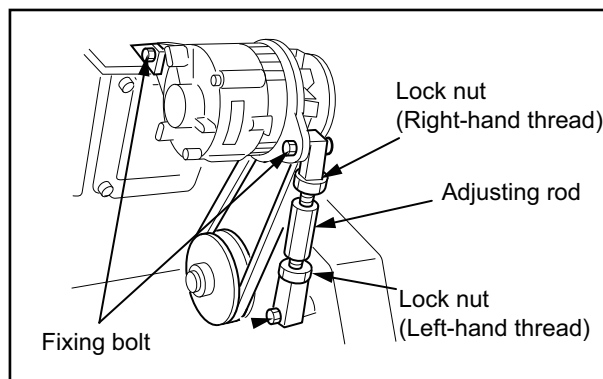


Fig. 8-2 Belt Tension (Alternator Side) - Adjust

Belt Tension (Sea Water Pump Side) - Adjust

1. Remove the belt cover.
2. Loosen all the retaining bolts of the water pump tension pulley bracket.
3. Loosen the lock nuts of the adjusting bolt. Turn the adjusting bolts to adjust the belt tension.
4. After the tension adjustment, tighten the lock nut of the adjusting bolt.
5. Install the belt cover.

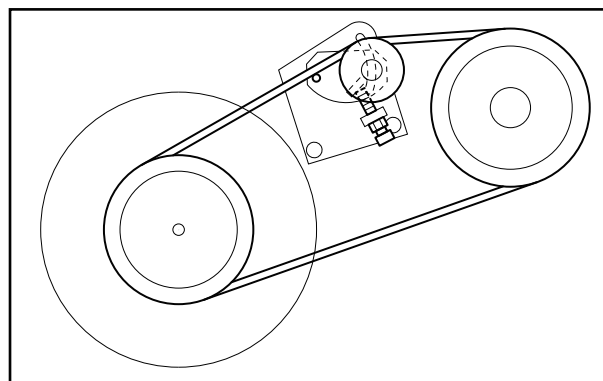


Fig. 8-3 Belt Tension (Sea Water Pump Side) - Adjust

Cautions on Operating Engine in Cold Weather Season

When the ambient temperature is low, the fuel and engine oil become thick, and the coolant can freeze. As a result, the engine fails to start, or the cylinder heads and heat exchanger may be damaged. To prevent such problems, follow the instructions given below.

Fuel



WARNING

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

Change oil to oil having a lower viscosity.

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

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

Engine Oil

Use engine oil suitable to ambient temperature surrounding the engine.

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

Coolant



CAUTION

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

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

The coolant is hot while engine is running and immediately after the engine stops. If the coolant expansion tank cap is opened when the coolant is hot, hot coolant steam will burst out and you could suffer serious burns. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

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

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

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

Maintenance After Cold Season is Over

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

Coolant (Sea Water) - Drain

When the ambient temperature drops below 0°C [32°F], the sea water used for cooling the engine can freeze and cause serious accidents such as sea water pump damage. To prevent such problems, drain the sea water after using the engine by following the procedures below.

1. Make sure that the kingston valve is closed.
2. Open the sea water drain cock or remove the plug, and then drain sea water.
3. Remove the sea water pump cover, and drain sea water.

Fuel System

Fuel System - Inspect

WARNING

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

Fuel Tank - Clean

CAUTION

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

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

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

Fuel Tank - Drain Water

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

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

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

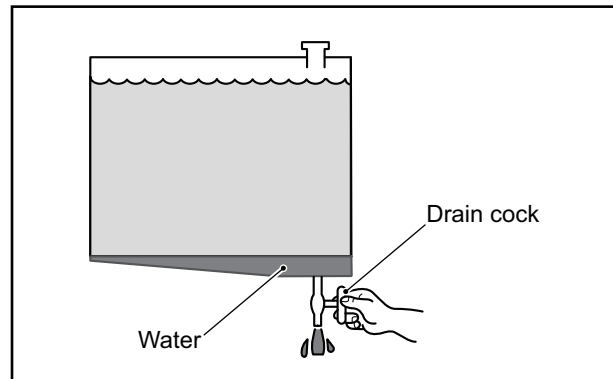


Fig. 8-4 Fuel Tank - Drain Water

Oil-Water Separator - Drain Water

WARNING

From water drain valve, fuel is also discharged at the same time. Wipe off any spilled fuel completely.

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

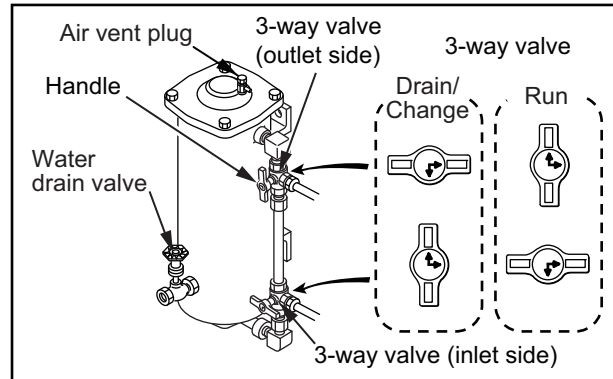


Fig. 8-5 Oil-Water Separator - Drain Water

Oil-Water Separator Element - Replace

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

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

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

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

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

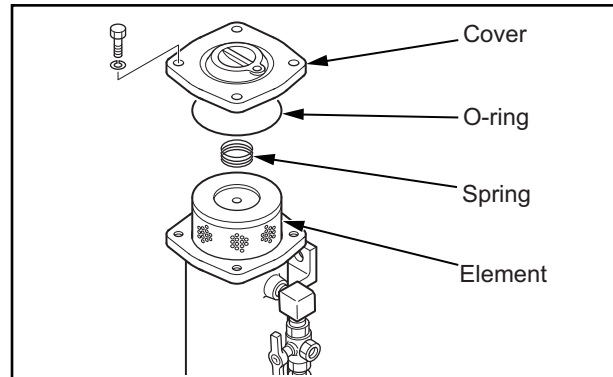


Fig. 8-6 Oil-Water Separator Element - Replace

Gauze Filter - Clean

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

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

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

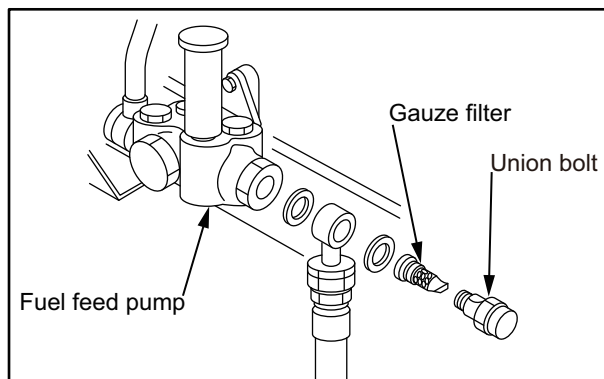


Fig. 8-7 Gauze Filter - Clean

Fuel Filter - Replace

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



WARNING

If filter case is dented, do not use the filter. Use of such filter may cause damage to filter during operation, leading to fuel leaks, and eventually may result in a fire.

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

CAUTION

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

Take care not to dent or scratch the fuel filter surfaces.

