

OPERATION & MAINTENANCE MANUAL

July 2016
Pub. No. 99250-28100

MITSUBISHI MARINE ENGINE

S6A3-T2MPTK3L

for Mitsubishi Turbocharger and Engine Europe B.V.

The operator and supervisor are requested to read this Operation and Maintenance Manual carefully before operating the engine or conducting inspection and maintenance.
Never operate the engine or conduct maintenance work without completely understanding this manual.



**MITSUBISHI HEAVY INDUSTRIES
ENGINE & TURBOCHARGER, LTD.**

Foreword

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

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

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

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

Limited Warranty

If Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. examines the returned parts and any failure at manufacturing is found, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. shall repair or exchange the parts. 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. However the warranty coverage is effective for the ultimate purchaser and each sub-sequent purchaser for emission-related parts.

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

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

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

Important Information

- ♦To avoid the potential hazard, accident prevention activities must be planned methodically and conducted continually by considering all aspects of engine operation, maintenance, and inspection. All involved personnel, including managers and supervisors, should actively participate, recognize their roles, and organize themselves and their work to ensure a safe environment.
- ♦The foremost safety objective is to prevent accidents which may result in injury or death, or equipment damage.
- ♦Always observe laws and regulations of the local or federal/national government.
- ♦Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. cannot foresee all potential dangers of the engine, potential dangers resulting from human error and other causes, or a danger caused by a specific environment in which the engine is used. Since there are many actions that cannot be performed or must not be performed, it is impossible to indicate every caution in this manual or on warning labels. As such, it is extremely important to follow instructions in this manual and also to take general safety measures when operating, maintaining, and inspecting the engine.
- ♦When the engine is used by individuals whose native language is not English, the engine owner must provide thorough safety guidance to the operators. Also, attach the warning and operational decals that describe the original warning label statements in the native language of the operators.
- ♦The engine must be operated, maintained, and inspected only by qualified persons who have thorough knowledge of engines and their dangers, and also have received risk avoidance training.
- ♦To prevent an accident, do not attempt to carry out any operation other than those described in this manual, and do not use the engine for any unapproved purpose.
- ♦When the ownership of the engine is transferred, be sure to give this manual to the new owner although the warranty does not transfer to the new owner. Also, inform MHIET of the name and address of the new owner of the engine.
- ♦This manual is copyrighted and all rights are reserved. No part of this manual, including illustrations and technical references, may be photocopied, translated, or reproduced in any electronic medium or machine readable form without prior written consent from Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.
- ♦For improvement of the engine, the contents in this manual are subject to change at any time without notice.
- ♦Pictures or illustrations of the product in this manual may differ from those of the product you have. Please note that, depending on specifications, the items described in this manual may differ from those on your engine in shape, or may not be installed on your engine.
- ♦Please contact your MHIET dealer if you need more information or if you have any questions.
- ♦If the manual is lost or damaged, please obtain a new copy at your MHIET dealer without delay.
- ♦Knowing the exact running time of the engine is very important. For safety operation, be sure to install the engine hour meter so that you know the exact running time and can conduct a timely maintenance that is described in this manual.

Warning Indication

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

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

Warning Statements

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

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

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



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



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



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



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

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

Units of Measurement

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

- ♦Pressure: 1 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, Standards and Others

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

Regulation for the Prevention of Air Pollution From Ships

Engine International Air Pollution Prevention Certificate and Technical File

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

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

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

Chapter 1

BASIC SAFETY PRECAUTIONS

Fire and Explosion Protection.....	1-1
Keep Flames Away	1-1
Keep Engine Surrounding Area Tidy and Clean	1-1
Pay Attention to Engine Room Ventilation	1-1
Do Not Open Side Covers Until Engine Cools	1-1
Be Alert for Leaking Fuel, Oil, or Exhaust Gas	1-1
Use Explosion-Proof Light.....	1-1
Prevention of Electric Short Circuit	1-1
Keep Fire Extinguishers and First-Aid Kit Handy.....	1-1
Stay Away From Rotating and Moving Parts.....	1-2
Keep Rotating Parts Covered for Safety	1-2
Check Work Area for Safety Before Starting....	1-2
Stay Away From Moving Parts During Operation	1-2
Lockout and Tagout	1-2
Be Sure to Stop Engine Before Inspection/Mainte- nance	1-2
Always Put Turning Tool Back in Place After Use.....	1-2
Prevention of Exhaust Gas Poisoning	1-3
Pay Attention to Ventilation When Operating Engine	1-3
Prevention of Hearing Loss	1-3
Wear Ear Plugs	1-3
Fall Prevention.....	1-3
Lift Engine Carefully	1-3
Do Not Climb Onto the Engine.....	1-3
Always Use a Stable Foothold During Maintenance.....	1-3
Burn Protection.....	1-4
Do Not Touch Engine During or Immediately After Operation.....	1-4
Refill Coolant Only After the Coolant Temperature Dropped.....	1-4
Do Not Remove Heat Shields	1-4
Be Careful When Opening and Closing of Radiator Cap	1-4
Do Not Touch High-Pressure Fuel Spray.....	1-4
Be Careful When Handling Fuel, Engine Oil, and Coolant (LLC)	1-4
Use Specified Fuel, Engine Oil, and LLC Only ...	1-4
Handle LLC Carefully	1-4
Proper Disposal of Waste Oil, LLC, and Coolant.....	1-4

When Abnormality Occurs	1-5
Do Not Add Coolant Immediately After a Sudden Stop Due to Overheating	1-5
Be Careful When Starting After an Abnormal Stop.....	1-5
Stop Engine Immediately When Engine Oil Pressure Has Dropped	1-5
If Belt Breaks, Stop Engine Immediately	1-5
Battery Safety Precautions	1-5
Be Careful When Handling Battery	1-5
Other Precautions	1-6
Do Not Tamper.....	1-6
Observe Safety Rules at Work Site.....	1-6
Wear Proper Work Clothing and Protective Gears	1-6
Never Break the Seals	1-6
Performance of Pre-Operation Inspection and Periodic Inspections	1-6
Engine Break-in.....	1-6
Warming Up Engine First	1-6
Cool Down the Engine Before Stopping.....	1-6
Do Not Operate the Engine in an Overloaded Condition	1-7
Prohibition of Continuous Low-Load Operation ...	1-7
Do Not Splash Water on Engine	1-7
Pre-cleaner is to be properly maintained	1-7
Use Proper Tools for Maintenance Work	1-7
Do Not Operate Starter for a Long Duration	1-7
Do Not Turn Off the Battery Switch During Operation	1-7
Engine Transportation Precautions	1-7
Warning Labels	1-8
Maintenance of Warning Labels.....	1-8

Chapter 2

NAME OF PARTS

Engine External Views	2-1
Front View	2-1
Rear View.....	2-1
Left View	2-2
Right View	2-2
Operating Devices	2-3
Starting and Stopping Device.....	2-3
Engine Protection Devices	2-4
Rotation Detection Pickup	2-4

**Chapter 3
OPERATION**

Checking Operational Environment.....3-1
 Preparation for Operation of New or Overhauled Engine.....3-1
 Preparation of Fuel System..... 3-1
 Preparation of Lubrication System..... 3-4
 Preparation of Cooling System 3-5
 Preparation of Electrical System..... 3-6
 Test Operation 3-7
 Normal Engine Operation3-8
 Pre-operation Inspection3-8
 Engine Exterior - Inspect 3-8
 Fuel Tank Oil Level - Check..... 3-9
 Fuel Tank - Drain Water..... 3-9
 Oil-Water Separator - Drain Water..... 3-10
 Engine Oil Level - Check..... 3-10
 Coolant Level - Check..... 3-11
 Damper Temperature - Check 3-11
 Control Cable - Check..... 3-11
 Start-up.....3-12
 Warm-up Operation3-12
 Engine Oil Pressure - Check 3-12
 Engine - Walk Around Check 3-12
 Operation3-13
 Precautions in Engine Operation 3-13
 Inspection During Operation 3-13
 Stopping3-14
 Emergency Stop..... 3-14
 Inspection After Stopping 3-14

**Chapter 4
FUEL**

Recommended Fuel4-1
 Handling Fuel4-1
 Fuel Quality Standard.....4-2

**Chapter 5
ENGINE OIL**

Recommended Engine Oil 5-1
 Genuine MHIET Engine Oil 5-1
 Other Commercial Engine Oils 5-1
 Engine Oil Quality Standard 5-2
 Selection of Oil Viscosity 5-3
 Handling Engine Oil 5-4
 Service Limits for Engine Oil 5-4
 Definition of Property Limit of Engine Oil .. 5-5
 Kinetic viscosity 5-5
 Base number 5-5
 Acid number 5-5
 Water content 5-5
 Flash point 5-5
 Insolubles 5-5
 Engine Oil Analysis Service 5-6

**Chapter 6
COOLANT**

Recommended Water for Coolant 6-1
 Long Life Coolant (LLC) 6-1
 Genuine MHIET LLC 6-1
 Other Commercial LLCs 6-2
 Requirements for Other Commercial LLCs .. 6-2
 General Quality Requirements for LLC 6-2
 LLC Quality Standard 6-3
 Maintenance of LLC..... 6-6
 Replacement Intervals of LLC..... 6-6
 LLC Concentration (GLASSY and PG GLASSY)..... 6-7
 LLC Concentration Measuring Method 6-8
 Necessity of LLC 6-11
 Characteristics of LLC Additives 6-11
 Examples of Abnormalities Caused by Amine Type LLC 6-11
 Pitting of Iron Parts 6-11
 Corrosion of Aluminum Parts 6-11
 Pitting and Clogging of Heat Exchanger 6-11

Chapter 7**MAINTENANCE SCHEDULE**

How to Use the Periodic

Maintenance Schedule 7-1

Periodic Maintenance Schedule 7-2

Chapter 8**PERIODIC INSPECTION AND
MAINTENANCE PROCEDURES**

Engine 8-1

Engine Exterior - Inspect 8-1

Belt and Belt Tension - Inspect and Adjust 8-2

Damper - Inspect 8-3

Fuel system 8-5

Fuel System - Inspect 8-5

Fuel Tank - Clean 8-5

Fuel Tank - Drain Water 8-5

Oil-Water Separator - Drain Water 8-6

Oil-Water Separator Element - Replace 8-6

Gauze Filter - Clean 8-7

Fuel Filter - Replace 8-8

Fuel Control Link Ball Joint - Inspect 8-9

Fuel Pipe - Inspect 8-10

Lubrication System 8-11

Engine Oil, Oil Filter, and Bypass Oil Filter -
Replace 8-11Ingress of Fuel and Water In Engine Oil -
Inspect 8-14

Governor Oil Filter - Replace 8-14

Oil Pipe - Inspect 8-15

Cooling system 8-16

Coolant - Change 8-16

Seawater - Drain 8-18

Seawater Pump Impeller - Inspect 8-18

Zinc Rod - Inspect 8-19

Seawater Strainer Mesh Filter - Clean
and Replace 8-20

Inlet and exhaust systems 8-21

Turbocharger - Inspect 8-21

Pre-Cleaner - Clean, Inspect, and Replace ... 8-22

Electrical System 8-23

Starter - Inspect 8-24

Alternator - Inspect 8-24

Chapter 9**LONG-TERM STORAGE**

Storing Engine in an Inoperable

Condition for 3 Months up to 1 Year ... 9-1

Preparation for Storage 9-1

Maintenance During Storage 9-1

When Using Engine After Storage 9-2

Storing Engine in an Operable Condition .. 9-2

Operation for Maintenance Purpose 9-2

Chapter 10**TRANSPORTATION**

Lifting Engine 10-1

Chapter 11**TROUBLESHOOTING**

General Precautions 11-1

Contact Your MHET Dealer for Repair Service. 11-1

Considerations Before Proceeding with

Corrective Action 11-1

Cautions Against Contamination 11-1

Cautions for Parts Handling 11-1

Safety Working Practices 11-1

Problems, Probable Causes, and Solutions . 11-2

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

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

Poor Output 11-4

Exhaust Smoke is White or Blue 11-5

Exhaust Smoke is Black or Grey 11-6

Excessive Fuel Consumption 11-7

Excessive Engine Oil Consumption 11-8

Overheating 11-8

Engine Oil Pressure Drop 11-9

When Fuel has Run Out 11-9

Chapter 12**MAIN SPECIFICATIONS****Chapter 13****ELECTRICAL WIRING DIAGRAM**

Electrical Wiring Diagram 13-1

List of Illustration

Fig. 1-1	Common Warning Labels.....	1-8	Fig. 6-9	Measuring procedure 6	6-9
Fig. 2-1	Engine Front View	2-1	Fig. 6-10	Measuring procedure 7	6-10
Fig. 2-2	Engine Rear View.....	2-1	Fig. 6-11	Measuring procedure 8	6-10
Fig. 2-3	Engine Left-Side View	2-2	Fig. 8-1	Belt Tension (Alternator Side) - Adjust	8-2
Fig. 2-4	Engine Right-Side View.....	2-2	Fig. 8-2	Belt Tension (Fresh-Water Pump Side) - Adjust	8-2
Fig. 2-5	Start Switch and Stop Switch	2-3	Fig. 8-3	Damper - Check Visually.....	8-3
Fig. 2-6	Manual Stop Lever	2-3	Fig. 8-4	Damper Temperature Control	8-4
Fig. 2-7	Stop Solenoid	2-3	Fig. 8-5	Fuel Tank - Drain Water	8-5
Fig. 2-8	Rotation Detection Pickup	2-4	Fig. 8-6	Oil-Water Separator - Drain Water	8-6
Fig. 3-1	Priming Pump Comparison	3-1	Fig. 8-7	Oil-Water Separator Element - Replace...	8-6
Fig. 3-2	A-type Priming Pump - Operation	3-2	Fig. 8-8	Gauze Filter - Clean	8-7
Fig. 3-3	B-type Priming Pump - Operation	3-2	Fig. 8-9	Fuel Filter - Replace.....	8-8
Fig. 3-4	Oil-Water Separator - Bleed Air	3-2	Fig. 8-10	Fuel filter	8-8
Fig. 3-5	Fuel Filter - Bleed Air	3-2	Fig. 8-11	Ball Joint - Check for Looseness	8-9
Fig. 3-6	Fuel Injection Pump - Bleed Air.....	3-3	Fig. 8-12	Fuel Control Link - Remove.....	8-9
Fig. 3-7	A-type Priming Pump Tightening Method ...	3-3	Fig. 8-13	High-pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace	8-10
Fig. 3-8	A-type Priming Pump Head Packing	3-3	Fig. 8-14	Low-pressure Fuel Pipe and Clip - Inspect.....	8-10
Fig. 3-9	Oil Filler and Oil Level Gauge	3-4	Fig. 8-15	Engine Oil - Drain.....	8-11
Fig. 3-10	Reserve Tank - Installing Position.....	3-5	Fig. 8-16	Oil Filter and Bypass Oil Filter - Replace	8-12
Fig. 3-11	Coolant Drain Cock (Engine Body)	3-5	Fig. 8-17	Oil filter	8-12
Fig. 3-12	Coolant Drain Cock (Water Pump)	3-5	Fig. 8-18	Oil filter - Change while engine is running	8-12
Fig. 3-13	Battery Fluid Level - Check	3-6	Fig. 8-19	Oil Filler and Oil Level Gauge	8-13
Fig. 3-14	Valve Open/Closed Position - Check ...	3-8	Fig. 8-20	Governor Oil - Drain	8-14
Fig. 3-15	Fuel Tank - Drain Water	3-9	Fig. 8-21	Governor Oil Filter - Replace.....	8-14
Fig. 3-16	Oil-Water Separator - Drain Water.....	3-10	Fig. 8-22	Oil Pipe and Clip - Inspect and Replace....	8-15
Fig. 3-17	Oil Filler and Oil Level Gauge	3-10	Fig. 8-23	Radiator Cap	8-16
Fig. 3-18	Damper Thermo Label	3-11	Fig. 8-24	Coolant Drain Cock (Engine).....	8-16
Fig. 3-19	Manual Stop Lever	3-14	Fig. 8-25	Coolant Drain Cock (Water Pump).....	8-17
Fig. 5-1	JUKOIL New Mariner	5-1	Fig. 8-26	Seawater Drain Cock (Heat Exchanger) ...	8-18
Fig. 5-2	Engine Oil Grade	5-1	Fig. 8-27	Seawater Pump Cover	8-18
Fig. 5-3	Selection of Oil Viscosity	5-3	Fig. 8-28	Seawater Pump Impeller - Inspect	8-18
Fig. 6-1	GLASSY Long Life Coolant	6-1	Fig. 8-29	Zinc Rod - Judge.....	8-19
Fig. 6-2	Coolant Freezing Temperature (GLASSY and PG GLASSY).....	6-7	Fig. 8-30	Zinc Rod Mounting Location (Heat Exchanger)	8-19
Fig. 6-3	Coolant tester	6-8	Fig. 8-31	Seawater Strainer Mesh Filter - Clean and Replace	8-20
Fig. 6-4	Measuring procedure 1	6-8			
Fig. 6-5	Measuring procedure 2	6-8			
Fig. 6-6	Measuring procedure 3	6-8			
Fig. 6-7	Measuring procedure 4	6-9			
Fig. 6-8	Measuring procedure 5	6-9			

Fig. 8-32 Mounting Orientation of Strainer Mesh
 Filter 8-20

Fig. 8-33 Arrangement to Top Cover 8-20

Fig. 8-34 Turbocharger - Inspect 8-21

Fig. 8-35 Pre-Cleaner - Wash 8-22

Fig. 8-36 Battery Fluid Level - Check 8-23

Fig. 8-37 Specific Gravity of Battery Electrolyte -
 Check 8-24

Fig. 8-38 Starter - Inspect 8-24

Fig. 8-39 Alternator - Inspect 8-24

Fig. 10-1 Lifting Hangers 10-1

Fig. 10-2 Hitching Wire Ropes 10-1

Fig. 13-1 Electric diagram (instrument panel) ... 13-1

List of Table

Table 3-1 Inspection During Operation 3-13

Table 4-1 Recommended Fuel 4-1

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

Table 5-1 Recommended Limits for Engine Oil
 Properties 5-2

Table 5-2 Engine Oil Properties 5-4

Table 6-1 Water Quality Standard 6-1

Table 6-2 LLC Quality Standard 6-3

Table 6-3 Recommended LLC Concentration 6-7

Table 7-1 PERIODIC MAINTENANCE CHART 7-2

Table 8-1 Types of Thermo Labels 8-4

Table 8-2 Specific Gravity of Battery Electrolyte ... 8-24

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

Table 11-1 The Starter Does not Crank or Cranks
 Slowly, Resulting in Start Failure 11-2

Table 11-2 Starter Cranks, but Engine Does Not
 Start 11-3

Table 11-3 Poor Output 11-4

Table 11-4 Exhaust Smoke is White or Blue 11-5

Table 11-5 Exhaust Smoke is Black or Grey 11-6

Table 11-6 Excessive Fuel Consumption 11-7

Table 11-7 Excessive Engine Oil Consumption 11-8

Table 11-8 Overheating 11-8

Table 11-9 Engine Oil Pressure Drop 11-9

Table 12-1 Main Specifications 12-1

Chapter 1 BASIC SAFETY PRECAUTIONS

Fire and Explosion Protection



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 the fuel and engine oil in a well-ventilated area. Make sure that the caps of fuel and engine oil containers are tightly closed.

Keep Engine Surrounding Area Tidy and Clean

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

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

Pay Attention to Engine Room Ventilation

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

Do Not Open Side Covers Until Engine Cools

Do not attempt to open the side cover of the crankcase before the engine cools down. Wait at least 10 minutes after stopping the engine. If fresh air flows into the crankcase while the engine is overheating, oil mist can be ignited and exploded.

Be Alert for Leaking Fuel, Oil, or Exhaust Gas

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

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

Use Explosion-Proof Light

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

Prevention of Electric Short Circuit

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

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

Keep Fire Extinguishers and First-Aid Kit Handy

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



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

Stay Away From Rotating and Moving Parts

WARNING

Keep Rotating Parts Covered for Safety

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



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

Never remove the protective covers.

