			Publication No.	0BLY3-G00100	
History of Revision					
Manual Name		Service Manual for Marine Diesel Engine			
Engine Model:		6LY3-ETP / 6LY3-STP / 6LY3-UTP			
Number of revision	Date of revision	Reason for correction	Outline of correction	Correction item No. (page)	Corrected by
New edition: October 2006					
	Oct. 2006	1. New edition. 2. Adding more information.	• Old edition : M2215-04E151. • Changed procedure of long storage. • Changed troubleshooting. • Added trouble code. • Added governor and timer structure. • Changed removing procedure of fuel injection pump. • Added ECS. • Added air heater. • Added fuse, relay and harness.	 2.6 3.2.1 & 3.2.2 3.3 6.1.3 & 6.1.4 6.1.5 6.5 & 12.1 13.6 13.7	Marine Business Development Dept.

Printed in Japan

FOREWORD

This service manual has been compiled for engineers engaged in sales, service, inspection and maintenance. Accordingly, descriptions of the construction and functions of the engine are emphasized in this manual, while items, which should already be common knowledge, are omitted.

One characteristic of a marine diesel engine is that its performance in a vessel is governed by the applicability of the vessel's hull construction and its steering system.

Engine installation, fitting out and propeller selection have a substantial effect on the performance of the engine and the vessel. Moreover, when the engine runs unevenly or when trouble occurs, it is essential to check a wide range of operating conditions - such as installation to the full and suitability of the ship's piping and propeller - and not just the engine itself. To get maximum performance from this engine, you should completely understand its functions, construction and capabilities, as well as proper use and servicing.

Use this manual as a handy reference in daily inspection and maintenance, and as a text for engineering guidance.

CONTENTS

FOR SAFETY

1. SAFETY LABELS

- Most accidents are caused by negligence of basic safety rules and precautions. For accident prevention, it is important to avoid such causes before development to accidents.
  Please read this manual carefully before starting repair or maintenance to fully understand safety precautions and appropriate inspection and maintenance procedures.
  Attempting at a repair or maintenance job without sufficient knowledge may cause an unexpected accident.

- It is impossible to cover every possible danger in repair or maintenance in the manual. Sufficient consideration for safety is required in addition to the matters marked **⚠ CAUTION** . Especially for safety precautions in a repair or maintenance job not described in this manual, receive instructions from a knowledgeable leader.

- Safety marks used in this manual and their meanings are as follows:

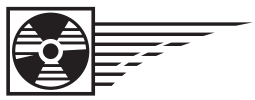
⚠ DANGER	**DANGER**-indicates an imminent hazardous situation which, if not avoided, WILL result in death or serious injury.
⚠ WARNING	**WARNING**-indicates a potentially hazardous situation which, if not avoided, COULD result in death or serious injury.
⚠ CAUTION	**CAUTION**-indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

- **NOTICE** - indicates that if not observed, the product performance or quality may not be guaranteed.

2. Safety Precautions

(1) SERVICE AREA

⚠ WARNING



• Sufficient Ventilation

Inhalation of exhaust fumes and dust particles may be hazardous to ones health. Running engines welding, sanding, painting, and polishing tasks should be only done in well ventilated areas.

⚠ CAUTION

• Safe / Adequate Work Area

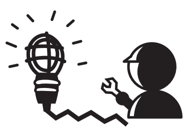
The service area should be clean, spacious, level and free from holes in the floor, to prevent "slip" or "trip and fall" type accidents.

⚠ CAUTION

• Clean, orderly arranged place

No dust, mud, oil or parts should be left on the floor surface.
[Failure to Observe]
An unexpected accident may be caused.

⚠ CAUTION



• Bright, Safely Illuminated Area

The work area should be well lit or illuminated in a safe manner. For work in enclosed or dark areas, a "drop cord" should be utilized. The drop cord must have a wire cage to prevent bulb breakage and possible ignition of flammable substances.

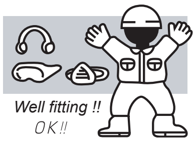
⚠ CAUTION

• Safety Equipment

Fire extinguisher(s), first aid kit and eye wash / shower station should be close at hand (or easily accessible) in case of an emergency.

(2) WORK - WEAR (GARMENTS)

⚠ CAUTION



• Safe Work Clothing

Appropriate safety wear (gloves, special shoes / boots, eye / ear protection, head gear, harness', clothing, etc.) should be used / worn to match the task at hand. Avoid wearing jewelry, unbuttoned cuffs, ties or loose fitting clothes around moving machinery. A serious accident may occur if caught in moving / rotating machinery.

(3) TOOLS

⚠ WARNING

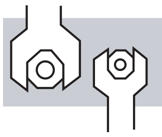
• Appropriate Lifting / Holding

When lifting an engine, use only a lifting device (crane, jack, etc.) with sufficient lifting capacity. Do not overload the device. Use only a chain, cable, or lifting strap as an attaching device. Do not use rope, serious injury may result.

To hold or support an engine, secure the engine to a support stand, test bed or test cart designed to carry the weight of the engine. Do not overload this device, serious injury may result.

Never run an engine without being properly secured to an engine support stand, test bed or test cart, serious injury may result.

⚠ WARNING



• Appropriate Tools

Always use tools that are designed for the task at hand. Incorrect usage of tools may result in damage to the engine and or serious personal injury.

(4) GENUINE PARTS and MATERIALS

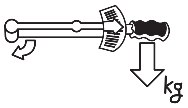
⚠ CAUTION

• Genuine Parts

Always use genuine YANMAR parts or YANMAR recommended parts and goods. Damage to the engine, shortened engine life and or personal injury may result.

(5) FASTENER TORQUE

⚠ WARNING

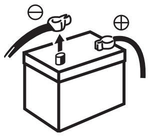


• Torquing Fasteners

Always follow the torque values and procedures as designated in the service manual. Incorrect values, procedures and or tools may cause damage to the engine and or personal injury.

(6) Electrical

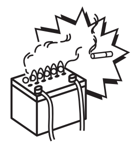
⚠ WARNING



• Short Circuits

Always disconnect the (-) Negative battery cable before working on the electrical system. An accidental "short circuit" may cause damage, fire and or personal injury. Remember to connect the (-) Negative battery cable (back onto the battery) LAST

⚠ WARNING



• Charging Batteries

Charging wet celled batteries produces hydrogen gas. Hydrogen gas is extremely explosive. Keep sparks, open flame and any other form of ignition away. Explosion may occur causing severe personal injury.

⚠ WARNING

• Battery Electrolyte

Batteries contain sulfuric acid. Do NOT allow it to come in contact with clothing, skin and or eyes, severe burns will result.

(7) WASTE MANAGEMENT

⚠ CAUTION

Observe the following instructions with regard to hazardous waste disposal. Negligence of these will have a serious impact on environmental pollution concerns.

1) Waste fluids such as lube oil, fuel and coolant shall be carefully put into separate sealed containers and disposed of properly.
2) Do NOT dispose of waste materials irresponsibly by dumping them into the sewer, overland or into natural waterways.
3) Waste materials such as oil, fuel, coolant, solvents, filter elements and batteries, must be disposed of properly according to local ordinances. Consult the local authorities or reclamation facility.

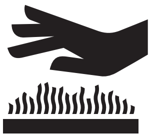
(8) FURTHER PRECAUTIONS

⚠ WARNING

• Fueling / Refueling

Keep sparks, open flames or any other form of ignition (match, cigarette, etc.) away when fueling / refueling the unit. Fire and or an explosion may result.

⚠ CAUTION



• Hot Surfaces.

Do NOT touch the engine (or any of its components) during running or shortly after shutting it down. Scalding / serious burns may result. Allow the engine to cool down before attempting to approach the unit.

⚠ WARNING

• Rotating Parts

Be careful around moving / rotating parts. Loose clothing, jewelry, ties or tools may become entangled causing damage to the engine and or severe personal injury.

⚠ DANGER

• Preventing burns from scalding

1) Never open the filler cap shortly after shutting the engine down. Steam and hot water will spurt out and seriously burn you. Allow the engine to cool down before attempt to open the filler cap.
2) Securely tighten the filler cap after checking the cooling water. Steam can spurt out during engine running, if tightening loose.

⚠ CAUTION

• Safety Label Check

Pay attention to the product safety label.
A safety label (caution plate) is affixed on the product for calling special attention to safety.If it is missing or illegible, always affix a new one.

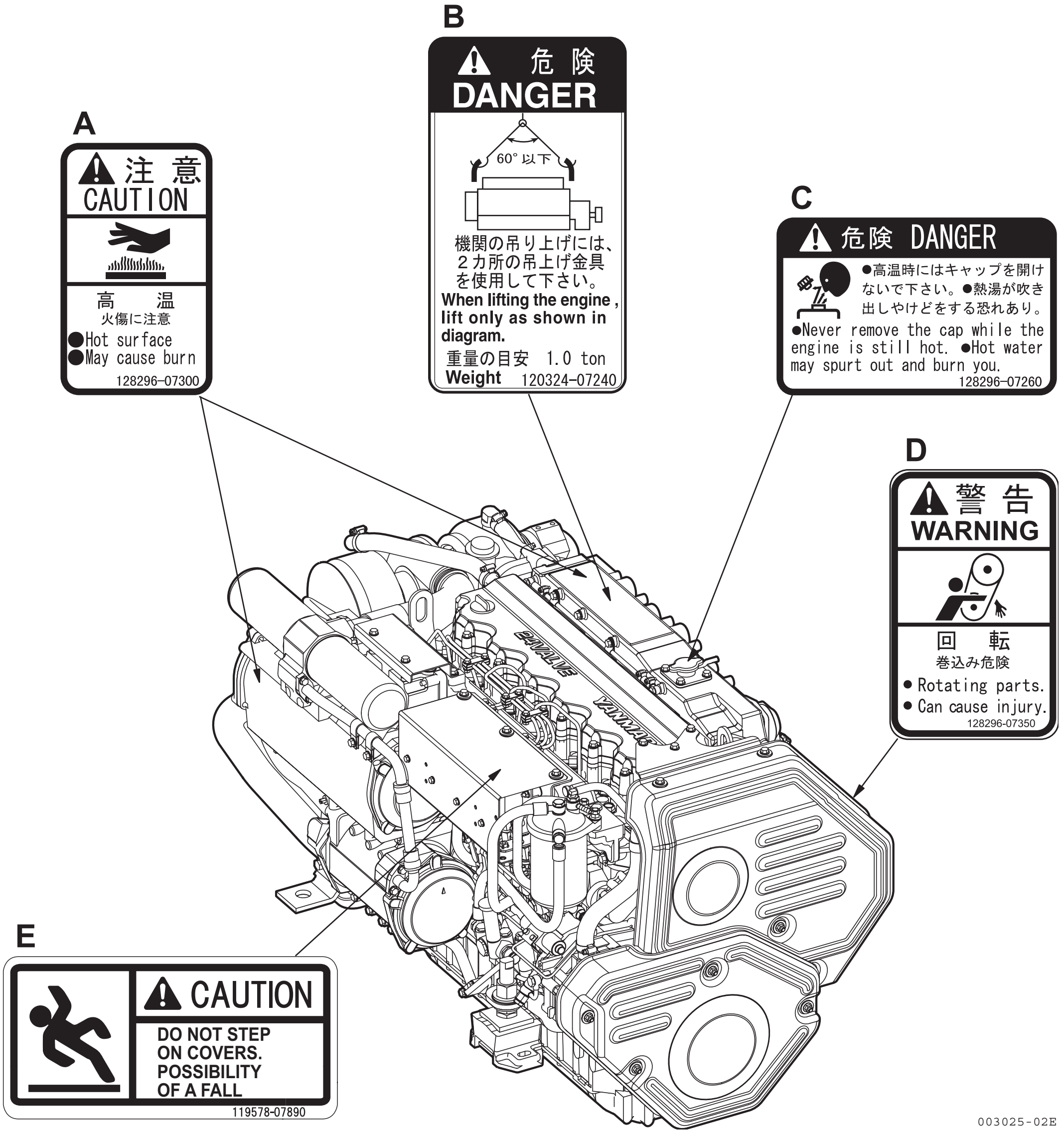
⚠ CAUTION

•Do not step on

Don't step on engine parts such as part cover, because there is the possibility of slipping and fall.

Warning Labels

To insure safe operation, warning device labels have been attached. Their location is shown below and they should always be visible. Please replace if damaged or lost.



Warning Labels	
No.	Part Code No.
A	128296-07300
B	120324-07240
C	128296-07260
D	128296-07350
E	119578-07890

3. Precautions for Service Work

(1) Precautions for Safety

Read the safety precautions given at the beginning of this manual carefully and always mind safety in work.

(2) Preparation for Service Work

Preparation is necessary for accurate, efficient service work. Check the customer ledger file for the history of the engine.

- Preceding service date
- Period / operation hours after preceding service
- Problems and actions in preceding service
- Replacement parts expected to be required for service
- Recording form / check sheet required for service

(3) Preparation before Disassembly

- Prepare general tools, special service tools, measuring instruments, oil, grease, non-reusable parts, and parts expected to be required for replacement.
- When disassembling complicated portions, put match-marks and other marks at places not adversely affecting the function for easy reassembly.

(4) Precautions in Disassembly

- Each time a parts is removed, check the part installed state, deformation, damage, roughening, surface defect, etc.
- Arrange the removed parts orderly with clear distinction between those to be replaced and those to be used again.
- Parts to be used again shall be washed and cleaned sufficiently.
- Select especially clean locations and use clean tools for disassembly of hydraulic units such as the fuel injection pump.

(5) Precautions for Inspection and Measurement

Inspect and measure parts to be used again as required to determine whether they are reusable or not.

(6) Precautions for Reassembly

- Reassemble correct parts in correct order according to the specified standards (tightening torques, and adjustment standards). Apply oil important bolts and nuts before tightening when specified.
- Always use genuine parts for replacement.
- Always use new oil seals, O-rings, packing and cotter pins.
- Apply sealant to packing depending on the place where they are used. Apply of grease to sliding contact portions, and apply grease to oil seal lips.

(7) Precautions for Adjustment and Check

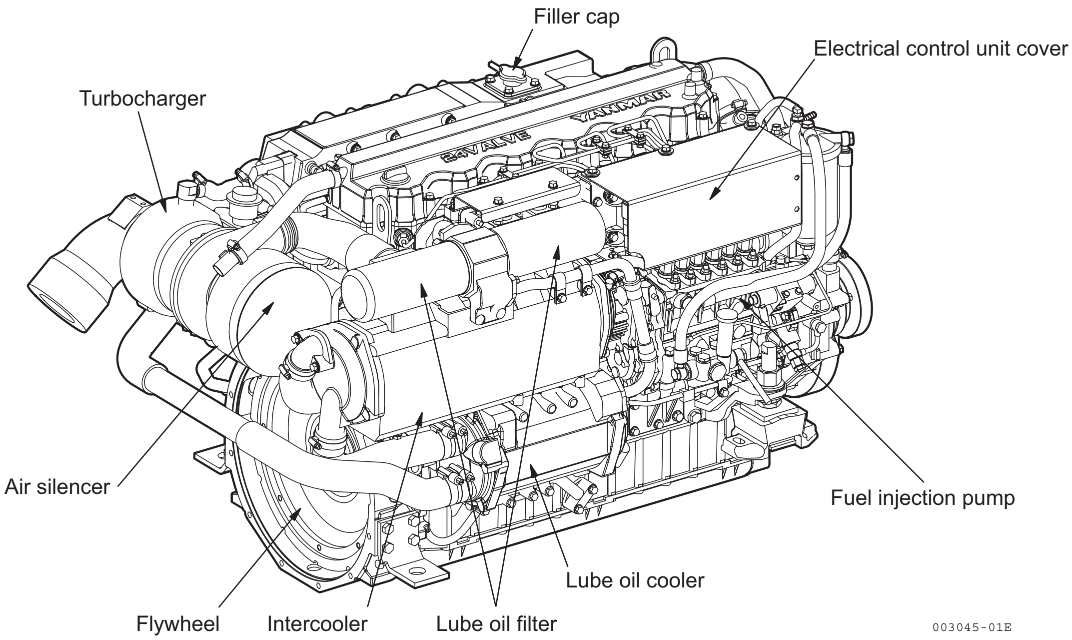
Use measuring instruments for adjustment to the specified service standards.

1. General

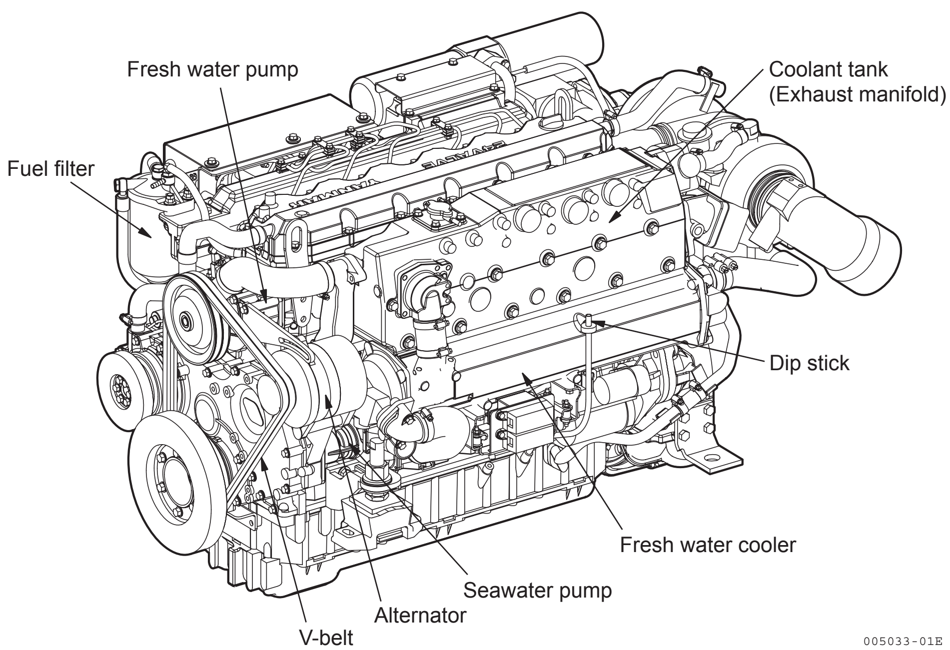
1.1 Exterior views

6LY3-ETP

●Operation side



●Non operation side



1.2 Main specifications

STP: 295kW(400hp) / 3198min^{-1}, UTP: 254kW(345hp) / 3198min^{-1}

Engine model		Unit	6LY3-ETP	6LY3-STP	6LY3-UTP
Marine gear model		-	-	-	-
Use		-	Pleasure use		
Type		-	Vertical water cooled 4 cycle diesel engine		
Combustion system		-	Direct injection		
Number of cylinders		-	6		
Bore x stroke		mm (inch)	105.9 x 110 (4.17 x 4.33)		
Displacement		ℓ	5.813		
Continuous power (Note 1)	Output at crankshaft / Engine speed	kW (HP) / min^{-1}	321 (436)/3198	295 (400)/3198	254 (345)/3198
Fuel stop power (Note 1)	Output at crankshaft / Engine speed	kW (HP) / min^{-1}	353(480)/3300 (at Fuel inlet temp. 40 °C)	324(440)/3300 (at Fuel inlet temp. 40 °C)	279(380)/3300 (at Fuel inlet temp. 40 °C)
High idling		min^{-1}	3500±25		
Low idling		min^{-1}	700±25		
Installation		-	Flexible mounting		
Direction of rotation	Crankshaft	-	Counterclockwise viewed from stern		
Cooling system		-	Fresh water cooling with heat exchanger		
Lubrication system		-	Complete enclosed forced lubrication		
Coolant capacity (fresh)		ℓ (quart)	Engine: 28 (30) Coolant recovery tank: 1.5 (1.6)		
Lubricating oil capacity (engine)	Rake angle	deg.	rake angle 0 deg		
	Total (Note 4)	ℓ (quart)	18.8 (19.9)		
	Effective (Note 5)		8.0 (8.5)		
Starting system	Type	-	Electric		
	Starting motor	V-kW	DC 12V - 3 kW		
	AC generator	V-A	12V - 80A		
Turbocharger	Model	-	RHC7W (IHI made)		
	Type	-	Water cooled		
Engine Dimension	Overall length	mm (inch)	1300.4 (51.2)		
	Overall width		801.3 (31.5)		
	Overall height		776.6 (30.6)		
Engine dry mass (without marine gear)		kg	640		
Recommended battery capacity		-	12V-150AH		

(Note)
1. Rating condition:
   Temperature of fuel; 40°C at FO pump inlet; ISO 8665
2. 1HP (metric horse power) ≒ 0.7355 kW
3. Fuel condition: Density at 15°C = 0.860 g / cm^3
4. The "Total" oil quantity includes oil in oil pan, channels, coolers and filter.
5. The effective amount of oil shows the difference in maximum scale of the dipstick and minimum scale.

1.3 Fuel oil, lubricating oil and cooling water

1.3.1 Fuel oil

IMPORTANT:
Only use the recommended fuel to obtain the best engine performance and to keep the durability of the engine, also to comply with the emission regulations.

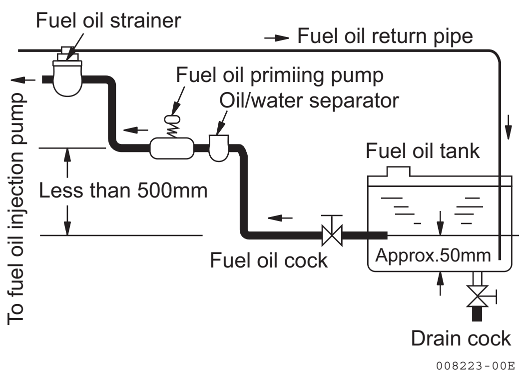
(1) Selection of fuel oil

Diesel fuel oil should comply with the following specifications.

- The fuel specifications need to comply with each national standard or international standards.
- ASTM D975 No.1-D
  No.2-D ...... for USA
- EN590: 96 .... for EU
- ISO 8217 DMX .... International
- BS 2869-A1 or A2 .... for UK
- JIS K2204-2 .... for JAPAN

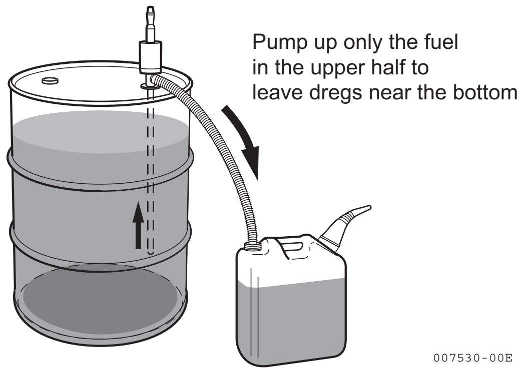
  The following requirements also need to be fulfilled.
- Cetane number should be equal to 45 or higher.
- Sulfur content of the fuel.
  It should not exceed 0.5% by volume. (Preferably it should be below 0.05%).
- Water and sediment in the fuel oil should not exceed 0.05% by volume.
- Ash should not exceed 0.01% by mass.
- 10% Carbon residue content of the fuel.
  It should not exceed 0.35% by volume. (Preferably it should be below 0.1%).
- Aromatics (total) content of the fuel.
  It should not exceed 35% by volume. (Preferably it should be below 30% and aromatics (PAH*) content of the fuel preferably it should be below 10%)
  PAH*: polycyclic aromatic hydrocarbons.
  - DO NOT use Biocide.
  - DO NOT use Kerosene, residual fuels.
  - DO NOT mix winter fuel and summer fuel.

Note:
Engine breakdown can be attributed to insufficient quality of fuel oil.