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

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

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

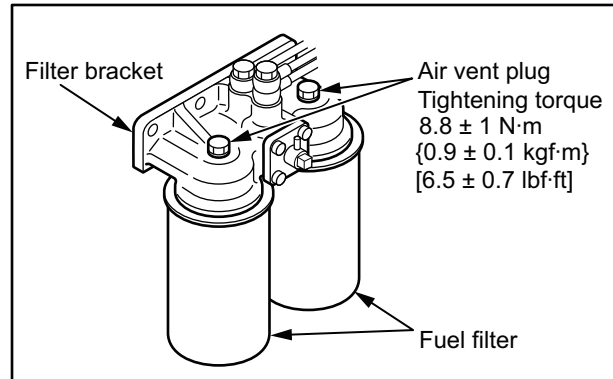


Fig. 8-8 Fuel Filter - Replace

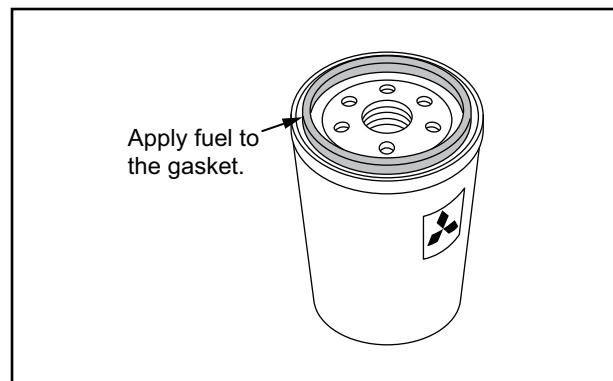


Fig. 8-9 Fuel Filter

Fuel Filter - Replace While Engine is Running

If the engine has to be operating 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 has to be stopped when replacing fuel filters.

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

(b) During fuel filter replacement, fuel may flow out from the stop side filter mounting surface. Be sure to place a drip pan 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 fuel filter is replaced, bleed the fuel filter.

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

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

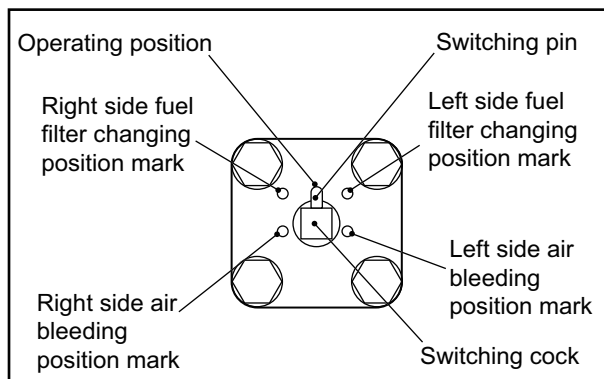


Fig. 8-10 Fuel Filter Switchover Cock

Fuel Control Link Ball Joint - Inspect

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

CAUTION

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

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

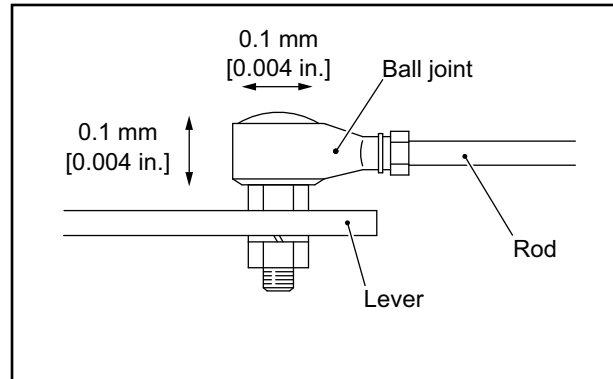


Fig. 8-11 Ball Joints for Looseness - Inspect

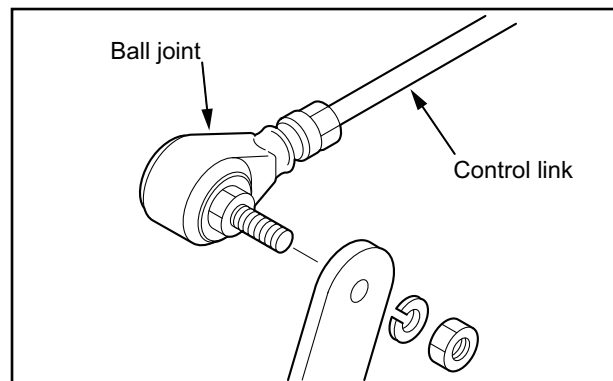


Fig. 8-12 Fuel Control Link - Remove

Fuel Pipe - Inspect

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

Check Visually

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

During Every Major Overhaul

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

During Every Other Major Overhaul

Replace all high pressure fuel injection pipes with new ones.

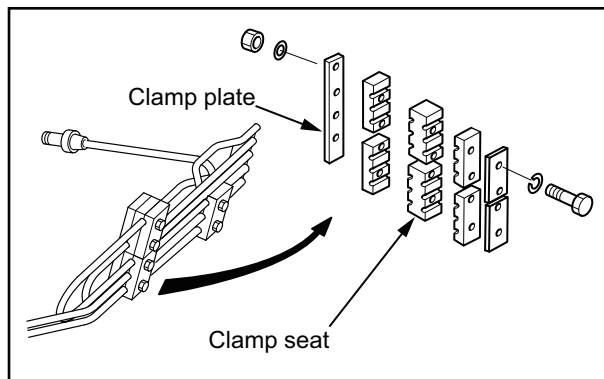


Fig. 8-13 High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

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

Check Visually

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

In Every Other Major Overhaul

Replace the pipe assembly with a new one.

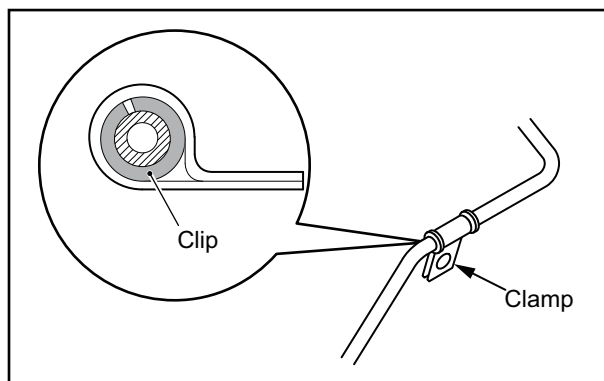


Fig. 8-14 Low Pressure Fuel Pipe, Oil Pipe and Clip - Inspect and Replace

Lubricating System

Engine Oil and Oil Filter - Replace

CAUTION

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

CAUTION

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

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

Also engine oil analysis is recommended when changing engine oil.

Do not reuse oil filter elements, as it is a paper type.

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.

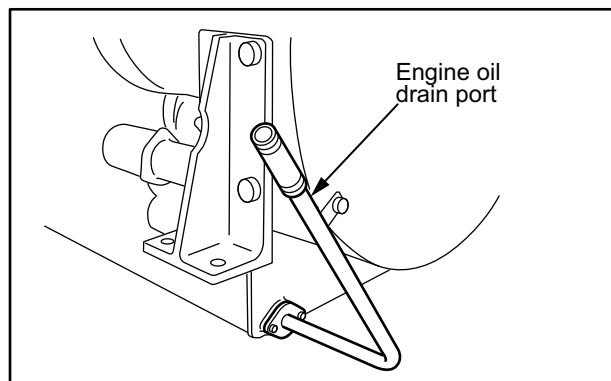


Fig. 8-15 Engine Oil - Drain Port

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 SPECIFICATIONS" (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/cm²} [29.01 psi].

Note: This procedure should be performed together with that of cooling system.

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" (3-9).

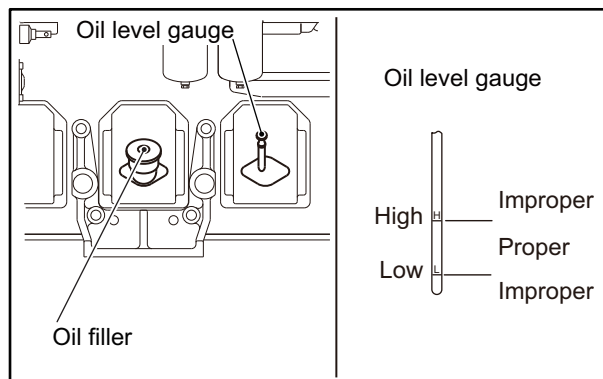


Fig. 8-16 Oil Filler and Oil Level Gauge

Oil Filter - Change



WARNING

If filter case is dented, do not use the filter. Filter damage or oil leakage may occur and it can cause fire hazard.