Check Work Area for Safety Before Starting

Before starting the engine, make sure no one is near the engine and no tools are left on or near the engine. Alert people in the area when starting the engine. When the starter device is posted with a sign that prohibits startup operation, do not operate the engine.

Stay Away From Moving Parts During Operation

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



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

Lockout and Tagout

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

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

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

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

Be Sure to Stop Engine Before Inspection/Maintenance

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

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

Always Put Turning Tool Back in Place After Use

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

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

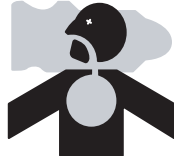
Prevention of Exhaust Gas Poisoning

WARNING

Pay Attention to Ventilation When Operating Engine

Check exhaust pipes and pipe joints for gas leaks.

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



Prevention of Hearing Loss

CAUTION

Wear Ear Plugs

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

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



Fall Prevention

WARNING

Lift Engine Carefully

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

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

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

The hangers attached to the engine are designed to lift the engine only. For the engine coupled with a generator, use the special hangers provided on the common bed. Do not use hangers on the engine. When the engine is equipped with a marine gear, make sure so that load is not imposed on the hangers of engine only.

Keep the angle formed by slings that are attached to hangers within 60 degrees. If the angle exceeds this limit, an excessive load could be imposed on the hangers and this could damage the hangers and result in a serious accident.

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

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



Do Not Climb Onto the Engine

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

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

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

Always Use a Stable Foothold During Maintenance

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

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

Do not put any unnecessary objects on a work platform.



Burn Protection

 CAUTION

Do Not Touch Engine During or Immediately After Operation

Do not touch any part of the engine during or immediately after operation. A hot engine can cause burns. Before conducting maintenance and inspection work, check the temperature of the engine with the gauge if the engine has cooled sufficiently.



Refill Coolant Only After the Coolant Temperature Dropped

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

Do Not Remove Heat Shields

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

Be Careful When Opening and Closing of Radiator Cap

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

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

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

When fastening the radiator cap, be sure to tighten securely.

Do Not Touch High-Pressure Fuel Spray

If fuel is leaking from the high-pressure fuel injection pipe, do not touch the fuel spray.

The fuel injection pipe delivers high pressure fuel. If the fuel spray contacts your skin, it goes into deep skin tissues and may result gangrene.

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

 CAUTION

Use Specified Fuel, Engine Oil, and LLC Only

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

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

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

Handle LLC Carefully

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

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

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

Proper Disposal of Waste Oil, LLC, and Coolant

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

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

When Abnormality Occurs

CAUTION

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

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

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

Be Careful When Starting After an Abnormal Stop

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

Stop Engine Immediately When Engine Oil Pressure Has Dropped

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

If Belt Breaks, Stop Engine Immediately

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

Battery Safety Precautions

CAUTION

Be Careful When Handling Battery

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



Other Precautions



CAUTION

Do Not Tamper

Unauthorized modification of the engine will void your warranty.

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

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

Observe Safety Rules at Work Site

Observe the safety rules established at your workplace.

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

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

Wear Proper Work Clothing and Protective Gears

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

Never Break the Seals

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

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

Performance of Pre-Operation Inspection and Periodic Inspections

Be sure to perform the pre-operation inspection and periodic inspection as instructed in this manual.

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

Engine Break-in

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

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

Warming Up Engine First

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

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

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

Cool Down the Engine Before Stopping

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

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

During cooling operation, check the engine for abnormalities.

Do Not Operate the Engine in an Overloaded Condition

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

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

Prohibition of Continuous Low-Load Operation

When operating the engine at a low load (30% or less), limit the operation to an hour or less. Carbon deposits accumulate in the cylinder and may cause faulty combustion. After one hour operation at low load, operate the engine at a load of 50% or higher for 30 minutes or longer to prevent accumulation of carbon deposits.

Do Not Splash Water on Engine

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

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

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

Pre-cleaner is to be properly maintained

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

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

Use Proper Tools for Maintenance Work

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

Do Not Operate Starter for a Long Duration

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

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

Do Not Turn Off the Battery Switch During Operation

Do not turn off the battery switch during operation.

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

Engine Transportation Precautions

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

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

Warning Labels



Maintenance of Warning Labels

Make sure all warning/caution labels are legible.

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

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

Replace damaged or fractured labels with new ones.

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

To obtain new warning labels, contact your MHIET dealer.



Fig. 1-1 Common Warning Labels

Chapter 2 NAME OF PARTS

Engine External Views

Front View

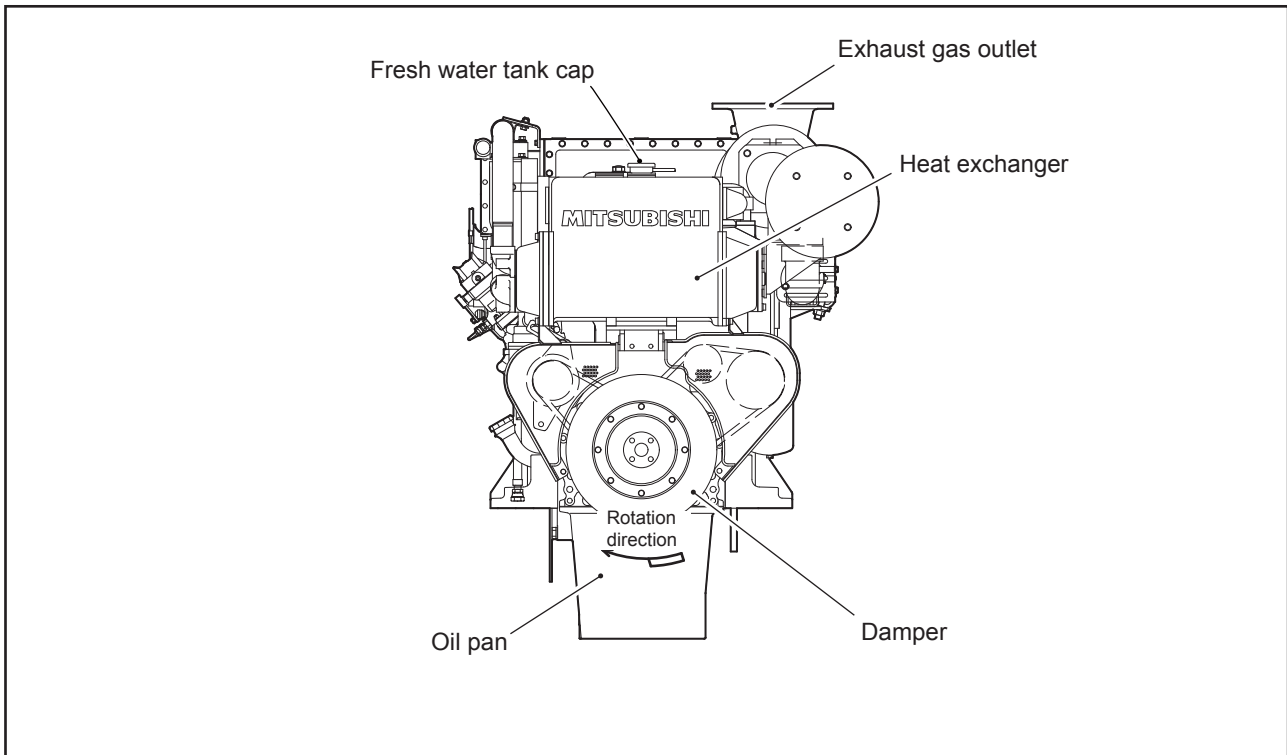


Fig. 2-1 Engine Front View

Rear View

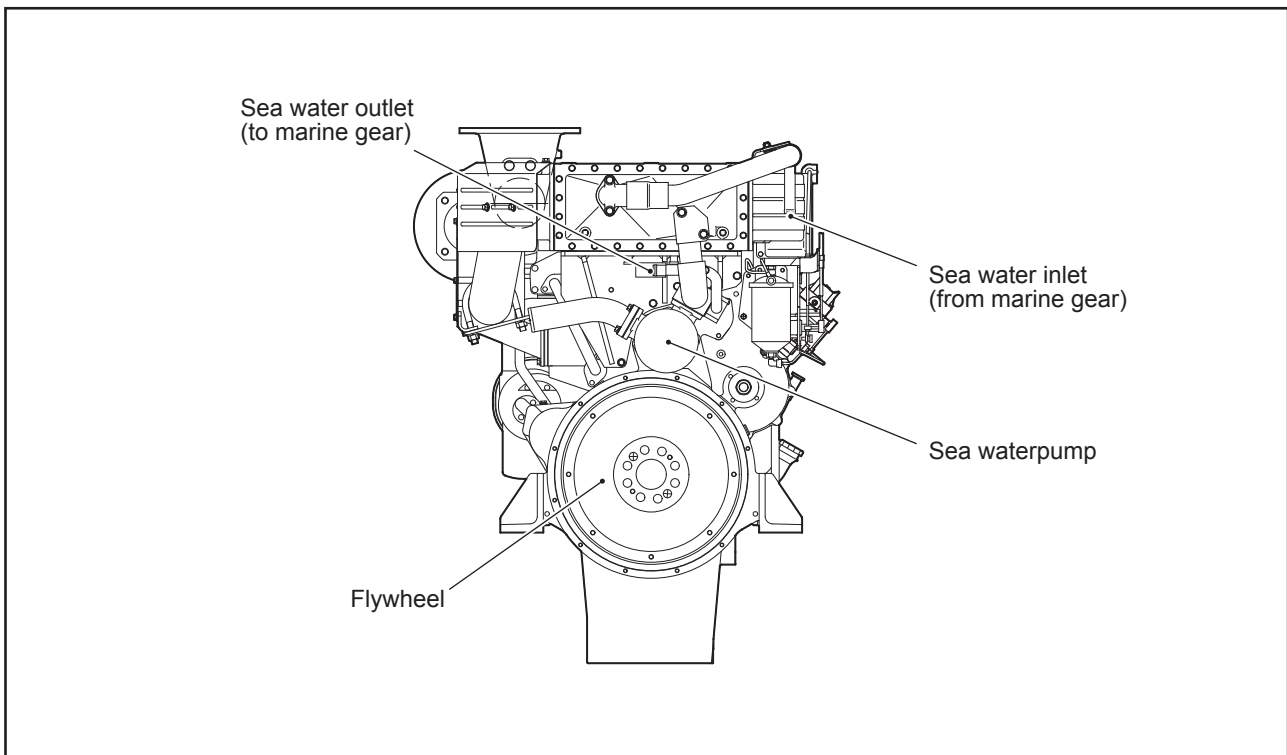


Fig. 2-2 Engine Rear View

Left View

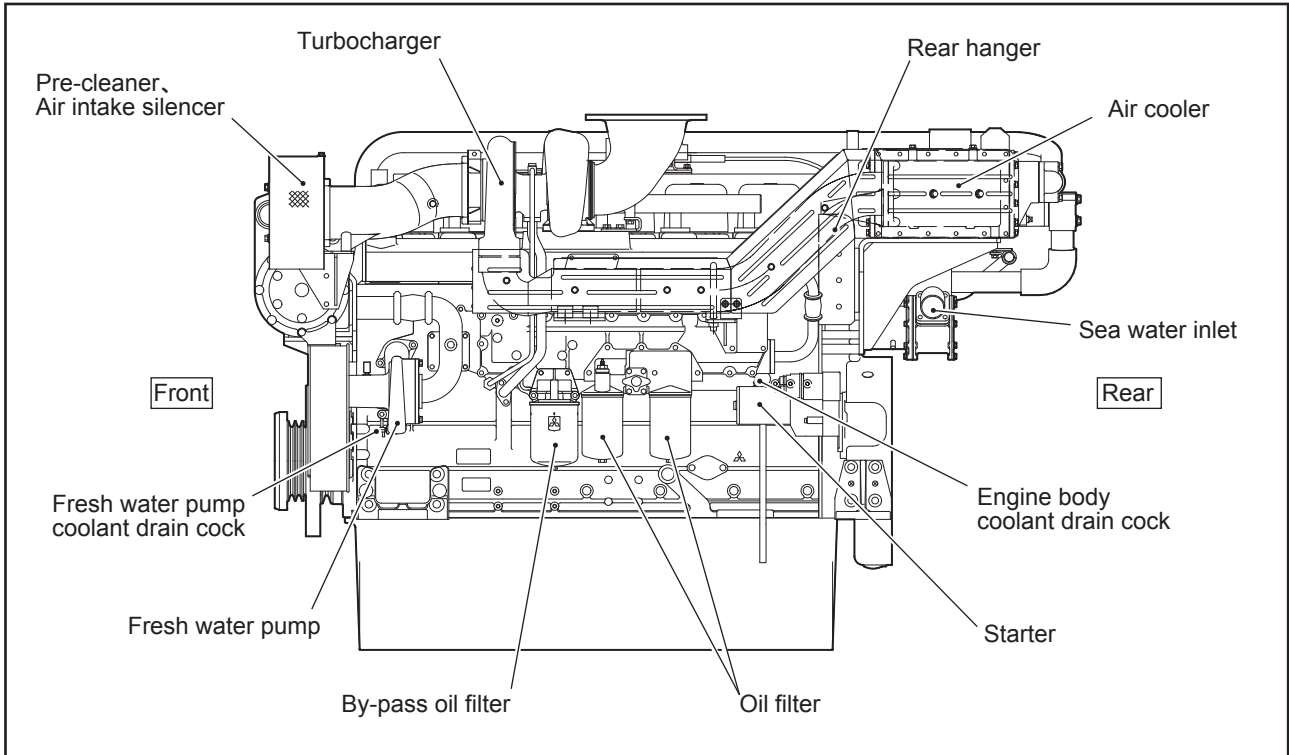


Fig. 2-3 Engine Left-Side View

Right View

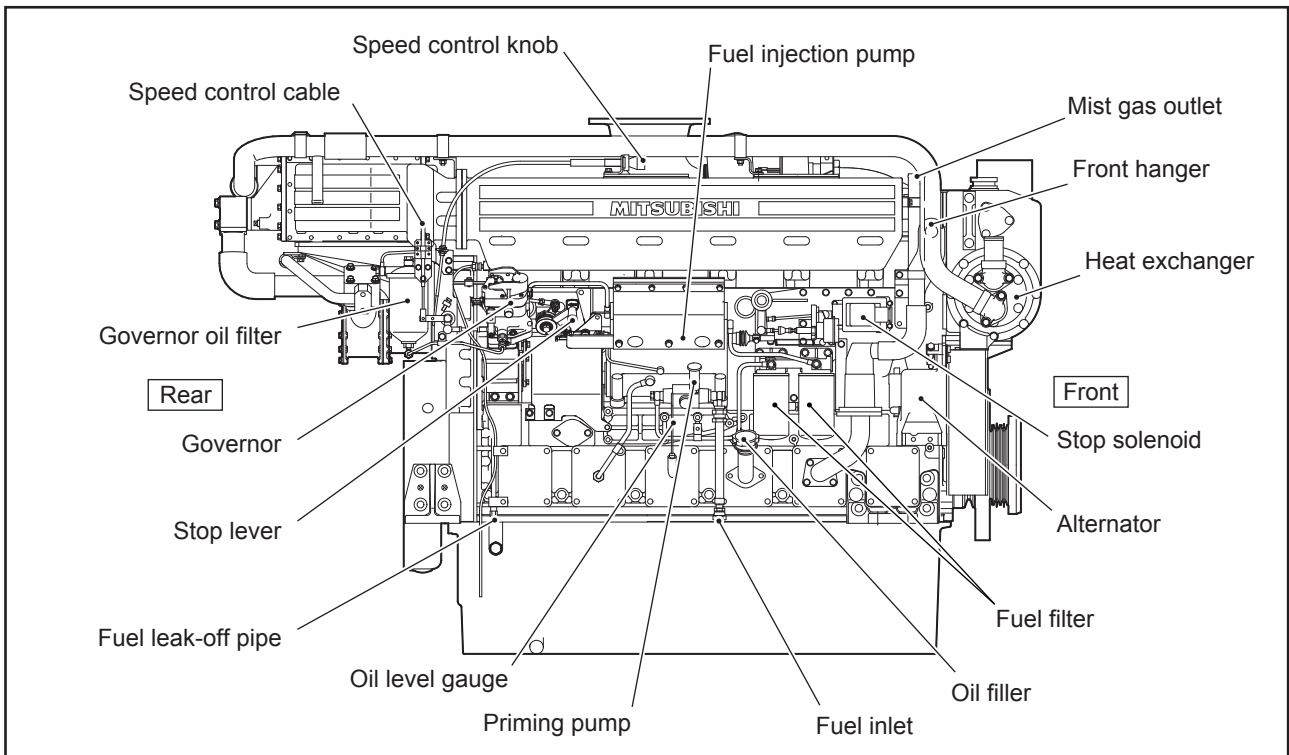


Fig. 2-4 Engine Right-Side View

Operating Devices

The type and shape of actually installed device vary with specifications.

Starting and Stopping Device

Start Switch

When the start switch on the operation panel is pressed, the starting system is activated and the engine will start.

Stop Switch

When the stop switch on the operation panel is pressed, the shutdown solenoid is activated and the control shaft of the fuel injection pump moves to the no-injection position to shut down the engine operation.

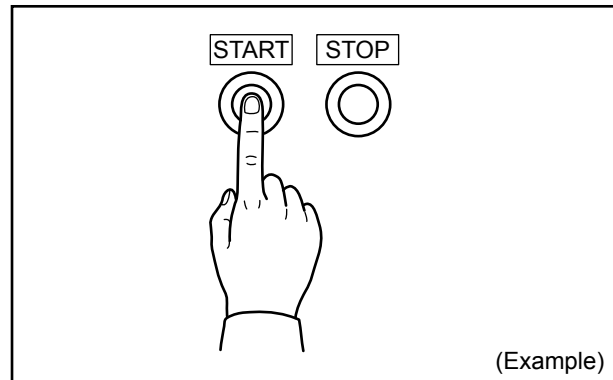


Fig. 2-5 Start Switch and Stop Switch

Manual Stop Lever

CAUTION

When stopping the engine with the manual stop lever, keep the manual stop lever at the stop position until the engine stops completely. If you release the lever before the engine stops completely, the engine may restart.

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

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

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

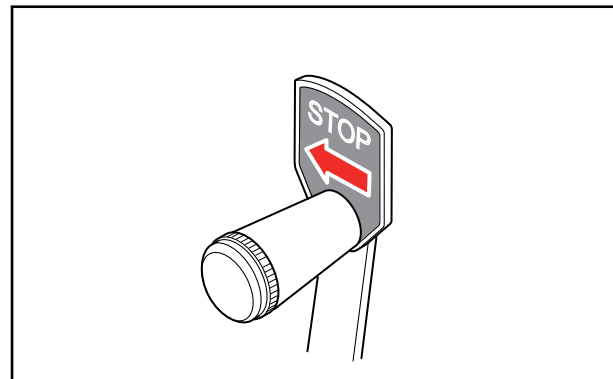


Fig. 2-6 Manual Stop Lever

Stop Solenoid

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

The stop solenoid moves the rack of fuel injection pump to cut the fuel to stop the engine.

The RUN OFF type stop solenoid is equipped on this engine. The solenoid is not energized while the engine is running, and energized by a stop signal to stop the engine.

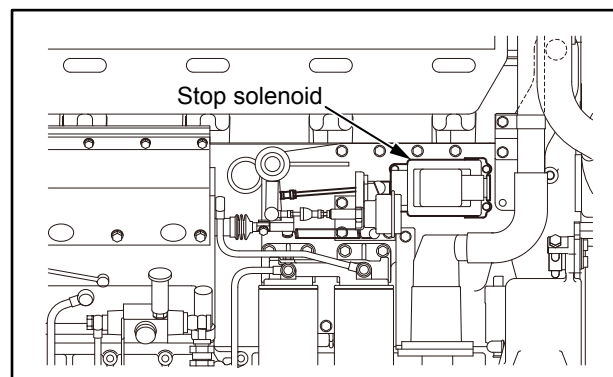


Fig. 2-7 Stop Solenoid

Engine Protection Devices

Rotation Detection Pickup

Alarm is activated when the engine rotational speed reaches the higher limit of rotational speed.