(2) Fuel handling

- Water and dust in the fuel oil can cause operation failure. Use containers which are clean inside to store fuel oil. Store the containers away from rain water and dust.
- Before supplying fuel, let the fuel container rest for several hours so that water and dust in the fuel are deposited on the bottom. Pump up only the clean fuel.
  Use the clear filtered fuel from the upper middle section of the container only, leaving any contaminated fuel at the bottom.
- When supplying fuel to a new boat for the first time, be sure to extract all fuel from the tank and check for impurities in the fuel.



(3) Fuel piping

Install the piping between the fuel tank and the fuel injection pump, as illustrated on the right.
Be sure to install a drain cock at the bottom of the fuel tank to remove water and dust.
Install an oil / water separator and a fuel filter in the middle of the fuel piping.

1.3.2 Lubricating oil

IMPORTANT:
Only use the recommended engine oil to keep the durability of the engine.

(1) Selection of engine lube oil

Use the following lube oil:

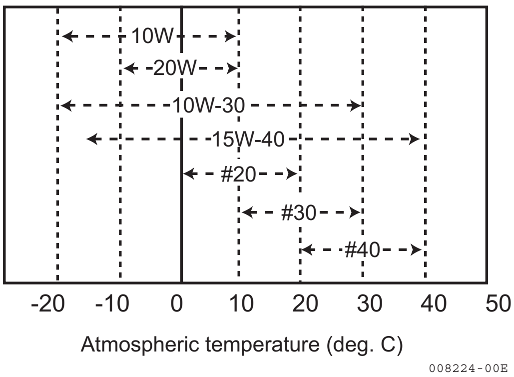
- API classification .... CD or higher

  TBN value: 9 or more

  The oil must be changed when the Total Base Number (TBN) has been reduced to 2.0.
  *TBN (mgKOH / g) test method;
  JIS K-2501-5.2-2 (HCl), ASTM D4739 (HCl)
- SAE viscosity 15W40

  If you operate your engine at temperatures below the limits shown below, consult your dealer for special lubricants and starting aids.

Selection of viscosity (SAE Service grade)



DO NOT use The following engine oils.
API: CG-4, CH-4
ACEA: E-1, E-2, B grade
JASO: DH-2, DL-1

Reason

- API CG-4, CH-4

  In case CG-4, CH-4 is to be used for YANMAR 6LY3 diesel engine series, there is a possibility that excessive wears occur on the valve train system due to the content of oil.
- ACEA E-1,E-2, B

  These fuels are developed for the different type of diesel engines.
- JASO DH-2, DL-1

  These fuels are developed for the different type of diesel engines.

(2) Selection of marine gear oil

Refer to the instruction book for each marine gear.

(3) Handling the lube oil

1) When handling and storing lubricating oil, be careful not to allow dust and water to enter the lubricating oil. Clean around the filler port before refilling.
2) Do not mix Lube oils of different types or brands. Mixing may cause the chemical characteristics of the lube oil to change and lubricating performance to drop, reducing the engine's life.
   Before supplying lube oil to the engine and marine gear for the first time, extract any lubricating oil remaining in the tank. Use new lubricating oil.
3) Lube oil supplied to the engine will undergo natural degradation with time even when the engine is not used.
   Lube oil should be replaced at the specified intervals, regardless of whether the engine is being used or not

⚠ CAUTION

Contact with engine oil may result in the roughened skin. Care should be taken so as not to contact with engine oil wearing protective gloves and clothing.
When handling the engine oil, make sure to use the protective gloves at any time.
If contact, wash with soap and water thoroughly.

1.3.3 Cooling water

Use clean soft water and always be sure to add LLC (Long Life Coolant) in order to prevent rust built up and freezing. (Do not use water only.)
The recommended LLC conform to the following specifications.

- JIS K-2234
- SAE J814C, J1941, J1034, J2036
- ASTM D3306
- ASTM D4985

IMPORTANT:

- Always be sure to add LLC to soft water. In particular, in cold season, to add LLC is important.
  Without LLC,
  Cooling performance will decrease due to scale and rust in the cooling water system.
  Cooling water may freeze to form ice; it expands approx. 9% in volume.
  This causes serious damage in the cooling system.
- Be sure to use the proper amount of coolant concentrate specified by the LLC manufacturer depending on the ambient temperature. LLC concentration should be 30% as a minimum and 60% as a maximum.
- DO NOT mix the different types of brand of LLC, otherwise harmful sludge may yield.
- DO NOT use hard water.
- Water should be free from sludge and / or particles.

⚠ CAUTION

When handling LLC, use protective gloves to avoid skin contact.
In case you have a contact with your skin or eyes, wash out it with clean water.

Consult your Yanmar dealer or distributor on the use of coolant/antifreeze, and detergents.
LLC, which provide good performance for example, are shown below.

- TEXACO LONG LIFE COOLANT ANTIFREEZE, both standard and pre-mixed. Product code 79947 and 7998.
- HAVOLINE EXTENDED LIFE ANTIFREEZE/COOLANT. Product code 7994

Handling of Coolant

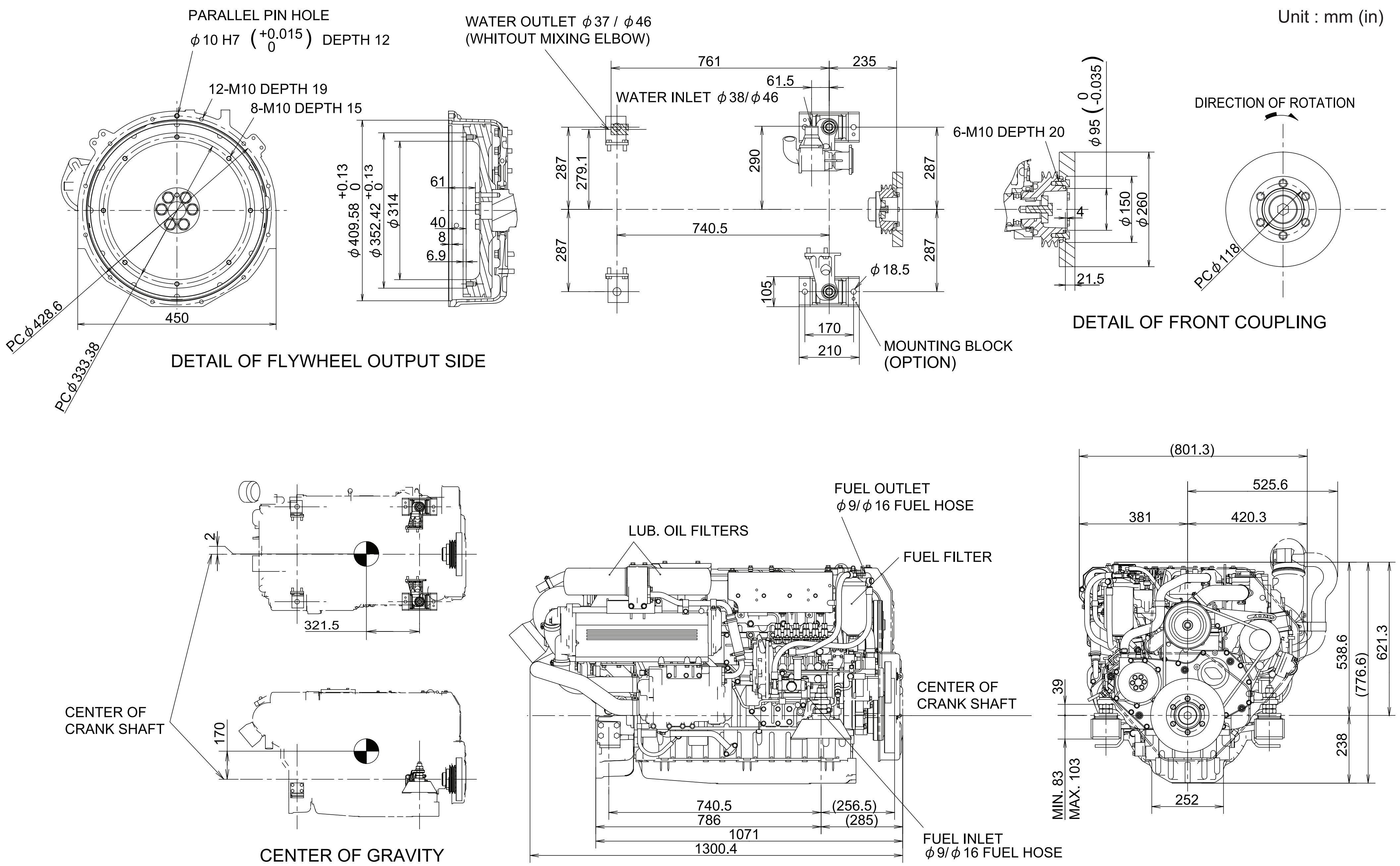
1) Choose LLC, which will not have any adverse effects on the materials (cast iron, aluminum, copper, etc.) of the engine's fresh water cooling system.
2) Replace the cooling water periodically, according to the maintenance schedule given in this operation manual.
3) Remove the scale from the cooling water system periodically, according to the instructions in this operation manual.

NOTICE

Excessive use of LLC also lowers the cooling efficiency of the engine. Be sure to use the mixing ratios specified by the antifreeze maker for your temperature range.

1.4 Engine outline

6LY3-ETP / STP / UTP (YT-15 MOUNT)

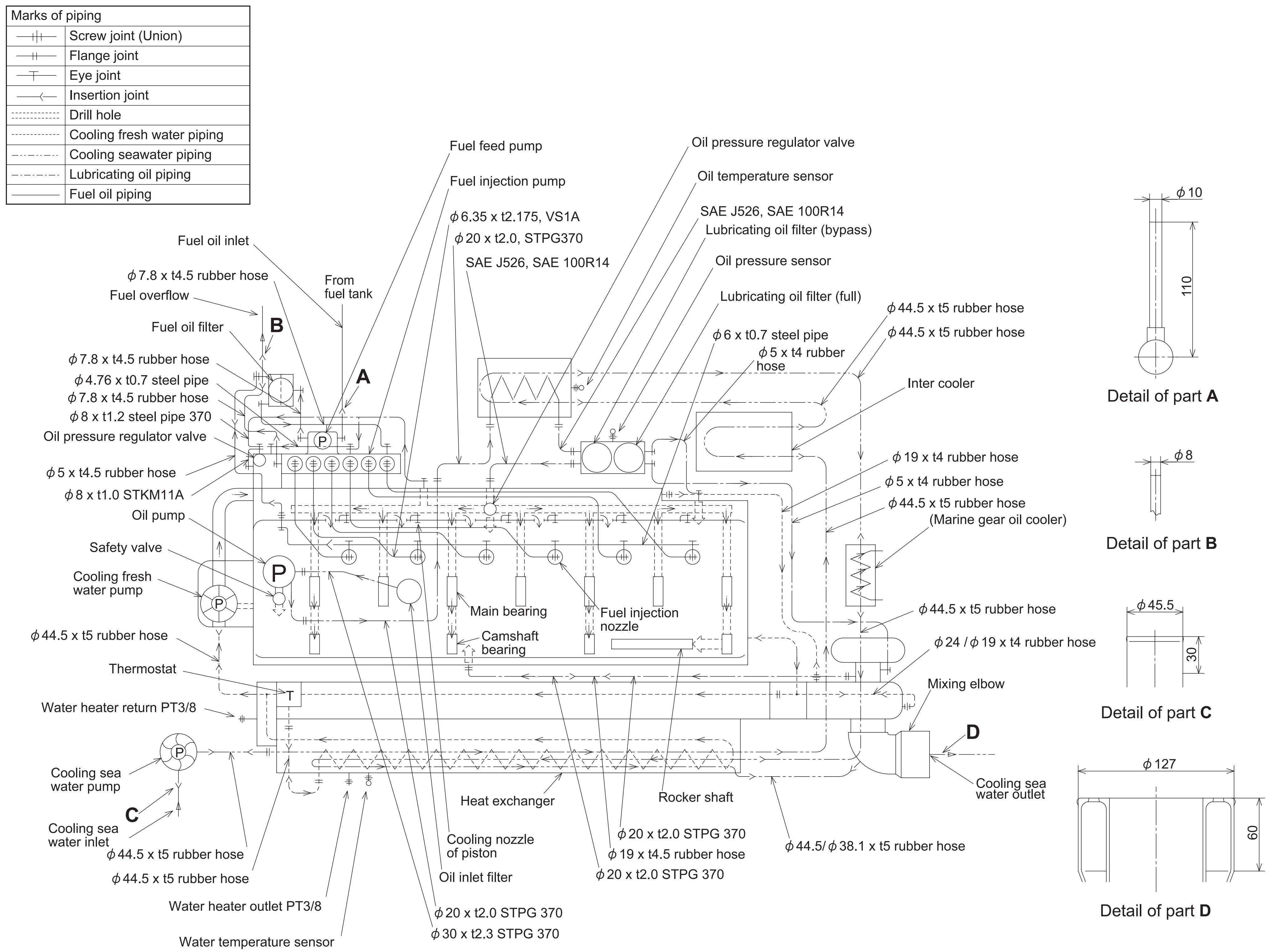


NOTES
1.DWG. SHOWS MOUNTING BLOCKS AT ORIGINAL HEIGHT.
(ENGINE WEIGHT WILL COMPRESS BLOCKS BY APPROX 3.5mm)
2.MOUNTING BLOCK PARTS NUMBER IS 127495-08320.
(YT-15 MOUNT)
3. ⯐ SHOWS CENTER OF GRAVITY.
4.MIXING ELBOW RUBBER HOSE INNER DIA. 5 INCH

007124-00E

1.5 Piping diagrams

6LY3-ETP



NOTE

Dimensions of steel and copper pipes show outside diameter and thickness.
Dimensions of rubber hoses show inside diameter and thickness.

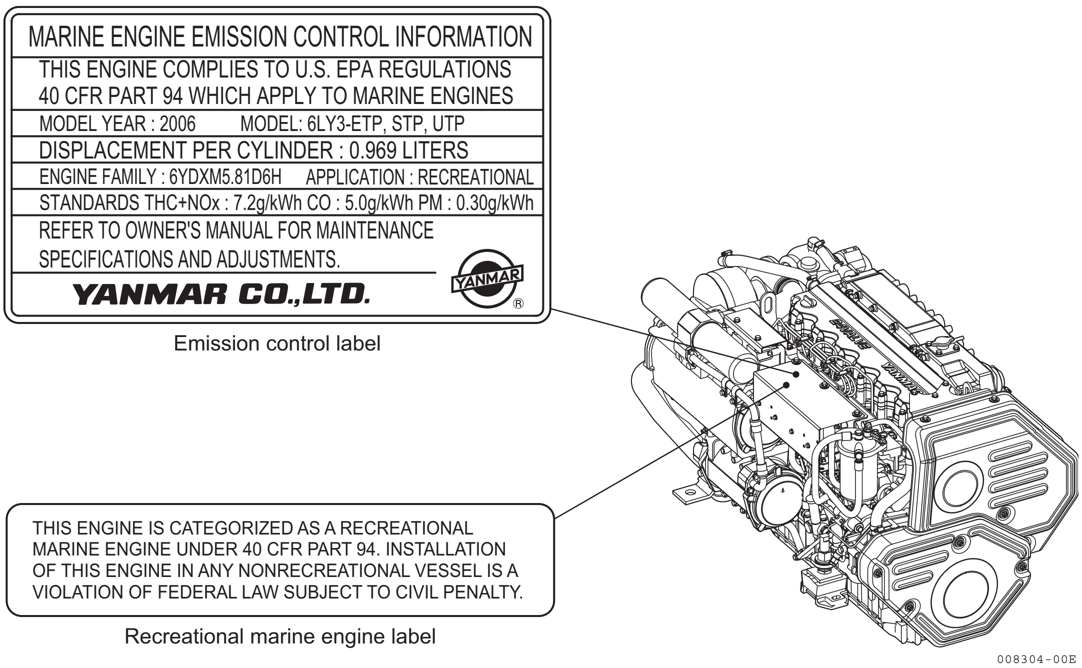
1.6 Exhaust gas emission regulation

6LY3 series engines are applicable with Marine Compression Ignition Engines Regulation of the EPA (40 CFR Part 94) in U.S.A. RCD Regulation and BSO Regulation in Europe and other regulations are applied to this engine.

1.6.1 Engine identification

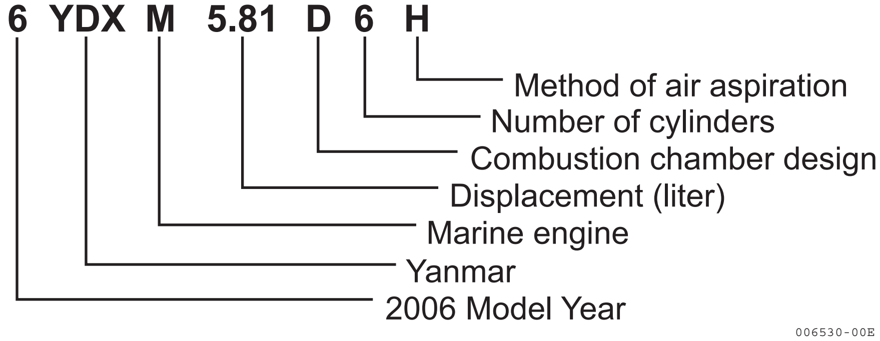
With the regulations on exhaust gas emission worldwide, it has become necessary to identify engines in a manner to determine which regulations they comply with.

(1) EPA emission labels and location



(2) EPA engine family name as assigned by EPA identifying engine family group

6YDXM5.81D6H and this identifies



1.6.2 EPA exhaust gas emission standard

(Unit: g / kWh)

Engine power	Category	Tier	Model year	NMHC + NOx	CO	PM
37kW and above	0.9-1.2 liter / cylinder	Tier 2	2006	7.2	5.0	0.3

Note 1. The transit smoke (ACC / LUG / PEAK) is not applicable.
Note 2. The EPA recommended fuel is used.
Note 3. As for Model year, the year, which a regulation is applicable to for recreational use, is shown.

1.6.3 EPA guarantee conditions for emission standard

In addition to making sure that these conditions are met, check for any deterioration that may occur before the required periodic maintenance times.

(1) Requirement on engine installation condition

1) Air intake negative pressure

kPa (mmAq)

Permissible
4.0 (400) and less

2) Exhaust gas back pressure

kPa (mmAq)

Permissible
20.0 (2000) and less

(2) Fuel oil and lube oil

1) Fuel: The diesel fuel oil ASTM D975 No.1-D or No.2-D, equivalent (Cetane No3.45 min.)
2) Lube oil: API grade, class CD

(3) Perform maintenance without fail.

Note:
Inspections to be carried out are divided by the user and by the maker and set down in the "Periodic Maintenance Schedule" in the operation manual (also in this manual) and should be checked carefully.

EPA allows to apply the maintenance schedule for the emission related parts as follows.
These must be performed to keep the emission values of the engine in the standard values during the warranty period. The warranty period is determined by the age of the engine or the number of hours of operation.
Inspection and maintenance not noted below are the same as the periodic maintenance.

Parts	Interval
Check fuel injection nozzle (cleaning)	1500 hours
Check fuel injection nozzle (adjustment)	3000 hours
Check fuel injection pump (adjustment)	
Check turbocharger (adjustment)	
Electronic engine control unit and its associated sensors and actuators	

2. Inspection and adjustment

2.1 Periodic maintenance schedule

The engine periodic inspection timing is hard to determine as it varies with the application, load status, qualities of the fuel and lubricating oils used and handling status. General rules are described here.

○: User-maintenance ◎: Parts replacement ●: Shop-inspection

System	Item		Before starting	*1 Every 50 hrs. or one month	*1 Every 250 hrs. or one year	*1 Every 500 hrs. or 2 years	*1 Every 1000 hrs. or 4 years	*1 Every 2000 hrs. or 8 years
Whole	Visual inspection of engine outside		○					
Fuel system	Check the fuel level, and refill		○					
	Drain the fuel tank				○			
	Drain the filter and the water separator			○				
	Replace the filter element				◎			
	Check the injection spray condition				● (1st time)		●	
	Overhaul and check of fuel feed pump							●
	Replace rubberized fuel pipes		Every two years or 2,000 hrs of operation*1					
Lubricating system	Check the lube oil level	Crankcase	○					
	Replace the lube oil	Crankcase		◎ (1st time)	◎			
	Replace the filter element			◎ (1st time)	◎			
	Clean lube oil cooler							●
Cooling system	Seawater outlet		○ During operation					
	Check coolant level		○					
	Check the impeller of seawater pump				○	◎		
	Replace the engine coolant		Every year When long life coolant is used of a specified type (see page 5), replacement period of two years can be obtained.					
	Clean & check the water passages						●	
	Clean seawater and fresh water system							●
	Replace anti-corrosion zinc				◎			

*1 Whichever comes first.

○: User-maintenance ◎: Parts replacement ●: Shop-inspection

System	Item	Before starting	*[1] Every 50 hrs. or one month	*[1] Every 250 hrs. or one year	*[1] Every 500 hrs. or 2 years	*[1] Every 1000 hrs. or 4 years	*[1] Every 2000 hrs. or 8 years
Air intake and exhaust system	Clean the air intake silencer			○			
	Clean the exhaust / water mixing elbow			○	◎		
	Clean the turbocharger blower			●			
	Flush intercooler			●			
Electrical system	Check the alarm indicators	○					
	Check the electrolyte level in the battery		○				
	Adjust the tension of the alternator driving belt		○		○	◎	
	Check the wiring connectors			○			
Cylinder head, etc.	Check for leakage of water and oil	○ After starting					
	Retighten all major nuts and bolts			●			
	Adjust intake / exhaust valve clearance			● (1st time)		●	
Miscellaneous items	Check the electronic control system	○	○ (1st time)				
	Adjust the propeller shaft alignment		● (1st time)		●		
	Check / replace flexible engine mounts			○		◎	

*[1] Whichever comes first.

Inspection and maintenance for EPA emission related parts

Parts	Interval
Check fuel injection nozzle (cleaning)	1500 hours
Check fuel injection nozzle (adjustment)	3000 hours
Check fuel injection pump (adjustment)	
Check turbocharger (adjustment)	
Check electronic engine control unit and its associated sensors and actuators	

2.2 Periodic inspection and maintenance procedure

2.2.1 Check before starting

Be sure to check the following points before starting an engine every day.

No.	Inspection Item
(1)	Visual inspection of engine outside
(2)	Check the fuel level, and refill
(3)	Check the lube oil level (Crankcase)
(4)	Seawater outlet
(5)	Check cooling water level
(6)	Check the alarm indicators
(7)	Check the leakage of water, lube oil and fuel
(8)	Check the electronic control system

(1) Visual inspection of engine outside

If any problem is found, do not use before the engine repairs have been completed.

- Oil leak from the lubrication system
- Fuel leak from the fuel system
- Cooling water leak from the cooling water system
- Damaged parts
- Loosened or lost bolts
- Fuel, coolant tank rubber hoses, V-belt cracked, loosened clamp

(2) Check the fuel level, and refill

Check the remaining fuel oil level in the fuel tank and refill the recommended fuel if necessary.

(3) Check the lube oil level (Crankcase)

1) Check the lube oil level of an engine with a dipstick. Insert the dipstick fully and check the oil level. The oil shall not be contaminated heavily and have appropriate viscosity. No cooling water or diesel fuel shall be mixed.
   The level shall be between the upper and lower limit lines on the dipstick.

Unit: liter (quart)

Engine oil capacity at rake angle 0 degree
Full: 18.8 (19.9)

2) If the remaining engine oil level is low, fill the oil pan with the specified engine oil to the specified level through the filler port.

[NOTICE]

The engine oil should not be overfilled to exceed the upper limit line. If engine oil is overfilled, the engine may intake the engine oil in the combustion chamber during the operation, causing a possible uncontrollable operation.

(4) Seawater outlet

Check whether seawater comes out just after the engine has started.
If seawater doesn't come out, shut down the engine immediately.
Check the leakage of seawater in the seawater pump and pipes. Check damage of the seawater pump impeller.