CAUTION

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

1. Clean around oil filters.
2. Place a drip pan 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 seating 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.

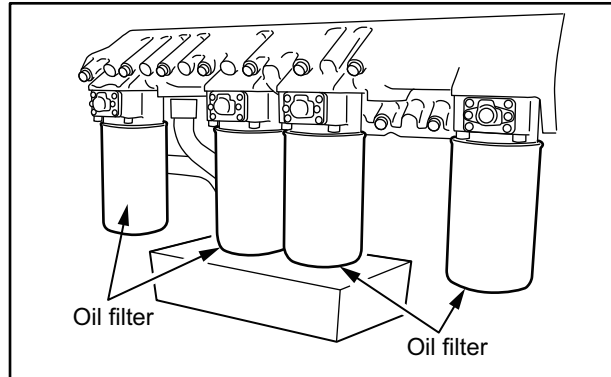


Fig. 8-17 Oil Filter - Change

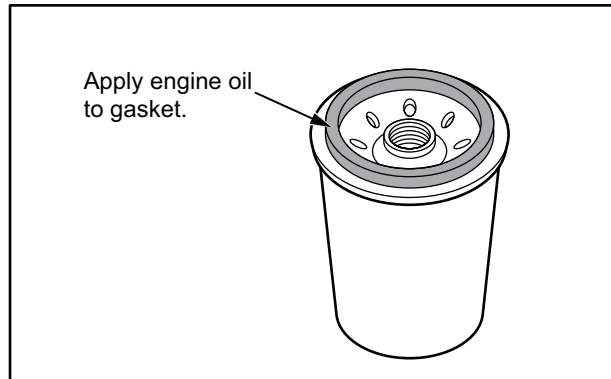


Fig. 8-18 Oil Filter

Oil Filter - Replace While Engine is Running

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

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

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

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

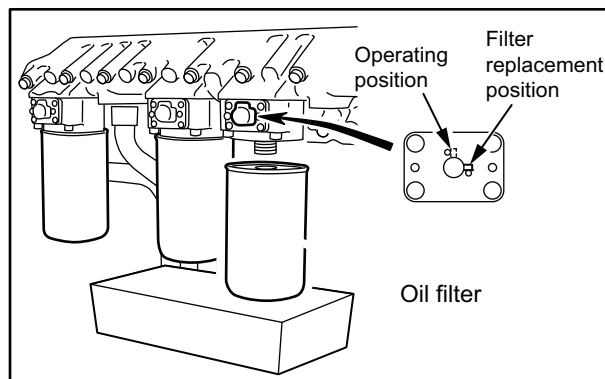


Fig. 8-19 Oil Filter - Replace While Engine is Running

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.

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.

Engine Oil for Ingress of Fuel and Water - Inspect

CAUTION

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

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

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

If water is mixed with the engine oil, oil may turn milky white in color.

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

If fuel or water mixture is found in the engine oil, find the cause and repair. If repair is not easily, contact a dealer of MHIET.

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.

Governor Oil Filter - Change

WARNING

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

1. Prepare a drip pan and place it under the governor oil filter.
2. Loosen the air vent plug and remove the drain plug. Drain oil from the filter into the drip pan.
3. Remove the oil pipe from the center bolt.
4. Remove the center bolt and remove the case from the bracket. Remove the used element from the case.
5. Install a new element in the case using the center bolt.
6. Install the case to the filter bracket. Tighten the center bolt.
7. Install the oil pipe to the center bolt.
8. Tighten the drain plug.
9. Remove the air vent plug. Fill up the filter with engine oil.
10. After filling up, install the air vent plug.

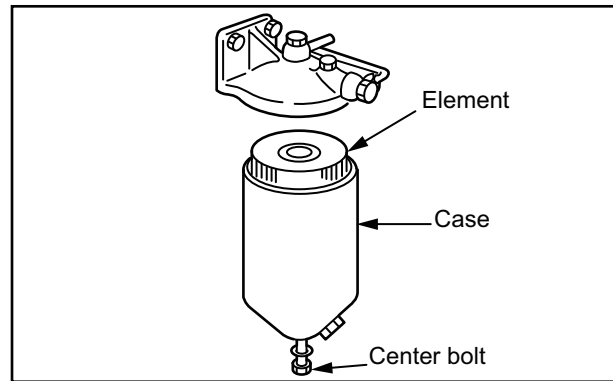


Fig. 8-20 Governor Oil Filter - Change

Cooling System

Coolant - Change

Coolant Expansion Tank Cap - Open/Close

CAUTION

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

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

Coolant is hot while engine is running and immediately after stopping. If the cap is opened when the coolant is hot, hot coolant steam will burst out and you could suffer serious burns. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

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

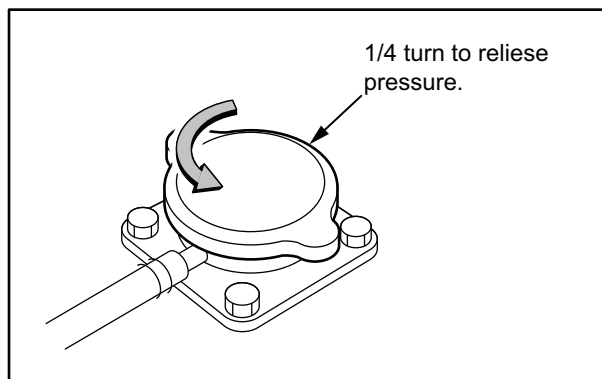


Fig. 8-21 Coolant Expansion Tank Cap

Coolant - Drain

1. Make sure the engine is cool, and then open the coolant expansion tank cap.
2. Place coolant receiving cans under drain cocks. Open the drain cocks to drain coolant.

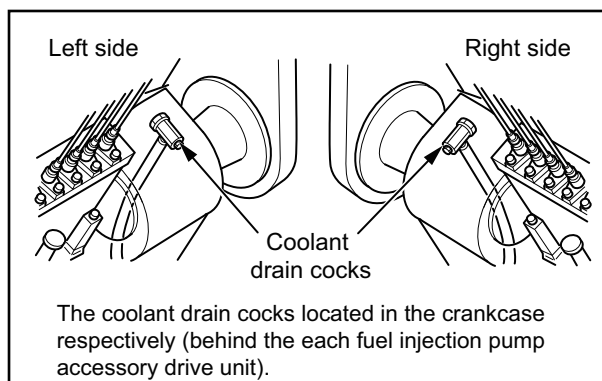


Fig. 8-22 Coolant Drain Cock (Engine)

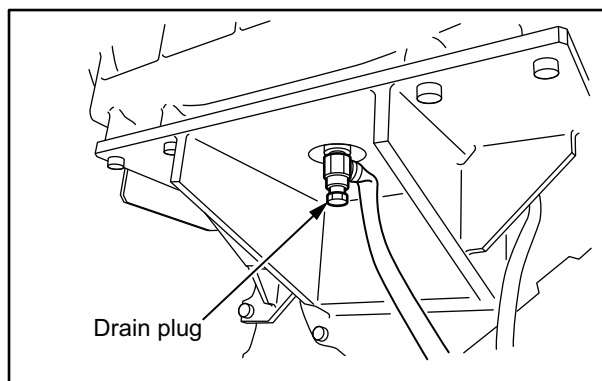


Fig. 8-23 Coolant Drain Cock (Coolant Expansion Tank)

Cooling System - Clean

CAUTION

Conduct the cooling system cleaning before operating the engine for the first time, or starting the engine after it has been in storage with coolant drained.