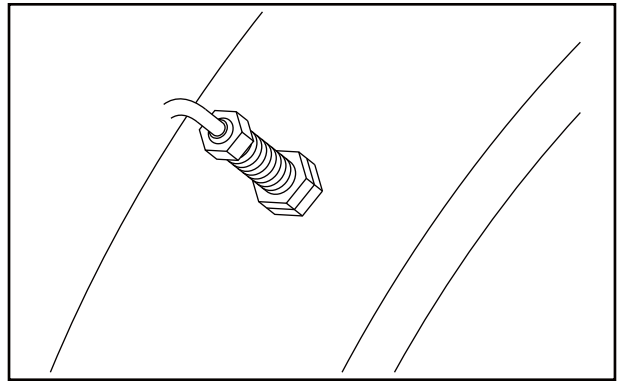


Fig. 2-8 Rotation Detection Pickup

Checking Operational Environment

CAUTION

Before proceeding with any operation of engine, make sure the following measures are taken. Operating environment should be adequate. If not, it causes various problems and may shorten the service life of the engine.

- ♦Prevent water (especially, seawater or rain water) and foreign particles from entering the air inlet opening.
- ♦Prevent foreign substances from entering to rotating parts.
- ♦Prevent accumulation of moisture, dust, and dirt on the electrical system.
- ♦Maintain the ambient temperature of 5 to 40°C [41 to 104°F].

Preparation for Operation of New or Overhauled Engine

Before proceeding with operation of a new or overhauled engine, conduct the inspections described in this section. Note that, for second operation onward, follow the instructions described in the "Normal Engine Operation" (3-8).

Preparation of Fuel System

CAUTION

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

CAUTION

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

1. Make sure the inside of the fuel tank and the fuel supply pipes to the engine are thoroughly clean.
2. Close the fuel tank drain valve.
3. Fill the fuel tank with fuel.
4. Remove the fuel feed pipe and check the discharged fuel for foreign substances such as dust.
5. Install the pipe to the engine fuel inlet port.
6. After checking the contact of the float switch, add fuel to "FULL" level.

Bleeding the Fuel System

WARNING

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

Note: There are two different types of priming pumps, type "A" and type "B". Operation varies depending on the type. Be sure to check the type before operation.

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

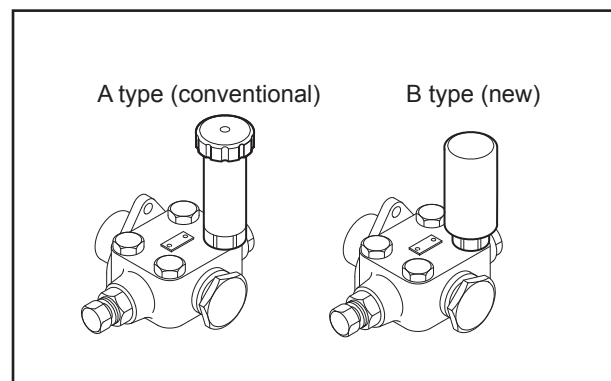


Fig. 3-1 Priming Pump Comparison

A-type Priming Pump - Operation

1. Turn the priming pump cap counterclockwise to unlock.
2. Push the priming pump cap several times to feed fuel to bleed air.
3. After bleeding air, turn the priming pump cap clockwise while pushing. Be sure to lock securely.

B-type Priming Pump - Operation

Move the priming pump handle up and down several times to feed fuel.

Note: Since there is no locking mechanism, you do not need lock and unlock the pump handle before and after air bleeding.

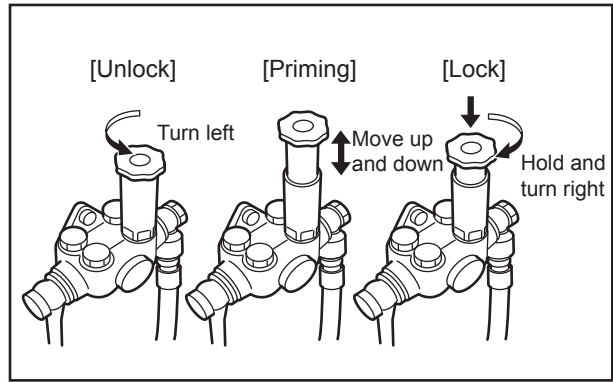


Fig. 3-2 A-type Priming Pump - Operation

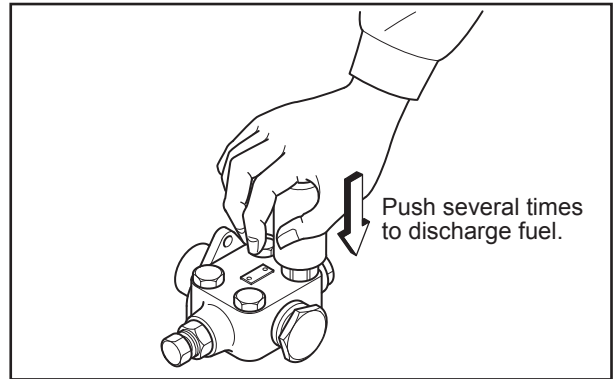


Fig. 3-3 B-type Priming Pump - Operation

Oil-Water Separator - Bleed Air

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

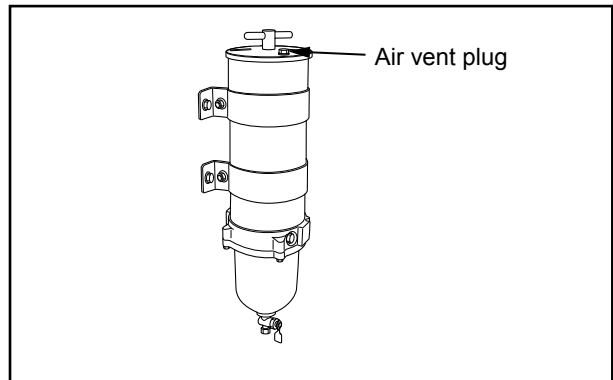


Fig. 3-4 Oil-Water Separator - Bleed Air

Fuel Filter - Bleed Air

CAUTION

If the air vent plug, thread of the bracket, or sealing washer is damaged, replace it with a new one.

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

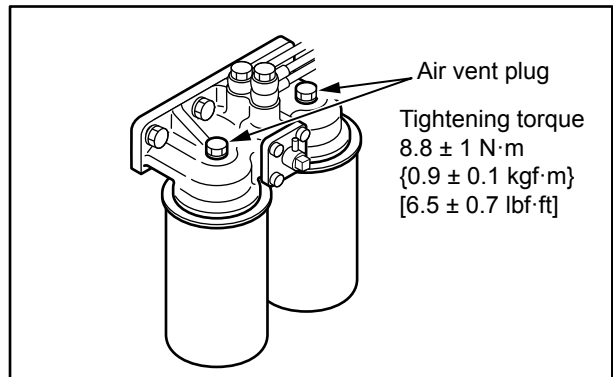


Fig. 3-5 Fuel Filter - Bleed Air

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, for the A-type priming pump, lock the priming pump cap by turning clockwise while pushing.
3. Tighten the air vent plug on the fuel injection pump.

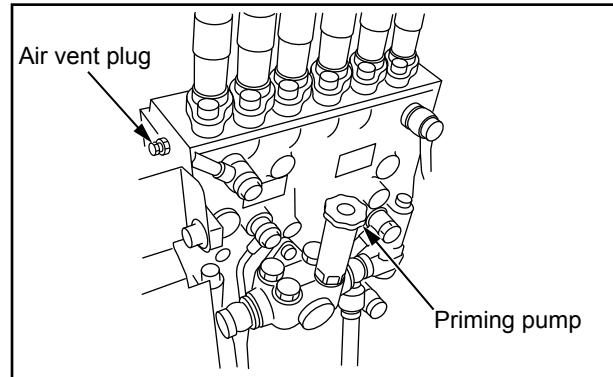


Fig. 3-6 Fuel Injection Pump - Bleed Air

Priming Pump Tightening Method

CAUTION

Securely tighten the A-type priming pump. If the priming pump is not tightened firmly, the internal threads will be worn due to engine vibration, and the priming pump may pop out, causing fuel to flow out. Or if the priming pump is excessively tightened, the head of the priming pump can be damaged. Be sure to tighten the pump by the correct angle.

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

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

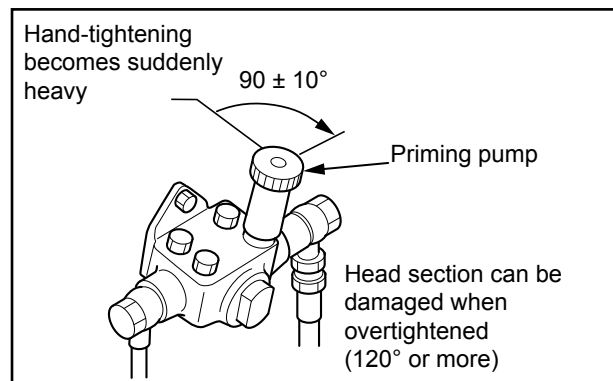


Fig. 3-7 A-type Priming Pump Tightening Method

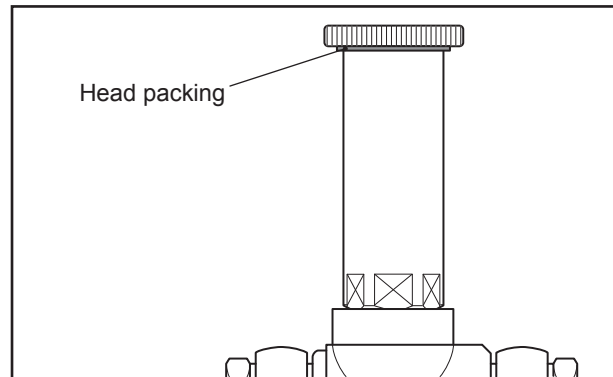


Fig. 3-8 A-type Priming Pump Head Packing

Preparation of Lubrication System Engine Oil - Refill

CAUTION

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

1. Remove the oil filler cap.
2. Add the specified engine oil to the specified level.
Note: For engine oil, refer to "[ENGINE OIL](#)" (5-1). For engine oil capacity, refer to "[MAIN SPECIFICATIONS](#)" (12-1).
3. Check the oil level in oil pan.
4. Pull out the oil level gauge and wipe it clean with a cloth.
5. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
6. The oil level should be between the maximum and minimum marks on the oil level gauge.
If the engine oil level is higher than the maximum mark on the oil level gauge, drain engine oil by opening the drain valve.
If the engine oil level is low, add the specified engine oil.
7. Check the oil pan and others for oil leaks. Repair if there is an oil leak.
8. With the manual stop lever placed in the pulled position, rotate the engine with starter for approx. 10 seconds to circulate oil to the engine thoroughly. Stop for 1 minute, then, repeat this operation two or three times to circulate oil to all parts of the engine.
Note: Also perform the items described under the Preparation of Cooling System.
9. Start the engine and run at no-load and low-idling condition for 5 to 10 minutes.
10. Stop the engine and leave it for 30 minutes or more, and then, check the oil level with the oil level gauge again and add oil to the specified level.
For details, refer to "[Test Operation](#)" (3-7).

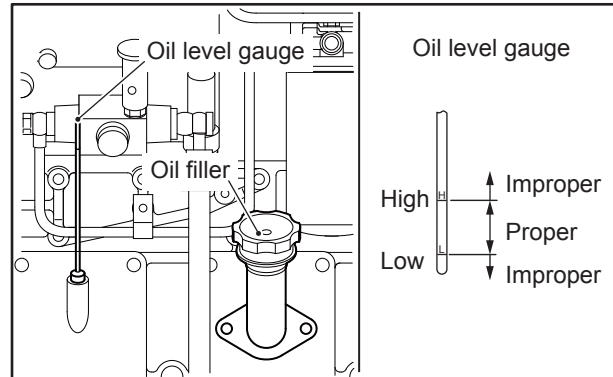


Fig. 3-9 Oil Filler and Oil Level Gauge

Preparation of Cooling System

Reserve Tank - Install

The installation of reserve tank is recommended to keep the reserve amount of cooling water and to ease the visual inspection of cooling water amount.

The transfer of cooling water between the fresh water tank and reserve tank depends on the pressure difference between the inside pressure of fresh water tank and the atmospheric pressure working on reserve tank.

Install the reserve tank to place its upper face between the heights of upper face of fresh water tank and low limit of water level in the fresh water tank.

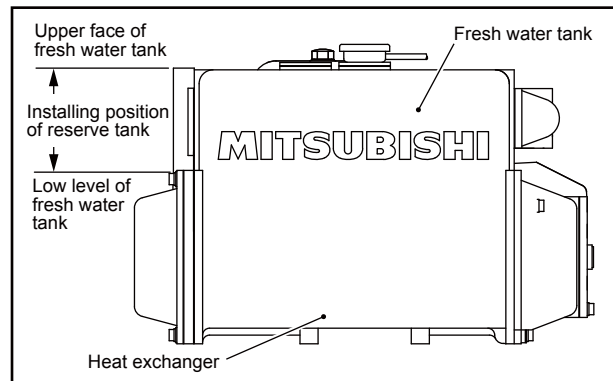


Fig. 3-10 Reserve Tank - Installing Position

Coolant - Refill

CAUTION

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

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

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

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

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

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

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

Note: Also perform the items described under the Lubrication System - Prepare.

6. Check the coolant level.

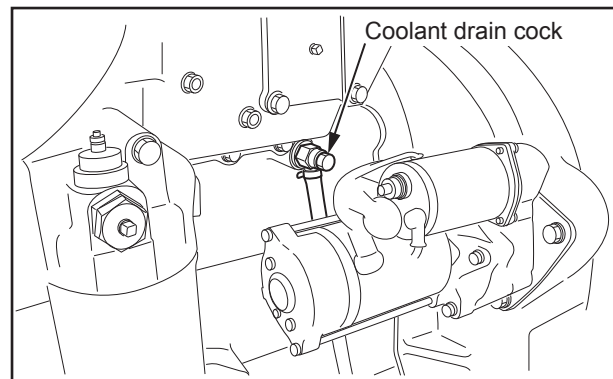


Fig. 3-11 Coolant Drain Cock (Engine Body)

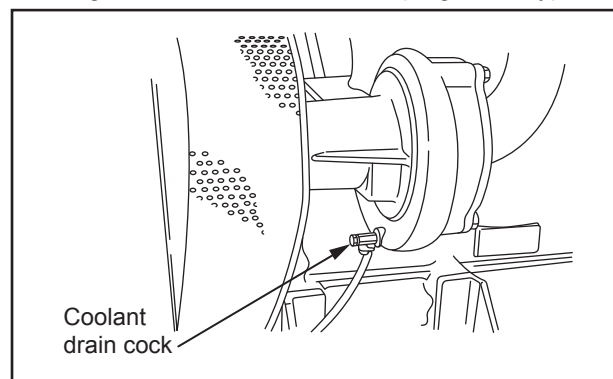


Fig. 3-12 Coolant Drain Cock (Water Pump)

Preparation of Electrical System

Battery - Check

⚠ CAUTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Battery Fluid Level - Check

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

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

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

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

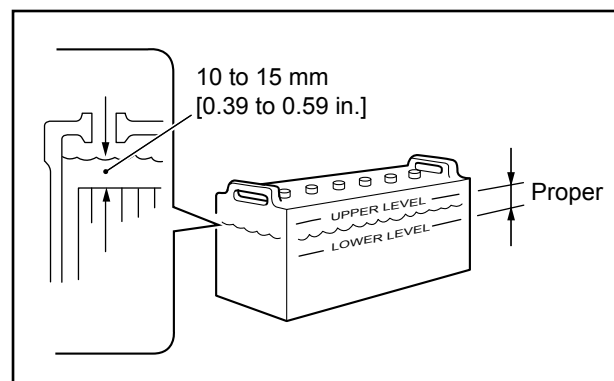


Fig. 3-13 Battery Fluid Level - Check

Test Operation

To conduct the test operation, follow the procedures below.

Note: For engine operation, refer to "Normal Engine Operation" (3-8).

Start and Stop

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

Inspection

CAUTION

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

1. Stop the engine and leave it for about 30 minutes.
2. During this period, walk around the engine to check for leaks of fluids such as fuel, engine oil, or coolant.
3. When 30 minutes has passed since the engine stop, check the oil level with the oil level gauge. The oil level should be between the high and low marks on the oil level gauge.
4. If the engine oil level is higher than the high mark on the oil level gauge, drain engine oil by opening the drain valve. If the engine oil is low, remove the oil filler cap, and add the specified engine oil.
5. Open the coolant filler cap and check the coolant level.
6. If the coolant level is low, add coolant to the specified level.

Normal Engine Operation

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

CAUTION

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

Pre-operation Inspection

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

Engine Exterior - Inspect

CAUTION

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

Inspect the engine exterior as instructed below:

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

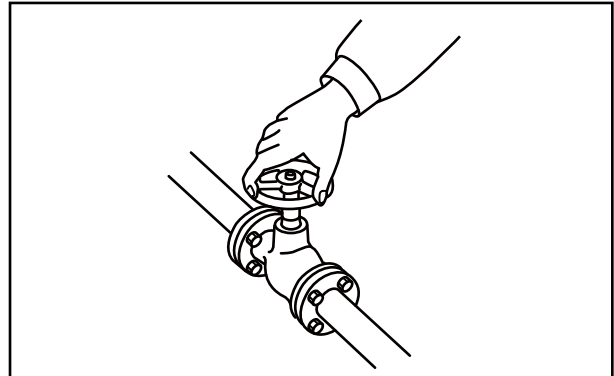


Fig. 3-14 Valve Open/Closed Position - Check

Fuel Tank Oil Level - Check

WARNING

Make sure that there is no open flame in the vicinity before handling fuel.
Wipe off any spilled fuel completely. It can cause a fire.

CAUTION

Do not remove the strainer during fuel tank filling.
The float switch, if equipped, may be defective if the fuel exceeds the lower limit warning level. Check and repair.
For the fuel to be used, refer to "FUEL" (4-1).

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

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

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

Fuel Tank - Drain Water

WARNING

Make sure that there is no open flame in the vicinity before handling fuel. Wipe off any spilled fuel completely. It can cause a fire.

CAUTION

Do not remove the strainer when filling the fuel. For the fuel to be used, refer to "FUEL" (4-1).
The water bleeding procedure described below is for a commonly used fuel tank, and sometimes it may be different from the procedure for the fuel tank installed on your engine.

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

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

1. Place the oil pan (capacity of 2 L [0.53 US gal.] or more) under the drain cock of fuel tank.
2. Open the drain cock of fuel tank and drain fuel at least 1 to 2 liters (0.26 to 0.53 US gal).
3. After the drained fuel shows no water or foreign substance, close the drain cock.

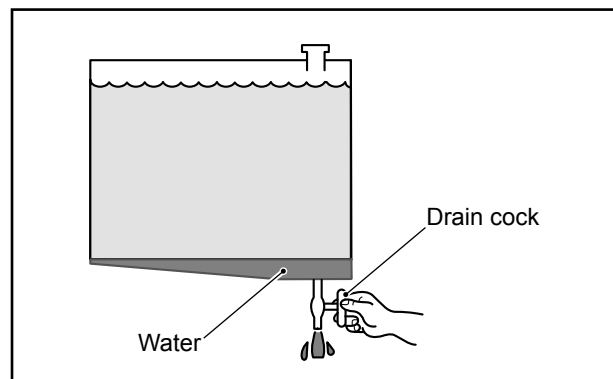


Fig. 3-15 Fuel Tank - Drain Water

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 fuel from overflowing. Wrap a cloth around the water separator just in case, as fuel may spill.

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

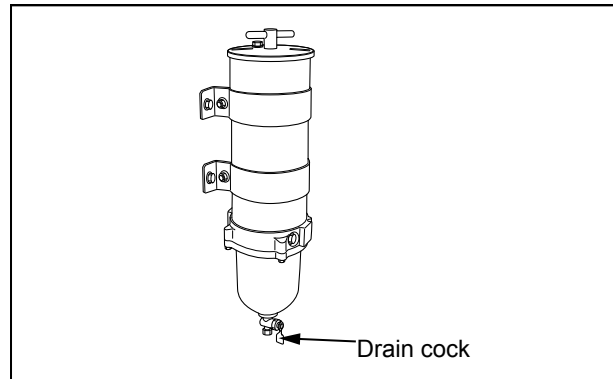


Fig. 3-16 Oil-Water Separator - Drain Water

Engine Oil Level - Check

⚠ CAUTION

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

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

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

For draining engine oil, refer to ["Engine Oil - Drain" \(8-11\)](#). For refilling engine oil, refer to ["Engine Oil - Refill" \(8-13\)](#).