(5) Check cooling water level

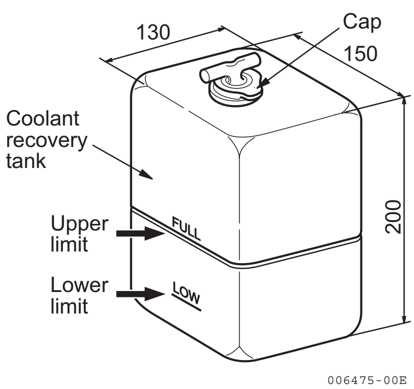
Daily inspection of cooling water should be done only by coolant recovery tank.

⚠ DANGER

- Never open the filler cap while the engine is still hot. Steam and hot water will spurt out and seriously burn you. Wait until the engine is cooled down after the engine stopped, wrap the filler cap with a rag piece and turn the cap slowly to gently release the pressure inside the flesh water tank.
- Securely tighten the filler cap after checking the flesh water tank. If the cap is tightened loosely, steam can spurt out during operation.

1) Checking cooling water volume
   Check the cooling water level in the coolant recovery tank. If the water level is close to the LOW mark, open the coolant recovery tank cap and replenish the coolant recovery tank with a 50% mixture of LLC and 50% clean soft water to the FULL mark.

   Standard
   The water level of the coolant recovery tank shall be between the upper and lower limit lines.



2) Replenishing engine with water
If the cooling water level in the coolant recovery tank is lower than the LOW mark, open the filler cap and check the cooling water level in the engine coolant tank. Replenish the engine with the coolant / water mixture, if the level is low.

- Check the cooling water level when the engine is cool.
  Checking when the engine is hot is dangerous. And the water volume is expanded due to the temperature.
- Daily cooling water level check and replenishing shall be done only at the coolant recovery tank. Usually do not open the filler cap to check or replenish.

Standard

Cooling water volume Unit: liter (quart)

Engine	Coolant recovery tank
28 (30)	1.5 (1.6)

IMPORTANT:
If the cooling water runs short quickly or when the coolant tank runs short of water with the coolant recovery tank level unchanged, water may be leaking or the air tightness may be lost.
Increasing the water level of the coolant recovery tank during operation is not abnormal.
The increased water in the coolant recovery tank returns to the coolant tank when the engine is cooled down.
If the water level is normal in the coolant recovery tank but low in the engine coolant tank, check loosened clamping of the rubber hose between the coolant tank and coolant recovery tank or tear in the hose.

(6) Check the alarm indicators

Before and after starting the engine, check to see that the alarm functions normally. Failure of alarm cannot warn the lack of the engine oil or the cooling water. Make it a rule to check the alarm function before and after starting engine every day. When pushing the start switch to the ON position before starting the engine, the alarm window appears with audible sound on the display for about 3 seconds then goes off. This alarm operation is normal.

When the sensor detects a problem during operation, the alarm indicator comes on with audible sound on the display.

Under normal conditions, the display shows the engine information such as engine speed, oil pressure, coolant (fresh water) temperature and so on.

(7) Check the leakage of water, lube oil and fuel.

Before and after starting the engine, check the leakage of cooling water and seawater from cooling water system. Also check the leakage of lube oil and fuel.

(8) Check the electronic control system

Make sure that the control lever can be operated smoothly before starting the engine. If it feels heavy to manipulate, consult your Yanmar dealer or distributor.

2.2.2 Inspection after initial 50 hours or one month operation

Be sure to check the following points after initial 50 hours or one month operation, whichever comes first.

No.	Inspection Item
(1)	Replace the engine lube oil and lube oil filter
(2)	Check the electronic control system
(3)	Adjust the propeller shaft alignment

(1) Replace the engine lube oil and lube oil filter (1st time)

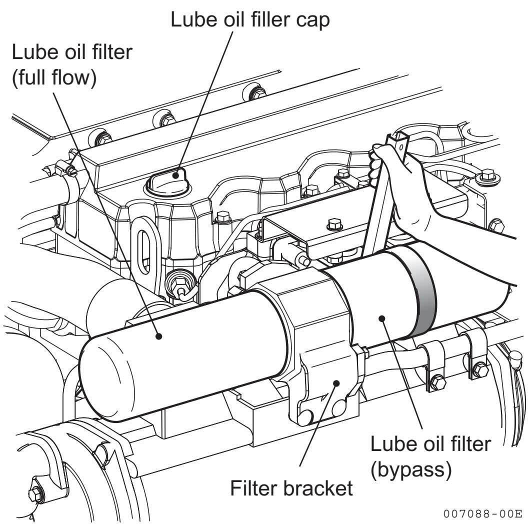
During initial operation of the engine, the oil is quickly contaminated due to the initial wear of internal parts. The lube oil must therefore be replaced early. Replace the lube oil filter at the same time.

It is easiest and most effective to drain the engine lube oil after operation while the engine is still warm.

⚠ CAUTION

Beware of oil burns if extracting the Lube oil while it is hot.

1) Remove the lube oil dipstick. Attach the oil drain pump and pump out the oil.
   For easier draining, remove the lube oil filler cap (yellow) at the top of the rocker arm cover.
2) Remove the lube oil filters with the filter detach / attach tool. (Turn counterclockwise.)
3) Clean the filter installation face of the filter bracket. Replace the filter(s) with new one(s). Apply lube oil on rubber packing and tighten by hand until rubber packing touches the sealing surface.
4) Turn an additional 3/4 of a turn for the full flow filter with the attachment tool. (Turn clockwise.)
   Turn an additional one turn for the bypass filter with the attachment tool. (Turn clockwise.)
5) Fill with new lube oil. (See 2.2.1)
6) Perform a trial run and check for oil leaks.
7) Approximately 10 minutes after stopping the engine, remove the oil dipstick and check the oil level. Add oil if the level is too low.



(2) Check the electronic control system

The electronic governor on the engine and the marine gear are connected to the control head, switch panel and display through the electronic devices such as the Interface Module and so on by wire harness.
The wiring may become loose after long hours of use. It is dangerous to control operation under these conditions, and the wiring must be checked periodically.

1) Checking the throttle control line
   Check whether the wiring has become loose.
2) Checking the control line for marine gear
   Check whether the wiring has become loose.

Check that the shifting of the marine gear moves correctly, when the control lever is put in NEUTRAL, FORWARD or REVERSE.

(3) Adjust the propeller shaft alignment

The flexible engine mounts are compressed a little in the initial engine operation and it may cause the centering misalignment between the engine & the propeller shaft.

1) Check unusual noise and vibration of the engine / boat hull, while increasing the engine speed gradually and lowering it.
2) If there is unusual noise and / or vibration, adjust the propeller shaft alignment. (Refer to 6.4.5 "Centering the Engine" in the installation manual for pleasure boat use.)

2.2.3 Inspection every 50 hours or monthly

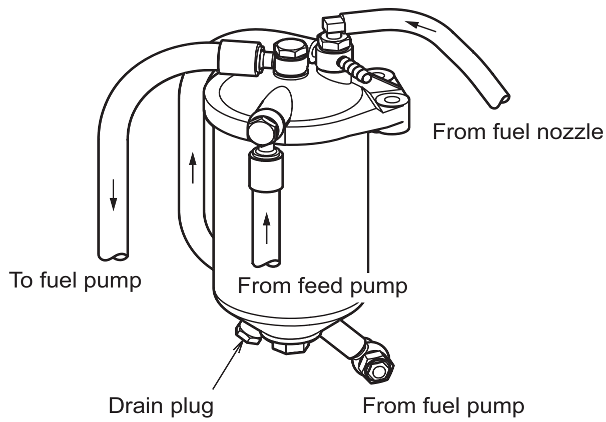
Be sure to check the following points every 50 hours or monthly, whichever comes first.

No.	Inspection Item
(1)	Drain the fuel filter and the water separator
(2)	Check the electrolyte level in the battery
(3)	Adjust the tension of the alternator driving belt

(1) Drain the fuel filter and the water separator

- Drain the fuel filter

1) Close the fuel cock of a fuel tank.
2) Loosen the drain plug. Drain off any water and dirt collected inside.



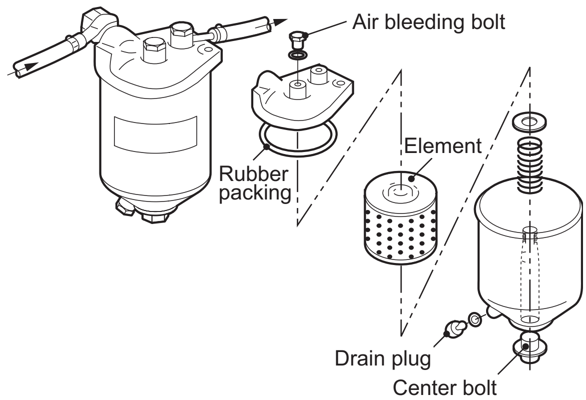
(Fuel filter) 007126-00E

- Drain the fuel / water separator (optional).

1) Close the fuel cock of the fuel tank.
2) Loosen the drain plug at the bottom of the water / oil separator and drain off any water and dirt from inside.

Note:
If nothing drips when the drain plug is opened, loosen the air bleeding plug on the top of the fuel / water separator by turning counter-clockwise 2-3 times. After draining, be sure to tighten the air bleeding plug.
(This may occur in case that the fuel / water separator position is higher than the fuel oil level in the fuel tank).

3) Remove the center bolt to disassemble the fuel / water separator.
   Clean the element inside with clean fuel.
4) When a fuel filter or fuel / water separator is provided on the hull, besides those installed on the engine, also drain and clean those or replace the element.
5) After reassembly of the fuel / water separator, be sure to vent air from the fuel system.



(Oil/water separator) 007127-00E

- Fuel system air bleeding procedures

1) Check the fuel level in the fuel tank. Replenish if Insufficient.
2) Loosen the air bleeding bolt at the top of the fuel / water separator by turning it 2 or 3 turns. Feed fuel with the fuel feed pump by moving the knob on the top of the feed pump up and down. When fuel, which does not contain air bubbles, comes out of the bolt hole, tighten the air bleeding bolt.
3) As the automatic air-bleeding system is applied to the fuel filter, there is not an air bleeding bolt on the fuel filter. Continue to feed fuel with the fuel feed pump by moving the knob on the top of the feed pump up and down. Stop feeding when the knob becomes heavy. This completes the air bleeding of the fuel system. Try starting the engine again.
4) In subsequent engine operation after the start-up, the automatic air-bleeding device works to purge the air in the fuel system. No manual air bleeding is required for normal engine operation.

(2) Check the electrolyte level in the battery

⚠ WARNING

Fire due to electric short-circuit

- Make sure to turn off the battery switch or disconnect the negative cable (-) before inspecting the electrical system. Failure to do so could cause short-circuiting and fires.
- Always disconnect the (-) Negative battery cable first before disconnecting the battery cables from battery. An accidental "Short circuit" may cause damage, fire and or personal injury.
  And remember to connect the (-) Negative battery cable (back onto the battery) LAST.

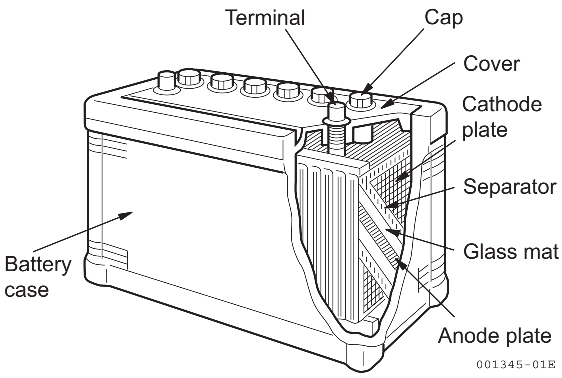
Proper ventilation of the battery area

Keep the area around the battery well ventilated, paying attention to keep away any fire source. During operation or charging, hydrogen gas is generated from the battery and can be easily ignited.

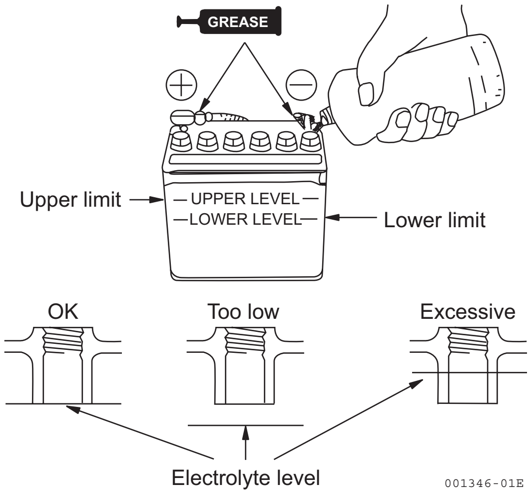
Do not come in contact with battery electrolyte

Pay sufficient attention to avoid your eyes or skin from being in contact with the fluid. The battery electrolyte is dilute sulfuric acid and causes burns. Wash it off immediately with a large amount of fresh water if you get any on you.

Battery structure

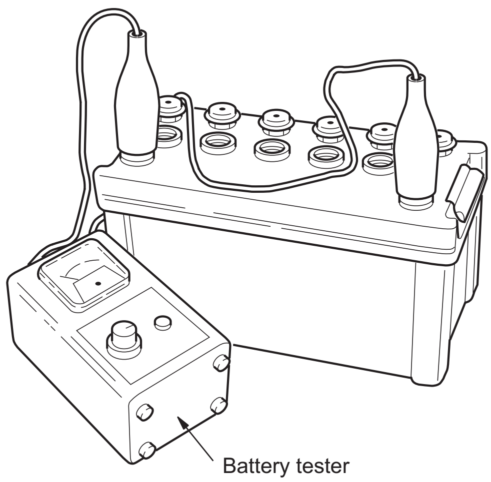


1) Electrolyte level
   - Check the level of fluid in the battery.
     When the amount of fluid nears the lower limit, fill with battery fluid (available in the market) to the upper limit. If operation continues with insufficient battery fluid, the battery life is shortened, and the battery may overheat and explode.
   - Battery fluid tends to evaporate more quickly in the summer, and the fluid level should be checked earlier than the specified times.
   - If the engine cranking speed is so slow that the engine does not start up, recharge the battery.
   - If the engine still will not start after charging, replace the battery.
   - Remove the battery from the battery mounting of the machine unit after daily use if letting the machine unit leave in the place that the ambient temperature could drop at -15°C or less. And store the battery in a warm place until the next use the unit to start the engine easily at low ambient temperature.



2) Battery charge
   Use a battery tester or hydrometer and check the battery condition. If the battery is discharged, recharge it.
   - Measurement with a battery tester
     When checking the battery with the batter tester, connect the red clip of the tester to the battery positive (+) terminal and black clip to the battery negative (-) terminal by pinching them securely, and judge the battery charge level from the indicator position.

     Green zone: Normal
     Yellow zone: Slightly discharged
     Red zone: Defective or much discharged



(Battery charge measurement with battery tester)

001347-01E

- Measurement with hydrometer

  When using a hydrometer, the measured specific gravity must be corrected according to the temperature at the time of measurement. The specific gravity of battery electrolyte is defined with 20°C as the standard. Since the specific gravity increases or decreases by 0.0007 when the temperature varies by 1°C, correct the value according to the equation below.

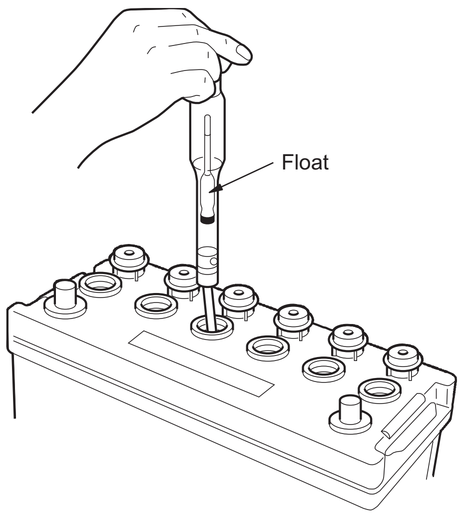
$S_{20} = St + 0.007 (t - 20)$

t: Electrolyte temperature at measurement

St: Specific gravity at measurement

S_{20}: Converted specific gravity at 20°C

001348-01E

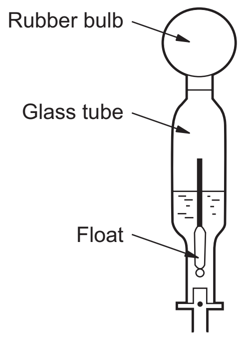


(Battery charge measurement with a hydrometer)

001349-01E

Specific gravity and remaining battery charge

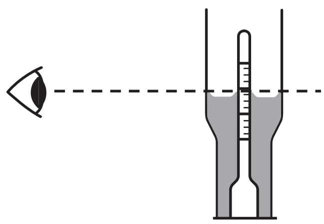
Specific gravity (20°C)	Discharged quantity of electricity (%)	Remaining charge (%)
1.28	0	100
1.26	10	90
1.24	20	80
1.23	25	75



(Hydrometer structure)

001350-01E

3) Terminals
   Clean if corroded or soiled.
4) Mounting bracket
   Repair or replace it if corroded.
   Retighten if loosened.
5) Battery appearance
   Replace the battery if cracked or deformed.
   Clean with fresh water if contaminated.



(How to read hydrometer)

008226-00E

(3) Adjust the tension of the alternator driving belts, while engine is not running!

When there is not enough tension in the V-belt, it will slip and the fresh water pump will fail to supply cooling water. Engine over-heating and seizure will result.

When there is too much tension in the V-belt, the belt will become damaged more quickly and the bearing of the fresh water pump may be damaged.

1) Check the tension of the V-belt by pressing on the middle of the belt with your finger [approx.98N(10kgf)].

The specified deflection should be as follows.

For used V-belt	8-10mm (0.315-0.393 inches)
For new V-belt	6-8mm (0.236-0.315 inches)

- "New V-belt" refers to a V-belt which has been used less than 5 minutes on a running engine.
- "Used V-belt" refers to a V-belt which has been used on a running engine for 5 minutes or more.

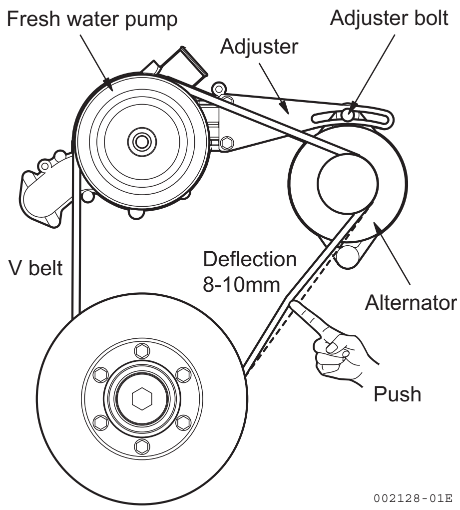
2) If the V-belt deflection is out of the limit, adjust the V-belt tension. Loosen the adjuster bolt and move the alternator to adjust the V-belt tension.

[NOTICE]

Be careful not to get any oil on the V- belt.

Oil on the belt causes slipping and stretching.

Replace the belt if it is damaged.



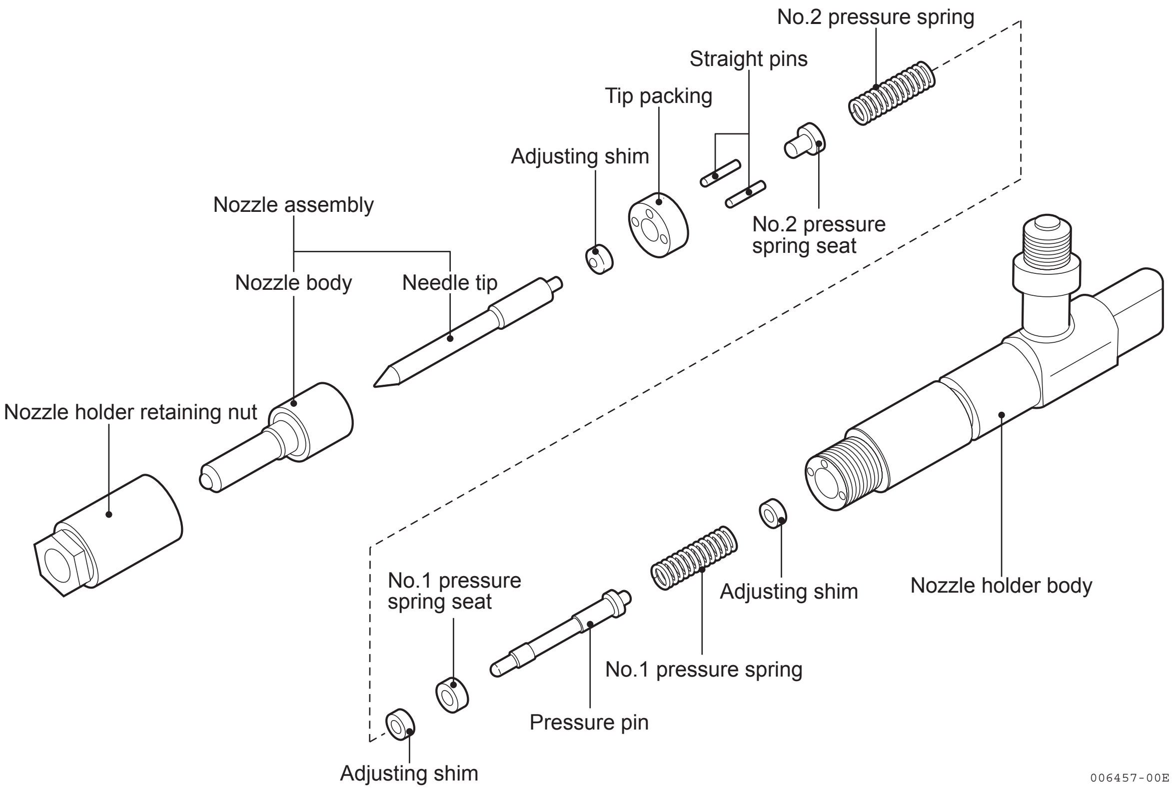
2.2.4 Inspection on initial 250 hours or one year

No.	Inspection Item
(1)	Check the injection spray condition
(2)	Adjust intake / exhaust valve clearance

(1) Check the injection spray condition (1st time)

This engine applies double spring nozzles manufactured by DENSO.

[Fuel injection nozzle structure]



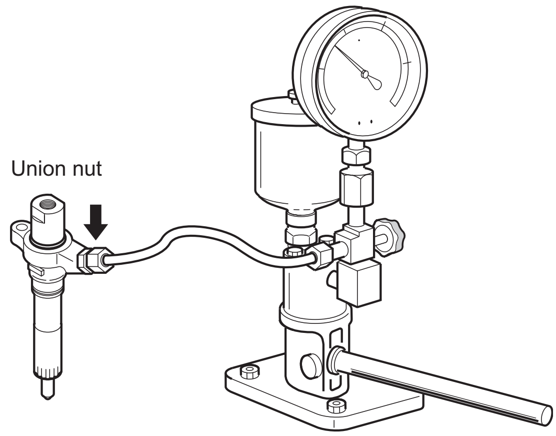
1) Injection pressure measurement
Check the No.1 (lower) opening pressure roughly for reference.
In case of measuring and adjusting the No.1 & No.2 opening pressure precisely, measure them at the authorized FIE service shops (Association of Diesel Specialists etc.), which can maintain the DENSO fuel nozzles.

Note:
Don't disassemble the nozzle holder retaining nut at Yanmar workshop.

a) Install the fuel injection nozzle to the nozzle tester and bleed air from the union nut.

⚠ WARNING

Never put your hands to the nozzle injection hole. Otherwise, your hands may be injured.