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

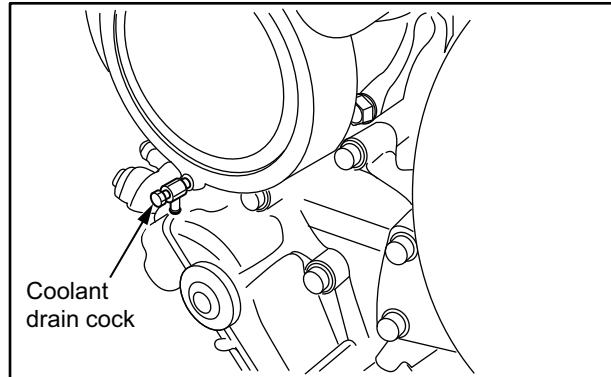


Fig. 8-24 Coolant Drain Cock (Fresh Water Pump)

Coolant - Refill

CAUTION

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

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

The coolant is hot while engine is running and immediately after stopping. If the cap is opened when the coolant is hot, hot coolant steam will burst out and you could suffer serious burns. To avoid a steam burn, wear thick rubber gloves or wrap a cloth around the cap.

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

CAUTION

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

1. Tighten the drain cocks and plugs firmly.
2. Remove the coolant expansion tank cap, and add a mixture of water and LLC of the specified concentration to the specified level.

Note: Determine the quantity of LLC using the LLC concentration chart. For the coolant, refer to **"COOLANT" (6-1)**.

For the coolant capacity, refer to **"MAIN SPECIFICATIONS" (12-1)**.

3. Check the coolant expansion tank and other parts for coolant leaks. If a leak is found, repair it.
4. When coolant reaches the specified level, tighten the coolant expansion tank cap firmly.
5. With the manual stop lever placed in the pulled position, crank the engine for approx 10 seconds using the starter. Stop the operation for 1 minute, then, repeat the above operation two or three times to bleed the cooling system.
6. Check the coolant level in the coolant expansion tank.

Sea Water Pump Impeller - Inspect

CAUTION

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

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

Note: Because of simple structure, the puller is not available as a special tool.

Please use commercially available one or make it by yourself.

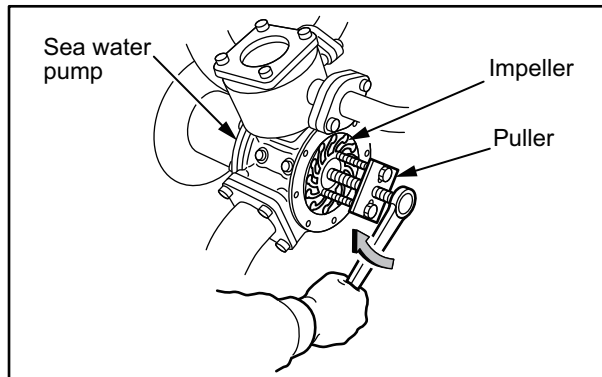


Fig. 8-25 Sea Water Pump Impeller - Inspect

Inlet and Exhaust Systems

Turbocharger - Inspect

CAUTION

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

CAUTION

The turbocharger inspection should be conducted if the color of the exhaust gas is abnormal.

Disconnect the pipe on the inlet side. Hold the compressor wheel nut by hand and move in the axis direction and from right to left and up and down to check looseness. Turn the wheel to check if it rotate smoothly. Replace the turbocharger if any abnormal movement is found.

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

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

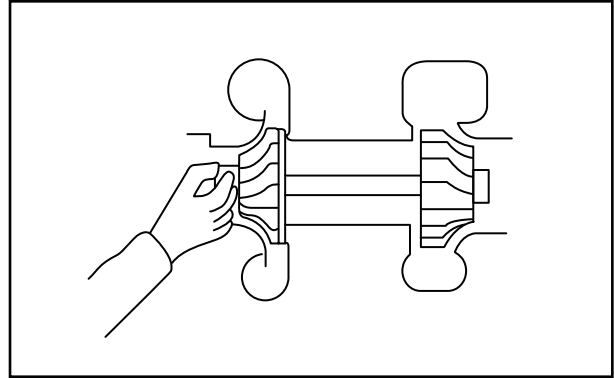


Fig. 8-26 Turbocharger - Inspect

Pre-Cleaner - Clean, Inspect and Replace



CAUTION

Be sure to stop the engine when overhauling pre-cleaners. If the engine is operated without the pre-cleaner, it can cause particles of foreign material to enter the engine and result in rapid wear of parts, leading to a shorter service life of the engine.

The pre-cleaner that is attached to the silencer of the turbocharger is to remove dust from intake air and keep the engine clean for optimum performance. Be sure to clean the pre-cleaner 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 break. If any defect are found, replace the pre-cleaner with a new one.
4. After cleaning, inspection or replacement, install the pre-cleaner to the silencer.

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

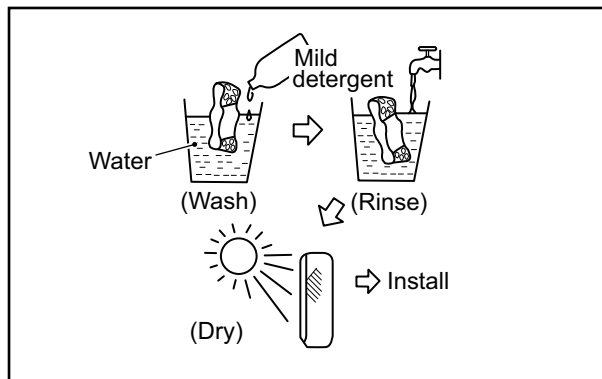


Fig. 8-27 Pre-Cleaner - Clean

Electrical System

Battery - Check

CAUTION

If battery electrolyte is spilled on your skin or clothes, flush immediately with plenty of water. If battery electrolyte gets into your eyes, flush them immediately with plenty of water and then get medical attention.

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

If the battery is not able to be fully recovered after charging for 24 hours more, do not use the battery.

If the engine is started with a low-level electrolyte battery, it may cause an explosion.

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

Battery Electrolyte Level - Inspect

The battery electrolyte evaporates in the use, and the electrolyte level gradually decreases. The proper electrolyte surface level is between the LOWER LEVEL and UPPER LEVEL marks.

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

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

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

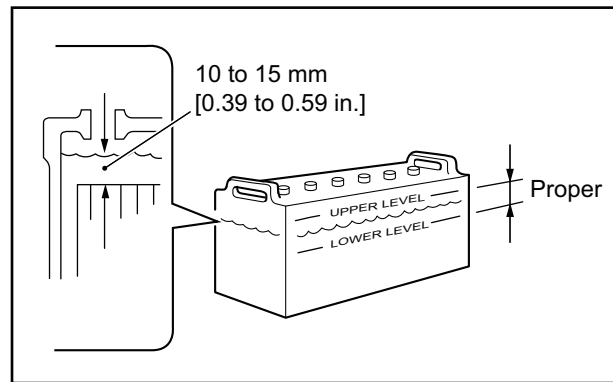


Fig. 8-28 Battery Electrolyte Level - Inspect

Specific Gravity of Battery Electrolyte - Check

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

Table 8-1 Specific Gravity of Electrolyte

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

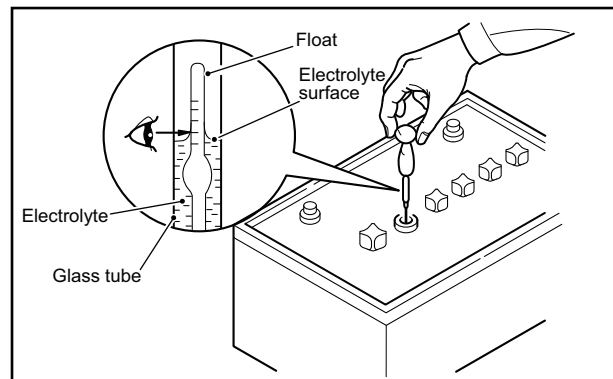


Fig. 8-29 Specific Gravity of Battery Electrolyte - Check

Starter - Inspect

Visually check the starter and ring gear for damage.

Note: If the starter is defective, consult a dealer of MHI-ET.