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

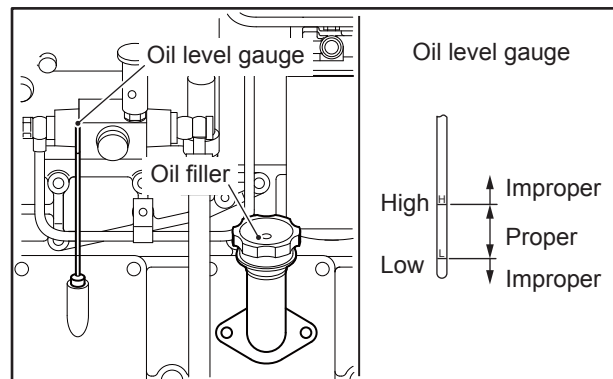


Fig. 3-17 Oil Filler and Oil Level Gauge

Coolant Level - Check

CAUTION

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

If the coolant level is low, add coolant to the specified level.

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

For the coolant, refer to "COOLANT" (6-1). For the coolant capacity, refer to "MAIN SPECIFICATIONS" (12-1).

Damper Temperature - Check

Damper Temperature Control With Thermo Label

Use of thermo label is recommended for damper temperature control. Check the thermo label before starting the engine as instructed below:

1. Make sure the color of the thermo label heat-sensitive area is black.
2. Record the highest temperature of heat-sensitive area. Record the temperature regularly, and check any abnormal temperature change.

CAUTION

If the temperature change is abnormal, contact your MHIET dealer.

Note: For the damper temperature limit and damper inspection, refer to "Damper - Inspect" (8-3).

Control Cable - Check

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

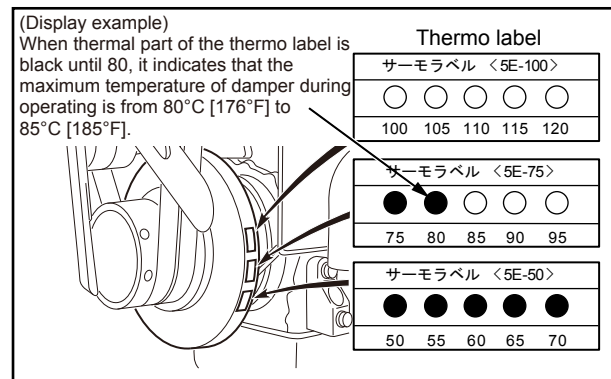


Fig. 3-18 Damper Thermo Label

Start-up

 **WARNING**

Before starting the engine, make sure no one is near the engine and that no tools are left on or near the engine. Also, alert the people in the vicinity before starting the engine.

CAUTION

Do not apply load to the engine at startup.

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

Warm-up Operation

 **WARNING**

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

Warm-up the engine at a low idle speed until the coolant temperature reaches approx. 50°C [122°F].

Engine Oil Pressure - Check

During warm-up operation, check if the oil pressure is within the range of standard value (0.3 MPa {3.1 kgf/cm²} [43.5 psi] or more).

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

Engine - Walk Around Check

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

Operation

Precautions in Engine Operation

WARNING

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

CAUTION

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

CAUTION

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

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

Do not turn the battery switch OFF during operation. If the battery switch is turned off during operation, it will not only stop the operation of instruments but also deteriorate the alternator diode and transistor. Never turn the key to the "START" position during operation. Otherwise, the starter may be damaged. When operating at low load (less than 30%), limit the operation to an hour or less. Carbon deposits accumulate in the cylinder and may cause faulty combustion. After a low-load operation for one hour or so, operate the engine at a load of 50% or higher for 30 minutes or longer to prevent accumulation of carbon deposit.

Pay attention to the generated voltage of generator set.

Inspection During Operation

During engine operation, check abnormal engine noise, odor, vibrations, or leaks from pipes.

Also carefully check the followings for abnormalities.

Table 3-1 Inspection During Operation

Inspection item	Criteria/Reference Value
Warning indicator/instruments	Lighting/numerical value normality
Engine speed/frequency	No large fluctuation
Breather mist volume	As usual
Exhaust color	As usual
Damper temperature	90°C [194°F] or lower
Engine oil pressure	0.39 MPa {3.98 kgf/cm ² } [56.6 psi] or more
Engine oil temperature (oil pan)	110°C [230°F] or lower
Coolant temperature	70 to 90°C [158 to 194°F]
Exhaust temperature	550°C [1022°F] or lower
Intake air pressure	0.15 to 0.25 MPa {1.53 to 2.55 kgf/cm ² } [21.8 to 36.3 psi]

Note: (a) If the engine stops due to engine oil pressure drop, be sure to locate the cause of problem and correct it before starting the engine.

(b) In the auto mode, the engine will stop immediately if the thermo switch is activated.

In the manual mode, run the engine under no load for about 1 minute to let the engine cool down and then stop the engine.

Before starting the engine again, find the cause and be sure to correct the problem.

Stopping

⚠ CAUTION

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

Do not race the engine immediately before shutdown.

Do not start the engine immediately after an abnormal stop. If the engine stops with a warning buzzer, be sure to find the cause and correct the problem before starting the engine again. After the operation has been resumed, check the engine for abnormalities again. If an abnormality is found, repair it immediately.

Engine stopping method varies depending on the specifications.

To stop, follow the instructions specified for the engine.

Emergency Stop

⚠ CAUTION

When stopping the engine by pulling the manual stop lever, keep pulling the lever until the engine stops completely. If you stop halfway, the engine may start again.

To perform an emergency stop, pull the manual stop lever fully to the stop direction (arrow). Keep pulling the manual lever until the engine stops completely.

Note: When the engine does not stop even if the manual stop lever is pulled, cut off the fuel supply.

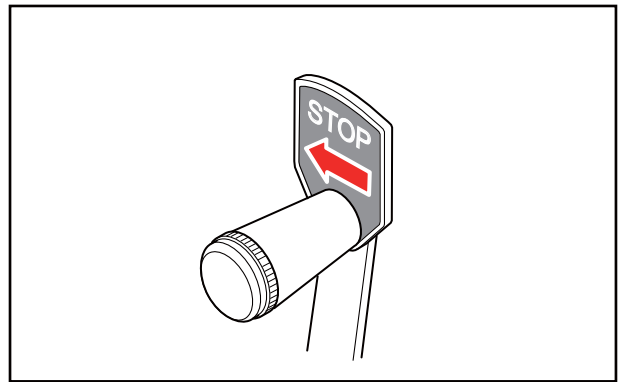


Fig. 3-19 Manual Stop Lever

Inspection After Stopping

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

Recommended Fuel

 **WARNING**

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

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

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

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

Table 4-1 Recommended Fuel

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

Handling Fuel

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

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

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

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

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

Fuel Quality Standard

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

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

Item		Recommended limit	Service limit	Test standard
Flash point		As stipulated by regulation		JIS K 2204 Diesel oil: 45/50°C [113/ 122°F] or higher JIS K 2205 Fuel oil A: 60°C [140°F] or higher
Distillation	Initial boiling point	170°C [338°F] or higher		JIS K 2254: ¹⁹⁹⁸ ISO 3405
	90% distillation temperature	330 to 380°C [626 to 716°F]		
Pour point (PP)		Lower than ambient temperature by 6°C [42.8°F] or lower		JIS K 2269: ¹⁹⁸⁷ ISO 3016
Cloud point (CP)		Ambient temperature or below		JIS K 2269: ¹⁹⁸⁷ ISO 3015
Cold filter plugging point (CFPP)		Lower than ambient temperature by 3°C [37.4°F] or lower		JIS K 2288: ²⁰⁰⁰ IP 309/96
Carbon residue (10% residual oil)		0.4 weight % or lower	1.0 weight % or lower	JIS K 2270: ²⁰⁰⁰ ISO 6615 ISO 10370
Cetane number		45 or more		
Cetane index (new method)		45 or more		JIS K 2280: ¹⁹⁹⁶ ISO/DIS 4264
Kinetic viscosity		2.0 mm ² /s [0.0031 in ² /s] or more at 30°C [86°F] 8.0 mm ² /s [0.0124 in ² /s] or more at 30°C [86°F]		
Sulfur content		0.2 weight % or lower	1.0 weight % or lower (Shorten engine oil change intervals)	JIS K 2541: ²⁰⁰⁰ Content as low as the diesel fuel is desirable. ISO 4260 ISO 8754
Water content and sediments		0.1 volume % or less		JIS K 2275: ¹⁹⁹⁶ ISO 3733
Ash content		0.03 weight % or lower		JIS K 2272: ¹⁹⁹⁸ ISO 6245
Copper corrosion (3 hrs at 50°C [122°F])		Discoloration = copper plate No. 3 or less (Dark tarnished)		ASTM JIS K 2513
Density at 15°C [59°F]		0.83 to 0.87 g/cm ³ [51.8169 to 54.3123 lb/ft ³]		JIS K 2249: ¹⁹⁹⁵ ISO 3675
Coking	250°C [482°F] × 24 hrs	Carbonization 75% or less	Carbonization 80% or less	Fed 791B
	230°C [446°F] × 24 hrs	Carbonization 55% or less	-	
	180°C [356°F] × 48 hrs	Tar-free	-	

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

Item	Recommended limit	Service limit	Test standard
Aromatics substances (by HPLC)	38% by volume or less (total of aroma)		JIS K 2536: 2003
Polycyclic aromatic content	8 volume % or less		ISO 3837
Asphaltene	0.1 weight % or lower		-
Fine foreign substances (foreign substances at fuel inlet)	5.0 mg/L or less		JIS B 9931: 2000 ISO 4405
Lubricity: MWSD (Measured mean Wear Scar Diameter) by HFRR wear test at 60°C [140°F] fuel tem- perature	460µm or less (calculated wear scar diameter at WS 1.4 kPa {0.0143 kgf/cm ² } [0.2031 psi])		ISO 12156-1
BDF: Biodiesel fuel (FAME: Fatty Acid Methyl Ester)	BDF quality shall meet JIS K 2390, or ASTM D 6751 or EN14214. BDF blending of 5% by volume or less is approved.		JIS K 2390: 2008 (standard for FAME as blend stock) ASTM D 6751 EN 14214

Recommended Engine Oil

⚠ CAUTION

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

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

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



Fig. 5-1 JUKOIL New Mariner

Other Commercial Engine Oils

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.

Several diesel engine oils are specified. And the recommended oils are API service classification CF-4 or CH-4 grade oils which are suitable for highly super-charged and loaded engines.

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

If 0.2% or less sulfur content fuel 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.

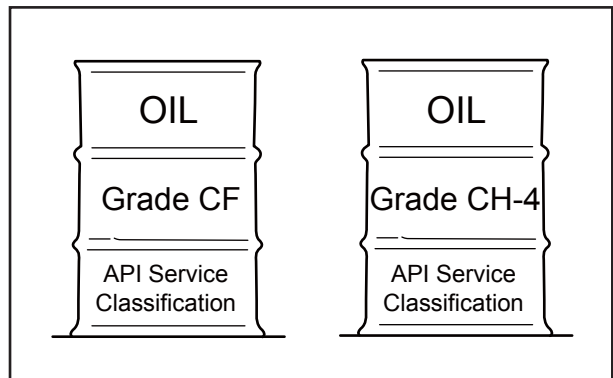


Fig. 5-2 Engine Oil Grade

Engine Oil Quality Standard

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

Table 5-1 Recommended Limits for Engine Oil Properties

Item		Unit	Recommended property value	Test method	
API/JASO standards			Grade CF *1	-	
SAE viscosity		-	15W-40	-	
ASTM Color		-	L4.0	JIS K 2580 ISO 2049	
Density	15°C [59°F]	g/cm ³ [lb/ft ³]	0.87 to 0.90 [54.3123 to 56.187]	JIS K 2249 ISO 3675 ISO 3838 ISO 649-4 ISO 91-1	
Kinetic viscosity	40°C [104°F]	mm ² /s [in ² /s]	100 to 110 [3.94 to 4.33]	JIS K 2283 ISO 3107 ISO 2904	
	100°C [212°F]		13.5 to 15.5 [0.532 to 0.610]		
Viscosity index		-	-	JIS K 2283 ISO 3107 ISO 2904	
Flash point		°C [°F]	225 to 250 [437 to 482]	JIS K 2265 ISO 3679 ISO 2719 ISO 2592	
Base number	Hydrochloric acid method Sulfur content in fuel	1.0 weight % or lower	mgKOH/g	10 or higher (up to 13)	JIS K 2501 ISO 3771 ISO 6618 ISO 6619 ISO 7537
		0.2 weight % or lower		8 or higher (up to 13)	
	Perchloric acid method Sulfur content in fuel	1.0 weight % or lower	mgKOH/g	13 or higher (up to 16)	
		0.2 weight % or lower		11 or higher (up to 16)	
Acid number		mgKOH/g	1.5 to 2.0	JIS K 2501 ISO 3771 ISO 6618 ISO 6619 ISO 7537	
Sulfur content		%	0.5 or less	JIS K 2541 ISO 4260 ISO 8754	
Sulfuric acid ash		%	2.0 or less	JIS K 2272 ISO 3987 ISO 6245	
Carbon residue content		%	2.0 or less	JIS K 2270 ISO 10370 ISO 6615	
High temperature shear viscosity	150°C [302°F]	mPa·S	3.7 or more	JPI-5S-36-91	
Pour point		°C [°F]	-25 [-13] or less	JIS K 2269 ISO 3015 ISO 3016	

Table 5-1 Recommended Limits for Engine Oil Properties

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

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

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

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

Selection of Oil Viscosity

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

Excessively high oil viscosity causes power loss and an abnormal rise in oil temperature, while excessively low oil viscosity accelerates wear due to inadequate lubrication, and also causes a decrease in engine output.

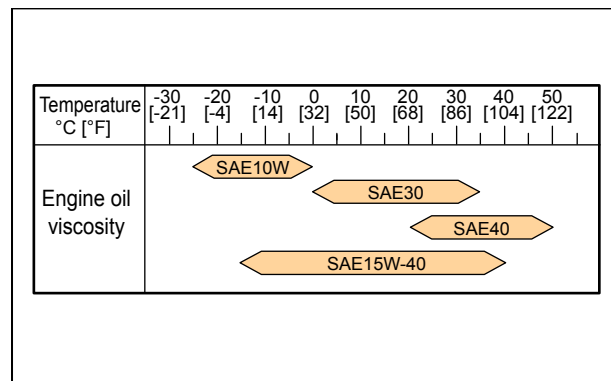


Fig. 5-3 Selection of Oil Viscosity

Handling Engine Oil

WARNING

Before filling the engine with engine oil, stop the engine and make sure there is no open flame in the vicinity. If oil is spilled or leaked on hot surfaces or electrical components, it could cause a fire. Wipe off any spilled oil immediately and thoroughly. After filling oil, securely close the filler cap.

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

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 MSDS of the engine oil and follow the instructions in the MSDS.

Service Limits for Engine Oil

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

The quality of engine oil and the operating condition of the engine have influence on deterioration of the engine oil. Change the engine oil in accordance with Chapter 7 PERIODIC MAINTENANCE CHART. However, only when the engine oil analyze result allows, the oil change interval may be extended. The limit of extended oil change interval is 500 hours.

For the determination of engine oil properties degradation, see the table below. If any of oil properties exceeds the limit, change the engine oil with new oil.

Table 5-2 Engine Oil Properties

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

Definition of 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

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

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

Acid number

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

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

Water content

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

Flash point

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

Insolubles

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

Engine Oil Analysis Service

For a long productive service life of engine, 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 countermeasures, 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.

Chapter 6 COOLANT

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

Recommended Water for Coolant

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

Table 6-1 Water Quality Standard

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

Long Life Coolant (LLC)

⚠ CAUTION

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

Be sure to use Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET) genuine long life coolant (LLC), "GLASSY long life coolant (ethylene glycol type)" or "PG GLASSY long life coolant (propylene glycol type)."

When using an LLC other than genuine MHIET long life coolant by necessity, be sure to use the non-amine type LLC that meets our requirements. Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. disclaims the warranty claim for defects due to the use of LLC that does not meet our requirements.

Genuine MHIET 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.

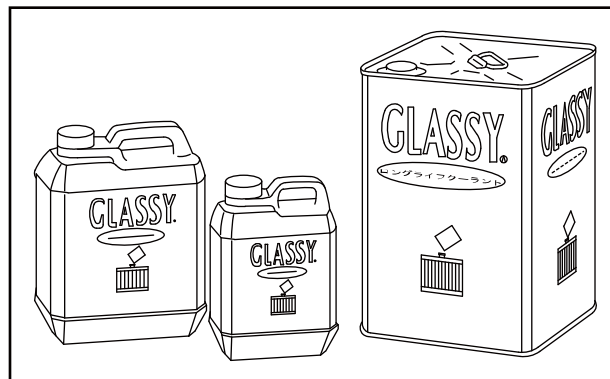


Fig. 6-1 GLASSY Long Life Coolant

Other Commercial LLCs

CAUTION

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

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

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

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

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

Requirements for Other Commercial LLCs

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

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

General Quality Requirements for LLC

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

LLC Quality Standard

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

Table 6-2 LLC Quality Standard

Test items		Standard value		
Visual inspection		No precipitation		
Specific gravity		Minimum 1.112 g/cm ³ [69.4199 lb/ft ³] (20/20°C) [68/68°F] (undiluted solution)		
Water content		5.0 weight % or lower (undiluted solution)		
Freezing temperature	30 volumetric % water solution	-14.5°C [5.9°F] or lower		
	50 volumetric % water solution	-34.0°C [-29.2°F] or lower		
Equilibrium reflex boiling point		155°C [311°F] or higher (undiluted solution)		
pH		7.0 to 11.0 (30 volumetric % water solution)		
Bubbling character (ASTM D3306-01)	30 volumetric % water solution	4.0 ml [0.0008 gal] or less		
	33 ¹ / ₃ vol % water solution	150 ml [0.032 gal] or less, deforming time 5 sec. or less		
Hard water compatibility		1.0 or less (50 volumetric % water solution)		
Metallic causticity (88±2°C [190.4±4°F], 336±2 Hr, 30 volumetric% water solution (eth- ylene glycol), 50 volumetric% water solution (pro- pylene glycol))	Metallic test piece	Mass change	Aluminum	±0.30 mg/cm ²
			Cast iron	±0.15 mg/cm ²
			Steel	±0.15 mg/cm ²
			Brass	±0.15 mg/cm ²
			Solder	±0.30 mg/cm ²
			Copper	±0.15 mg/cm ²
		Visual inspection of test piece after testing	Except the contact between the test piece and spacer, any corrosion should not be observed. Discoloration is allowed.	
		Bubble formation during test	Bubble shall not overflow.	
	Property of liquid after test	pH	6.5 to 11.0	
		pH change	±1.0	
Precipitation		0.5 volumetric % water solution or less		
Visual inspection of liquid		No significant discoloration. No signifi- cant changes such as separation and gel generation.		

Table 6-2 LLC Quality Standard

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

Table 6-2 LLC Quality Standard

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

Maintenance of LLC

 **CAUTION**

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

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

Replacement Intervals of LLC

CAUTION

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

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

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

LLC Concentration (GLASSY and PG GLASSY)

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

Table 6-3 Recommended LLC Concentration

Ambient 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%

- 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.
- Coolant temperature will increase by approx. 1.5°C [34.7°F] for 60% concentration of GLASSY (ethylene glycol) and approx. 3°C [37.4°F] for 90% concentration of PG GLASSY (propylene glycol). Check heat exchanger capacity of the cooling system to avoid overheating.