(Bleeding air from the union nut)
007674-00E

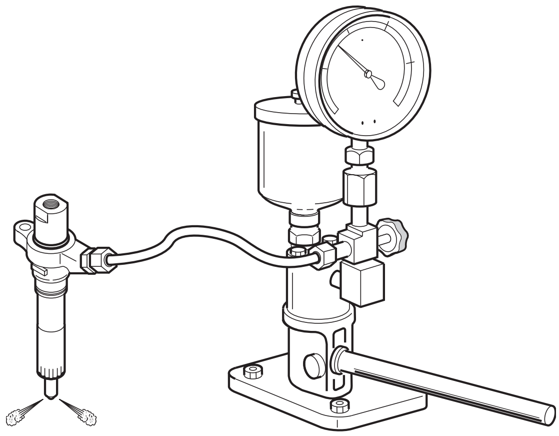
b) Pump the tester handle several times as quickly as possible to discharge foreign matter from the injection hole.
c) Slowly pump the tester handle and observe the pressure gauge.
d) Read the pressure gauge when the injection pressure begins to decrease.
Judge if the nozzle operates normally or not by hearing the swishing sound.

Standard MPa (kgf / cm^2)

No.1 opening pressure
24.00-24.98 (245-255)

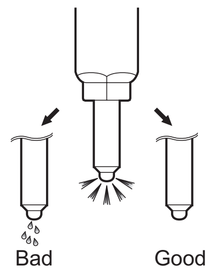
If No.1 opening pressure is out of the specified range, measure it precisely at a authorized FIE service shop again or replace the used nozzle with new one.

Note:
Only No.1 opening pressure can be measured in this method. The special tool is necessary to measure No.1 & No.2 opening pressures precisely. Measure them at a authorized FIE service shop.



(Testing the valve opening pressure)
007675-00E

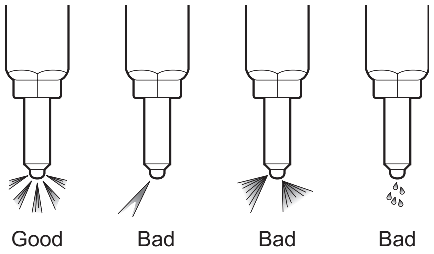
e) After the injection test, check that no drops from the injection hole.



(Fuel drop check after injection test)

006464-00E

2) Spray pattern inspection
Check the spray condition. If the spray condition is improper, clean the nozzle at a authorized FIE service shop or replace with new one.

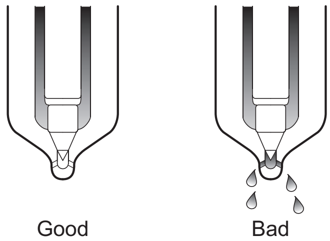


(Checking the spray condition)

006465-00E

3) Leak test
Increase the pressure to near the specified injection pressure of 0.98 to 1.96MPa (10 to 20 kgf / cm^2).
Check for oil leakage from the injection hole and around the retaining nut. If leakage occurs from the nozzle, replace, clean or overhaul the nozzle.

Note:
In case of disassembling the nozzle holder retaining nut, ask a authorized FIE service shop to clean, adjust or overhaul it.



(Checking leakage from fuel injection nozzle)

006466-00E

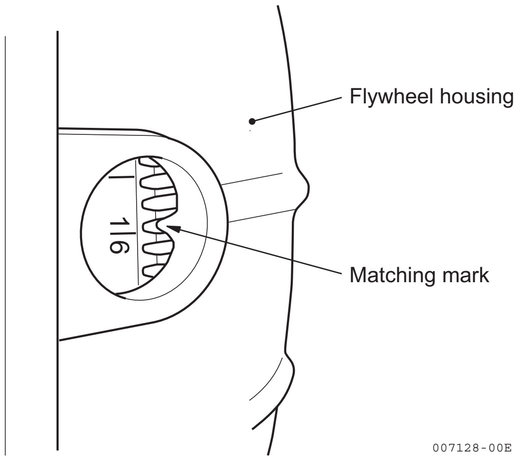
(2) Adjust intake / exhaust valve clearance

Make measurement and adjustment while the engine is cold.

1) Valve clearance measurement

a) Remove the rocker arm cover.

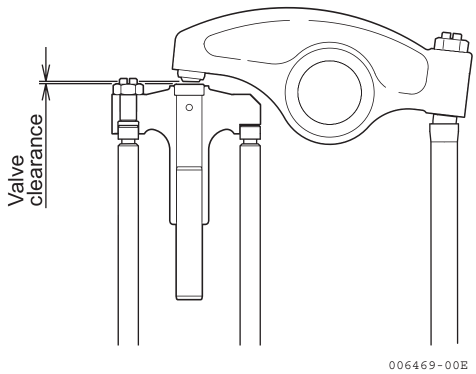
b) Set the No.1 cylinder (flywheel side) in the compression top dead center (T.D.C.). Turn the crankshaft to bring the piston of the No.1 cylinder to its compression top dead center while adjusting the matching mark of a flywheel housing and the top mark of a flywheel.
(At compression T.D.C. both intake and exhaust valves are closed.)



Note:

- The crankshaft shall be turned clockwise as seen from the gear case side.
- The No.1 cylinder position is on the opposite side of the gear case.
- Since there is a clearance between the rocker arm and valve bridge at compression top dead center, the position of compression T.D.C. can be checked by hand. Also see that the top mark on the flywheel aligns with the matching mark on the flywheel housing. If there is no valve clearance, disassemble and inspect around the valve seat, since the valve seat may be worn abnormally.

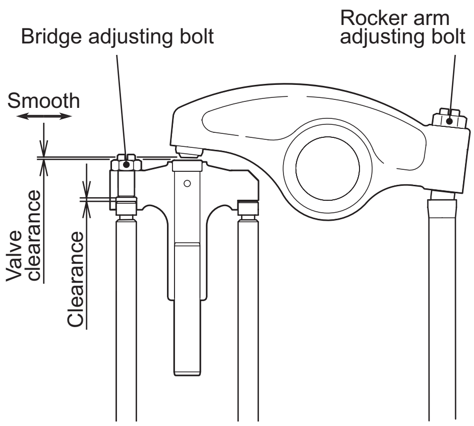
c) Valve clearance measurement
Insert a thickness gage between the rocker arm and the valve bridge, and record the measured valve clearance.
(Use it as the data for estimating the wear state.)



d) Measuring other cylinders
Turn the crankshaft 120° and make adjustment for the No.4 cylinder. Then adjust the No.2 cylinder according to the order of ignition.
The cylinder to be adjusted first does not have to be the No.1 cylinder. Select and adjust the cylinder where the piston is the nearest to the top dead center after turning, and make adjustment for other cylinders in the order of ignition by turning the crankshaft 120° each time.

2) Valve clearance adjustment

a) Loosen the adjusting bolt of a valve bridge
Loosen the lock nut of a valve bridge adjusting-bolt more than one turn to give a clearance between an adjusting bolt and a valve. And check the valve for any inclination of valve cap, entrance of dirt or wear.

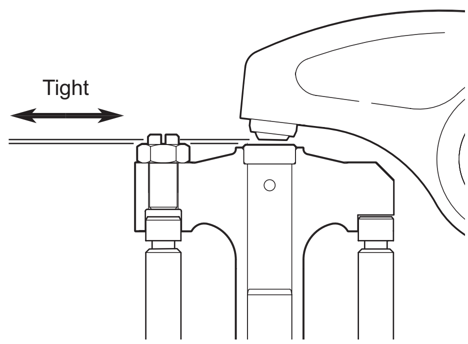


b) Measure valve clearance temporarily
Insert a thickness gage between the rocker arm and the valve bridge, and adjust the valve clearance by using the rocker arm adjusting bolt. Don't adjust the bridge adjusting-bolt.
Tighten the rocker arm adjusting bolt lightly (temporarily).

Standard valve clearance (mm)

Intake valve	0.15-0.25
Exhaust valve	0.45-0.55

c) Tighten the bridge adjusting-bolt gradually while moving a thickness gage, and confirm the position where the movement of the thickness gage becomes heavy (the position where the adjusting bolt touches the valve top).
Then tighten the bridge adjusting bolt more 45 degrees, and lock the bolt with the locknut.



d) Loosen the rocker arm adjusting bolt and readjust the valve clearance by using the rocker arm adjusting bolt.

Standard valve clearance (mm)

Intake valve	Exhaust valve
0.15-0.25	0.45-0.55

Note:
If the valve bridge is not replaced with new one or not moved to other cylinder, the above procedures of a, b, c is not necessary.

e) Apply lube oil to both sides (valve and push rod, contact surface) of rocker arm.

f) Adjusting other cylinders
Turn the crankshaft 240° then and make adjustment for the No.4 cylinder. Then adjust the No.2 cylinder in the order of ignition.
The cylinder to be adjusted first does not have to be the No.1 cylinder. Select and adjust the cylinder where the piston is the nearest to the top dead center after turning, and make adjustment for other cylinders in the order of ignition by turning the crankshaft 120° each time.

2.2.5 Inspection every 250 hours or one year

Be sure to check the following points every 250 hours or one year operation, whichever comes first.

No.	Inspection Item
(1)	Drain the fuel tank
(2)	Replace the fuel filter element
(3)	Replace the engine lube oil (Crankcase)
(4)	Replace the lube oil filter element
(5)	Check the impeller of the seawater pump
(6)	Replace anti-corrosion zinc
(7)	Clean the air intake silencer
(8)	Clean the exhaust / water mixing elbow
(9)	Clean the turbocharger blower
(10)	Flush intercooler
(11)	Check the wiring connectors
(12)	Retighten all major nuts and bolts
(13)	Check flexible engine mounts

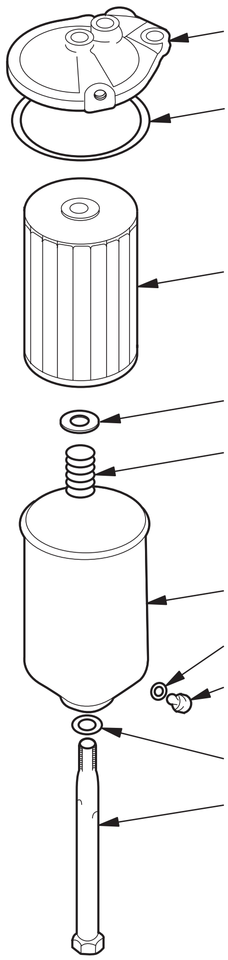
(1) Drain the fuel tank

Open the drain cock of the fuel tank to extract drain (water, dust, etc.) from the tank's bottom. Receive the drain in a container. Drain until fuel with no water and dust flows out. Then close the drain cock.

(2) Replace the fuel filter element

When the engine is operated on light diesel oil, replace the fuel filter element every 250 hours or one year of operation.

1) Close the fuel cock of the fuel tank.
2) Remove the center bolt at the bottom of the filter and take out the filter element.
3) Replace the element with new one and tighten the center bolt.
4) After reassembly, be sure to bleed air from the fuel system.



- Fuel system air bleeding procedures

1) Check the fuel level in the fuel tank. Replenish if Insufficient
2) Loosen the air bleeding bolt of the fuel filter by turning it 2 or 3 turns.
3) Feed fuel with the fuel feed pump by moving the knob on the top of the feed pump up and down.
4) Allow the fuel containing air bubbles to flow out from the air bleeding bolt holes. When the fuel coming out no longer contains bubbles, tighten the air bleeding bolt. This completes the air bleeding of the fuel system. Try starting the engine.
5) If the air bleeding of the fuel system is not completed, loosen the air bleeding bolt at the top of the fuel / water separator by turning it 2 or 3 turns. When fuel without air bubbles comes out of the bolt hole, tighten the air bleeding bolt. Try starting the engine again.
6) In subsequent engine operation after the start-up, the automatic air-bleeding device works to purge the air in the fuel system. No manual air bleeding is required for normal engine operation.

(3) Replace the engine lube oil (Crankcase)

It is easiest and most effective to drain the engine lube oil after operation while the engine is still warm.

⚠ CAUTION

Beware of oil burns if extracting the lube oil while it is hot.

See 2.2.2(1) for the procedure.

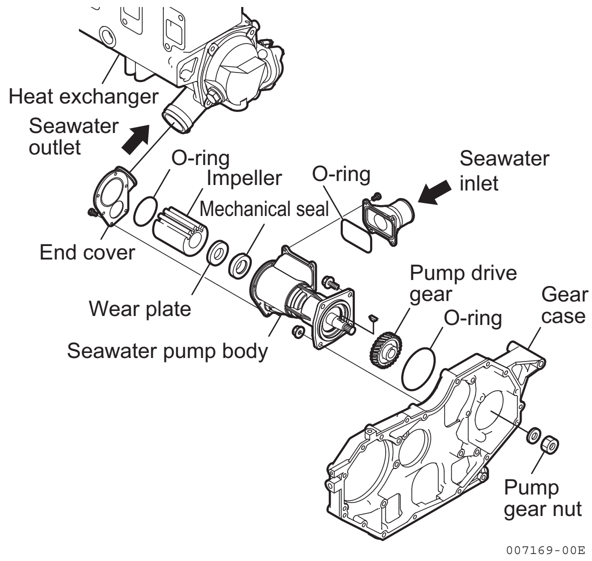
(4) Replace the lube oil filter element

See 2.2.2(1) for the procedure.

(5) Check the impeller of the seawater pump

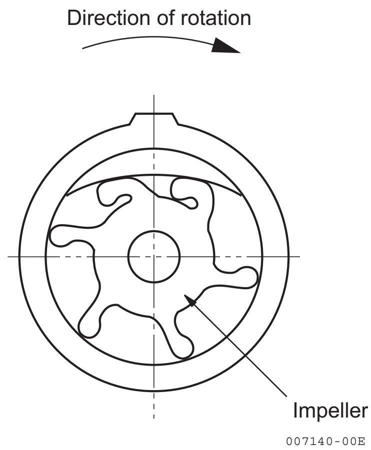
Depending on the use, the inside parts of the seawater pump deteriorate and discharge performance drops. At the specified interval or when the volume of seawater discharged is reduced, inspect the seawater pump in accordance with the following procedures;

1) Loosen the end cover bolts and remove the end cover.
2) Illuminate the inside of the seawater pump with a flashlight and inspect.
3) If any of the following problems are found, disassembly and maintenance (replacement) are necessary:
   Impeller blades are cracked or nicked.
   Edges or surfaces of the blades are damaged or scratched.
   Wear plate is damaged.
4) If no damage is found when inspecting the inside of the pump, reassemble the end cover.
5) If a large amount of water leaks continuously from the seawater pump during operation, disassembly and maintenance (replacement) are necessary.

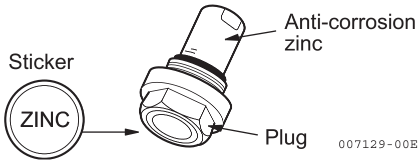


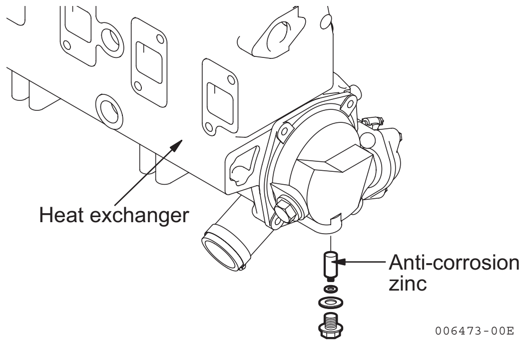
NOTICE

The seawater pump turns in the direction as shown in the right figure, and the impeller must be installed while considering the impeller direction. If the impeller has been removed for any reason and must be reassembled, be very careful not to make a mistake and turn it in the wrong direction. Additionally, if the engine is being turned manually, be careful to turn it in the correct direction. Incorrect turning will twist the impeller and damage it.



(6) Replace anti-corrosion zinc





The timing for replacing anti-corrosion zinc varies depending on the characteristics of the seawater and operational conditions.
Inspect the zinc periodically and remove the corroded area on the surface.
Replace the anti-corrosion zinc when it has decreased to less than 1/2 of the original volume. If replacement of zinc is neglected and operation is continued with a small volume of anti-corrosion zinc, corrosion of the seawater cooling system will occur and water leakage or parts breakage will result.
The label shown in the figure is stuck on the plugs which have the anti-corrosion zinc.
Be sure to close the seacock before removing the plug to replace the anti-corrosion zinc.

(7) Clean the air intake silencer

Disassemble the intake silencer and clean the inside thoroughly.

1) Remove the silencer by taking off the clamp.
2) Clean the element with a neutral detergent.
3) Reassemble after it is completely dry.

(8) Clean the exhaust / water mixing elbow

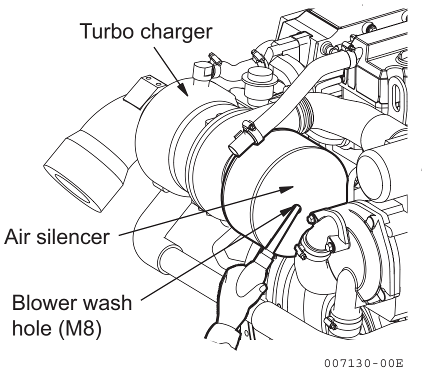
The mixing elbow is attached to the turbocharger. The exhaust gas is mixed with seawater in the mixing elbow.

1) Clean dirt and scale out of the exhaust gas passage and seawater way in the mixing elbow.
2) Repair the crack or damage of the mixing elbow by welding, or replace if necessary.
3) Inspect the gasket and replace if necessary.

(9) Clean turbocharger blower

Contamination of the turbocharger blower causes the blower revolutions to drop and engine output to fall.
If a drop of engine output is noted (by about 10%), clean the blower:

1) Prepare blower cleaning agent, fresh water and a small pitcher.
2) Remove M8 bolt for blower wash on the side surface of a silencer and also drain plug (M8 bolt and washer) of a intercooler.
3) Pour about 50cc of blower cleaning agent little by little at about 10 seconds intervals through the M8 hole under load operation
4) Wait about 3 minutes, and pour 50cc fresh water into the air inlet in the same manner at about 10 seconds intervals.
5) Run the engine at load for about 10 minutes to dry the turbocharger and check that engine output has recovered.
   If the output has not recovered, repeat the above cleaning cycle 3 or 4 times.
6) If filter is dirty, clean it with detergent, dry it and install it to the silencer.
   Replace if broken.
7) Don't forget to reassemble M8 bolt to silencer and drain plug to intercooler.



NOTICE

1. Do not pour a large quantity of blower cleaning agent or fresh water in at once.
   The blower may be broken or water-hammer may occur.
2. If the air silencer is removed from turbocharger, defat the silencer, turbocharger and inside of hose sufficiently then assemble them. If oil is stuck on those parts, they may come off during engine running.

(10) Flush intercooler

Contamination of the intercooler causes the engine output to fall.
If a drop of engine output is noted (by about 10%), flush and clean the intercooler:

1) Remove the side cover on flywheel side and inspect the inside of the tubes for rust or scale buildup from seawater.
2) If rust or scale is seen inside the tubes, remove the intercooler from the engine.
3) Flush and clean the tubes with a wire brush if necessary.

(11) Check the wiring connectors

Check whether each connection part doesn't loose.

(12) Retighten all major nuts and bolts

After long time usage, the nuts and bolts used may loosen.
Check and retighten the nuts and bolts such as;

1) Flexible engine mount bolts
2) Shaft coupling bolts
3) Exhaust flange bolts
4) Intake silencer fasteners
5) Other nuts and bolts

Retighten the major nuts and bolts bellow by the standard tightening torques.
Refer to chapter 14 for the tightening torques of the major parts.

1) Cylinder head bolts
2) Crankshaft pulley bolts
3) Fuel injection nozzle set bolts
4) Fuel injection pipe joint nut
5) Others

Retighten the following major bolts by the standard tightening torques as requested.

1) Rod bolts
2) Flywheel retainer bolts
3) Metal cap bolts

(13) Check flexible engine mounts

The flexible engine mounts are compressed a little in the initial engine operation and it may cause the centering misalignment between the engine & the propeller shaft.

1) Check the crack on the rubber of engine mounts. If it is found, replace the engine mount(s) with new one.
2) Check unusual noise and vibration of the engine / boat hull, while increasing the engine speed gradually and lowering it.

If there is unusual noise and / or vibration, adjust the propeller shaft alignment. (Refer to 6.4.5 "Centering the Engine" in the installation manual for pleasure boat use.)

2.2.6 Inspection every year

No.	Inspection Item
(1)	Replace the engine coolant

(1) Replace the engine coolant.

Be sure to replace the fresh water every year. When the long life coolant is used of the specified type, the replacement period of two years can be obtained.

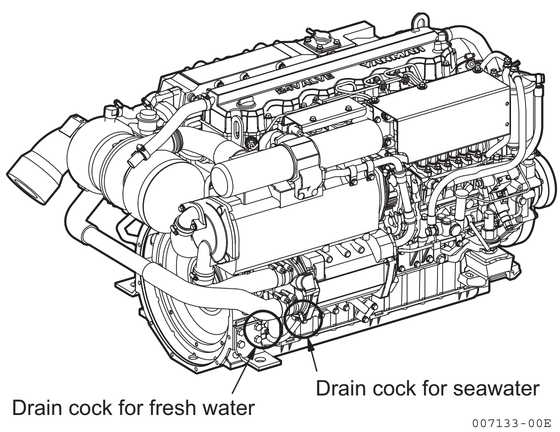
Use clean soft water and be sure to add the Long Life Coolant Antifreeze (LLC) to the cooling water in order to prevent rust built up and freezing.

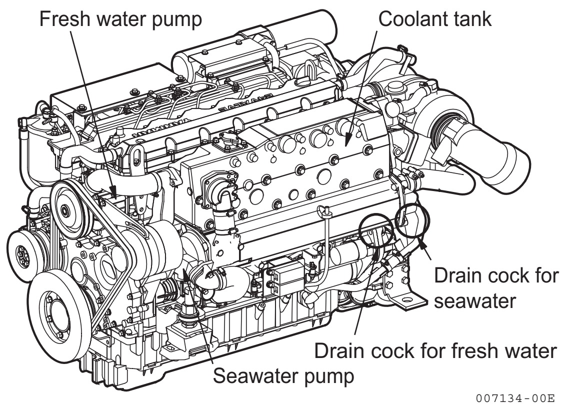
Cooling performance drops when cooling water is contaminated with rust and scale.

Even if antifreeze or antirust is added, the cooling water must be replaced periodically because the properties of the agent will degenerate.

1) Open the two cooling water cocks for fresh water and extract the fresh water.

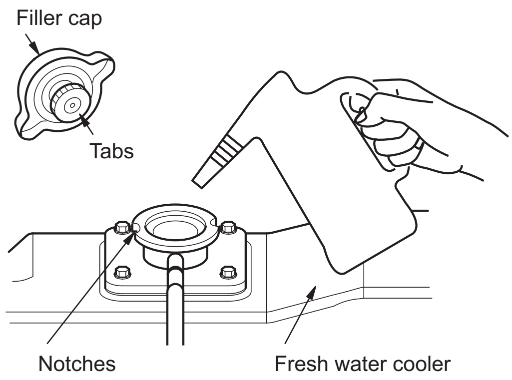
	Fresh water line	Sea water line
No. of cocks	2	2





2) Close the two cocks for fresh water. Be sure to check that the two cocks for seawater are closed.

3) Remove the filler cap of the fresh water cooler by turning the cap counterclockwise 1/3 of a turn.
4) Pour cooling water slowly into the coolant tank so that air bubbles do not develop. Pour until the water overflows from the filler port.

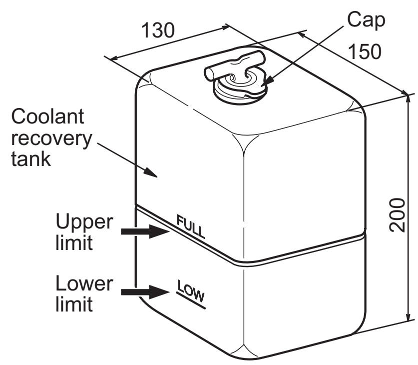


5) After supplying cooling water, fit the filler cap and tighten it firmly. To reassemble the cap, align the tabs on the bottom of the cap with the notches on the filler port and turn clockwise 1/3 of a turn.