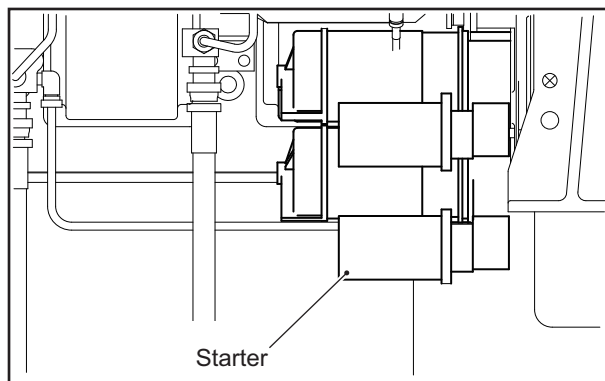


Fig. 8-30 Starter - Inspect

Alternator - Inspect

Visually check the alternator for damage.

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

Also, visually check the inside for dust and saline matter as the alternator is an air cooling type.

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

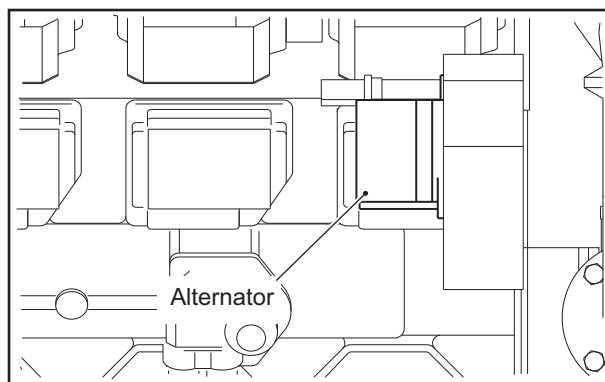


Fig. 8-31 Alternator - Inspect

Chapter 9 LONG-TERM STORAGE

CAUTION

If the engine has been left unattended for 3 months or more, the internal engine parts can rust, and that may cause damage to the engine.

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

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

Preparation for Storage

1. Drain used engine oil, and pour new oil.
2. Prepare a fuel mixture containing 50% rust-preventive fuel (NP-9), and fill the fuel tank with it.
3. Run the engine under no load speeds for 5 to 10 minutes.
4. Immediately before stopping the engine, spray volatile corrosion inhibitor (VCI) (approx. 1g for example) through the inlet port to prevent rust on the air intake system.
5. Stop the engine, and drain the fuel mixture from the fuel tank.
6. Fill the engine oil to the fuel tank to prevent the fuel tank from the rust.
However, for FRP tank, it is not necessary.
7. Apply rust-preventive oil (NP-3-2) liberally on the exposed sections of mechanical surfaces.
8. Seal the air inlet, exhaust outlet, breather and other openings with an adhesive cloth tape or vinyl.
9. Loosen the belt.
10. Apply a thin coat of grease to the terminals of starter and alternator, and cover the openings. Cover these sections with polyethylene sheet or processed polyethylene paper, and place desiccants in the polyethylene covers.
11. Disconnect the cables from the battery terminals, and charge the battery. Clean the terminals, apply a thin coat of grease to the terminals, and store the battery in a cool and dry room.
12. Cover the whole engine.

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

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

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

Recommended Rust-Preventive Oil and Corrosion Inhibitor

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

JIS		Recommended product	Usage
K2246	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
Z1519	-	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 electrolyte level and then charge the battery.

When Using Engine After Storage

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

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

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

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

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

Note: For starting the engine, refer to ["Start" \(3-15\)](#).

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

Storing Engine in an Operable Condition

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

Operating Engine for Maintenance

Operate the engine for maintenance at least once a month as described 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 up the engine, make sure the engine oil pressure rises.
3. Operate the engine about 5 to 10 minutes under no load as the maintenance operation.

Note: For starting the engine, refer to ["Start" \(3-15\)](#).

Lifting Engine

WARNING

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

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

Keep the engine balanced during lifting by considering the engine's center of gravity.

The hangers equipped with the engine is designed for lifting the engine only. When mounting generator on the engine, use the special hanger of common bed.

Hangers of engine cannot be used.

When mounting marine gear on the engine, be sure not to apply the load on the hangers of engine only. Keep the angle formed by slings attached to hangers within 60°. If the angle exceeds this limit, excessive load could be imposed on the hangers and this could damage the hangers and result in a serious accident. Attach wire ropes to the hangers after removing the pipe cover and the insulator near the hangers. To prevent wire ropes from contacting the engine, use a cloth or other soft padding.

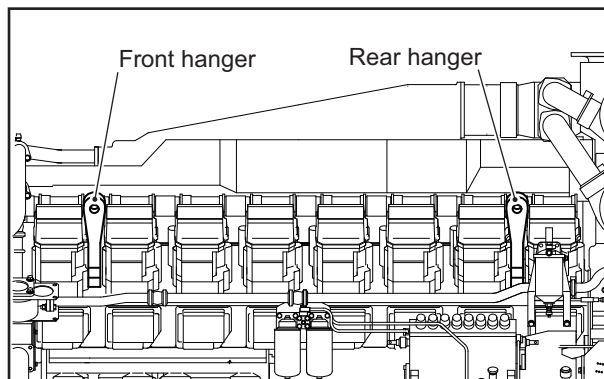


Fig. 10-1 Hanger

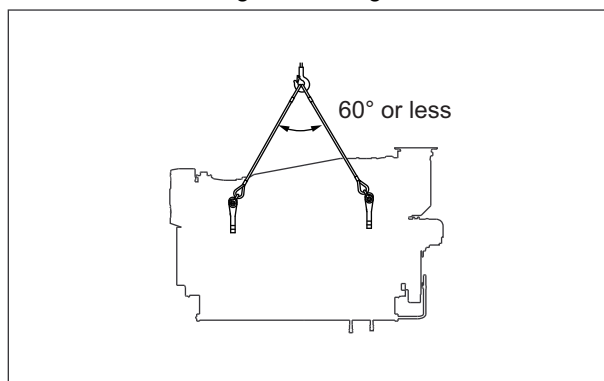


Fig. 10-2 Attaching Wire Ropes

General Precautions

Contact a Dealer of MHIET for Repair Service

Repairing a malfunctioning engine may require special equipments or involve potentially dangerous work, except for relatively simple procedures such as changes and addition of fuel, engine oil and coolant. When repairing malfunctioning engine, contact a dealer of MHIET.

Considerations Before Work

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

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

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

Cautions Against Contamination

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

When disassembling a component, take measures to prevent dust and foreign materials from entering the component being disassembled.

Cautions Regarding Parts Handling

Handle parts carefully.

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

Safety Work

Be sure to use wrenches of the correct size. Using a wrench of the wrong size can cause not only nut damage but 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 down during lifting and can result in the damage to the parts or personal injury.

Troubleshooting

If Engine Tends to Overheat

CAUTION

Remove the coolant expansion tank cap only after the engine has cooled to room temperature. To open the coolant expansion tank cap, open slowly to release pressure. Opening the coolant expansion tank cap while the engine is hot causes steam and hot coolant to blow out and can result in skin burns.

Do not stop engine while the engine is hot. Coolant temperature will rise and the engine could be seized. 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 95°C [203°F] or if ENG. WATER HIGH TEMP. ALARM lamp glows with warning buzzer, the engine is overheating. If the engine continues to operate with load under such conditions, it will result in failures 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
 - ♦Sea water pump impeller damage

After checking the points above and you have not found any problems, contact a dealer of MHIET.

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 Procedures When Abnormal Decrease in Engine Oil Pressure Occurs

Item to be inspected	Remedy	Page
Decrease in amount of engine oil	Refill	8-12
Oil viscosity is too low	Use engine oil of appropriate viscosity according to ambient temperature	5-3
Clogged oil filter	Replace oil filter	8-11
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.