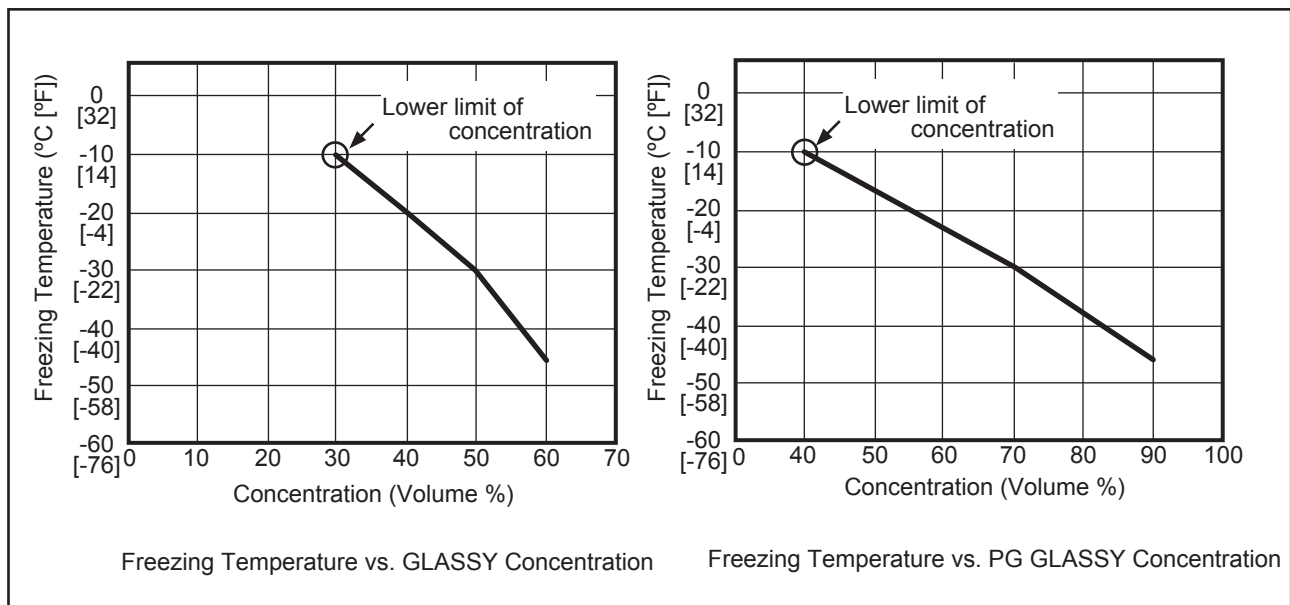


Fig. 6-2 Coolant Freezing Temperature (GLASSY and PG GLASSY)

LLC Concentration Measuring Method

Tool

Coolant tester

Part No. : 37591-00100

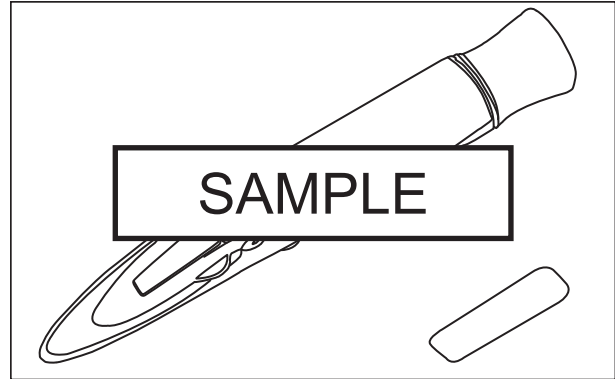


Fig. 6-3 Coolant tester

Calibration

1. Place 1 or 2 drips of distilled or tap water on the prism.

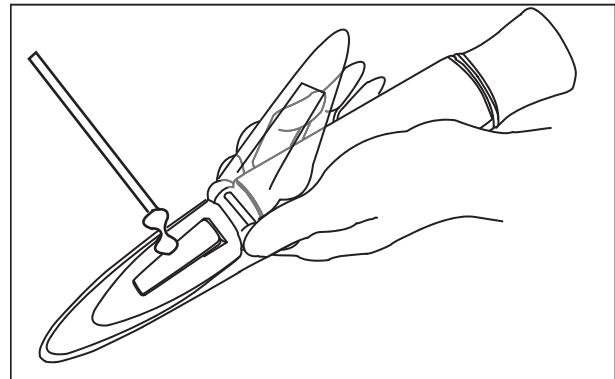


Fig. 6-4 Measuring procedure 1

2. Close the daylight plate gently.

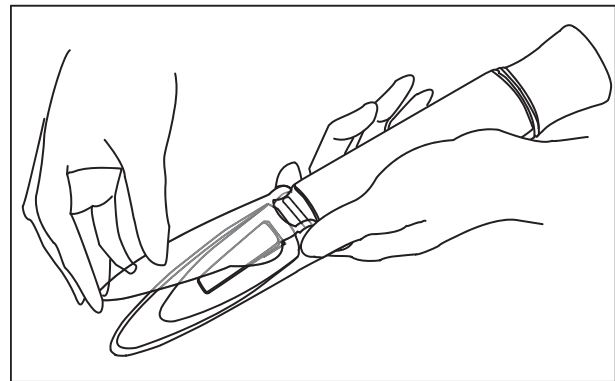


Fig. 6-5 Measuring procedure 2

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

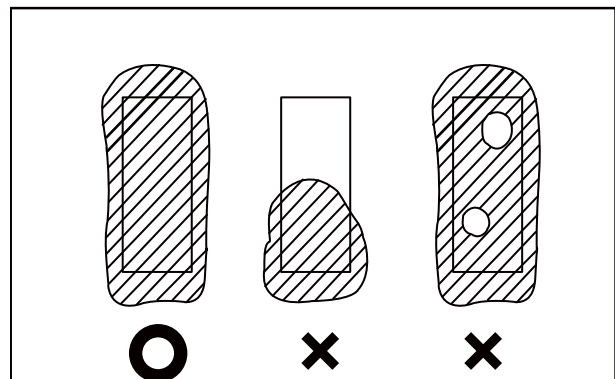


Fig. 6-6 Measuring procedure 3

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

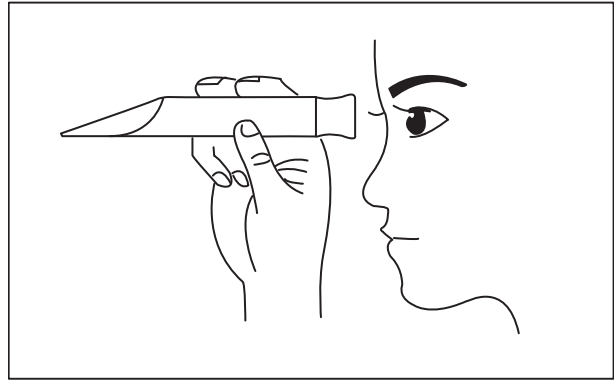


Fig. 6-7 Measuring procedure 4

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

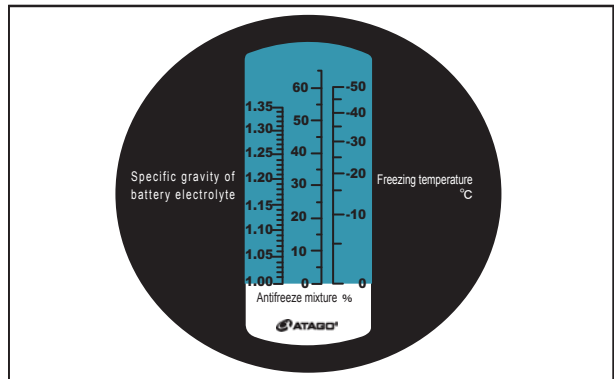


Fig. 6-8 Measuring procedure 5

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

CAUTION

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

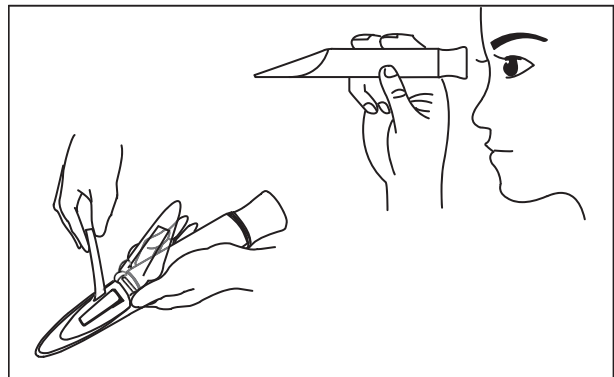


Fig. 6-9 Measuring procedure 6

Measurement

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

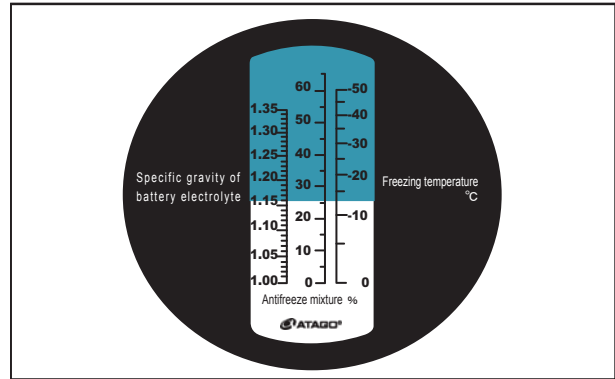


Fig. 6-10 Measuring procedure 7

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

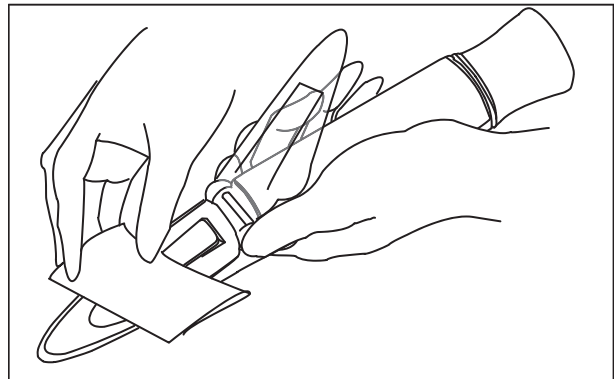


Fig. 6-11 Measuring procedure 8

Necessity of LLC

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

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

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

Characteristics of LLC Additives

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

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

Examples of Abnormalities Caused by Amine Type LLC

Pitting of Iron Parts

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

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

Corrosion of Aluminum Parts

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

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

Pitting and Clogging of Heat Exchanger

When LLC deteriorates or when its concentration in the coolant becomes low, the anti-corrosion performance of LLC lowers and it 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 troubles such as water leak and clogging in the heat exchanger.

Chapter 7 MAINTENANCE SCHEDULE

How to Use the Periodic Maintenance Schedule

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

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

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

Be sure to inspect the items which are included in the applicable interval and shorter intervals. For example, in the 2000 hour maintenance, also inspect those items listed in every 50, 250, 500, and 1000 hours.

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

Periodic Maintenance Schedule

Table 7-1 PERIODIC MAINTENANCE CHART

Service interval	Service Items	Page
Every day	Engine Exterior - Inspect	3-8
	Fuel Tank Oil Level - Check *1	3-9
	Engine Oil Level - Check	3-10
	Coolant Level - Check	3-11
	Fuel Control Link Ball Joint - Inspect	8-9
	Damper Temperature - Check	3-11
	Battery Fluid Level - Check *1	3-6
	Oil-Water Separator - Drain Water *1	-
	Valves and Plugs - Check	-
First 100 hours of operation (Only for the first time)	Engine Oil, Oil Filter, and Bypass Oil Filter - Replace	8-11
	Fuel Filter - Replace	8-8
	Valve Clearance - Inspect and Adjust	*
	Outer Bolts and Nuts on the Engine and Bolts on Engine Bed - Retighten	*
Every 250 service hours	Engine Oil, Oil Filter, and Bypass Oil Filter - Replace	8-11
	Belt and Belt Tension - Inspect and Adjust	8-2
	Pre-Cleaner - Clean, Inspect, and Replace	8-22
Every 500 service hours	Also the service contents the items for every 100 and 250 service hours.	—
	Gauze Filter - Clean	8-7
	Governor Oil Filter - Replace	8-14
Every 1000 service hours	Also the service contents the items for every 100, 250 and 500 service hours.	—
	Fuel Filter - Replace	8-14
	Oil-Water Separator Element - Replace	8-6
	Seawater Pump Impeller - Inspect	8-18
	Turbocharger Rotor Movement and Looseness - Inspect	*
	Valve Clearance - Inspect and Adjust	*
	Fuel Injection Nozzle - Inspect and Adjust	*
Every 2000 service hours or every 1 years	Also the service contents the items for every 500, 100, 250 and 1000 service hours.	—
	High Pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace	8-10
	Low-pressure Fuel Pipe and Clip - Inspect	8-10
	Fuel Injection Nozzle Tips - Replace	*
	Fuel Control Link Ball Joint - Inspect	*
	Seawater Pump Impeller - Replace	*
	Bolts and Nuts on Exhaust and Air Inlet Pipes - Retighten	*
	Damaged Harness and Loose Terminal - Inspect	*
	Axis - Check	*

Table 7-1 PERIODIC MAINTENANCE CHART

Service interval	Service Items	Page
	Also the service contents for the items for very 500, 100, 250, 1000 and 2000 service hours.	-
Every 4000 service hours	Engine Overhaul Cylinder Head - Disassembly and Inspect Valve Mechanism - Inspect Cylinder Liner Inside Surface - Inspect	*
	Belt - Replace	*
	Damper - Inspect	*
	Fuel Injection Timing - Inspect and Adjust	*
	Fuel Injection Pump Coupling Bolt and Laminated Plate - Inspect	*
	Fuel Link Ball Joints (for Stop Solenoid and Governor) - Replace	*
	Heat Exchanger - Clean	*
	Thermostat Operation - Check	*
	Inter Cooler Element - Clean	*
	Starter - Inspect	*
	Alternator - Inspect	*
Every 8000 service hours or every 2 years	Coolant (Fresh Water) - Change	*

Table 7-1 PERIODIC MAINTENANCE CHART

Service interval	Service Items	Page	
Every 8000 service hours or 3 years whichever comes first.	Including the service items for every 100, 250, 500, 1000, 2000, and 4000 service hours	-	
	Engine Overhaul	Piston - Check Piston Cooling Nozzle - Inspect Crankshaft - Inspect Main Bearing - Replace Thrust Plate - Replace Connecting Rod Bearing - Replace Camshaft Bushing - Inspect Cylinder Liner - Replace Piston Ring - Replace Inlet and Exhaust Valves - Replace Inlet and Exhaust Valve Seat Rings - Replace Valve Rotator - Replace Damper - Replace	*
	Fuel Flexible Hose - Replace	*	
	Fuel Injection Pump - Inspect and Test (Replace parts as needed)	*	
	Governor - Inspect and Test (Replace parts as needed)	*	
	Clamp Seat for High-Pressure Fuel Injection Pipe - Replace	*	
	Oil Cooler - Clean	*	
	Water Pump Unit Seal and Ball Bearing - Replace	*	
	Seawater Pump Unit Seal and Ball Bearing - Replace	*	
	Tension Pulley Bearing - Replace	*	
	Thermostat - Replace	*	
	Coolant Hose - Replace	*	
	Cap of Radiator - Replace	*	
	Turbocharger - Major Overhaul	*	
	Electrical Components - Inspect	*	
Relays - Replace	*		
Every 16000 service hours or 3 years whichever comes first. (12000 hours: recommended)	Including service items for every 100, 250, 500, 1000, 2000, 4000, and 8000 service hours	-	
	Replace the following parts with new ones: Piston, connecting rod bushing, piston pin, rocker bushing, 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 inspection and maintenance of the parts that are not supplied by MHIET, follow the instructions in the supplier's operation manual.
- (b) Items marked with * in the maintenance schedule require special tools and specialized maintenance service. Please contact your MHIET dealer for maintenance of those items.
- (c) Be sure to conduct periodic inspection at specified intervals, either service hours or years, whichever comes first.

Engine

Engine Exterior - Inspect

 **CAUTION**

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

Inspect the engine exterior as instructed below:

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

Belt and Belt Tension - Inspect and Adjust

CAUTION

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

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

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

Adjust the belt tension properly by following the procedures below:

Belt - Inspect

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

Belt Tension (Alternator Side) - Adjust

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

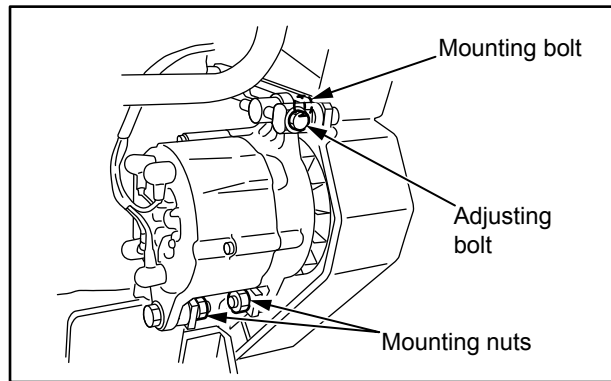


Fig. 8-1 Belt Tension (Alternator Side) - Adjust

Belt Tension (Fresh-Water Pump Side) - Adjust

1. Remove the belt cover.
2. Loosen all tension bracket retaining bolts.
3. Loosen the lock nut of adjusting bolt, and turn the adjusting bolt. Then, adjust the belt tension.
4. After tension is adjusted, tighten the lock nut of the adjusting bolt and the mounting bolt of tension bracket.
5. Install the belt cover.

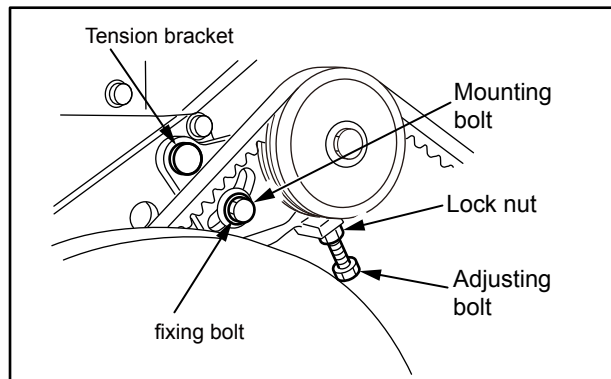


Fig. 8-2 Belt Tension (Fresh-Water Pump Side) - Adjust

Damper - Inspect

Damper - Check Visually

CAUTION

Do not use a closed type cover for the protection of damper.

The damper deteriorates, or its performance degrades due to the heat, which may cause serious engine problems.

visually check the damper for oil leak, scratch, deformation such as bulge of the cover (by applying a scale to it), and discoloration or peeling of paint due to heat. Especially, check carefully for the bulge of the cover (by applying a scale to it), oil leak from the caulking, discoloration and peeling of paint due to the heat.

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

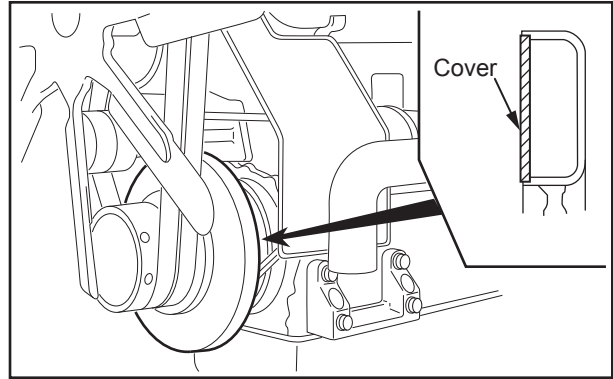


Fig. 8-3 Damper - Check Visually

Damper Temperature Control

To ensure the proper function of damper, heat must be dissipated from its surface to prevent excessive heating. MHIET inspects each engine before shipment to make sure that the temperature of damper does not excessively rise. However, the damper temperature varies depending on ambient conditions. Therefore, obey the instructions below, provide sufficient ventilation for the damper, and pay attention to the facility.

1. Make sure the temperature of the damper outer surface does not exceed 90°C [194°F] after operating the engine at the rated power for about an hour.
2. When installing a protective cover to the damper, provide adequate ventilation so that the damper temperature is 90°C [194°F] or below.
3. We recommend the use of the thermo label for temperature control.