⚠ DANGER

If the filler cap is loose, hot steam and water will spout out which may cause burns.

6) Remove the coolant recovery tank cap and fill with coolant mix to the lower limit. Replace the cap to the coolant recovery tank.
   Coolant recovery tank capacity: 1.5 ℓ(3.2 pints)
7) Check the rubber hose connecting the coolant recovery tank to the fresh water cooler. Be sure the hose is securely connected and there is no looseness or damage.
   When the hose is not watertight, an excessive amount of cooling water will be used.



2.2.7 Inspection every 500 hours or two years

No.	Inspection Item
(1)	Check the impeller of the seawater pump
(2)	Clean the exhaust / water mixing elbow
(3)	Adjust the tension of the alternator driving belt
(4)	Adjust the propeller shaft alignment

(1) Check the impeller of the seawater pump

Note:
The impeller must be replaced with new one periodically (every 500 hrs or 2 years, whichever comes first).

Refer to 2.2.5 for the procedure.

(2) Clean the exhaust / water mixing elbow

Replace the used mixing elbow with new one, even if any damage is not found.

(3) Adjust the tension of the alternator driving belt

Refer to 2.2.3(3) for the procedure.

(4) Adjust the propeller shaft alignment

The rubber tension of the flexible engine mounts is lost after many hours' use. This leads to a drop in vibration absorption performance, and also causes centering misalignment of the propeller shaft.

1) Check unusual noise and vibration of the engine and the boat hull with increasing the engine speed gradually and lowering it.
2) If necessary, adjust the propeller shaft alignment. (Refer to 6.4.5 "Centering the Engine" in the installation manual for pleasure boat use.)

2.2.8 Inspection 2,000 hours or every two years

Inspect every 2,000 hours or two years of engine operation, whichever comes first.

No.	Inspection Item
(1)	Replace rubberized fuel pipes

(1) Replace rubberized fuel pipes

Replace the rubberized fuel pipes with new ones every two years or 2,000 hours of engine operation, whichever comes first, even if the engine has been out of service. Rubberized fuel lines tend to dry out and become brittle after two years or 2,000 hours of engine operation, whichever comes first.

2.2.9 Inspection every 1,000 hours or four years

Be sure to check the following points every 1,000 hours or four years operation, whichever comes first.

No.	Inspection Item
(1)	Check the injection spray condition
(2)	Clean & check the water passages
(3)	Adjust the tension of the alternator driving belt
(4)	Adjust intake / exhaust valve clearance
(5)	Check / replace flexible engine mounts

(1) Check the injection spray condition

Adjustment is necessary to obtain the optimal fuel injection to ensure the best possible engine performance.

Refer to 2.2.4(1) for the procedure.

(2) Clean & check the water passages

When it is used for a long time, cleaning of the cooling water passages such as cooling water rubber hoses and heat exchanger is periodically necessary. Because trash, scale, rust, and so on collect in the cooling water passages and the cooling performance declines.

1) Check the rubber hoses & clamps and replace with new ones if necessary.
2) If trash, scale or rust is found in heat exchangers, clean them.

(3) Adjust the tension of the alternator driving belt

Replace the alternator driving belt with new one every 1000 hours or four years, whichever comes first, even if there is no crack or damage in the surface.

Refer to 2.2.3(3) for the procedure.

(4) Adjust intake / exhaust valve clearance

Inspection and adjustment must be made to correct opening / closing timing lags of the intake / exhaust valves, which might arise due to normal wear by the long time use.

Refer to 2.2.4(2) for the procedure.

(5) Check / replace flexible engine mounts

The rubber tension of a flexible engine mount is lost after long time use.
This leads to a drop in vibration absorption performance, and also causes centering misalignment of the propeller shaft.

1) Be sure to replace the flexible engine mounts every 1000 hours or 4 years, whichever comes first.
2) Check unusual noise and vibration of the engine / boat hull, while increasing the engine speed gradually and lowering it.
3) If there is unusual noise and / or vibration, adjust the propeller shaft alignment. (Refer to 6.4.5 "Centering the Engine" in the installation manual for pleasure boat use.)

2.2.10 Inspection every 2000 hours or eight years

No.	Inspection Item
(1)	Overhaul and check of fuel feed pump
(2)	Clean lube oil cooler
(3)	Clean seawater and fresh water system

(1) Overhaul and check of fuel feed pump

Fuel feed pump must be overhauled and checked to ensure optimal engine performance.

1) Fuel feed pump disassembly
   Follow the procedure below to disassemble the fuel feed pump.
   a) Remove the piston spring stopper plug, and pull out the piston and piston spring.
   b) Remove the snap ring, and pull out the tappet assembly.
   c) Pull out the inter-spindle.
   d) Remove the priming pump.
   e) Remove the discharge valve spring stopper, and remove the valve and spring from inside.
   f) Remove the O-ring.
2) Fuel feed pump inspection
   a) Block the priming pump with your finger and check whether the pressed-in piston returns by spring force. If the piston returns, the piston does not have enough negative pressure. Always replace the priming pump as a set.
   b) Check the piston spring for cuts, cracks, uneven wear and rust.
   c) If the piston, inter-spindle, or tappet assembly are extremely worn, replace the part.
   d) Check the contact surface of the valve and valve seat for defects.
   e) When there is play in a valve seat which has been calked into the feed pump body, the whole fuel pump body must be replaced.

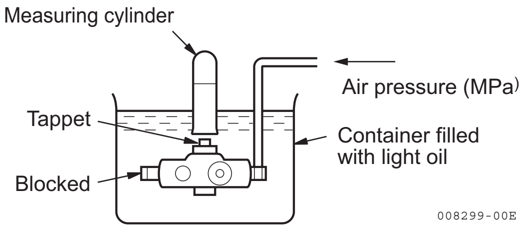
   Refer to chapter 6 for the procedure of adjustment.

   Note:
   Play in the valve seat hinders the opening and closing of the valve, causing insufficient fuel supply and abnormal wear of the tappets and camshaft.

3) Fuel feed pump reassembly

a) To reassemble the fuel feed pump, follow the assembly procedure in reverse order.

b) When the pump has been reassembled, perform the air-tightness test.
Apply 0.3MPa (3kg / cm^2) of air pressure to the discharge outlet of the pump, and check for air leaks from the O-ring. If air is leaking, replace the O-ring.



(2) Clean lube oil cooler

Rust and scale are deposited inside the seawater system during long time use.

This lowers cooling performance, so it is necessary to clean and maintain the lube oil cooler.

The internal contamination of the lube oil cooler reduces cooling efficiency and accelerates the lube oil cooler degeneration.

1) Remove the lube oil cooler from an engine.
2) Flush and clean the inside (seawater passage) of the cooler tubes with a nylon brush, which will fit inside.
3) Clean the outside (lube oil passage) of the cooler tubes.
4) When reassembling, don't forget to install O-rings and separator packing.
5) Put the pressure of 0.2 MPa on the lube oil passage, and inspect that there is no leakage.

(3) Clean seawater and fresh water system

Rust and scale are deposited inside the seawater and fresh water cooling system during long time use. This lowers cooling performance, so it is necessary to clean and maintain the following parts in addition to replacing the cooling water.

1) Cleaning and inspection of cooling water rubber hoses.

a) Remove the cooling water rubber hoses for the fresh water line and the seawater line.

b) Check the dust and trash inside the hoses. If necessary, clean it.

c) Check the crack and the deterioration of the rubber hoses. If necessary, replace with new ones.

d) Replace the used hose clips with new ones, if necessary.

2) Inspection of cooling water heat exchanger

a) Cooler core inspection

Note:
Disassemble and wash when the cooling water temperature reaches 85°C.

- Inspect the inside of the tubes for rust or scale buildup from seawater, and clean with a nylon brush if necessary.
- Check the joints at both ends of the tubes for looseness or damage, and repair if loose, Replace if damaged or corroded.
- Check tubes and replace if leaking.
- Clean any scale or rust off the outside of the tubes.

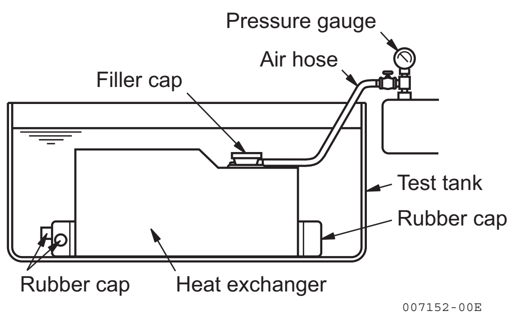
b) Heat exchanger body inspection

- Check heat exchanger body and side cover for dirt and corrosion. Replace, if excessively corroded, or cracked.
- Inspect seawater and fresh water inlets and outlets, retighten any joints as necessary.
- Check the exhaust gas intake flange and passage, and replace if corroded or cracked.

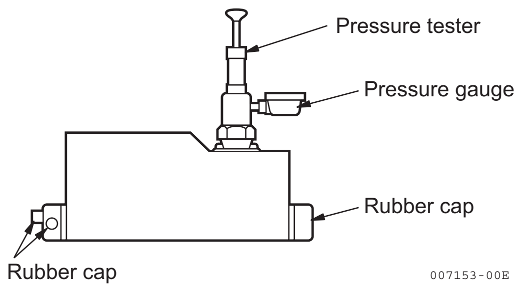
c) Heat exchanger body water leakage test

- Compressed air / water tank test
  Fit rubber covers on the fresh water and seawater inlets and outlets. Place the heat exchanger in a water tank, feed in compressed air from the overflow pipe and check for air bubbles (leakage).

Test pressure	0.20MPa (2kgf / cm^2)



- Use of the tester
  Fit the fresh and seawater inlets and outlets with rubber covers and fill the fresh water tank with fresh water. Fit a pressure cap tester in place of the pressure cap, operate the pump for one minute and set the pressure at 0.15 MPa (1.5 kg / cm^2, 21.33 lb / $in.^2$). If there are any leaks, the pressure will not rise. If there is no leak, the pressure will not fall.



d) Pressure cap inspection

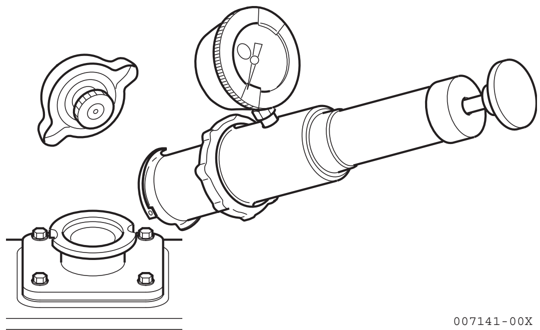
⚠ DANGER

Do not open the pressure cap while the engine is running or right after stopping because high temperature steam will be blown out. Remove the cap only after the water cools down.

- Remove scale and rust and check the seat and seat valve, etc. for scratches or wear. Check the spring for corrosion or settling. Replace if necessary.

Note:
Clean the pressure cap with fresh water as it will not close completely if it is dirty.

- Fit the adopter on the tester to the pressure cap. Pump until the pressure gauge is within the specified pressure range 93-123kPa (0.95-1.25 kgf / cm^2) and note the gauge reading. The cap is normal if the pressure holds for six seconds. If the pressure does not rise, or drop immediately, inspect the cap and repair or replace as necessary.

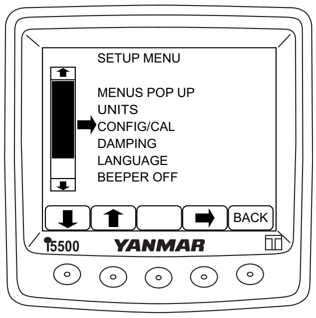


007141-00X

2.3 Adjusting the no-load minimum speed

Low idle speed setting
After warming an engine up, adjust and set the low idle speed by using a digital display as follows.

1) Make display a setup menu on the digital display.
2) Select "CONFIG / CAL" and push the button under the right arrow and the "CONFIG / CAL" screen will appear.
3) Select "ENGINE SETTING" and push the button under the right arrow and "ENTER PASSWARD" screen appear. The "ENGINE SETTINGS" screen will appear, after entering the password.
4) Select "ENTER IDLE RPM" and push the button under the right arrow and the "IDLE RPM SETTING" screen will appear.
5) The engine low idle speed can be set every 20 min^{-1} among from 700 min^{-1} to 800min^{-1}. Adjust the low idle speed by using + button or - button. Push the "SET" button and the beep will sound.



006476-00X

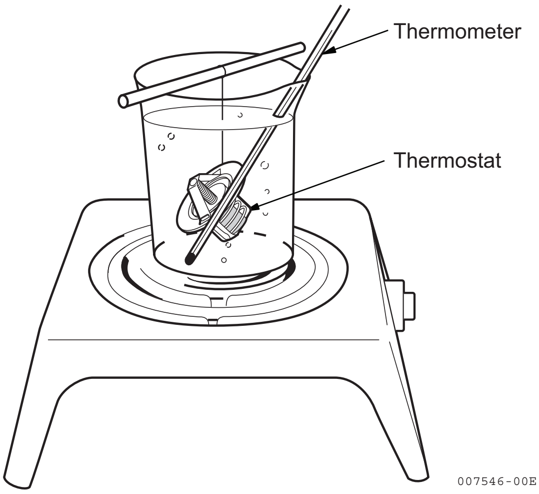
Standards (Unit: min^{-1})

Low idle speed
700 ± 25

Note:
The high idle speed is fixed and can't be changed.

2.4 Thermostat inspection

(1) Put the thermostat in a beaker with fresh water, and heat it on an electric stove. The thermostat is functioning normally if it starts to open between 69-73 deg C, and opens until 10mm or more at 85 deg C. Replace the thermostat if it is not functioning normally.



Valve opening temperature (deg C)*	Full open lift (Temperature) (mm)
69-73	10 or more (85deg C)

* Valve opening temperature is carved on the flange.

(2) Normally the thermostat should be inspected every 500 hours of operation. But it should be inspected before this interval, if the cooling temperature rises abnormally or white smoke is emitted for a long time after engine starting.

(3) Replace the thermostat every year or 2000 hours of operation, whichever comes first.

2.5 Test running

Perform the test running for an engine as follows after the maintenance job:

2.5.1 Preliminary precautions

Before making a test running, make sure of the following points.

(1) Warm the engine up.

(2) Remove any precipitation from the F.O. filter. water separator, and F.O tank.

(3) Use only lube oil recommended by Yanmar.

(4) Be sure to add Long Life Coolant Antifreeze (LLC) to cooling fresh water.

(5) Provide good ventilation in an engine room.

2.5.2 Test running procedure

1) Supply the fuel oil, lube oil and coolant / water.
2) Start the engine, and carry out idling operation at a low speed (700 to 900 rpm^{-1}) for a few minutes.
3) Run in at the rated speed (no-load) for about five minutes. Check any water, fuel or lube oil leakage and existence of abnormal vibration or noise. Also check the oil pressure, cooling water temperature and exhaust gas color.
4) Adjust the no-load minimum and maximum speed. (Refer to 2.3.)
5) Perform loaded operation as required.
6) Shut down the engine after test running (for about 10 minutes).

Note:
Check the levels of the lube oil and coolant / water again and add as required.

2.5.3 Check points and precautions during running

Step	Item	Instructions	Precautions
1	Checks before operation	1) Make sure that the seacock is open. 2) Make sure there is enough lube oil and coolant / water. 3) Operate the electronic control head and check if it works property.	3) Alarm indicator doesn't appear on the display.
2	No load operation; warm up operation	1) Check the lube oil pressure and coolant temperature on the display. 2) When the engine starts, check the following: • There is no leakage of water, fuel and lube oil. • Exhaust gas does not leak. • There is no abnormal indication on the display. • There is no abnormality in seawater discharge, engine vibration or engine sound. 3) To warm up the engine, operate at low speed for about 5 minutes, raise the speed to the no-load rated speed and then to max. speed.	2) • Fit leaks if any. • Check the intake / exhaust valves, fuel injection nozzle and cylinder head. 3) Do not raise the engine speed abruptly.
3	Cruising (load) operation	1) Do not operate the engine at full load yet, but raise the speed gradually for about 10 minutes until it reaches the rated speed. 2) Make sure that exhaust gas color and temperature are normal. 3) Check the instrument panel and see if the water temperature and oil pressure are normal.	
4	Stopping the engine	1) Before stopping the engine, operate it at 650-700 min^{-1} for about 5 minutes. 2) Raise engine speed to 1,800 min^{-1} just before stopping the engine and idle the engine for about 3-4 seconds.	1) Stopping the engine suddenly during high speed operation increases the temperature of engine parts. 2) This procedure prevents carbon from being deposited on the valve seats, etc.
5	Checks after stopping the engine	1) Check again for water and oil leaks. 2) Make sure that no nuts and bolts are loose. 3) Close the sea cock and fuel cocks. 4) When the temperature is expected to fall below freezing, drain the seawater. 5) Turn off the battery switch.	1) Check the oil seal area. 2) Especially the engine installation bolts. 4) Drain from the sea water pump.

2.6 Long storage

Observe the following instructions when the engine is to be stored for a long period without operation:

1) Drain seawater in cold season or before the long time storage.

[NOTICE]

Do not drain coolant in cold season or before the long time storage.
Negligence of adding anti-freeze will cause the cooling water remaining inside the engine to be frozen and expanded to damage the engine parts.

2) Remove the mud, dust and oil deposit and clean the outside.
3) Perform the nearest periodic inspection before the storage.
4) Drain or fill the fuel oil fully to prevent condensation in the fuel tank.
5) Disconnect the battery cable from the battery negative (-) terminal.
6) Cover the silencer and electric parts with PVC (Poly Vinyl Chloride) cover to prevent water and dust from depositing or entrance.
7) Select a well-ventilated location without moisture and dust for storage.
8) Perform recharging once a month during storage to compensate for self-discharge.
9) When storing an engine for long time, run the engine periodically according to the following procedure because the rust occurrence inside the engine, the rack agglutination of the fuel pump, and so on are likely to occur. (In case that the engine is equipped with a boat,)
   a) Replace the lube oil and the filter with new ones before the engine running.
   b) Supply fuel if the fuel in the fuel tank was removed, and bleed the fuel system.
   c) Confirm that there is the coolant in the engine.
   d) Operate the engine at the low idling speed for about five minutes. (If it can be done, once a month)

3. Troubleshooting

3.1 Preparation before troubleshooting

If the signs of a trouble appear, it is important to lecture on the countermeasure and treatment before becoming a big accident not to shorten the engine life.

When the signs of a trouble appear in the engine or a trouble occurs, grasp the trouble conditions fully by the next point and find out the cause of sincerity according to the troubleshooting. Then repair the trouble, and prevent the recurrence of the trouble.

1) What's the occurrence phenomenon or the trouble situation?
   (e.g. Poor exhaust color)
2) Investigation of the past records of the engine
   Check a client control ledger, and examine the history of the engine.
   - Investigate the engine model name and the engine number. (Mentioned in the engine label.)
     Examine the machine unit name and its number in the same way.
   - When was the engine maintained last time?
   - How much period and / or time has it been used after it was maintained last time?
   - What kind of problem was there on the engine last time, and what kind of maintenance was done?
3) Hear the occurrence phenomenon from the operator of the engine in detail.
   5W1H of the occurrence phenomenon: the investigation of when (when), where (where), who (who), what (what), why (why) and how (how)
   - When did the trouble happen at what kind of time?
   - Was there anything changed before the trouble?
   - Did the trouble occur suddenly, or was there what or a sign?
   - Was there any related phenomenon.
     (e.g. Poor exhaust color and starting failure at the same time)
4) After presuming a probable cause based on the above investigation, investigate a cause systematically by the next troubleshooting guide, and find out the cause of sincerity.

3.2 Troubleshooting

It is important to thoroughly under stand each system and the function of all of the parts of terse systems. A careful study of the engine mechanism will make this possible. When problems arise, it is important to carefully observe and analyze the indications of trouble in order to save time in determining their cause. Begin by checking the most easily identifiable causes of difficulty. Where the cause of the difficulty is not readily apparent, make a thorough examination of the system from the very beginning, proceeding until the point of trouble can be determined. While experience is an important factor in pinpointing engine problems, careful study and understanding of the engine mechanism combined with good common sense will help you to rapidly become more expert at troubleshooting.

3.2.1 Troubleshooting from trouble symptom

Trouble symptom	Causes	Corrective action	Remarks
Digital display and control head are not turned on.	The battery voltage is low. (Discharging battery)	Check the electrolyte level in the battery and the specific gravity of battery liquid.	Refer to 13.2.
		Charge the battery or replace.	Refer to 13.2.
		Check the short of electric circuit.	Refer to 13.
	The battery voltage is low (Charging defect)	Check the damaged wire between alternator and battery and the tangency with both terminals.	Refer to 13.4.
		Check the tension of V belt.	Refer to 2.2.3(3).
		Check the alternator.	Refer to 13.4.
	Wiring of the control system isn't accomplished.	Connect the control system wires (+ and -) with battery.	Refer to 13.
	Disconnecting connectors	Wire each connector according to the manual.	Refer to 13.
	Contact failure of each connector terminal	Check each connector terminal and confirm the tangency.	
	Fuse burns out. (AUX POWER: 10A)	Check the fuse.	Refer to 3.2.2.

Trouble symptom	Causes	Corrective action	Remarks
An engine data (with engine speed, temperature and so on) isn't displayed on LCD display screen.	The battery voltage is low. (Discharging battery)	Check the electrolyte level in the battery and the specific gravity of battery liquid.	Refer to 13.2.
		Charge the battery or replace.	Refer to 13.2.
		Check the short of electric circuit.	Refer to 13.
	The battery voltage is low (Charging defect)	Check the open-circuit of wire between alternator and battery and the tangency with both terminals.	Refer to 13.4.
		Check the tension of V belt.	Refer to 2.2.3(3).
		Check the alternator.	Refer to 13.4.
	Wiring of the control system isn't accomplished.	Connect the control system wires (+ and -) with battery.	Refer to 13.
	Disconnecting connectors	Wire each connector according to the manual.	Refer to 13.
	Contact failure of each connector terminal	Check each connector terminal and confirm the tangency.	
	Fuse burns out. (IGN. PANEL: 10A)	Check the fuse.	Refer to 3.2.2.
	Fuse burns out. (ECU: 20A)	Check the fuse.	Refer to 3.2.2.
	Fuse burns out. (IGN. SIG: 10A)	Check the fuse.	Refer to 3.2.2.
	Fuse burns out. (IGN. 1st Station: 5A)	Check the fuse.	Refer to 3.2.2.
	Fuse burns out. (IGN. 2nd Station: 5A)	Check the fuse.	Refer to 3.2.2.
	Detecting error (U0146/12)	→	DTC: Refer to 3.3.

Trouble symptom	Causes	Corrective action	Remarks
Starting trouble The starting motor doesn't rotate and the engine can't start.	The battery switch is off.	Turn on the battery switch.	Refer to 13.
	The battery voltage is low. (Discharging battery)	Check the electrolyte level in the battery and the specific gravity of battery liquid.	Refer to 13.2.
		Charge the battery or replace.	Refer to 13.2.
		Check the short of electric circuit.	Refer to 13.
	The battery voltage is low. (Charging defect)	Check the breaking wire between alternator and battery and the tangency with both terminals.	Refer to 13.4.
		Check the tension of V belt.	Refer to 2.2.3(3).
		Check the alternator.	Refer to 13.4.
	The fuse burns out. (IGN. PANEL: 10A)	Replace.	Refer to 3.2.2 and 13.7.
	The fuse burns out. (ECU: 20A)	Replace.	Refer to 3.2.2 and 13.7.
	The fuse burns out. (STARTER RELAY: 50A)	Replace.	Refer to 3.2.2 and 13.7.
	The fuse burns out. (IGN. 1st Station: 5A)	Replace.	Refer to 3.2.2 and 13.7.
	The fuse burns out. (IGN. 2nd Station: 5A)	Replace.	Refer to 3.2.2 and 13.7.