Case of Problems, and Probable Causes and Remedies

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

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

Causes		Remedies
Electrical system	Faulty wire connection	♦Check fuse. ♦Check wiring connection of each relay between battery, starter and starter switch.
	Insufficiently charged battery	♦Check alternator. (Refer to P8-22) ♦Check and adjust belt. (Refer to P8-2)
	Weak battery	♦Check specific gravity of battery electrolyte. (Refer to P8-21) ♦Charge the battery. ♦Change battery.
	Faulty starter or starter relay	♦Contact your MHIET dealer.
Lubricating system	Oil viscosity too high	♦Use appropriate engine oil. (Refer to P5-1)
	Excessive oil	♦Check amount of engine oil. (Refer to P3-12)
Basic engine	Rapid wear of sliding parts, or locked	♦Contact your MHIET dealer.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Starter Cranks, but Engine Does Not Start

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

Causes		Remedies
Fuel system	Run out of fuel, blocked pipe	♦Inspect fuel tank, supply fuel, bleed air. (Refer to P8-4) ♦Check fuel pipes and valves.
	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1) ♦Remove dust, water or impurities. (Refer to P8-4)
	Fuel leakage in fuel pipes and injection pipes	♦Check defects of fuel and injection pipes and retighten, if necessary. ♦Contact your MHIET dealer.
	Clogged fuel filter	♦Inspect and replace fuel filter. (Refer to P8-7) ♦Inspect and replace oil-water separator element. (Refer to P8-5) ♦Clean gauze filter. (Refer to P8-6)
	Faulty fuel feed pump operation	♦Contact your MHIET dealer.
	Faulty fuel injection pump	♦Check fuel injection pump rack stroke. ♦Contact your MHIET dealer.
	Faulty fuel injection nozzle	♦Contact your MHIET dealer.
Air intake system	Insufficient amount of air	♦Clean and inspect inlet system. ♦Contact your MHIET dealer.
Control system	Faulty governor operation	♦Check fuel control link operation. ♦Contact your MHIET dealer.
Basic engine	Low compression pressure	♦Contact your MHIET dealer.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Insufficient Output

Table 11-4 Insufficient Output

Causes		Remedies
Fuel system	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1)
	Clogged fuel filter	•Inspect and replace fuel filter. (Refer to P8-7) •Clean gauze filter. (Refer to P8-6)
	Faulty fuel feed pump operation	•Contact your MHIET dealer.
	Faulty fuel injection pump	•Contact your MHIET dealer.
	Faulty fuel injection nozzle	•Contact your MHIET dealer.
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Contact your MHIET dealer.
	Improper amount of injected fuel	•Check fuel injection pump rack stroke. •Contact your MHIET dealer.
Cooling system	Overheat, overcooled	•Check belt and adjust its tension. (Refer to P8-2) •Check sea water pump impeller and drive shaft. •Check heat exchanger. •Check control system. •Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of air	•Check turbocharger. (Refer to P8-19) •Clean, inspect and replace pre-cleaner. (Refer to P8-20) •Check intake air pressure and leakage of intake air. •Check intake air temperature. •Contact your MHIET dealer.
	Increase resistance of exhaust air	•Check exhaust pipe. •Contact your MHIET dealer.
Basic engine	Low compression pressure	•Contact your MHIET dealer.
	Faulty valve timing	•Contact your MHIET dealer.
	Rapid wear of sliding parts	•Contact your MHIET dealer.
Control system	Governor malfunction	•Contact your MHIET dealer.
Rig	Excessive load	•Check propeller and propeller shaft. •Remove deposits.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Exhaust Smoke is White or Blue

Table 11-5 Exhaust Smoke is White or Blue

Causes		Remedies
Fuel system	Improper fuel properties	•Check cetane index, and use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Contact your MHIET dealer.
	Faulty fuel injection nozzle	•Contact your MHIET dealer.
	Uneven fuel injection	•Check the ignition noise and exhaust smoke temperature. •Contact your MHIET dealer.
	Incorrect fuel injection timing	•Contact your MHIET dealer.
Lubricating system	Combustion of engine oil	•Check amount of engine oil. (Refer to P3-12) •Contact your MHIET dealer.
Cooling system	Overcooling	•Check control system. •Inspect thermostat. •Contact your MHIET dealer.
Basic engine	Faulty valve timing	•Contact your MHIET dealer.
	Low compression pressure	•Contact your MHIET dealer.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Exhaust Smoke is Black or Gray

Table 11-6 Exhaust Smoke is Black or Gray

Causes		Remedies
Fuel system	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1)
	Faulty fuel feed pump operation	•Contact your MHIET dealer.
	Faulty fuel injection pump	•Contact your MHIET dealer.
	Faulty fuel injection nozzle	•Contact your MHIET dealer.
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Contact your MHIET dealer.
	Uneven fuel injection	•Check exhaust gas temperature. •Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of air	•Check intake air pressure and leakage of intake air. •Check intake air temperature and ventilation device. •Contact your MHIET dealer.
	Increase resistance of exhaust air	•Check exhaust pipe. •Contact your MHIET dealer.
Basic engine	Low compression pressure	•Contact your MHIET dealer.
	Faulty valve timing	•Contact your MHIET dealer.
	Rapid wear of sliding parts	•Contact your MHIET dealer.
Load system	Excessive load	•Check load system. •Contact your MHIET dealer.
Rig	Excessive load	•Propeller Matching Re-adjust.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Excessive Fuel Consumption

Table 11-7 Excessive Fuel Consumption

Causes		Remedies
Fuel system	Faulty fuel injection nozzle	•Contact your MHIET dealer.
	Faulty fuel injection timing	•Check fuel injection pump couplings. •Contact your MHIET dealer.
	Improper fuel properties	•Use appropriate fuel. (Refer to P4-1)
	Fuel leakage in fuel pipes and injection pipes	•Check defects of fuel and injection pipes and retighten, if necessary. •Contact your MHIET dealer.
Cooling system	Overcooling	•Check control system. •Inspect thermostat •Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of air	•Check intake air pressure and leakage of intake air. •Check intake air temperature and ventilation device. •Contact your MHIET dealer.
	Increase resistance of exhaust air	•Check exhaust pipe. •Contact your MHIET dealer.
Basic engine	Low compression pressure	•Contact your MHIET dealer.
	Faulty valve timing	•Contact your MHIET dealer.
	Rapid wear of sliding parts	•Contact your MHIET dealer.
Rig	Excessive load	•Propeller Matching Re-adjust.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Excessive Engine Oil Consumption

Table 11-8 Excessive Engine Oil Consumption

Causes		Remedies
Fuel system	Faulty fuel injection timing	•Check fuel injection pump couplings. •Contact your MHIET dealer.
Lubricating system	Oil leakage to the outside of engine	•Check oil leakage. •Contact your MHIET dealer.
	Engine oil viscosity too low	•Use appropriate oil viscosity. (Refer to P5-1)
	Engine oil temperature is high	•Check amount of engine oil. (Refer to P3-12) •Check oil cooler and oil thermostat •Contact your MHIET dealer.
Cooling system	Overheating	•Check control system. •Inspect thermostat. •Contact your MHIET dealer.
Inlet and exhaust systems	Entry of oil to air intake	•Contact your MHIET dealer.
	Worn parts in valve operating system	•Contact your MHIET dealer.
Basic engine	Wear of sliding parts	•Contact your MHIET dealer.
Load system	Excessive load	•Load System- Check •Contact your MHIET dealer.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Overheating

Table 11-9 Overheating

Causes		Remedies
Cooling system	Low coolant level	•Check coolant leakage •Check Coolant Level. (Refer to P3-13)
	Faulty fresh water pump operation	•Contact your MHIET dealer.
	Faulty thermostat operation	•Contact your MHIET dealer.
Load system	Excessive load	•Check load system. •Contact your MHIET dealer.
Basic engine	Rapid wear of sliding parts	•Contact your MHIET dealer.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

Engine Oil Pressure Drop

Table 11-10 Engine Oil Pressure Drop

Causes		Remedies
Lubricating system	Low engine oil level	•Check amount of engine oil.(Refer to P3-12)
	Faulty engine oil property (viscosity)	•Analyze oil property. Use appropriate engine oil. (Refer to P5-6)
	Oil temperature too high	•Check cooling system. •Contact your MHIET dealer.
	Clogged oil filter	•Inspect and replace oil filter. (Refer to P8-11)
	Faulty oil pump operation	•Contact your MHIET dealer.
	Faulty relief valve operation	•Contact your MHIET dealer.
Control system	Faulty pressure unit operation	•Check control system and wires. •Contact your MHIET dealer.
Basic engine	Rapid wear of sliding parts	•Contact your MHIET dealer.
	Increase clearance of sliding part	•Contact your MHIET dealer.
Load system	Excessive load	•Check load system. •Contact your MHIET dealer.