Thermo Label - Use

When the thermo label reaches the specified temperature, the white heat-sensitive area turns into black color.

Note: Once the heat-sensitive area turns its color, it will never return to the original color again. Therefore, even when the temperature of damper is dropped after the engine has stopped, the thermo label still indicates the highest temperature when the engine was running.

1. Attach the thermo label to the damper outer circumference or front end near the outside diameter.
2. Record the highest temperature by checking the thermo label heat-sensitive area when the engine is not running.
Record the temperature regularly, and check any abnormal temperature change.

Note: (a) When the increase in thermo label temperature is observed, look for the abnormality of engine or other causes. Then, replace the thermo label with a new one, and check the temperature change again.

(b) If the temperature indication of thermo label comes close to the limit temperature of damper, or if there is any abnormal temperature change, contact your MHIET dealer.

(c) For damper temperature limit, refer to "Damper - Inspect" (8-3).

Table 8-1 Types of Thermo Labels

Part name	Part number	Measurable temperature range
Thermo label 100-120	32522-04211	100 to 120°C [212 to 248°F]
Thermo label 75-95	32522-04111	75 to 95°C [167 to 203°F]
Thermo label 50-70	32522-04311	50 to 70°C [122 to 158°F]

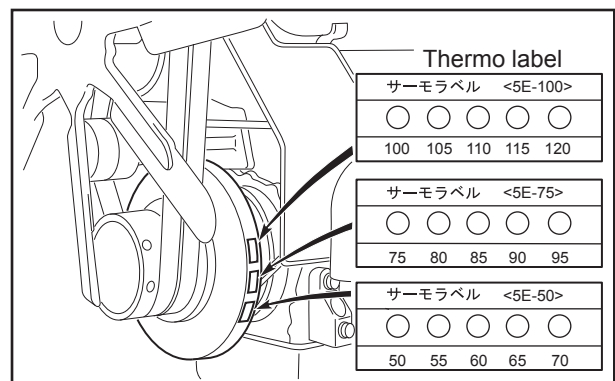


Fig. 8-4 Damper Temperature Control

Fuel system

Fuel System - Inspect

WARNING

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

Fuel Tank - Clean

CAUTION

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

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

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

Fuel Tank - Drain Water

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

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

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

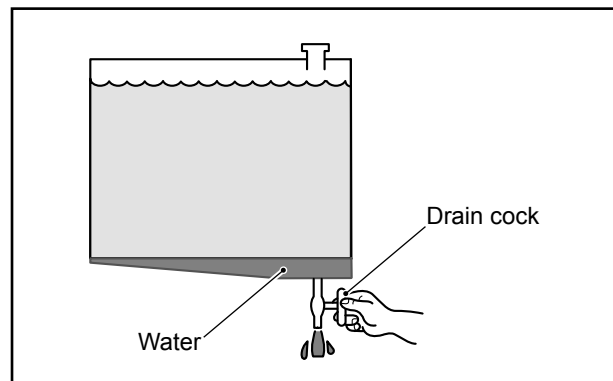


Fig. 8-5 Fuel Tank - Drain Water

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 fuel from overflowing. Wrap a cloth around the water separator just in case, as fuel may spill.

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

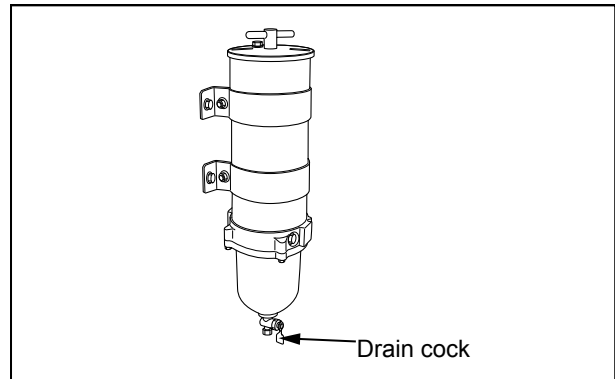


Fig. 8-6 Oil-Water Separator - Drain Water

Oil-Water Separator Element - Replace

1. Turn the T-handle, and remove the upper lid.
2. Open the drain cock, and drain fuel in the oil-water separator.
3. Close all drain cocks after draining.
4. Replace the element with a new one.
5. Fill the oil-water separator with fuel.
6. Attach the upper lid, and tighten the T-handle.
7. After replacing the element, open the fuel supply valve to the engine, then bleed air from the fuel system.

Note: To bleed air form oil-water separator, refer to ["Oil-Water Separator - Bleed Air" \(3-2\)](#).

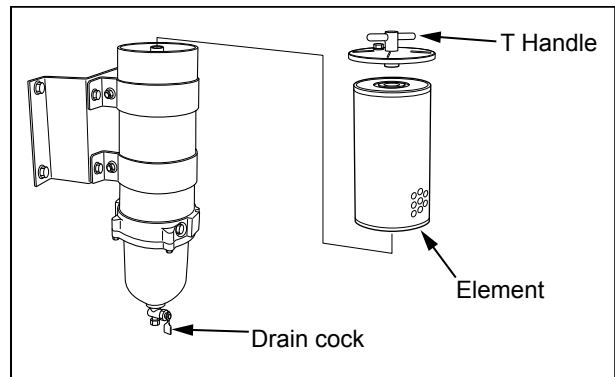


Fig. 8-7 Oil-Water Separator Element - Replace

Gauze Filter - Clean

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

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

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

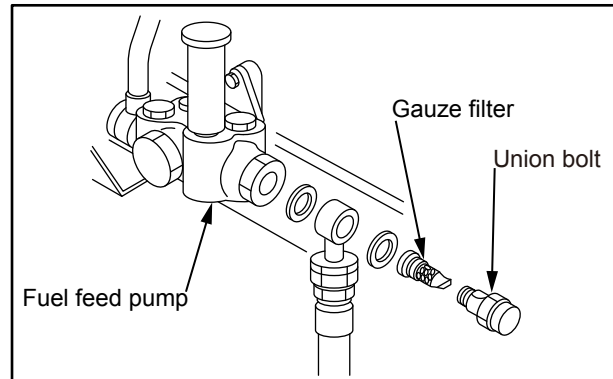


Fig. 8-8 Gauze Filter - Clean

Fuel Filter - Replace

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



WARNING

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

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

CAUTION

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

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

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

Note: To bleed air from the fuel filter, refer to "[Fuel Filter - Bleed Air](#)" (3-2).

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

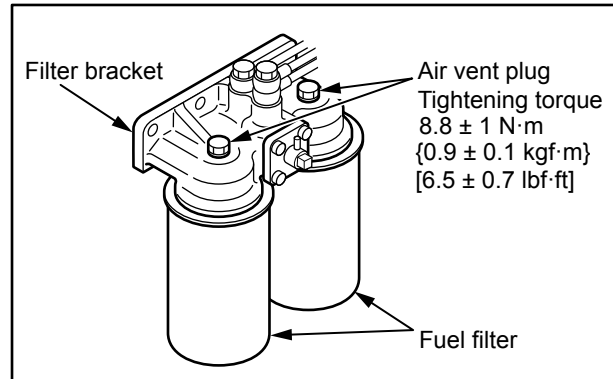


Fig. 8-9 Fuel Filter - Replace

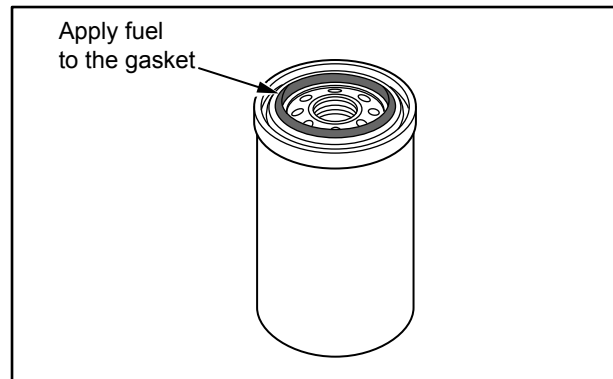


Fig. 8-10 Fuel filter

Fuel Control Link Ball Joint - Inspect

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

CAUTION

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

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

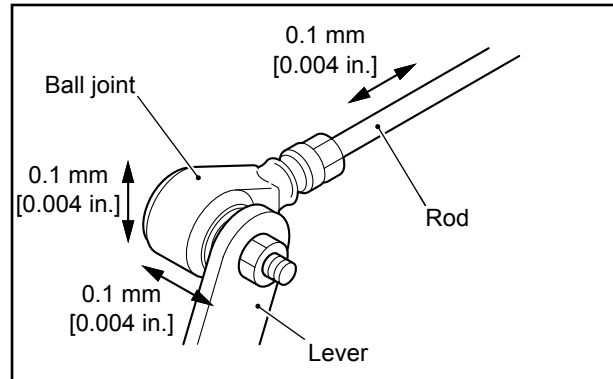


Fig. 8-11 Ball Joint - Check for Looseness

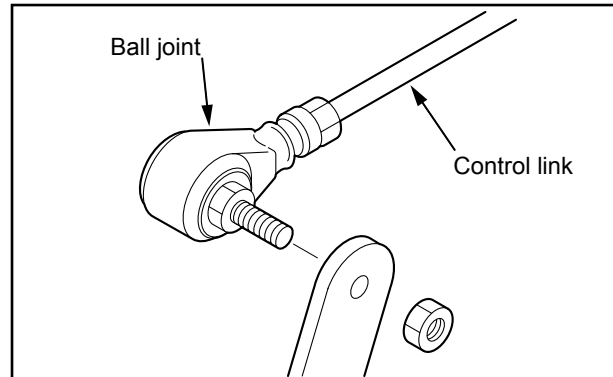


Fig. 8-12 Fuel Control Link - Remove

Fuel Pipe - Inspect

WARNING

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

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

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

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

Visual Inspection

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

Every Major Overhaul

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

Every Other Major Overhaul

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

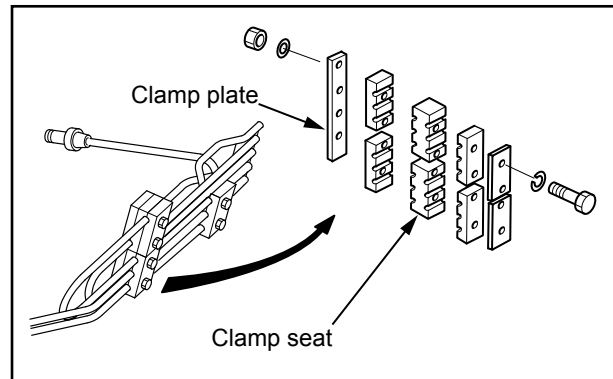


Fig. 8-13 High-pressure Fuel Injection Pipe and Clamp Seat - Inspect and Replace

Low-pressure Fuel Pipe and Clip - Inspect

Visual Inspection During Overhaul

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

Every Other Major Overhaul

Replace the pipe assembly with a new one.

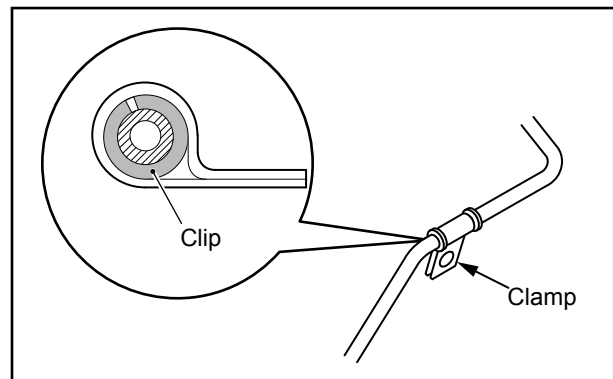


Fig. 8-14 Low-pressure Fuel Pipe and Clip - Inspect

Lubrication System

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

CAUTION

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

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

CAUTION

Do not dump drain oil casually into the sewage. It is prohibited by the law. For the disposal of drained oil, consult with your MHET dealer.

Change the engine oil, oil filter, and bypass oil filter at a time.

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

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

Engine Oil - Drain

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

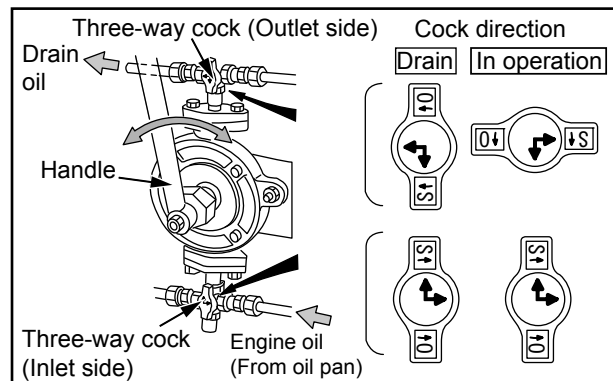


Fig. 8-15 Engine Oil - Drain

Oil Filter and Bypass Oil Filter - Replace

WARNING

If the filter case is dented, do not use the filter. Such filter may be damaged during operation and cause a fire due to oil leak.

CAUTION

Do not use a filter wrench to install the oil filter and bypass oil filter. Tighten the filter by hand. Be careful not to dent or scratch the oil filter surface.

1. Clean the area around the oil filter.
2. Prepare drip pans, and place them under oil filters and bypass oil filter.
3. Using a filter wrench, remove oil filters and bypass 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 filters and bypass filter to make sure the gasket is properly seated in the groove.
6. Apply clean engine oil to the gasket.
7. Install the oil filters and bypass oil filter to the filter bracket. When the gasket comes in contact with the mounting surface of the filter bracket, further rotate the filter by $3/4$ to a full turn.

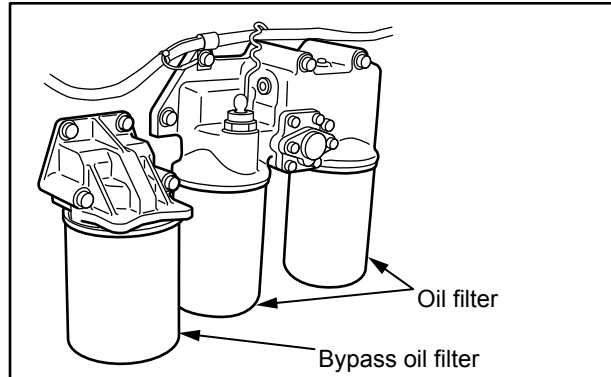


Fig. 8-16 Oil Filter and Bypass Oil Filter - Replace

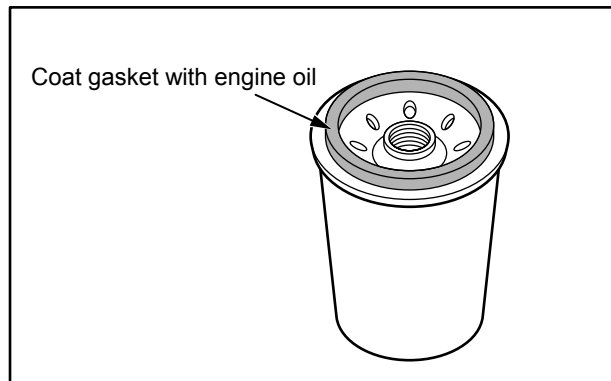


Fig. 8-17 Oil filter

Oil filter - Change while engine is running

The oil filter can be replaced while the engine is running, by turning the switchover cock located between the oil filters.

Note: When changing the oil filters using the switchover cock, be sure to decrease the engine speed and operate it at 600 min^{-1} (Non-load minimum engine speed).

1. Remove the switchover cock cover.
2. Turn the hexagon-head bolt using a wrench and set the pin to either the right or left position. In left, the left side oil filter can be replaced. If right, the right side oil filter can be replaced.
3. After finishing the replacement, set the pin position in the operating position and put the cover back into place.

Note: When replacnig the oil filters, engine oil may flow from the oil filter bases. Be sure to place a receiving tray under the oil filter bases.

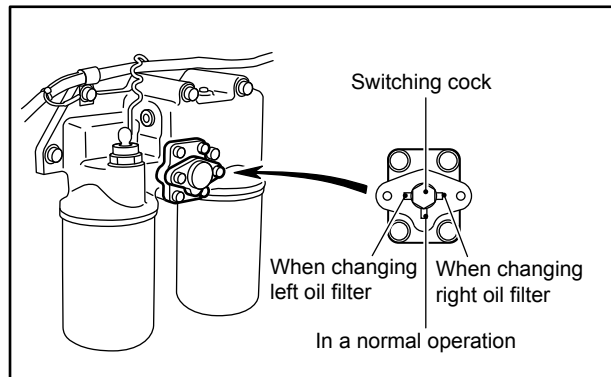


Fig. 8-18 Oil filter - Change while engine is running

Engine Oil - Refill

CAUTION

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

1. Remove the oil filler cap.
2. Add the specified engine oil to the specified level.
Note: For engine oil, refer to "**ENGINE OIL**" (5-1). For engine oil capacity, refer to "**MAIN SPECIFICATIONS**" (12-1).
3. Check the oil level in oil pan.
4. Pull out the oil level gauge and wipe it clean with a cloth.
5. Insert the oil level gauge fully into the oil level gauge guide and then pull it out again.
6. The oil level should be between the maximum and minimum marks on the oil level gauge.
If the engine oil level is higher than the high mark on the oil level gauge, drain engine oil by opening the drain valve. If the engine oil level is low, add the specified engine oil.
7. Install the oil filler cap after engine oil is refilled.
8. Check the oil pan and others for oil leaks. Repair if there is an oil leak.
9. With the manual stop lever placed in the pulled position, rotate the engine with starter for approx. 10 seconds to circulate oil to the engine thoroughly. Stop the rotation for 1 minute, then, repeat the rotation two or three times to circulate the engine oil to each engine parts.
Note: Also, perform the items described under the Preparation of Cooling System.
10. Check the oil level with the oil level gauge again, and add oil to the specified level.

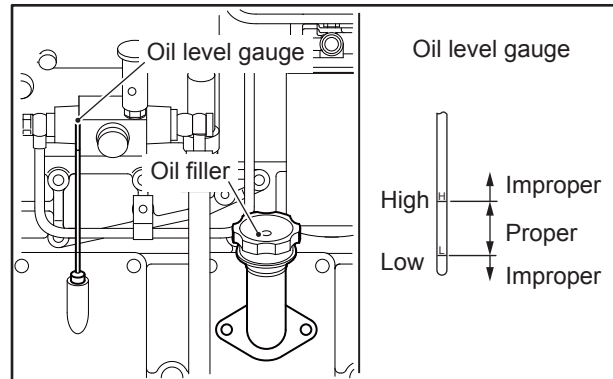


Fig. 8-19 Oil Filler and Oil Level Gauge

Ingress of Fuel and Water In Engine Oil - Inspect

CAUTION

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

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

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

If water is mixed, oil may turn milky white.

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

If the coolant enters the engine oil during operation, moisture vapor is discharged from the breather. In such a case, locate the fuel or water leak, and repair properly.

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

Governor Oil Filter - Replace

WARNING

When draining oil or replacing oil filters, be sure to wear gloves. Hot engine oil and parts can 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 with the new filter 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. Add engine oil until the filter is filled with oil.
10. After the oil has been filled, install the air vent plug.

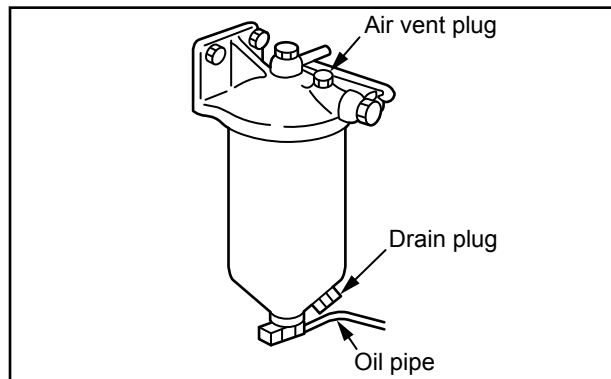


Fig. 8-20 Governor Oil - Drain

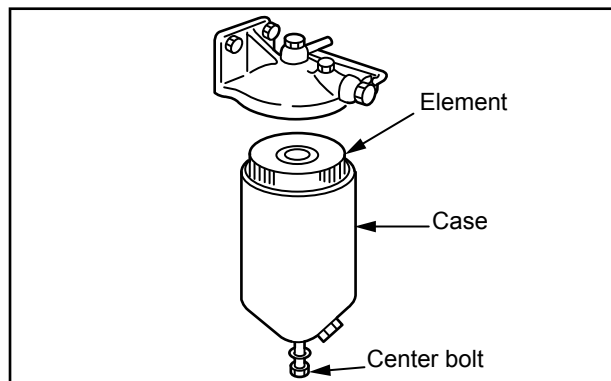


Fig. 8-21 Governor Oil Filter - Replace

Oil Pipe - Inspect

Oil Pipe and Clip - Inspect and Replace Visual Inspection During Overhaul

Loosen clamp fixing bolts, and check clips and pipes for wear. If defective, replace the pipe assembly with a new one.