Trouble symptom	Causes	Corrective action	Remarks
The starting motor doesn't rotate and the engine can't start.	The trouble of the starter relay. (The contact failure)	Check the operation of a starter relay with a service tool and a tester. If there is a malfunction, replace it.	Refer to 13.7 for relay location.
The pinion gear of a starter doesn't mesh.	The loose of a magnet-switch terminal.	Check a magnet-switch and around a terminal. If a malfunction is found, repair or replace.	Refer to 13.
	The contact failure of a magnet-switch.		
	The coil disconnection of a magnet switch.		
	The burr on tooth top.	Repair with sand paper or replace.	Refer to 13.3.
	The trouble of the clearance between a pinion and a ring gear.	Check the clearance.	Refer to 13.3.
The pinion gear of a starting motor meshes but the starting motor doesn't rotate.	The loose of battery and starting motor terminals.	Check the contact condition of terminals. If the trouble is found, repair.	Refer to 13.3.
	The disconnect of a starter coil.	Replace or repair.	Refer to 13.3.
	The clutch slip.	Replace or repair.	Refer to 13.3.
	Battery cable resistance is big. (The wire diameter is thin)	Replace it with a cable having proper wire diameter.	Refer to 13.3.
	The battery voltage is low. (Battery discharge)	Check the electrolyte level in the battery and the specific gravity of battery liquid.	Refer to 13.2.
		Charge the battery or replace.	Refer to 13.2.
		Check the short-circuit of electric circuit.	Refer to 13.

Trouble symptom		Causes	Corrective action	Remarks
	(continued)	The battery voltage is low. (Faulty charging)	Check the disconnect between a alternator and a battery and the contact condition of both terminals.	Refer to 13.4.
			Check the V-belt tension.	Refer to 2.2.3(3).
			Check the malfunction of an alternator.	Refer to 13.4.
(continued)		The main moving parts seized.	Disassemble and inspect the trouble part(s). Repair or replace.	Refer to 4.3.
		The control lever is not in Neutral position. "Starter Interlock"	Shift the lever in Neutral.	Refer to 12.1.3.
		"Emergency Stop" switch is pressed.	Turn off the "Emergency Stop" switch on control panel.	Refer to 12.1.2.
		The crank speed sensor detects overspeed error (P0219).	→	DTC (Diagnostic Trouble Code). Refer to 3.3 and 13.5.1.
		The camshaft speed sensor detects overspeed error (P0219).	→	DTC Refer to 3.3 and 13.5.1.
		The disconnect and short-circuit errors (P0335 and P0340) of both speed sensors are detected.	→	DTC Refer to 3.3 and 13.5.1.
		The disconnect and short-circuit error (P1210) of a rack actuator is detected.	→	DTC Refer to 3.3 and 6.1.3.
		The rack movement error (P1211) of a rack actuator is detected.	→	DTC Refer to 3.3 and 6.1.3.
		A battery cable isn't connected.	Connect a minus terminal to engine body and a plus terminal to the starter B terminal.	

Trouble symptom	Causes	Corrective action	Remarks
The starting motor rotates but the engine can't start.			
Fuel isn't supplied.	The viscosity of fuel is high and fuel doesn't flow.	Check fuel property and use the recommended fuel.	Refer to 1.3.1.
	Fuel line is frozen.	Warm up fuel.	
	Air in the fuel system.	Bleed air in the fuel system.	Refer to 2.2.3(1).
	Fuel filter is clogged.	Check fuel filter and replace if necessary.	Refer to 6.4.
	No fuel in a fuel tank.	Refuel.	Refer to 1.3.1.
	A fuel cock is closed.	Open the fuel cock.	Refer to 1.3.1.
	Clogged fuel system.	Check the fuel system and repair if necessary.	Refer to 1.3.1.
	Trouble of fuel feed pump.	Check and repair or replace if necessary.	Refer to 6.3.
Faulty fuel injection nozzle.	Trouble of valve seat.	Check fuel spray condition with a tester. If malfunction is found, ask a FIE shop for maintenance or replace.	Refer to 2.2.4(1).
	Sticking of needle valve.		
	Wear of nozzle seat.		
	Clogged fuel nozzle hole(s).		
	Decrease of opening pressure.		
Faulty fuel injection pump.	Wear of plunger.	Check. If malfunction is found, ask a FIE shop for maintenance or replace. (If measuring hysteresis with a service tool, the movement of rack can be checked.)	Refer to 6.1.7.
	Plunger spring broken.		
	Plunger stuck.		
	Delivery valve spring broken.		
	Air in the fuel system.	Bleed air in the fuel system.	Refer to 2.2.3(1).
Faulty other fuel injection system.	The difference of injection timing by faulty fitting of fuel injection pump.	Check the injection timing control and the pump fitting. If the timing difference is found, reassemble.	Refer to 6.1.6.
	Loose of fuel injection pipe.	Retighten if necessary.	Refer to 4.3.2(29).
	Damaged fuel injection pipe.	Replace if necessary.	
	Air in fuel injection pipe.	Bleed air.	

Trouble symptom		Causes	Corrective action	Remarks
	Faulty cylinder air compression by compressed air leakage.	Compressed air leakage from intake / exhaust valves.	Lap the valve seat or replace valve(s).	Refer to 5.2.2.
		No clearance of intake / exhaust valve.	Adjust the valve clearance.	Refer to 5.2.9.
		Faulty cylinder head gasket.	Replace the head gasket.	Refer to 4.3.2(21).
		Wear on the top of cylinder.	Disassemble, check and measure the dimension. If wear is found, replace the cylinder block.	Refer to 5.1.5.
		Wear of piston ring(s).	Disassemble, check and measure the dimension. If wear is found, replace.	Refer to 5.3.3.
		Sticking of piston ring(s).	Disassemble and check. If sticking is found, clean or replace.	Refer to 5.3.3 and 4.3.2(9).
		Lack of tightening torque of cylinder head bolts.	If loose, tighten more without loosening.	Refer to 4.3.2(21).
		Damaged valve spring.	If damaged, replace.	Refer to 5.2.4.
	In a cold weather an air heater doesn't operate.	Air heater terminal is disconnected, loosened or in contact failure.	Check around the terminal. If faulty, repair.	Refer to 13.7.
		Air heater relay terminal is disconnected, loosened or in contact failure.		
		Faulty air heater.	Remove and check the air heater. Replace if necessary.	Refer to 13.6.
		Faulty air heater relay.	Check the operation of relay with tester. Replace if necessary.	Refer to 13.6.
		Fuse burns out. (Air heater A or B: 250A)	Replace.	Refer to 3.2.2 and 13.7.

Trouble symptom	Causes	Corrective action	Remarks
	Clogged intake / exhaust lines.	Check. Replace if necessary.	
An engine cannot be controlled. Engine speed doesn't increase. (The engine speed is fixed at low idling.)	Faulty main throttle: Detected error (P0120/0)	→	DTC: Refer to 3.3.
	Faulty main and sub throttle: Detected Error (P0120/0, P0220/3, 4)	→	DTC: Refer to 3.3.
	Fuse (AUX POWER:10A) burns out. Detected error (P0120/7)	Replace.	Refer to 3.2.2 and 13.7.
	Faulty inside of control head.	Check the input value of acceleration sensor with service tool. If error is not detected and malfunction is found, replace.	Refer to the service tool manual.
	Communication error of i8320: Detected error (0146/12)	→	DTC: Refer to 3.3.
An engine cannot be controlled. Engine speed doesn't rise to more than 1800 min^{-1}.	Crankshaft speed sensor error: Detected error (P0335/4)	→	DTC: Refer to 3.3.
	Camshaft speed sensor error: Detected error (P0340)	→	DTC: Refer to 3.3.
	Difference error of speeds: Detected error (P0335)	→	DTC: Refer to 3.3.
	Disconnect and short circuit error of rack position sensor: Detected error (P1201)	→	DTC: Refer to 3.3.
	Disconnect and short circuit error of boost sensor: Detected error (P0235)	→	DTC: Refer to 3.3.
	Over-boost error: Detected error (P0234)	→	DTC: Refer to 3.3.
	Abnormal rise error of coolant temperature: Detected error (P0118)	→	DTC: Refer to 3.3.
	Disconnect and short circuit error of timer electromagnetic valve: Detected error (P1220 or P1225)	→	DTC: Refer to 3.3 and 6.1.4.
	Unachievable specified value error of timer: Detected error (P0216)	→	DTC: Refer to 3.3.

Trouble symptom	Causes	Corrective action	Remarks
An engine cannot be controlled. Engine speed doesn't increase. Other symptom.	Engine overloaded.	Check around propeller and dirt of boat hull.	
	Faulty inside of control head.	Check the input value of acceleration sensor with service tool. If error is not detected and malfunction is found, replace.	Refer to service tool manual.
An engine cannot be controlled. Engine speed is not reduced.	Faulty inside of control head.	Check the input value of acceleration sensor with service tool. If error is not detected and malfunction is found, replace.	Refer to service tool manual.
	Disconnect and short circuit error of rack position sensor: Detected error (P1201).	→	DTC: Refer to 3.3.
	Fuel injection pump rack is stuck.	Check the rack hysteresis with a service tool. If malfunction is found, replace the fuel injection pump.	Refer to service tool manual.
An engine cannot be controlled. The gear box can not be engaged or disengaged.	The gear box connector is disconnected.	Wire according to the manual.	Refer to 13.1.1.
	Faulty contact of gear box connector.	Check the connector terminal. Repair if necessary.	Refer to 13.1.1.
	Open-circuit of gear box harness.	Check the harness.	Refer to 13.1.1.
	Faulty electromagnetic valve of gear box.	Replace electromagnetic valve.	Refer to clutch manual of another volume.
	Low level of gear box oil.	Check lube oil level. If low, refill.	↑
	Faulty gear box hydraulic oil pump.	Disassemble and check. Replace if necessary.	↑
	Wear of clutch friction discs.	Disassemble and check. Replace if necessary.	↑
An engine cannot be controlled. The shift position cannot be changed.	Seized clutch friction discs.	Disassemble and check. Replace if necessary.	↑

Trouble symptom		Causes	Corrective action	Remarks
Engine speed is not stable.		In case that low idle hunting will occur, check according to the following procedure and confirm an effect. 1) Change control gain pattern by service tool. 2) Raise low idle speed with 20 min^{-1} step. 3) Replace the fuel injection pump. 4) Check the following items. If malfunction is found, repair or replace. Note: Especially when the rotational fluctuation is not cyclic and the wire harness may be broken, the quality of the harness can be judged by operating the engine with the harness for the check.		
	Malfunction of fuel injection nozzle.	Faulty valve and / or seat.	Check fuel spray condition with a tester. If malfunction is found, ask a FIE shop for maintenance or replace.	Refer to 2.2.4(1).
		Sticking of needle valve.		
		Wear of seat.		
		Clogged fuel injection hole(s).		
		Decrease of fuel opening pressure.		
	Uneven fuel injection volume.	Faulty movement of fuel injection pump plunger.	Check. If malfunction is found, ask a FIE shop for maintenance or replace. (If measuring hysteresis with a service tool, the movement of rack can be checked.).	Refer to service tool manual.
		Damaged fuel injection pump plunger.		
		Damaged plunger spring.		
		Improper installation of fuel injection pump.	Reinstall according to this manual.	Refer to 6.1.6.
		Clogged fuel filter.	Check and replace if necessary.	Refer to 6.4.
		Clogged fuel system.	Check and repair.	Refer to 1.3.1.
		Air in fuel system.	Check and bleed air.	Refer to 1.3.1 and 2.2.3.
		Faulty movement of fuel feed pump.	Check and repair or replace if necessary.	Refer to 6.3.
		Faulty actuation of a hydraulic timer.	Check with service tool. DTC: Refer to 3.3.	DTC: Refer to 3.3.
		Engine overloaded.	Check around propeller and dirt of boat hull.	
		Seized main moving part(s).	Check and repair or replace if necessary.	Refer to 4.
		Clutch slip.	Check and repair or replace if necessary.	Refer to marine gear manual of another volume.

Trouble symptom	Causes	Corrective action	Remarks
Engine stops suddenly.	"EMERGENCY STOP" switch on switch panel was pressed.	Turn off the "EMERGENCY STOP" switch.	Refer to 12.1.2.
	Open-circuit of "EMERGENCY STOP".	Check the continuity of circuit and specify the part of being broken. Replace the damaged harness.	Refer to 13.1.1.
Fuel supply stops.	No fuel in a fuel tank.	Refuel.	Refer to 1.3.1.
	Air in fuel system.	Bleed air.	
	Fuel with water in a tank.	Drain the fuel tank.	
	Closed fuel cock(s).	Open the cock(s).	
	Clogged fuel filter.	Replace the filter.	Refer to 6.4.
	Damaged fuel pipe(s).	Check fuel system and repair.	Refer to 1.3.1.
	Faulty fuel feed pump.	Check the feed pump and repair or replace.	Refer to 6.3.
	Seized main moving part(s).	Check and repair or replace if necessary.	Refer to 4.
	Clogged air cleaner.	Clean or replace.	Refer to 2.2.5(7).
Engine does not stop.	When the mounting method of fuel injection pump brackets is improper, the pump body is deformed and the rack movement is not smooth. With faulty rack movement the fuel injection quantity cannot be cut down.	Disassemble the fuel injection pump brackets and reassemble according to this manual. After reassembling, check the hysteresis with a service tool to check the movement of rack.	Refer to service tool manual.
	Because of seized fuel injection pump plunger, the rack becomes fixed. With faulty rack movement the fuel injection quantity cannot be cut down.	Replace the fuel injection pump. After that, check the hysteresis with a service tool to check the movement of rack.	Refer to service tool manual.

Trouble symptom		Causes	Corrective action	Remarks
White exhaust smoke in cold weather.				
	Air heater doesn't work well.	The battery voltage is low. (Battery discharge)	Check the electrolyte level in the battery and the specific gravity of battery liquid.	Refer to 13.2.
			Charge the battery or replace.	Refer to 13.2.
			Check the short-circuit of electric circuit.	Refer to 13.
		The battery voltage is low. (Faulty charging)	Check the disconnect between a alternator and a battery and the contact condition of both terminals.	Refer to 13.4.
			Check the V-belt tension.	Refer to 2.2.3(3).
			Check the malfunction of an alternator.	Refer to 13.4
		Disconnect, loose and faulty contact of air heater terminal.	Check around terminal and repair if necessary.	Refer to 13.6.
		Disconnect, loose and faulty contact of air heater relay terminal.	Check around terminal and repair if necessary.	Refer to 13.7.
		Faulty air heater.	Disassemble and check. Replace if necessary.	Refer to 13.6.
		Faulty air heater relay.	Check the relay with service tool and tester. Replace if necessary.	Refer to 13.7 and service tool manual.
		Fuse burns out. (Air heater A or B: 250A)	Replace.	Refer to 3.2.2.
		Water temperature sensor error (P0115/3, 4) is detected.	→	DTC: Refer to 3.3.
	Improper fuel.	Low cetane number.	Replace fuel.	Refer to 1.3.1.
		Excessive aromatics content of fuel.	Replace fuel.	Refer to 1.3.1.
	Faulty fuel injection nozzle.	Faulty valve and / or seat.	Check fuel spray condition with a tester. If malfunction is found, ask a FIE shop for maintenance or replace.	Refer to 2.2.4(1).
		Sticking of needle valve.		
		Wear of seat.		
		Clogged fuel injection hole(s).		
		Decrease of fuel opening pressure.		

Trouble symptom		Causes	Corrective action	Remarks
White exhaust smoke from warm engine				
	Faulty fuel injection nozzle.	Faulty valve and / or seat.	Check fuel spray condition with a tester. If malfunction is found, ask a FIE shop for maintenance or replace.	Refer to 2.2.4(1).
		Sticking of needle valve.		
		Wear of seat.		
		Clogged fuel injection hole(s).		
		Decrease of fuel opening pressure.		
	Improper fuel.	Low cetane number.	Replace fuel.	Refer to 1.3.1.
		Excessive aromatics content of fuel.	Replace fuel.	Refer to 1.3.1.
	Engine oil burns because of excessive oil-up in the cylinder.	Seized piston.	Disassemble and check. Replace if necessary.	Refer to 4.
		Wear of piston rings.	Check and replace.	Refer to 5.3.3.
		Sticking of piston rings.	Check, clean and replace.	Refer to 5.3.3.
		Scarring or wear of cylinder.	Disassemble and check. Repair or replace if necessary.	Refer to 5.1.5.
	Engine oil burns because of excessive oil-down in the cylinder.	Scarring or wear of intake / exhaust valves.	Disassemble, check and measure the dimension. Repair or replace if necessary.	Refer to 5.2.3.
		Scarring or wear of valve guides.	Disassemble check and measure the dimension. Repair or replace if necessary.	Refer to 5.2.3.
		Damaged stem seal.	Replace if necessary.	Refer to 5.2.

Trouble symptom		Causes	Corrective action	Remarks
Black exhaust smoke				
	Faulty fuel injection nozzle.	Faulty valve seat.	Check fuel spray condition with a tester. If malfunction is found, ask a FIE shop for maintenance or replace.	Refer to 2.2.4(1).
		Sticking of needle valve.		
		Wear of seat.		
		Clogged fuel injection hole(s).		
		Decrease of fuel opening pressure.		
	Faulty combustion because of insufficient intake air volume.	Clogged air cleaner	Clean or replace.	Refer to 2.2.5(7).
		Decrease of charging air pressure.	Check the turbocharger. Clean the blower of turbocharger.	Refer to 10.5.
		Charging air temperature is too high.	Check the impeller of seawater pump. Check the clogged seawater line and the dirt of inter cooler core.	Refer to 9.
		Engine room is hermetically closed.	Check the ventilation.	
	Faulty combustion because of the blow-by gas and the decreased compression air pressure.	No valve-clearance.	Readjust valve-clearance.	Refer to 5.2.9.
		Faulty contact of intake / exhaust valves and seats.	Lap the valve and seat. Replace valve if necessary.	Refer to 5.2.2.
		Seized main moving parts.	Disassemble and check. Replace if necessary.	Refer to 4.
		Wear of piston ring.	Check and replace.	Refer to 5.3.3.
		Sticking of piston ring.	Check and clean or replace.	Refer to 5.3.3.
	Miscellaneous.	Engine overloaded.	Check around propeller and dirt of boat hull	
		The injection timing is improper.	Check the injection timing control and the assembling condition. If the timing is not correct, reinstall or replace the timer.	

Trouble symptom	Causes	Corrective action	Remarks
Insufficient engine output (Reduced maximum engine speed, reduced boat speed)			
Engine overloaded. Reduction of max. speed is not because of output reduction.	Increased ship resistance.	Check around propeller and dirt of boat hull. Check the deadweight of boat.	
	Excessive burden than usual.		
Faulty fuel injection nozzle.	Faulty valve and / or seat.	Check fuel spray condition with a tester. If malfunction is found, ask a FIE shop for maintenance or replace.	Refer to 2.2.4(1).
	Sticking of valve.		
	Wear of seat.		
	Clogged fuel injection hole(s).		
	Decrease of fuel opening pressure.		
Insufficient fuel supply.	The cock of a fuel tank isn't open sufficiently or is closed.	Open the cock fully. Take care so that it doesn't close by itself.	Refer to 1.3.1.
	Clogged fuel filter.	Replace fuel filter.	Refer to 6.4.
	Faulty fuel feed pump.	Disassemble and maintain.	Refer to 6.3.
	Wear of fuel injection pump plunger.	Ask a FIE shop for maintenance.	Refer to 6.1.5.
Insufficient intake air volume.	Clogged air cleaner	Clean or replace.	Refer to 2.2.5(7).
	Decrease of charging air pressure.	Check the turbocharger. Clean the blower of turbocharger.	Refer to 10.5.
	Charging air temperature is too high.	Check the impeller of seawater pump. Check the clogged seawater line and the dirt of inter cooler core.	Refer to 9.
	Clogged exhaust gas passage.	Check exhaust passage.	Refer to 7.2.
	Faulty ventilation unit in an engine room.	Check the ventilation unit.	
Faulty combustion because of blow-by and reduced air compression pressure.	No valve clearance.	Adjust valve clearance.	Refer to 5.2.9.
	Faulty contact between valve and seat.	Lap the valve or replace.	Refer to 5.2.2.
	Seized main moving parts.	Disassemble and check. Replace if necessary.	Refer to 4.
	Wear of piston ring.	Check and replace if necessary.	Refer to 5.3.3.
	Sticking of piston ring.	Check and clean or replace.	Refer to 5.3.3.

3.2.2 Troubleshooting of fuse

When a fuse burns out,
Case 1) When the location of short-circuit on a harness is found or when the causes of short-circuit are clarified, repair as a temporary solution and replace the fuse. But it is recommended to replace the harness because of the possibility of decreasing waterproof quality on the harness and connector.
2) When not finding cause, replace a fuse and follow. If the fuse burns out again, replace the harness.

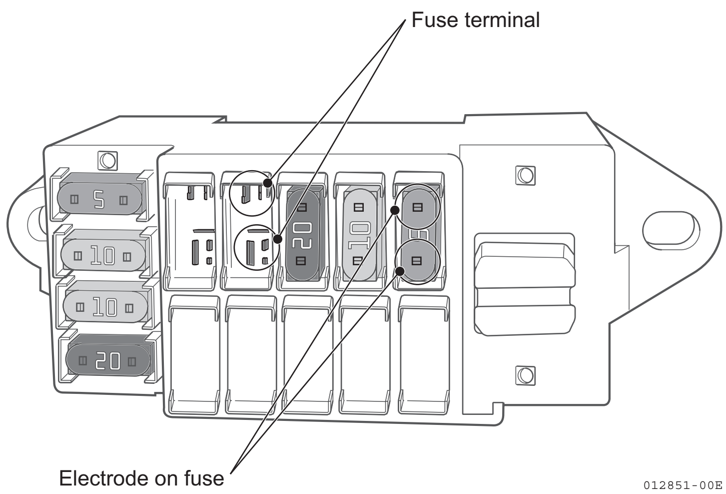
(1) Troubleshooting list

The phenomenon and the check position when each fuse burns out are shown in the following table. Also, the procedure, which specifies a short circuit part for the corrective action, is shown in the table. When the replaced fuse burns out again, replace the corresponding harness.

No.	Size	Application	Trouble symptom		Key switch	Corrective action
			at engine stop	at engine running		
1.	10A	AUX POWER	The engine can start. Error (P0120/0) is detected. The digital display isn't turned on.	Error (P0120/0) is detected. The digital display isn't turned on.	off	Check a continuity between the negative side of the fuse and GND (engine body). (Refer to the below figure.) In case of continuity, the engine harness may be short-circuit. Replace it. (Refer to 3.2.2(3).) In case of no continuity, replace a fuse and follow. If the fuse burns out again, the harness may be short-circuit. Replace it.
2.	10A	IGN. PANEL (Switch panel)	The engine can not start. ECU isn't turned on.	The engine will shut down. After that the engine can not start.	off	Check a continuity between the negative side of the fuse and GND. (Refer to the below figure.) In case of continuity, replace a fuse and follow. In case of no continuity, the engine harness may be short circuit. Remove the harness 12-pin connector above fuel injection pump and check a continuity again. (Refer to 3.2.2(3) and 12.1.) In case of continuity, the engine harness may be short circuit. Replace it. In case of no continuity, a TELEFLEX harness may be short circuit. Replace it.