Note: The table above also includes the parts which MHIET does not supply. For the parts MHIET does not supply, inspect and maintain them following the manufacturer's operation manual.

When Fuel has Run Out

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

1. Stop the engine completely.
2. Add fuel to the fuel tank.
For filling fuel tank, refer to "Fuel Tank Oil Level - Check" (3-11).
3. Bleed air from the fuel system.
For bleeding fuel system, refer to "Fuel System - Bleed Air" (3-1).
4. Restart the engine.
For starting the engine, refer to "Start" (3-15).

Chapter 12 MAIN SPECIFICATIONS

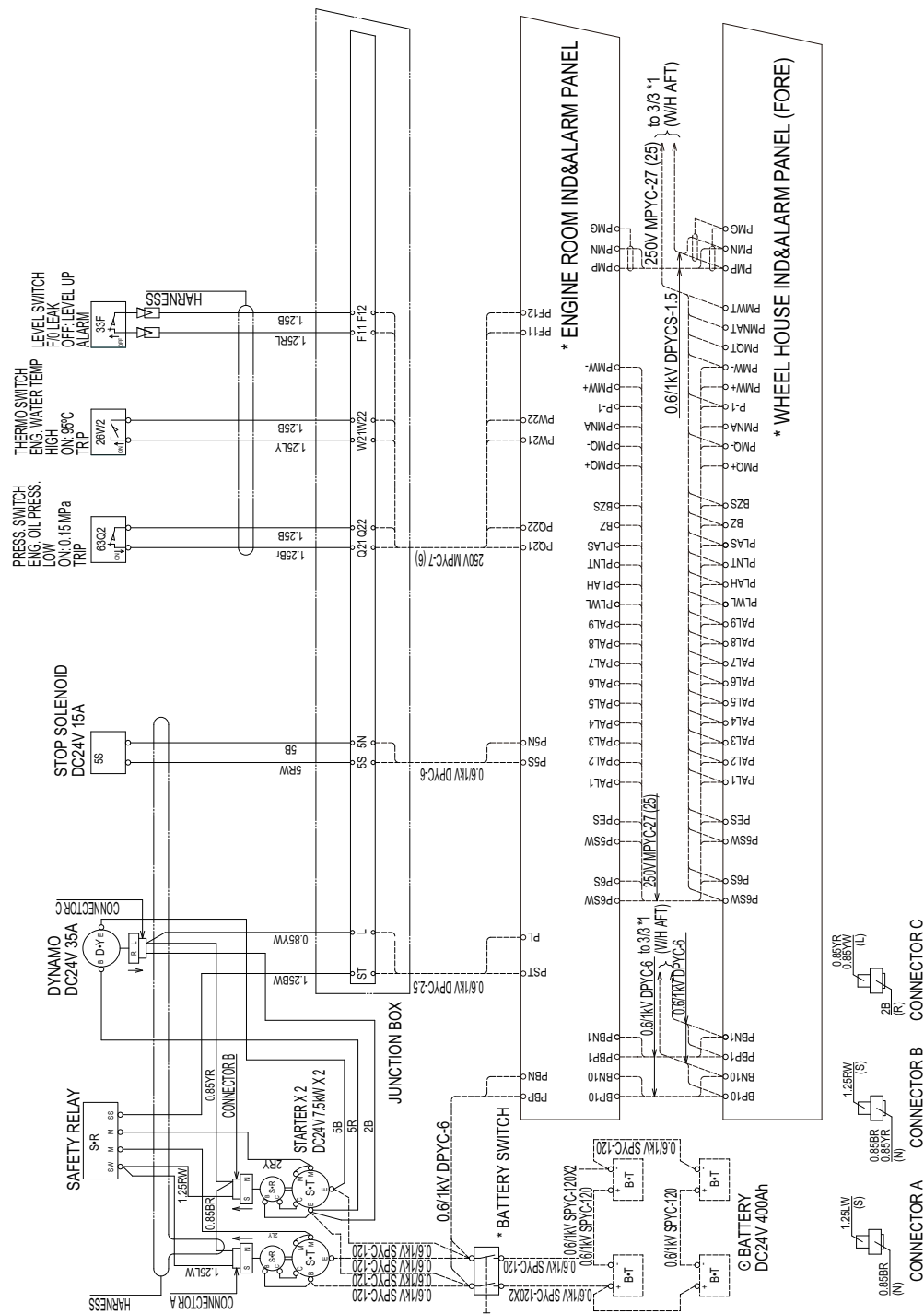
Main Specifications

Table 12-1 Main Specifications

Item	Specifications
Model	S16R-T2MPTK
Rated output	1380 kW / 1650 min ⁻¹
Type	Water-cooled 4-stroke cycle, turbocharged with intercooler
No. of cylinders, arrangement	16-V
Cylinder bore x stroke	φ170 × 180 mm [6.69 × 7.09 in.]
Displacement	65.4 L [3992 cu. in.]
Combustion system	Direct injection system
Compression ratio	14.5 : 1
Firing order	1-9-6-14-2-10-4-12-8-16-3-11-7-15-5-13
Rotational direction	Counterclockwise as viewed from the stern.
Dimensions (L x W x H)	3086 × 1622 × 1960 mm [121.50 × 68.86 × 77.17 in.]
Dry weight	7000 kg [15432 lb] ±10%
Fuel	Diesel fuel "Representative engine test fuel oil: fuel composition DMX (diesel fuel)"
Fuel injection pump	Mitsubishi PS8 × 2
Fuel Filter	Cartridge type paper-element
Fuel injection nozzle	Hole type
Fuel injection starting pressure	34.3 MPa {350 kgf/cm ² } [4975 psi]
Governor	Hydraulic type (all-speed control)
Lubrication method	Forced circulation (pressure feed by oil pump)
Lubrication oil	CF or CH-4 grade oil (API service classification)
Engine oil capacity	Approx. 290 L [76.62 US gal]
Oil Filter	Cartridge type paper-element
Oil cooler	Fresh-water multi-plate type
Cooling method	Sea water indirect cooling
Cooling fresh water capacity	Approx. 280 L [73.98 US gal]
Starting system	Electric start
Starter	DC24 V - 7.5 kW×2
Alternator	DC24 V - 35 A
Turbocharger	Mitsubishi TD10 x 4