Every Other Major Overhaul

Replace the pipe assembly with a new one.

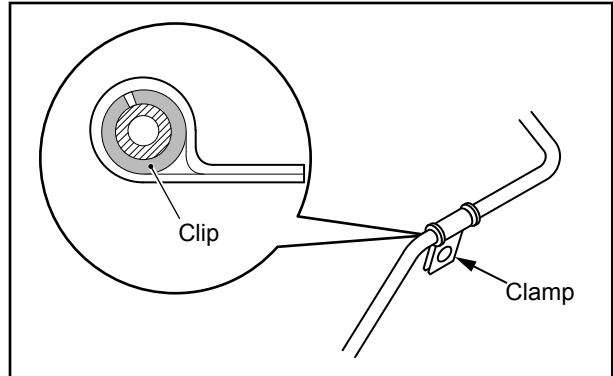


Fig. 8-22 Oil Pipe and Clip - Inspect and Replace

Cooling system

Coolant - Change

CAUTION

Do not dump the used coolant (containing LLC) casually into the sewage. Such a way of disposal is strictly prohibited by laws and regulations. Obey the applicable laws and regulations for the disposal of coolant.

CAUTION

When a coolant mixed with the LLC recommended by our company is used, replace the coolant every 8000 hours or 2 years, whichever comes first for the continuous use engine. For the emergency use engine, be sure to replace the coolant once every 2 years.

Radiator Cap - Open/Close

WARNING

Never open the radiator cap during the operation or immediately after stopping. Stop the engine, and then open the cap after the coolant temperature has dropped sufficiently.

Place a waste cloth over the radiator cap, and loosen the cap about a quarter-turn or stand the lever to the upright position to release internal pressure.

Do not open the radiator cap when the engine is running or immediately after stopping. You can get burn yourself due to hot steam. To prevent burn injuries from hot steam, wear thick rubber gloves or wrap a cloth around the cap.

When fastening the radiator cap, be sure to tighten securely.

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

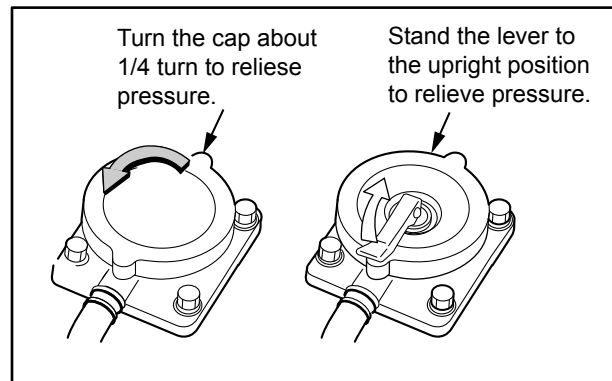


Fig. 8-23 Radiator Cap

Coolant - Drain

1. To drain coolant immediately after engine operation, run the engine at low idle for 5 to 6 minutes to lower the coolant temperature to 70 to 80°C [158 to 176°F].
2. Open the coolant inlet.
3. Place a coolant receiving can, and open the coolant drain cock and plug to drain the coolant.

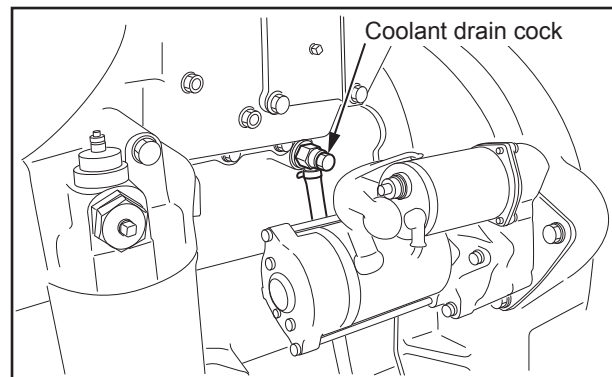


Fig. 8-24 Coolant Drain Cock (Engine)

Cooling System - Clean

CAUTION

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

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

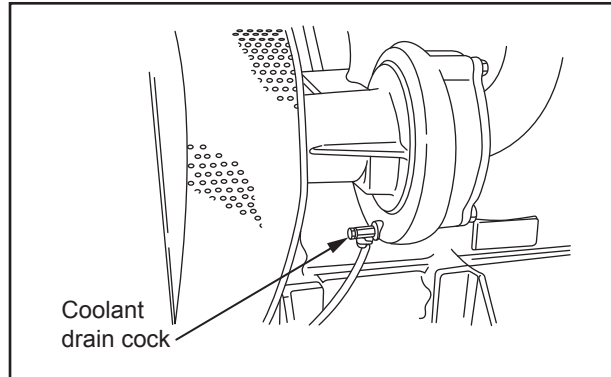


Fig. 8-25 Coolant Drain Cock (Water Pump)

Coolant - Refill

CAUTION

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

1. Close coolant drain cocks and plugs firmly.
2. Open the coolant filler port and add a mixture of water and coolant (LLC) having the specified concentration.
Note: Determine the amount of LLC using the LLC concentration chart.
For the coolant, refer to ["COOLANT" \(6-1\)](#). For the coolant capacity, refer to ["MAIN SPECIFICATIONS" \(12-1\)](#).
3. Check the heat exchanger, etc. for coolant leaks. If a leak is found, repair it.
4. When coolant reaches the full level, close the coolant filler securely.
5. With the manual stop lever placed in the pulled position, crank the engine for approximately 10 seconds using the starter. Stop for approximately 1 minute, and then repeat the cranking 2 or 3 times to bleed air from the cooling system.
Note: Also, perform the items described under the Preparation of Lubrication System.
6. Check the coolant level.

Seawater - Drain

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

1. Make sure that the kingston valve is closed.
2. Open the seawater drain cock or remove the plug to drain seawater.
3. Remove the seawater pump cover, and drain seawater from the seawater pump.

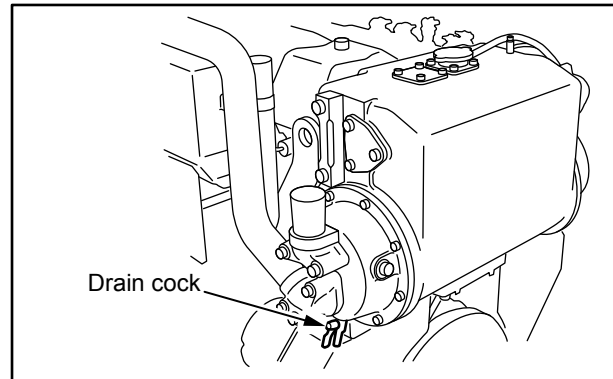


Fig. 8-26 Seawater Drain Cock (Heat Exchanger)

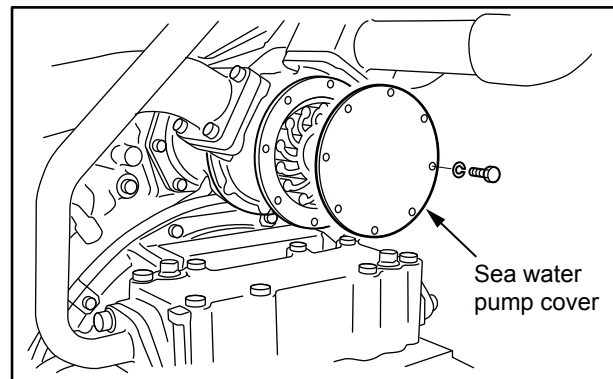


Fig. 8-27 Seawater Pump Cover

Seawater Pump Impeller - Inspect

CAUTION

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

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

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

Please use commercially available puller or make it by yourself.

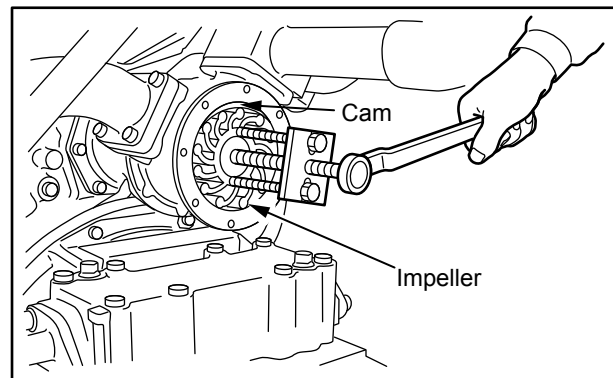


Fig. 8-28 Seawater Pump Impeller - Inspect

Zinc Rod - Inspect

Zinc rods (zinc electrodes) are installed at various sections of the seawater passage to prevent corrosion caused by seawater.

1. Remove each zinc rod and remove deposits (scale) from the surface of rod.
2. If the zinc rod has worn to half the original size, replace it with a new zinc rod. If the zinc rod is not less than half the original size, reinstall it.

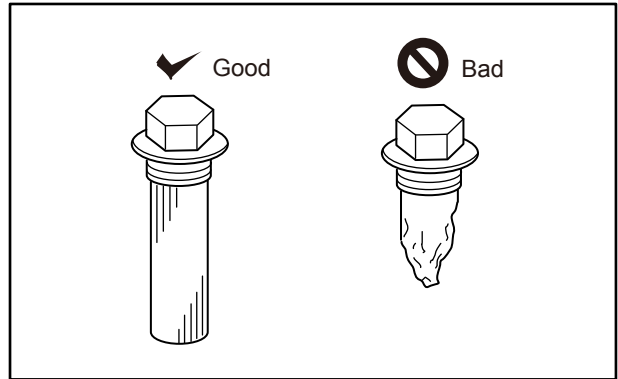


Fig. 8-29 Zinc Rod - Judge

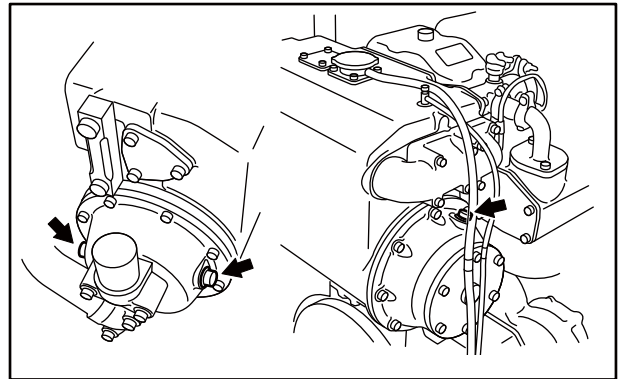


Fig. 8-30 Zinc Rod Mounting Location
(Heat Exchanger)

Seawater Strainer Mesh Filter - Clean and Replace

CAUTION

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

Piping shall be free from deformation and stress.

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

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

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

Be sure to tighten to the proper tightening torque.

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

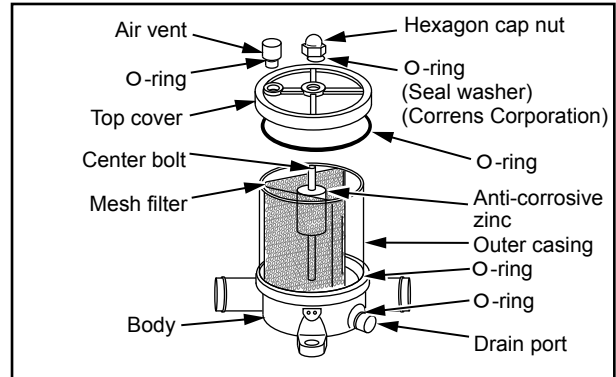


Fig. 8-31 Seawater Strainer Mesh Filter - Clean and Replace

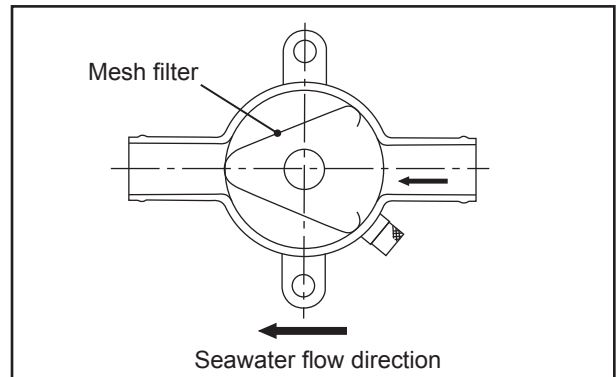


Fig. 8-32 Mounting Orientation of Strainer Mesh Filter

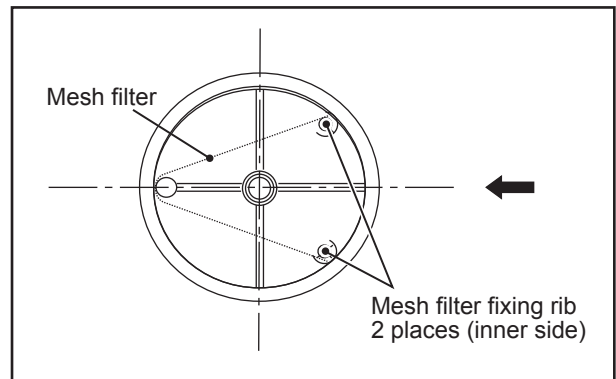


Fig. 8-33 Arrangement to Top Cover

Inlet and exhaust systems

Turbocharger - Inspect

CAUTION

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

CAUTION

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

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

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

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

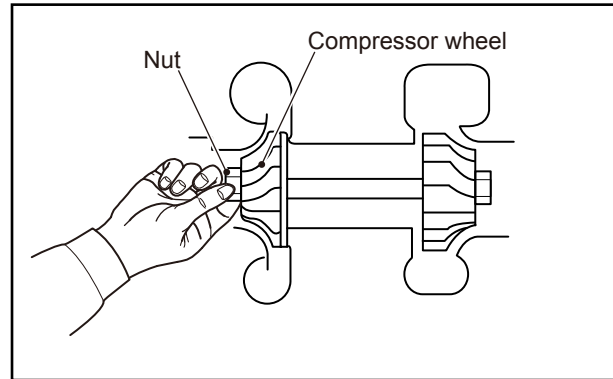


Fig. 8-34 Turbocharger - Inspect

Pre-Cleaner - Clean, Inspect, and Replace

CAUTION

Never conduct the maintenance of pre-cleaner during engine operation. If dust and dirt enter the engine, it will cause rapid wear of parts, shortening the service life of the engine.

The pre-cleaner, which is attached to the silencer of the turbocharger, prevents foreign substances from entering the engine, and keeps the engine clean for optimum performance. Always keep it clean as instructed below.

Note: If the specification of pre-cleaner differs from the contents of this operation manual, follow the air cleaner manufacturer's operation manual.

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

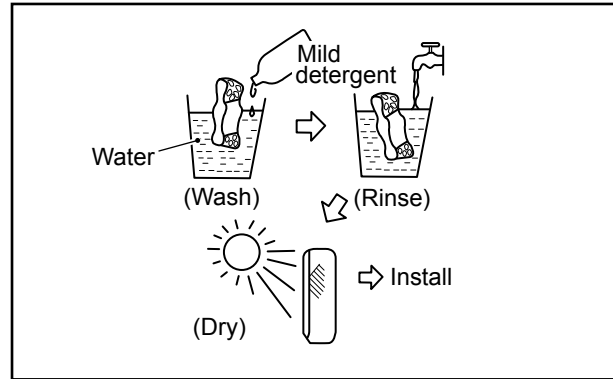


Fig. 8-35 Pre-Cleaner - Wash

Electrical System

Battery - Check

CAUTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Battery Fluid Level - Check

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

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

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

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

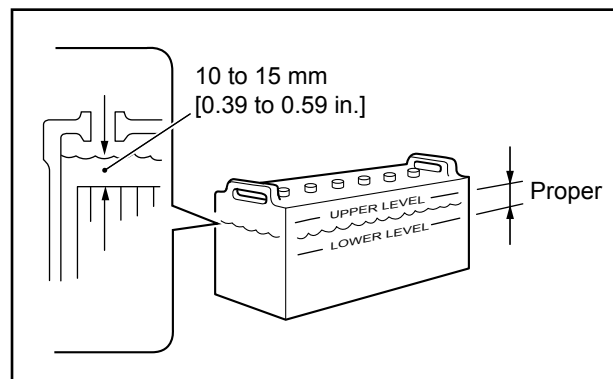


Fig. 8-36 Battery Fluid Level - Check

Specific Gravity of Battery Electrolyte - Check

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

Table 8-2 Specific Gravity of Battery Electrolyte

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

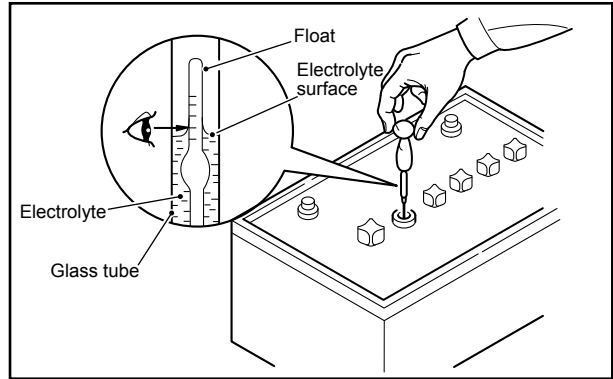


Fig. 8-37 Specific Gravity of Battery Electrolyte - Check

Starter - Inspect

Visually inspect the starter and ring gear for damage.

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

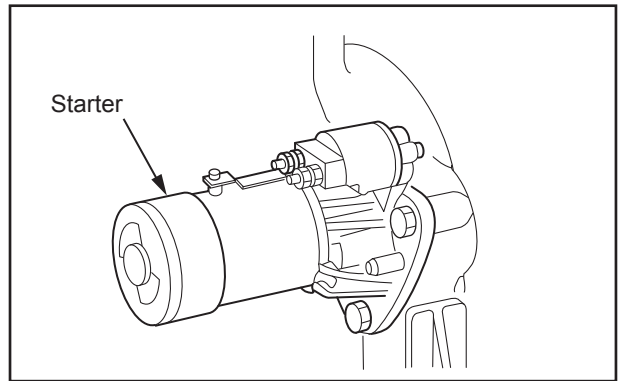


Fig. 8-38 Starter - Inspect

Alternator - Inspect

Visually inspect the alternator for damage.

Remove the belt and turn the pulley by hand to check the smooth rotation. Check the pulley for wear.

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

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

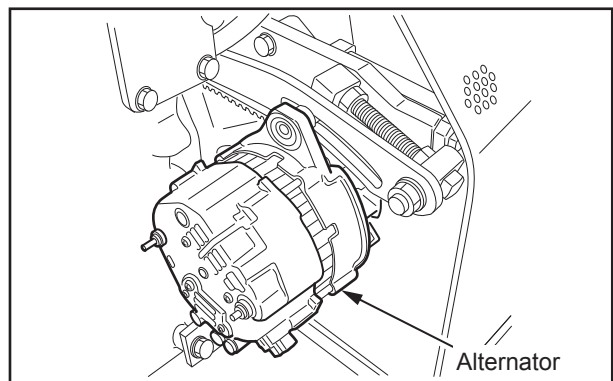


Fig. 8-39 Alternator - Inspect

Chapter 9 LONG-TERM STORAGE

CAUTION

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

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

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

Preparation for Storage

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

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

(b) It is not necessary to drain coolant since it contains LLC. (LLC must be the specified concentration. For the LLC concentration, refer to "[LLC Concentration \(GLASSY and PG GLASSY\)](#)" (6-7).)