* Continuity test of fuse:
Check the continuity by touching the corresponding fuse terminal or a electrode in the fuse box and the cylinder block nearby with a tester.
In case of fuses on relay assembly (refer to 3.2.2(2)), open the fuse cover and check the continuity by touching the corresponding fuse terminal or a electrode on the fuse and the cylinder block nearby with a tester.

Fuse box

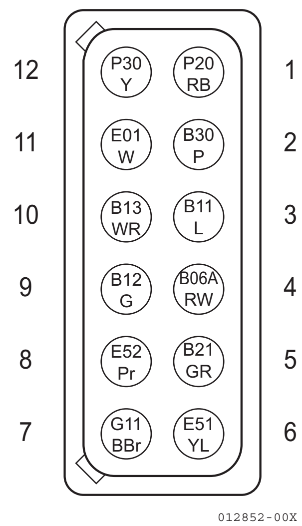


No.	Size	Application	Trouble symptom		Key switch	Corrective action
			at engine stop	at engine running		
3.	20A	ECU	The engine can not start. ECU isn't turned on.	The engine will shut down. After that the engine can not start.	–	Replace a engine harness. (Refer to 3.2.2(3).)
4.	10A	IGN. SIG (Switch ON signal)	The engine can start. Error (U0146/12) is detected.	Error (U0146/12) is detected.	on	Check a continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, engine harness may be short circuit. Replace it. (Refer to 3.2.2(3).) In case of no continuity, replace a fuse and follow it. If the fuse burns out again, main harness may be short circuit. Replace it.
5.	5A	S. tool (Service tool)	The normal operation of the engine is possible but the service tool can not be used.	The normal operation of the engine can be continued.	on	Check a continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, engine harness may be short circuit. Replace it. (Refer to 3.2.2(3).) In case of no continuity, replace a fuse and follow it. If the fuse burns out again, main harness may be short circuit. Replace it.
6.	250A	Air heater A or B	The normal operation of the engine is possible. As the air heater A is not turned on, the startability of engine in low temperature becomes worse.	The normal operation of the engine can be continued. As the air heater A is not turned on, the white smoke may increase when the engine is cold.	off	Check an air heater. If it is OK, check the operations of the air heater relay. If it is NG, replace it.
					on	Check the operations of the air heater relay. If OK, check its continuity. If NG, replace the air heater relay.
					off	Check the continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, harness (B) may be short circuit. Replace it. (Refer to 3.2.2(3).) In case of no continuity, remove the harness from the air heater terminal and check the continuity between the harness and GDN. In case of continuity, main harness may be short circuit. Replace it. In case of no continuity, replace the fuse and follow it. If the fuse burns out again, main harness may be short circuit. Replace it.

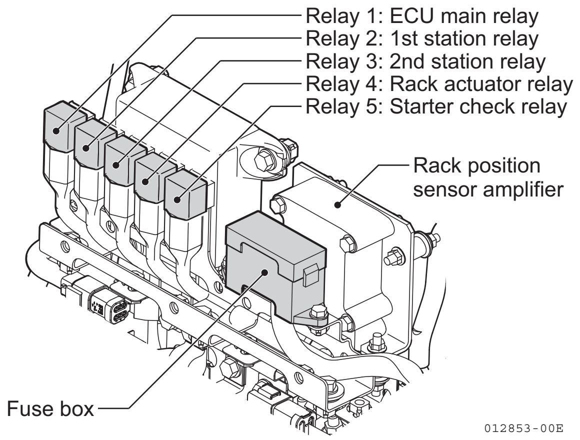
No.	Size	Application	Trouble symptom		Key switch	Corrective action
			at engine stop	at engine running		
7.	150A	ALTERNA-TOR	The normal operation of the engine is possible.	The normal operation of the engine can be continued. As the alternator can not charge, the battery will discharge fully.	off	Check the continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, harness (A) may be short circuit. Replace it. (Refer to 3.2.2(3).) In case of no continuity, replace the fuse and follow it. If the fuse burns out again, main harness may be short circuit. Replace it.
8.	50A	STARTER RELAY	The engine can not start. When a starter switch is turned on, the starter relay operates but the engine can not rotate and the speed sensor error is detected.	The normal operation of the engine can be continued.	off	Check the continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, check the starter relay. In case of no continuity, replace the fuse and follow it. If the fuse burns out again, check the starter relay.
					on	Check the operation of a starter relay. If it is OK, harness (F) may be short circuit. Replace it. (Refer to 3.2.2(3).) If it is NG, the relay may be damaged and the harness (c) is short circuit. Replace them. In case that the fuse will burn out again, replace starter.
9.	5A	IGN. SIG 1st Station	The engine can not start. ECU isn't turned on.	The engine will shut down. After that the engine can not start at 1st station.	on	Check the continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, check the below procedure *. In case of no continuity, replace the fuse and follow it. If the fuse burns out again, check the procedure *. * Remove the 12-pin connector of engine harness above fuel injection pump. (Refer to 3.2.2(3) and 12.1.) Check the continuity between each of 1 and 9 pins of 12-pin connector of engine harness and GND. (Refer to the figure on next page.) In case of continuity, engine harness may be short-circuit. Replace it. In case of no continuity, remove the TELEFLEX extension harness from the connector of switch panel. Check the pins of TELEFLEX extension harness in the same manner.

No.	Size	Application	Trouble symptom		Key switch	Corrective action
			at engine stop	at engine running		
10.	5A	IGN. SIG 2nd Station	The engine can not start. ECU isn't turned on.	The engine will shut down. After that the engine can not start at 1st station.	on	Check the continuity between the negative side of the fuse and GND. (Refer to Page 57.) In case of continuity, check the below procedure *. In case of no continuity, replace the fuse and follow it. If the fuse burns out again, check the procedure *. * Remove the 12-pin connector of engine harness above fuel injection pump. (Refer to 3.2.2(3) and 12.1.) Check the continuity between each of 1 and 3 pins of 12-pin connector of engine harness and GND. (Refer to the figure below.) In case of continuity, engine harness may be short-circuit. Replace it. In case of no continuity, remove the TELEFLEX extension harness from the connector of switch panel. Check the pins of TELEFLEX extension harness in the same manner.

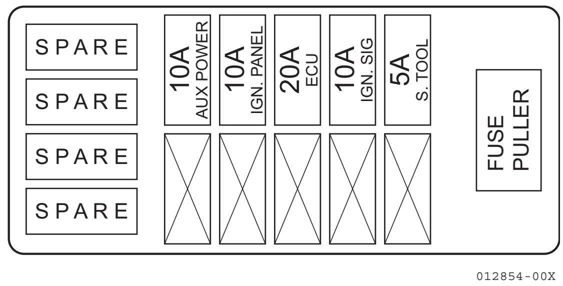
Pin numbers of 12-pin connector



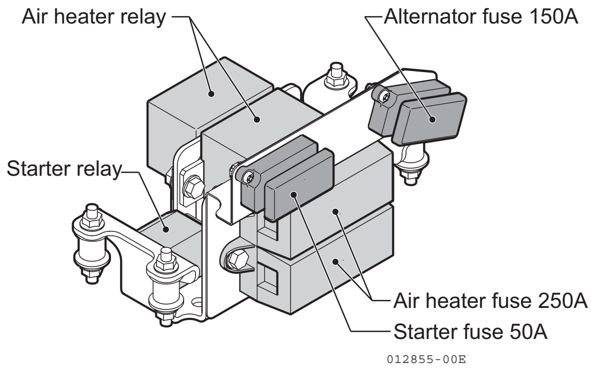
(2) Fuse and relay location



Fuse location label for fuse box

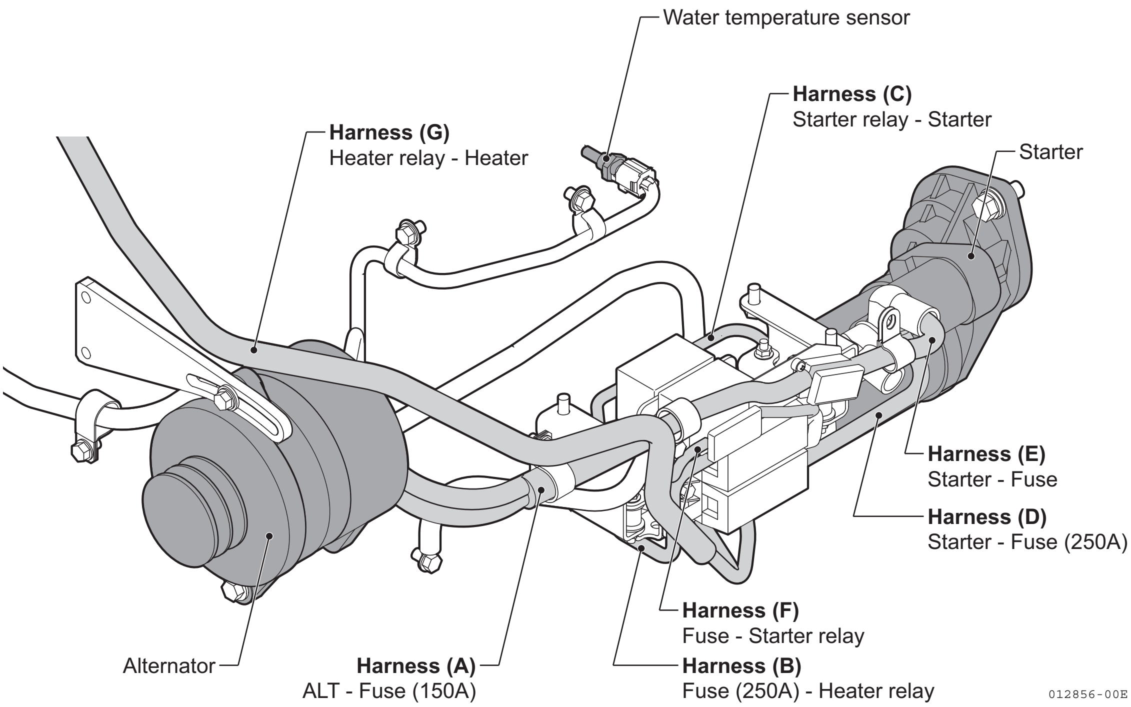


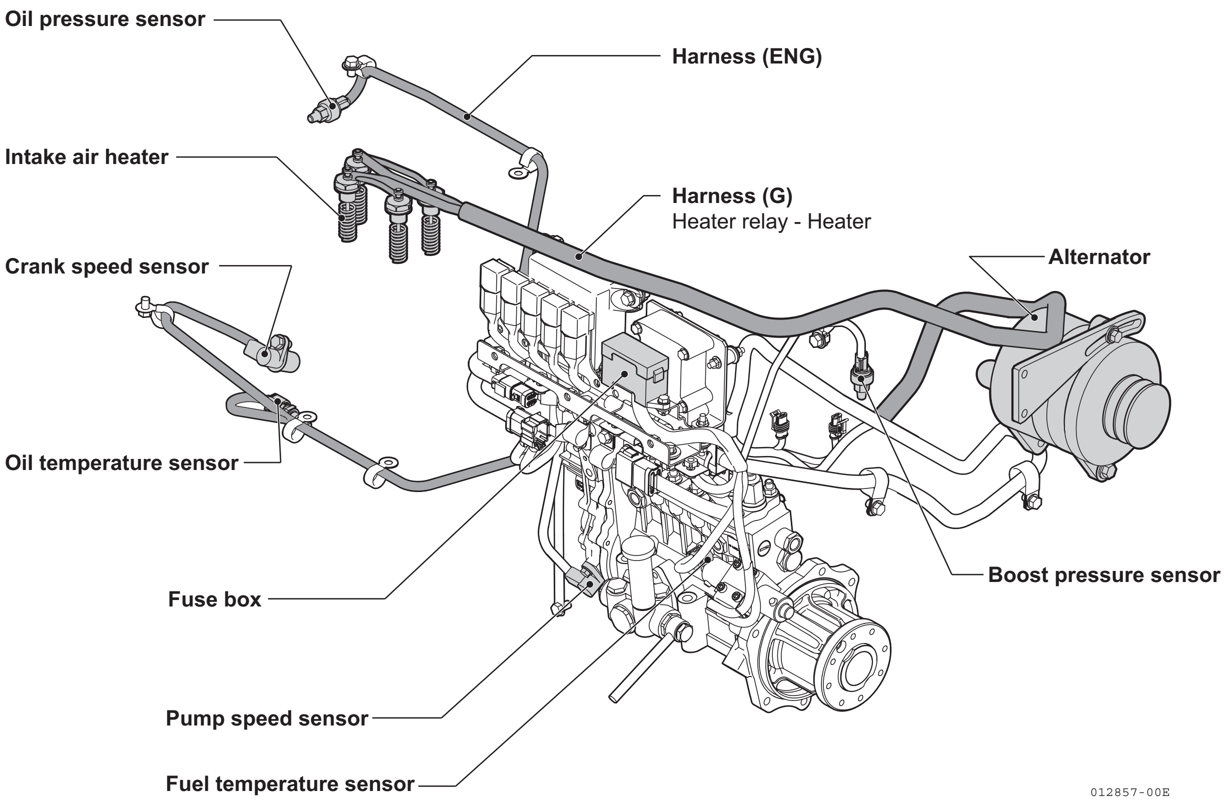
Relay assembly under exhaust manifold



(3) Wire harness location

Harness (ENG): Harness assembly for engine electric devices.
Harness (A) : for alternator (Connection between alternator B terminal and alternator fuse).
Harness (B) : for air heater A / B (Connection between heater relays A / B and heater fuses A / B).
Harness (C) : for starter (Connection between starter relay and starter S terminal).
Harness (D) : for starter / air heater (Connection between starter relay, starter S terminal and heater fuses A / B).
Harness (E) : for starter / alternator (Connection between starter B terminal and alternator fuse).
Harness (F) : for starter (Connection between starter relay and starter S terminal fuse).
Harness (G) : for air heater (Connection between heater relays A / B and heater A / B).




Oil pressure sensor
Harness (ENG)
Intake air heater
Harness (G)
Heater relay - Heater
Alternator
Crank speed sensor
Oil temperature sensor
Boost pressure sensor
Fuse box
Pump speed sensor
Fuel temperature sensor
012857-00E

3.3 Trouble code

The failure information of the following table is displayed on the TELEFLEX display, when a trouble may occur to the engine.

3.3.1 List of DTC (Diagnostic Trouble Code)

DTC	Level	Description
P0115	2	Water Temperature Sensor
P0118	2	Water temperature Too High
P0120	3	Main Throttle Position Sensor
P0180	2	Fuel Temperature Sensor
P0183	2	Fuel Oil Temperature Too High
P0195	2	Lube Oil Temperature Sensor
P0198	2	Lube Oil Temperature Too High
P0216	3	Injection Timing Control Device
P0219	1	Crank / Cam Over Revolution
P0220	2	Sub-Throttle Sensor
P0234	2	Over Boost
P0235	2	Boost Pressure Sensor
P0335/0	2	Cam / Crank Speed Incompatibility
P0335/4	2	Crank Speed Sensor
P0340	2	Cam Speed Sensor
P0520	2	Lube Oil Pressure Sensor
P0522	2	Lube Oil Pressure Too High
P0562	1	ECU Power Supply Voltage
P0605	3	EEPROM Error
P1202	2	Rack Position Sensor
P1210	2	Rack Actuator
P1211	3	Rack Actuator Mechanical Malfunction
P1220/1225	3	Advance / Retard Timer Actuator (Solenoid)
P1230	3	Sensor 5V Voltage
P1240	3	ECU Power Supply Voltage Open
P1603	3	ECU Temperature Too High
U0146	3	i8320 Communication Error

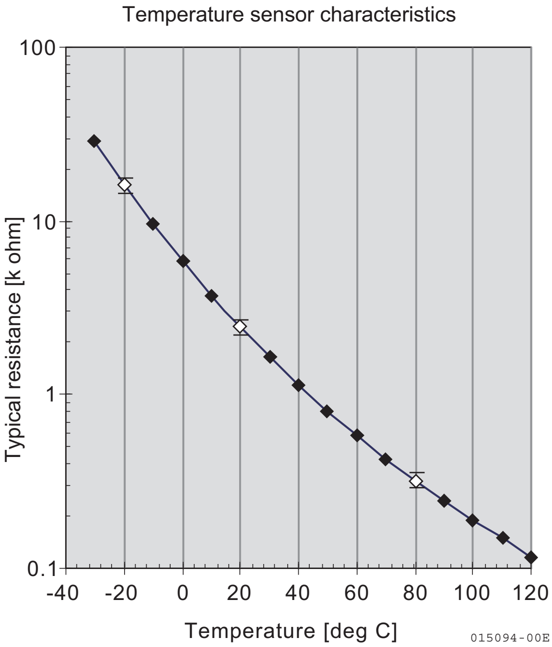
Note: The figures of the ”Level” column shows the hierarchy of the trouble text and have the following meanings.
Level 1: The message of the trouble part appears on the display generally.
Level 2: Only the "ENGINE ALARM" message appears on the display generally and the trouble part appears when operating the display.
Level 3: The trouble part can be seen when doing the operation to move from LEVEL 2 to LEVEL 3.

Diagnosis by DTC

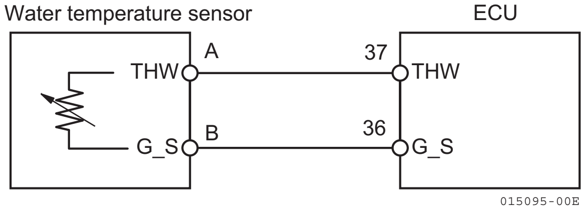
(1) P0115/3, 4 (Water Temp Sensor)

DTC	P0115/3, 4	Water Temperature Sensor

<Sensor specification chart>



<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0115/3	1. Key SW ON. 2. Input voltage above 4.8V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor
P0115/4	1. Key SW ON. 2. Input voltage below 0.2V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor

Fail Mode	Engine takes following water temperature as default. -15 deg C at engine stop (for starting). 60 deg C at engine running.
Limited Operation	*No limited operation.*
Fail Release	Yes. When input voltage goes to normal range (0.2 - 4.8V) for 0.5s.
Remarks	White smoke increase at cold condition. Black smoke may increase at starting.

<Content of trouble>

DTC / FMI	Probable cause
P0115/3	(1) Open circuit of wire-harness (signal and GND) or short to high voltage such as 5V or battery. (2) Sensor failure. (3) ECU failure.
P0115/4	(1) Wire-harness (signal) short to GND level. (2) Sensor failure. (3) ECU failure.

Corrective action:
Follow "Temperature Sensor Diagnosis Procedure"

(2) P0118/0 (Water Temperature Too High)

DTC	P0118/0	Water Temperature Too High

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0118/0	1. Key SW ON. 2. Water temperature above 110 deg C. 3. 0.5s. 4. "HOT ENGINE", "PWR REDUCTION" on TELEFLEX display.	Fresh water system Seawater system Sensor

Fail Mode	Engine over heat condition results in limited operation.
Limited Operation	**Maximum engine speed is limited to 1800min^{-1}.**
Fail Release	Yes. When water temperature got below 95deg C.
Limited Operation Release	Yes. After fail released and also throttle position at low idle position.
Remarks	

<Content of trouble>

DTC / FMI	Probable cause
P0118/0	Seawater pump impeller
	Seacock
	Seawater system
	Fresh water volume
	Fresh water system
	Contamination of heat exchanger
	Thermostat
	Fresh water pump
	V belt
	Faulty sensor of coolant temperature

Diagnosis procedure:
(1) Check seawater pump impeller.
(2) Check seacock.
(3) Check seawater system.
(4) Check fresh water volume.
(5) Check fresh water system.
(6) Check Contamination of heat exchanger.
(7) Check thermostat.
(8) Check fresh water pump.
(9) Check V belt.
(10) Check coolant temperature sensor.
(11) Check wire-harness.

(3) P0120/0 (Main Throttle Position Sensor)

DTC	**P0120/0**	**Main Throttle Position Sensor**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0120/0	1. Key SW ON. 2. Teleflex i2 module (i832X) send message that indicates throttle malfunction status. 3. - 4. "MAIN THROTTLE", "CHECK ENGINE" on TELEFLEX display.	Main throttle head

Fail Mode	Target engine speed ramp down to low idle speed and stay until sub-throttle get activated. Sub-throttle will be selectable with sub-throttle lamp blinking. If sub-throttle is selected, lamp tunes on. Once sub-throttle is selected, sub-throttle keeps working even if main throttle would get back to normal.
Limited Operation	Yes. (1) If sub-throttle is selected: Sub-throttle operation. (2) If sub-throttle is inactive: Engine speed fixed at low idle or 1000 min^{-1}. (Idle in Neutral and 1000 min^{-1} in forward / reverse.)
Fail Release	Yes. When ECU receives data of no error status from i2 module.
Limited Operation Release	(1) If sub-throttle is active: No. (2) If sub-throttle is inactive: Yes. After Main throttle fail released.
Remarks	CAN communication error is stated as DTC U0146 "CAN communication gateway" not "Main throttle position sensor".

Limited Operation	
Fail Release	Yes. (i2 module Communication error)
Remarks	This DTC comes from only communication between i2 module and ECU. TELEFLEX control head malfunction will detected as “Main Throttle Position Sensor Error”. Marine gear transmission control (shift) function is independent from throttle function. This means that shifting function should be controlled as i2 module function. (If i2 module is not powered, then U0146 occur and shift function may get inactive.) Back to normal communication after receiving data from i2 module. If sub-throttle is selected before communication get back to normal, main throttle will stay inactive.

Fail Mode:
*Sub-throttle will be selectable with sub-throttle lamp blinking.
*If sub-throttle is selected, lamp tunes on.
*Once sub-throttle has selected (activated), sub-throttle keeps working even if main-throttle goes back to normal status.
*Marine gear transmission control (shift) function is independent from engine control, which means shifting function should be controlled by control head.

<Content of trouble>

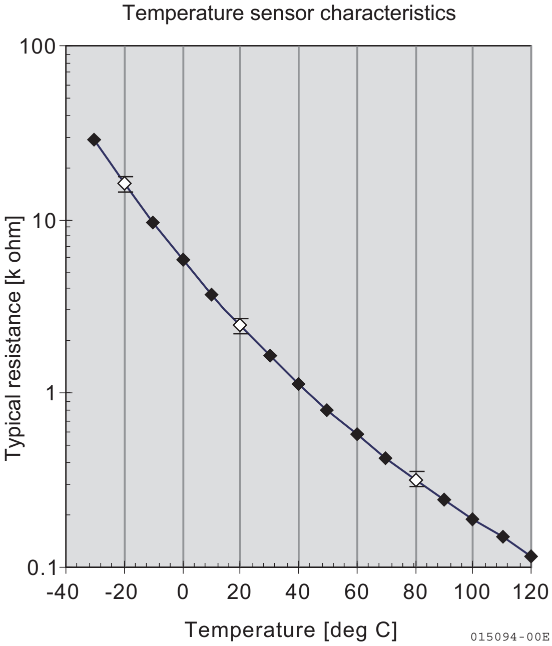
DTC / FMI	Probable cause
P0120/0	(1) Teleflex wire-harness of throttle control head unit. (2) Teleflex throttle head malfunction.