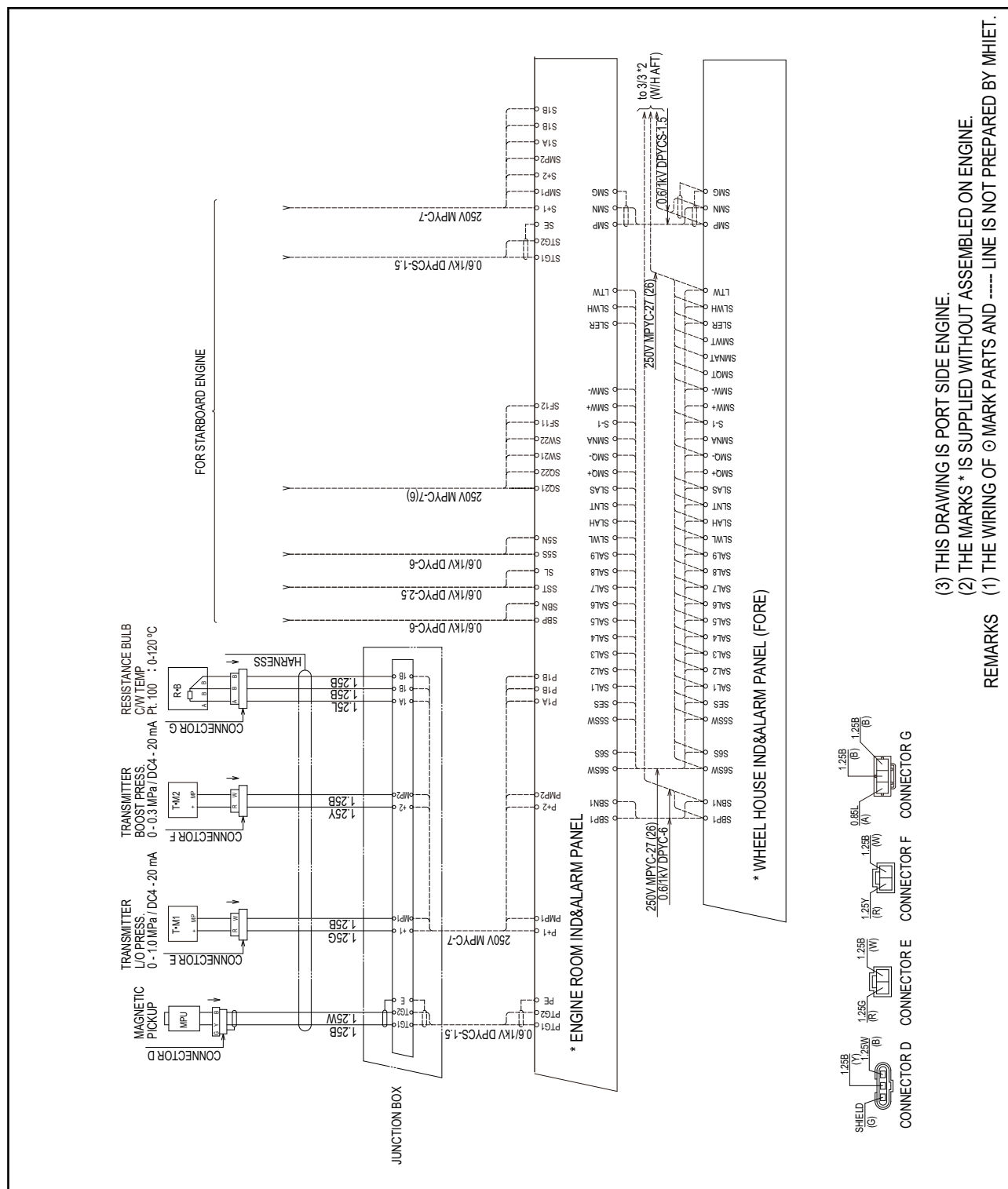
Note: The specifications above are subject to change without notice.

Electrical Wiring Diagram



REMARKS (1) THE WIRING OF ☉ MARK PARTS AND ----- LINE IS NOT PREPARED BY MHJET.

Fig. 13-1 Electric Wiring Diagram 1/3



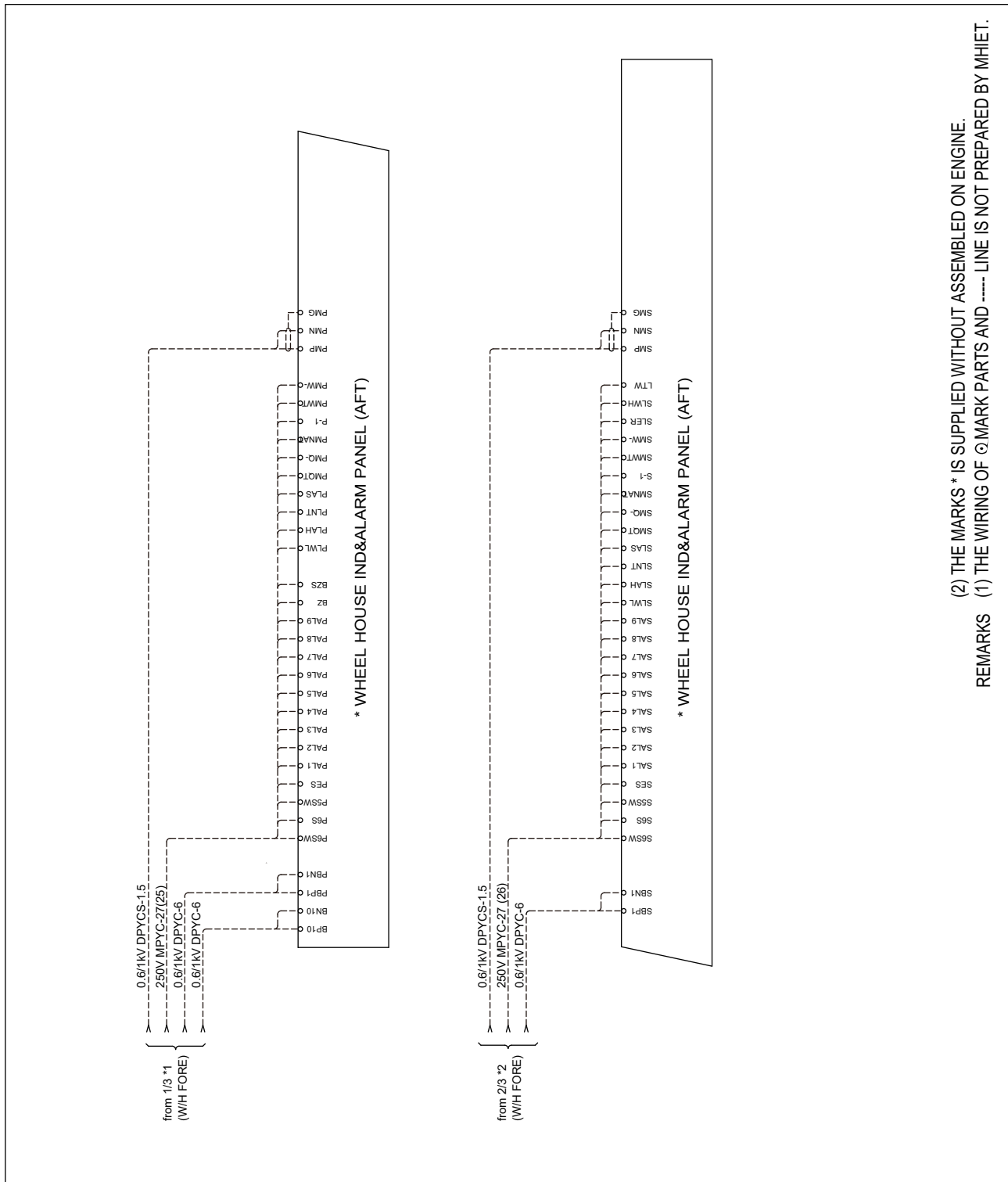


Fig. 13-3 Electric wiring diagram 3/3

REVISION HISTORY

Title	Mitsubishi Marine Engine S16R-T2MPTK OPERATION & MAINTENANCE MANUAL
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Revision	Revision date	Revised content
-	February 2012	First edition issued.
-	June 2018	Changed the document number, cover Pub. No. 99405-M0100 (issued in February 2012) and issued it as a new publication.
1	July 2020	Added precautionary text of "Limitation of Continuous Under Light Load Operation".
2	November 2020	• Add "QRcode" in Cover page. • Changed the recommended limit/Service limit value of Fine foreign substances (foreign substances at fuel inlet) in the Fuel Properties Table to "10mg/L or less".
3	April 2021	Changed the maintenance interval from "100 hours or every 10 years" to "16000 hours or every 10 years" in Chapter 7.
4	January 2022	Changed the permissible mixing ratio of biodiesel fuel in the fuel properties table from "5 volume% or less" to "7 volume% or less in Chapter 4 FUEL.
5	March 2024	Important Information • Added a precaution regarding labels. Chapter 5 • Revised the recommended engine oil. • Updated the table of engine oil quality standards.

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