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

Recommended Rust-Preventive Oil and Corrosion Inhibitor

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

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

Maintenance During Storage

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

When Using Engine After Storage

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

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

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

Note: To bleed air from the fuel system, refer to "[Bleeding the Fuel System](#)" (3-1).

8. Check the engine oil and coolant level.
 9. When the emergency generator is equipped with a water heater, turn the water heater switch to the ON position, and wait until the cooling water temperature becomes a proper value (35°C [95°F] or higher).
 10. Inspect every part of the engine.
 11. Remove the rocker covers, and lubricate the valve mechanisms.
 12. 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.
 13. After starting, make sure the engine oil pressure rises.
 14. Conduct a warm-up operation for a sufficient duration to fully lubricate all the components.
- Note: For engine starting procedure, refer to "[Start-up](#)" (3-12).
15. Apply load and increase the engine speed to the rated speed.

Storing Engine in an Operable Condition

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

Operation for Maintenance Purpose

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

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

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

Lifting Engine

WARNING

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

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

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

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

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

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

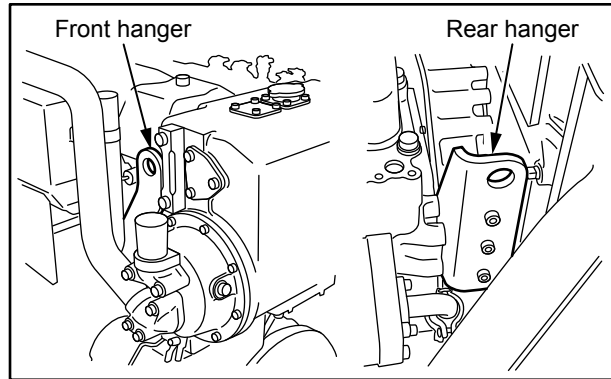


Fig. 10-1 Lifting Hangers

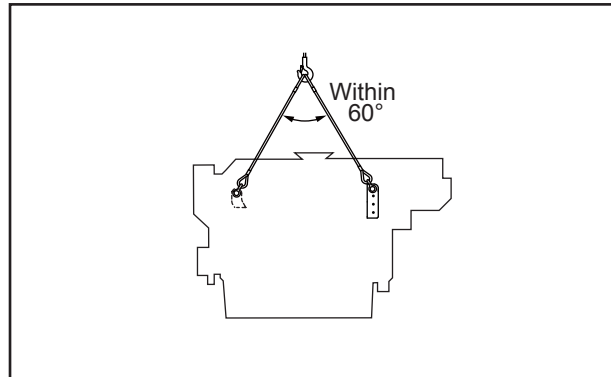


Fig. 10-2 Hitching Wire Ropes

General Precautions

Contact Your MHIET Dealer for Repair Service

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

Considerations Before Proceeding with Corrective Action

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

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

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

Cautions Against Contamination

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

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

Cautions for Parts Handling

Handle parts carefully.

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

Safety Working Practices

Be sure to use a tool suitable for the size. Using a tool of wrong size can cause not only the damage to the part but also the personal injury.

Use correct tools, and perform work with the utmost care.

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

Before proceeding with engine inspection, change the switch on generator panel from auto mode to manual mode, and place the battery switch to the OFF position so that the engine will not start in the event of power failure. And also, prepare an auxiliary or temporary generator set in case of unexpected electric power interruption, or notice the condition to the electricity user before the inspection.

Problems, Probable Causes, and Solutions

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

Table 11-1 The Starter Does not Crank or Cranks Slowly, Resulting in Start Failure

Possible cause		Solution
Electrical system	Faulty wire connection	<ul style="list-style-type: none"> ♦Fuse - Inspect ♦Wiring connection of each relay between battery, starter, and starter switch - Inspect
	Battery charge failure	<ul style="list-style-type: none"> ♦Alternator - Inspect (Refer to P8-24) ♦Belt - Inspect and Adjust (Refer to P8-2)
	Weak battery	<ul style="list-style-type: none"> ♦Specific gravity of battery electrolyte - Check (Refer to P8-24) ♦Battery - Charge ♦Battery - Replace
	Faulty starter or faulty safety relay	♦Contact your MHIET dealer.
Lubricating system	Oil viscosity too high	♦Use appropriate engine oil. (Refer to P5-1)
	Excessive oil level	♦Engine oil level and lubrication system - Check (Refer to P3-10)
Engine	Sliding parts rapid wear or lock	♦Contact your MHIET dealer.

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

Starter Cranks, but Engine Does Not Start

Table 11-2 Starter Cranks, but Engine Does Not Start

Possible cause		Solution
Fuel system	Run out of fuel, blocked pipe	♦Fuel Tank - Inspect, Refill, and Bleed Air (Refer to P8-3) ♦Fuel Pipes and Valves - Inspect
	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1) ♦Dust, water, or impurities - Remove (Refer to P8-5)
	Fuel leaks from fuel line or injection pipe	♦Fuel Line and Injection pipes - Check and Tighten ♦Contact your MHIET dealer.
	Clogged fuel filter	♦Fuel filter - Inspect and Replace (Refer to P8-8) ♦Gauze filter - Clean (Refer to P8-7)
	Fuel feed pump malfunction	♦Contact your MHIET dealer.
	Fuel injection pump malfunction	♦Fuel injection pump rack stroke - Inspect ♦Contact your MHIET dealer.
	Fuel injection nozzle malfunction	♦Contact your MHIET dealer.
Air Intake system	Insufficient amount of intake air	♦Turbocharger - Inspect (Refer to P8-21) ♦Pre-cleaner - Clean, Inspect and Replace (Refer to P8-22)
Control system	Governor malfunction	♦Fuel control link - Check (Refer to P8-9) ♦Contact your MHIET dealer.
Engine	Compression pressure drop	♦Contact your MHIET dealer.

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

Poor Output

Table 11-3 Poor Output

Possible cause		Solution
Fuel system	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	♦Fuel injection pump drive coupling - Inspect ♦Contact your MHIET dealer.
	Improper maximum injection volume	♦Fuel injection pump rack stroke - Inspect ♦Contact your MHIET dealer.
	Clogged fuel filter	♦Fuel filter - Inspect and Replace (Refer to P8-8) ♦Gauze filter - Clean (Refer to P8-7)
	Fuel feed pump malfunction	♦Contact your MHIET dealer.
Cooling system	Overheating or overcooling	♦Fan and heat exchanger - Inspect ♦Control system - Inspect ♦Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	♦Turbocharger - Inspect (Refer to P8-21) ♦Pre-cleaner - Clean, Inspect and Replace (Refer to P8-22) ♦Intake air pressure and intake air leaks - Inspect ♦Intake air temperature and ventilation system - Inspect ♦Contact your MHIET dealer.
	Increase of exhaust resistance	♦Turbocharger - Inspect (Refer to P8-21) ♦Check exhaust pipes and silencer. ♦Contact your MHIET dealer.
Control system	Faulty governor control	♦Contact your MHIET dealer.
Engine	Compression pressure drop	♦Contact your MHIET dealer.
	Faulty valve timing	♦Contact your MHIET dealer.
	Worn sliding parts	♦Contact your MHIET dealer.

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

Exhaust Smoke is White or Blue

Table 11-4 Exhaust Smoke is White or Blue

Possible cause		Solution
Fuel system	Improper fuel properties	♦Check cetane index, and use appropriate fuel. (Refer to P4-1)
	Faulty fuel injection timing	♦Fuel injection pump drive coupling - Inspect ♦Contact your MHIET dealer.
	Uneven volume of fuel injection	♦Ignition noise and exhaust smoke temperature - Inspect ♦Contact your MHIET dealer.
	Fuel injection nozzle malfunction	♦Contact your MHIET dealer.
Lubricating system	Combustion of engine oil	♦Engine oil level and lubrication system - Check (Refer to P3-10) ♦Contact your MHIET dealer.
Cooling system	Overcooling	♦Heat exchanger - Check ♦Control system - Inspect ♦Thermostat - Inspect ♦Contact your MHIET dealer.
Engine	Faulty valve timing	♦Contact your MHIET dealer.
	Compression pressure drop	♦Contact your MHIET dealer.

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

Exhaust Smoke is Black or Grey

Table 11-5 Exhaust Smoke is Black or Grey

Possible cause		Solution
Fuel system	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1)
	Fuel feed pump malfunction	♦Contact your MHIET dealer.
	Fuel injection pump malfunction	♦Contact your MHIET dealer.
	Fuel injection nozzle malfunction	♦Contact your MHIET dealer.
	Faulty fuel injection timing	♦Fuel injection pump drive coupling - Inspect ♦Contact your MHIET dealer.
	Uneven volume of fuel injection	♦Ignition noise and exhaust smoke temperature - Inspect ♦Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	♦Turbocharger - Inspect (Refer to P8-21) ♦Pre-cleaner - Clean, Inspect and Replace (Refer to P8-22) ♦Intake air pressure and intake air leaks - Inspect ♦Intake air temperature and ventilation system - Inspect ♦Contact your MHIET dealer.
	Increase of exhaust resistance	♦Turbocharger - Inspect (Refer to P8-21) ♦Check exhaust pipes and silencer. ♦Contact your MHIET dealer.
Engine	Compression pressure drop	♦Contact your MHIET dealer.
	Faulty valve timing	♦Contact your MHIET dealer.
	Worn sliding parts	♦Contact your MHIET dealer.
Control system	Excessive load	♦Control system and governor controller - Check ♦Contact your MHIET dealer.

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

Excessive Fuel Consumption

Table 11-6 Excessive Fuel Consumption

Possible cause		Solution
Fuel system	Fuel injection nozzle malfunction	♦Contact your MHIET dealer.
	Faulty fuel injection timing	♦Fuel injection pump drive coupling - Inspect ♦Contact your MHIET dealer.
	Improper fuel properties	♦Use appropriate fuel. (Refer to P4-1)
	Fuel leaks from fuel line or injection pipe	♦Fuel lines and injection pipes - Check and Retighten ♦Contact your MHIET dealer.
Cooling system	Overcooling	♦Check fan and heat exchanger. ♦Control system - Inspect ♦Thermostat - Inspect ♦Contact your MHIET dealer.
Inlet and exhaust systems	Insufficient amount of intake air	♦Turbocharger - Inspect (Refer to P8-21) ♦Pre-cleaner - Clean, Inspect and Replace (Refer to P8-22) ♦Intake air pressure and intake air leaks - Inspect ♦Intake air temperature and ventilation system - Inspect ♦Contact your MHIET dealer.
	Increase of exhaust resistance	♦Turbocharger - Inspect (Refer to P8-21) ♦Check exhaust pipes and silencer. ♦Contact your MHIET dealer.
Engine	Compression pressure drop	♦Contact your MHIET dealer.
	Faulty valve timing	♦Contact your MHIET dealer.
	Worn sliding parts	♦Contact your MHIET dealer.

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

Excessive Engine Oil Consumption

Table 11-7 Excessive Engine Oil Consumption

Possible cause		Solution
Fuel system	Faulty fuel injection timing	<ul style="list-style-type: none"> ♦Fuel injection pump drive coupling - Inspect ♦Contact your MHIET dealer.
Lubricating system	Oil leaking on outside engine	<ul style="list-style-type: none"> ♦Oil leaks - Inspect ♦Contact your MHIET dealer.
	Faulty engine oil property (viscosity)	<ul style="list-style-type: none"> ♦Analyze oil property. Use appropriate engine oil. (Refer to P5-1)
	Excessive engine oil temperature	<ul style="list-style-type: none"> ♦Engine oil level and lubrication system - Check (Refer to P3-10) ♦Oil cooler and oil thermostat - Inspect ♦Contact your MHIET dealer.
Cooling system	Overheating	<ul style="list-style-type: none"> ♦Heat exchanger - Check ♦Control system - Inspect ♦Thermostat - Inspect ♦Contact your MHIET dealer.
Inlet and exhaust systems	Oil entry to the air chamber	<ul style="list-style-type: none"> ♦Oil leakage to the turbocharger - Check ♦Contact your MHIET dealer.
	Worn parts in valve system	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.
Control system	Excessive load	<ul style="list-style-type: none"> ♦Control system and governor controller - Check ♦Contact your MHIET dealer.
Engine	Worn sliding parts	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.

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

Overheating

Table 11-8 Overheating

Possible cause		Solution
Cooling system	Insufficient coolant level	<ul style="list-style-type: none"> ♦Coolant leaks - Inspect ♦Coolant level - Check (Refer to P3-11)
	Water Pump faulty operation	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.
	Faulty thermostat operation	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.
	Faulty heat exchanger operation	<ul style="list-style-type: none"> ♦Heat exchanger - Inspect and Clean
Control system	Excessive load	<ul style="list-style-type: none"> ♦Fuel injection pump rack stroke - Inspect ♦Control system and governor controller - Check ♦Contact your MHIET dealer.
Engine	Worn sliding parts	<ul style="list-style-type: none"> ♦Contact your MHIET dealer.

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

Engine Oil Pressure Drop

Table 11-9 Engine Oil Pressure Drop

Possible cause		Solution
Lubricating system	Low engine oil level	♦Engine oil level and lubrication system - Check (Refer to P3-10)
	Faulty engine oil property (viscosity)	♦Oil property analysis. Use appropriate engine oil. (Refer to P5-1)
	Excessive engine oil temperature	♦Cooling system - Check ♦Contact your MHIET dealer.
	Clogged oil filter	♦Oil filter and bypass oil filter - Inspect and Replace (Refer to P8-12)
	Faulty oil pump operation	♦Contact your MHIET dealer.
	Faulty relief valve operation	♦Contact your MHIET dealer.
Control system	Oil pressure gauge failure	♦Control system and wiring - Inspect ♦Contact your MHIET dealer.
Engine	Rapid wear of sliding parts	♦Contact your MHIET dealer.
	Increased clearance of sliding part	♦Contact your MHIET dealer.
Load system	Excessive load	♦Fuel loading system - Check ♦Contact your MHIET dealer.

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

When Fuel has Run Out

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

1. Turn the starter switch to the "OFF" position.
2. Add fuel to the fuel tank.
For refilling fuel tank, refer to ["Fuel Tank Oil Level - Check" \(3-9\)](#).
3. Bleed air from the fuel system.
To bleed air from the fuel system, refer to ["Bleeding the Fuel System" \(3-1\)](#).
4. Start the engine.
For engine starting procedure, refer to ["Start-up" \(3-12\)](#).

Chapter 12 MAIN SPECIFICATIONS

Table 12-1 Main Specifications

Item	Specification
Engine model	S6A3-T2MPTK3L
Continuous output	558 kW / 1,900 min ⁻¹
Type	Vertical, water-cooled, 4-stroke cycle, turbocharged with inter cooler
No. of cylinders - Arrangement	6 cylinders, in-line
Cylinder bore x stroke	ø150 × 175 mm [5.91 × 6.89 in.]
Displacement (declared value)	18.56 L [1132.77 cu in.]
Combustion system	Direct injection system
Compression ratio	14.5 : 1
Firing order	1-5-3-6-2-4
Direction of rotation	Counterclockwise as viewed from flywheel side
Dimensions (L x W x H)	2189 × 1127 × 1421 mm [86.18 × 44.37 × 55.94 in.]
Dry weight	Approx. 2100 kg [4630 lb]
Fuel	Diesel fuel
Fuel injection pump	PS6 type
Fuel filter	Cartridge type paper-element
Fuel injection nozzle	Hole type
Fuel injection starting pressure	29.4 MPa {299.8 kgf/cm ² } [4264.1 psi]
Governor	Hydraulic type (all-speed control)
Lubricating method	Forced circulation (pressure feed by oil pump)
Lube oil	Category CF oil (API service classification)
Engine oil capacity	Approx. 110 L [29.06 US gal.]
Oil filter	Cartridge type paper-element
Oil cooler	Water-cooled, multi-plate type
Cooling method	Freshwater cooler directly connected to engine
Cooling freshwater capacity	Approx. 36 L [9.51 US gal.]
Starting system	Electric start
Starter	DC 24V - 6 kW
Alternator	DC 24 V - 35 A
Turbocharger	Mitsubishi TD13L4

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

Chapter 13 ELECTRICAL WIRING DIAGRAM

Electrical Wiring Diagram

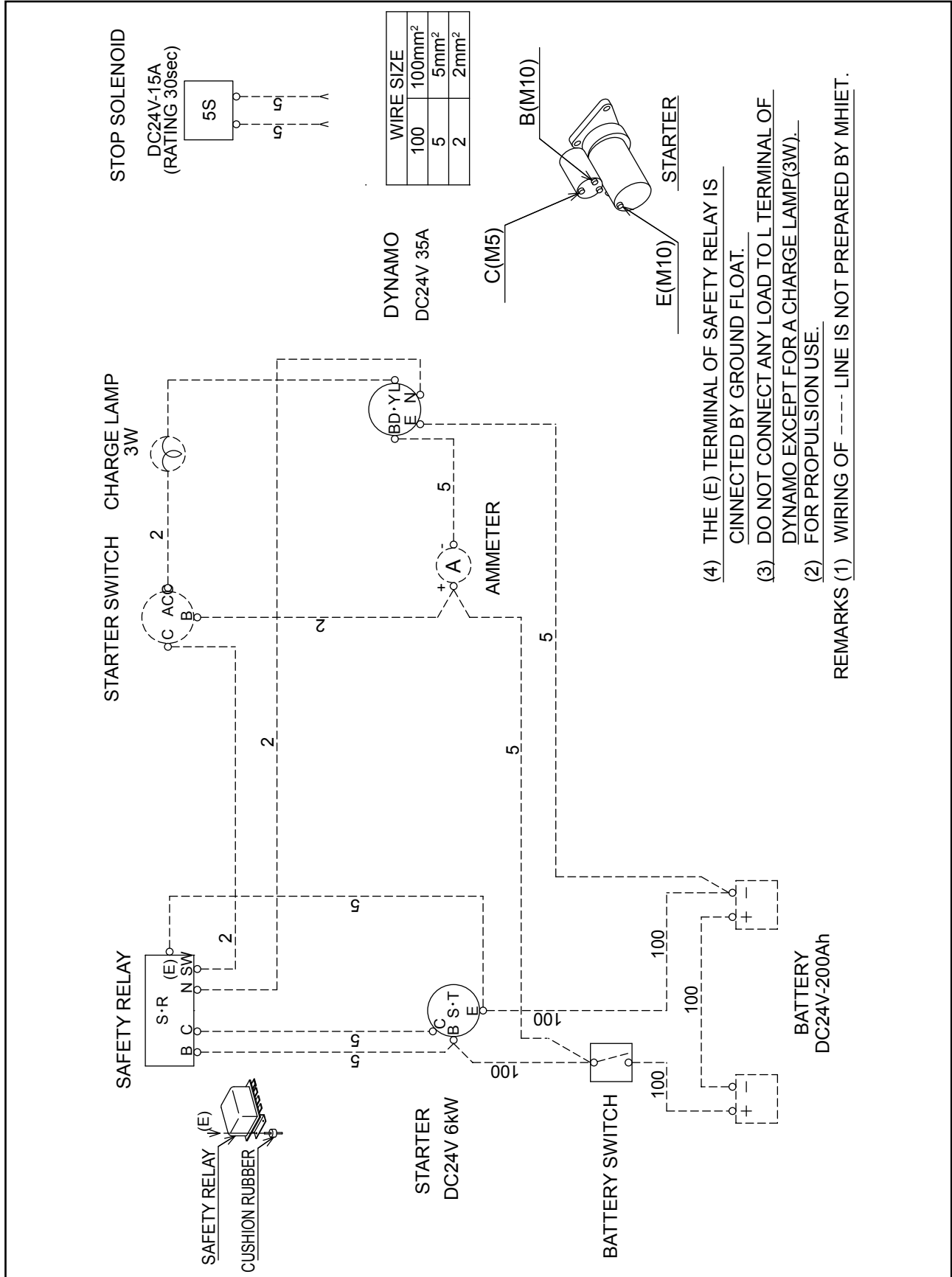


Fig. 13-1 Electric diagram (instrument panel)

July 2016

OPERATION & MAINTENANCE MANUAL

S6A3-T2MPTK3L

for Mitsubishi Turbocharger and Engine Europe B.V.

Pub. No. 99250-28100