Diagnosis procedure:
(1) Check wire-harness and connector of throttle control head unit.
(2) Check TELEFLEX i2 Module (i832X) software.
(3) Replace TELEFLEX Throttle Control Head

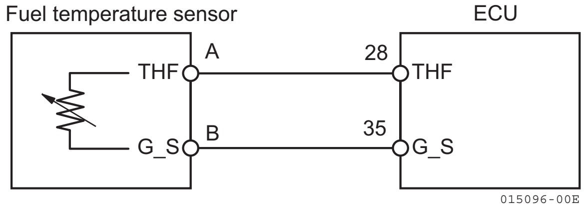
(4) P0180/3, 4 (Fuel Temperature Sensor)

DTC	P0180/3, 4	Fuel Temperature Sensor

<Sensor specification chart>



<Electrical circuit chart>



< DTC detect condition >

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0180/3	1. Key SW ON. 2. Input voltage above 4.8V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor
P0180/4	1. Key SW ON. 2. Input voltage below 0.2V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor

Fail Mode	Engine takes following fuel temperature as default. 50 deg C. *Above value can be monitored by "YANMAR Service tool". (Diagnostic Test → Analog Input.)
Fail Release	Yes. When input voltage goes to normal range (0.2 - 4.8V) for 0.5s.
Limited Operation	*No limited operation.*
Remarks	

<Content of trouble>

DTC / FMI	Probable cause
P0180/3	(1) Open circuit of wire-harness or short to high voltage such as 5V or battery. (2) Sensor failure. (3) ECU failure.
P0180/4	(1) Wire-harness short to GND level. (2) Sensor failure. (3) ECU failure.

<Diagnosis procedure>

* Follow "Temperature Sensor Diagnosis Procedure".

(5) P0183/0 (Fuel Temperature Too High)

DTC	P0183/0	Fuel Temperature Too High

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0183/0	1. Key SW ON. 2. Fuel temperature above 90 deg C. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	FO system FO sensor

Fail Mode	Fuel temperature exceeds the acceptable range for fuel system.
Limited Operation	**No limited operation.**
Fail Release	Yes. When fuel temperature got below 85deg C.
Remarks	Normal fuel temperature is about 40 deg C at inlet port of injection pump and about 52 deg C at outlet port.

<Content of trouble>

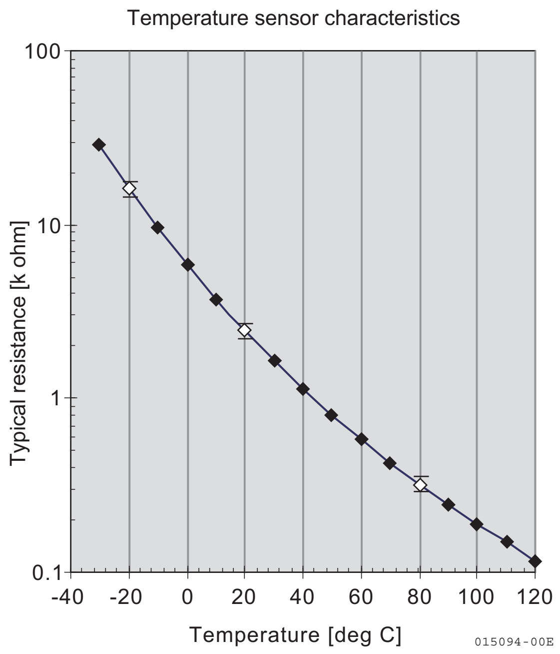
DTC / FMI	Probable cause
P0183/0	Fuel cock. (Fuel isn’t supplied.)
	Fuel filter.
	Fuel system.
	Fuel temperature sensor.

<Diagnosis procedure>
(1) Check fuel cock.
(2) Check fuel filter.
(3) Check fuel system.
(4) Check fuel temperature sensor.

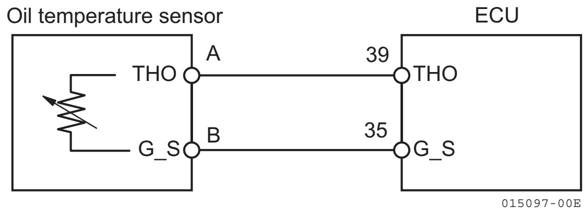
(6) P0195/3, 4 (Lubrication Oil Temperature Sensor)

DTC	P0195/3, 4	Lubrication Oil Temperature Sensor

<Sensor specification chart>



<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0195/3	1. Key SW ON. 2. Input voltage above 4.8V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor
P0195/4	1. Key SW ON. 2. Input voltage below 0.2V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor

Fail Mode	Engine takes following oil temperature as default. 90 deg C.
Limited Operation	*No limited operation.*
Fail Release	Yes. When input voltage goes to normal range (0.2 - 4.8V).
Remarks	

<Content of trouble>

DTC / FMI	Probable cause
P0195/3	(1) Open circuit of wire-harness or short to high voltage such as 5V or battery. (2) Sensor failure. (3) ECU failure.
P0195/4	(1) Wire-harness short to GND level. (2) Sensor failure. (3) ECU failure.

<Diagnosis procedure>
* Follow "Temperature Sensor Diagnosis Procedure".

(7) P0198/0 (Lubrication oil temperature Too High)

DTC	**P0198/0**	**Lubrication Oil temperature Too High**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0198/0	1. Key SW ON. 2. Lubrication oil temperature above 120deg C. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Lube oil system Cooling seawater system Sensor

Fail Mode	
Limited Operation	*No limited operation*
Fail Release	Yes. When oil temperature got below 115deg C for 0.5s.
Remarks	Normal oil temperature at rated speed is about 90 deg C.

<Content of trouble>

DTC / FMI	Probable cause
P0198/0	Seawater pump impeller
	Seacock
	Seawater system
	Lube oil cooler
	Lube oil volume
	Lube oil temperature sensor

<Diagnosis procedure>
(1) Check seawater pump impeller.
(2) Check seacock.
(3) Check seawater system.
(4) Check lube oil cooler.
(5) Check lube oil level.
(6) Check lube oil temperature sensor.

(8) P0216/7 (Injection Timer Device)

DTC	P0216/7	Injection Timer Device

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0216/7	1. Engine running. 2. Does not meet target value of injection timer phase. 3. 10s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Timer device Speed sensor Lube oil system Timer solenoid (Adv / Ret)

Fail Mode	Engine can not control Injection timer. Injection timing will be fully retarded or may stick at fixed position.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	***No.***
Remarks	ECU would detect DTC of P1220 or P1225 if injection timing control solenoid (timer solenoid) has problem with wire-harness. White smoke or black smoke may increase than usual because of fail mode of injection timing control.

<Content of trouble>

DTC / FMI	Probable cause
P0216/7	Timer or hydraulic device. Timer mechanical problem.
	Lube oil volume (Leak flow > 0.2 kgf / mm^2)
	Check lube oil pressure.
	Check timer electromagnetic valve.
	Replace timer electromagnetic valve.

<Diagnosis procedure>

(1) Check crank and cam speed by service tool and see if they are stable.
  (1a) If not stable, check the speed sensor.
    (Ex. contaminant on sensor core, sensor bad attachment.)
(2) Check performance of timer device with service tool.
  (2a) If stayed at the retarded or advanced position, check the wire-harness of hydraulic timer solenoids and also check solenoid valve. (Replace wire-harness or timer solenoids if something wrong.)
  (2b) If injection timing is not changing and stayed at same point (except at the retard and advanced position), replace fuel injection pump (FIP) with timer device.
    *May have some mechanical problem of injection timing device.

(9) P0219/0 (Engine Over Rev.)

DTC	P0219/0	Engine Over Rev.

<DTC detect condition >

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0219/0	1. Engine running. 2. Engine speed of cam or crank exceed to 3900min^{-1}. 3. - 4. "OVER REV" on TELEFLEX display	Injector FIP Crank / Cam Speed Sensor Pulsar (gear) Wire-harness

Fail Mode	Engine stop by rack position to be set at stop position. *Break rack actuator relay.
Limited Operation	***Engine stop.***
Fail Release	***No.***
Remarks	***Require key off to reset fail mode.***

<Content of trouble>

DTC / FMI	Probable cause
P0219/0	Speed sensor (Crank or Cam). *wire-harness. *sensor contaminants on the sensor core.
	Rack position sensor.
	Rack actuator performance.
	Fuel injection pump.
	Injector.
	Check fuel system.

<Diagnosis procedure>

(1) Check if there is / are any other DTC detected such as "Rack Position Sensor" or "Rack Actuator" related DTC.

(1a) If there is / are, countermeasure the DTC(s) first.

(2) Check if DTC is detected by "really" over revolution states.

(2a) If It was not over rev, check the speed sensor. (Attachment, some contaminants on the sensor core, connector, wire-harness etc)

(3) Check the Fuel injection pump.

(4) Check injection nozzle and fuel line.

(5) Check fuel injection pump hysteresis. (Rack actuator performance.)

(5a) If hysteresis resulted in NG, replace fuel injection pump (including position sensor amplifier).

(10) P0220/3, 4 (Sub-Throttle Sensor)

DTC	P0220/3, 4	Sub-Throttle Sensor

<Electrical circuit chart>
Refer to "Sub-Throttle Indicator, Emergency Throttle Position Sensor".

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0220/3	1. Key SW ON. 2. Input voltage above 4.8V. 3. 0.5s. 4. "SEC THROTTLE" on TELEFLEX display.	Wire-harnessSensor
P0220/4	1. Key SW ON. 2. Input voltage below 0.2V. 3. 0.5s. 4. "SEC THROTTLE" on TELEFLEX display.	Wire-harnessSensor

<Remarks>
*If sub-throttle position sensor is replaced from YANMAR standard parts, check the specification of throttle potentiometer.

Fail Mode	Fail mode will be different by the status of main throttle. (1) If sub-throttle is active: Target engine speed ramps down to low idle speed and target speed is set to low idle in neutral and 1000 min^{-1} in non-neutral condition. (2) If sub-throttle is inactive (main throttle is active): No fail mode happens to throttle control.
Limited Operation	
Fail Release	(1) If sub-throttle is active: No. (2) If sub-throttle is inactive: Yes.
Remarks	If sub-throttle is active, key off is required to reset fail mode.

<Content of trouble>

DTC / FMI	Probable cause
P0220/3	(1) Sub-throttle position sensor GND wire-harness open. (2) Sub-throttle position sensor signal wire-harness short to battery or sensor 5V.
P0220/4	(1) Sub-throttle position "signal" wire-harness open or short to GND. (2) Sub-throttle position "sensor 5V" wire-harness open or short to GND.

<Diagnosis procedure>
(1) Check sub-throttle voltage by YANMAR Service Tool.
(2) Check wire-harness and connectors.
If wire-harness is NG, replace wire-harness.
(3) Check sub-throttle position sensor.

(11) P0234/0 (Over Boost)

DTC	**P0234/0**	**Over Boost**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0234/0	1. Key SW ON. 2. Boost pressure above 250kPa. 3. 0.5s. 4. "PWR REDUCTION", "TURBO BOOST" on TELEFLEX display.	Turbo charger Boost pressure sensor

Fail Mode	Turbo charger over boost condition.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	Yes. When boost pressure got below 200kPa.
Limited Operation Release	Yes. After fail released and also throttle position at low idle position.
Remarks	

<Content of trouble>

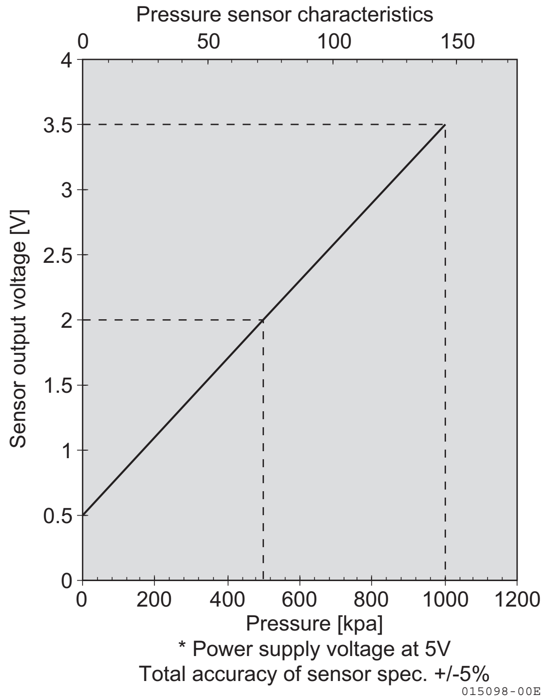
DTC / FMI	Probable cause
P0234/0	Turbo charger / waste gate
	Boost pressure sensor

<Diagnosis procedure>
(1) Check the waste gate.
(2) Replace boost pressure sensor.

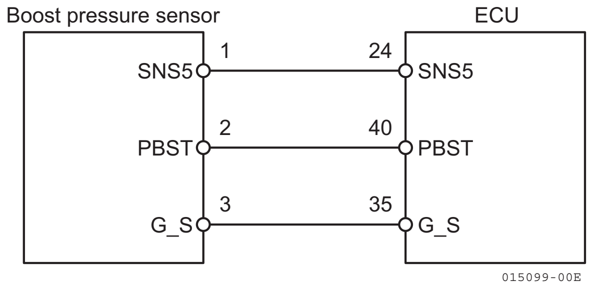
(12) P0235/3, 4 (Boost Pressure Sensor)

DTC	P0235/3, 4	Boost Pressure Sensor

<Sensor specification chart>



<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0235/3	1. Key SW ON. 2. Input voltage above 3. 6V. 3. 0.5s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Wire-harness Boost Pressure Sensor
P0220/4	1. Key SW ON. 2. Input voltage below 0.2V. 3. 0.5s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Wire-harness Boost Pressure Sensor

Fail Mode	Engine takes following boost pressure as default. 0 kPa.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	Yes. When input voltage goes to normal range (0.5 - 3.6V).
Limited Operation Release	Yes. After fail released and also throttle position at low idle position.
Remarks	*Sensor supply voltage must be kept below 6 V. Once sensor supply voltage exceeded 6 V, sensor have been damaged in a large possibility and strongly recommend to replace all pressure sensor. To check if exceeded voltage is supplied, check the status of DTC 1230/0.

<Content of trouble>

DTC / FMI	Probable cause
P0235/3	(1) "Signal" wire-harness open or short to GND level. (2) "Sensor 5V" wire-harness open. (3) Sensor failure.
P0220/4	(1) "Signal" wire-harness open or short to GND level. (2) "Sensor 5V" wire-harness open. (3) Sensor failure.

<Diagnosis procedure>

* Follow "Pressure Sensor Diagnosis Procedure".

(13) P0335/0 (Cam / Crank Speed Incompatibility)

DTC	**P0335/0**	**Cam / Crank Speed Incompatibility**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0335/0	1. Engine running. 2. Difference between cam and crank speed more than 50min^{-1}. 3. 0.5s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Wire-harness Crank speed sensor Cam speed sensor

Fail Mode	Engine will keep controlling engine speed with cam signal. *ECU uses crank speed as normal condition. Engine can not control Injection timer and have fail mode of injection timer control which injection timing will be fully retarded.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	Yes. When difference between cam and crank speed got within 15 min^{-1}.
Limited Operation Release	Yes. After fail released and also throttle position at low idle position.
Remarks	White smoke or black smoke may increase than usual because of fail mode of injection timing control.

<Content of trouble>

DTC / FMI	Probable cause
P0335/0	(1) Crank and cam speed sensor: (Contaminants, wire-harness, poor connection of connector, attachment.) (2) Bad flywheel status. (3) Electrical noise.

<Diagnosis procedure>

(1) Check crank and cam speed if they are stable by service tool.

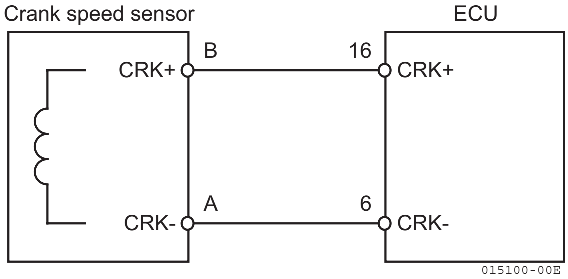
(1a) If not stable, check the sensor wire-harness, attachment and contaminants of sensor core.

(2) Check the status of flywheel sensor detection hole.

(14) P0335/4 (Crank Speed Sensor)

DTC	P0335/4	Crank Speed Sensor

<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0335/4	1. Engine running. 2. Crank speed detect 0 min^{-1} during starter is activated (key position at "START") orcrank speed suddenly goes 0 min^{-1} while engine running. 3. 1s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Crank Speed Sensor Starter Wire-harness

Fail Mode	Engine will keep controlling engine speed with cam signal. *ECU uses crank speed as normal condition. Engine can not control Injection timer and have fail mode of injection timer control which injection timing will be fully retarded.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	Yes. When difference between cam and crank speed got within 15 min^{-1}.
Limited Operation Release	Yes. After fail released and also throttle position at low idle position.
Remarks	White smoke or black smoke may increase than usual because of fail mode of injection timing control. This error is also detected when the key position is "START" and gear is in neutral but the starter is not running. (Such case as no battery cable is connected to starter.)

<Content of trouble>

DTC / FMI	Probable cause
P0335/4	(1) Crank speed sensor wire-harness open or short. (2) Crank speed sensor connector poor connection. (3) Bad flywheel condition.

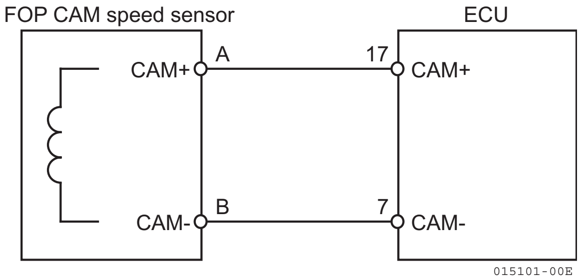
Diagnosis procedure:
(1) Check if starter is turning.
(2) Check wire-harness.
(3) Check the connector terminal.
(4) Check the speed sensor attachment states (Dust etc).
(5) Check sensor output signal.

(15) P0340/4 (Cam Speed Sensor)

DTC	P0340/4	Cam Speed Sensor

General explanation

<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0340/4	1. Engine running. 2. Crank speed detect 0min^{-1} during starter is activated (key position at "START") orcrank speed suddenly goes 0min^{-1} while engine running. 3. 1s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Cam Speed Sensor Starter Wire-harness

Fail Mode	Engine will keep controlling engine speed with crank signal. Engine can not control Injection timer and have fail mode of injection timer control which injection timing will be fully retarded.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	Yes. When difference between cam and crank speed got within 15 min^{-1}.
Limited Operation Release	Yes. After fail released and also throttle position at low idle position.
Remarks	White smoke or black smoke may increase than usual because of fail mode of injection timing control. This error is also detected when the key position is "START" and gear is in neutral but the starter is not running. (Such case as no battery cable is connected to starter.)

<Content of trouble>

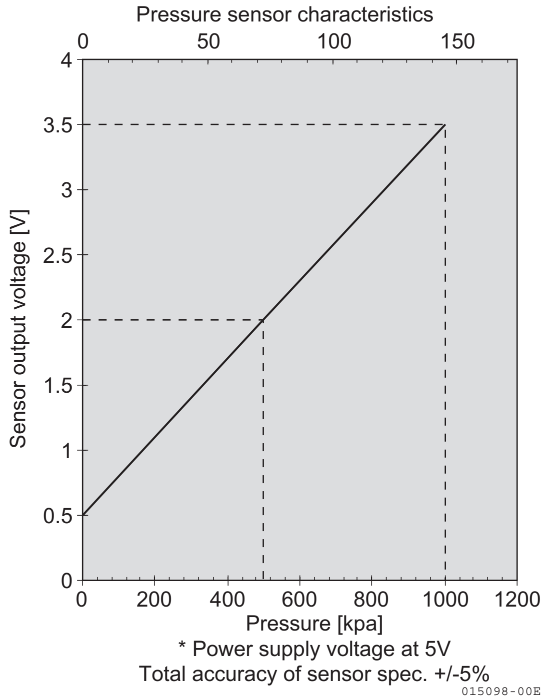
DTC / FMI	Probable cause
P0340/4	(1) Cam speed sensor wire-harness open or short. (2) Cam speed sensor connector poor connection.

<Diagnosis procedure>
(1) Check if starter is turning.
(2) Check wire-harness.
(3) Check the connector of terminal.
(4) Check the sensor attachment states (Dust, etc).
(5) Check sensor output signal.

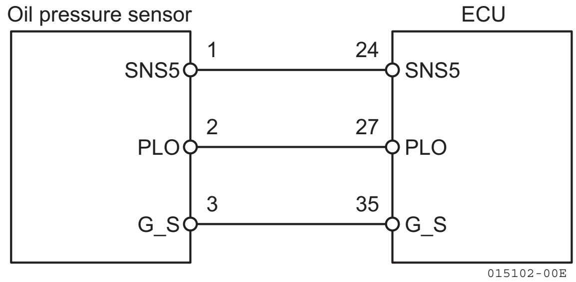
(16) P0520/3, 4 (Lubrication Oil Pressure Sensor)

DTC	P0520/3, 4	Lubrication Oil Pressure Sensor

<Sensor specification chart>



<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0520/3	1. Key SW ON. 2. Input voltage above 3.6V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor
P0520/4	1. Key SW ON. 2. Input voltage below 0.2V. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor

Fail Mode	-
Limited Operation	*No limited operation*
Fail Release	Yes. When input voltage goes to normal range (0.2 - 3.6V).
Remarks	Oil pressure is monitored for engine diagnosis use only. Sensor supply voltage must be kept below 6 V. Once sensor supply voltage exceeded 6 V, sensor have been damaged in a large possibility and strongly recommend to replace all pressure sensor. To check if exceeded voltage is supplied, check the status of DTC 1230/0.

<Content of trouble>

DTC / FMI	Probable cause
P0520/3	(1) "Signal" wire-harness short to high voltage such as 5V or battery. (2) "Sensor GND" wire-harness for oil pressure sensor open. [TBD] (3) Sensor malfunction.
P0520/4	(1) "Signal" wire-harness open or short to GND level. (2) "Sensor 5V" wire-harness open. (3) Sensor malfunction.

<Diagnosis procedure>
* Follow " Pressure Sensor Diagnosis Procedure".

(17) P0522/1 (Lubrication Oil Pressure Too Low)

DTC	**P0522/1**	**Lubrication Oil Pressure Too Low**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0522/1	1. Key SW ON. 2. Lubrication oil pressure below standard which is related to engine speed. 20kPa @1000min-1, 200kPa @3000min^{-1}. 3. 0.5s. 4. "OIL PRESSURE" on TELEFLEX display.	Lube oil system

Fail Mode	
Limited Operation	*No limited operation*
Fail Release	Yes. When oil pressure got over normal value.
Remarks	May damage the engine if kept running with oil pressure at low condition.

<Content of trouble>

DTC / FMI	Probable cause
P0522/1	Check lube oil level.
	Check lube oil pump.
	Check lube oil system.
	Check lube oil filter.
	Check lube oil pressure sensor.

<Diagnosis procedure>
(1) Check lube oil level.
(2) Check lube oil pressure by mechanical gauge such as a bourdon pressure gauge.
(3) Check lube oil pump.
(4) Check lube oil system.
(5) Check lube oil filter.
(6) Check lube oil pressure sensor.

(18) P0562/0, 1 (ECU Power Supply Voltage)

DTC	P0562/0, 1	ECU Power Supply Voltage

<Electrical circuit diagram>
*Refer to ”Main RL, 1st Station RL, 2nd Station RL”

< DTC detect condition >

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0562/0	1. Key SW ON. 2. ECU supply voltage above 16V. 3. 2.5s. 4. "CHECK ENGINE" on TELEFLEX display.	Battery Alternator Wire-harness
P0562/1	1. Key SW ON. 2. ECU supply voltage below 9V. 3. 2.5s. 4. "LOW VOLTAGE" on TELEFLEX display.	Battery Alternator Wire-harness

Fail Mode	
Limited Operation	*No limited operation.*
Fail Release	Yes. When input voltage goes to normal range (9.5 - 15.5V).
Remarks	*If battery is connected switchover + / - otherwise, ECU will not be damaged. But alternator will be damaged.

<Content of trouble>

DTC / FMI	Probable cause
P0562/0	(1) Wrong spec. battery be installed (Such as 24V) (2) Wrong battery wiring connection (3) Wire-harness open or short (ECU - Batt, Alt - Batt) (4) Alternator malfunction
P0562/1	(1) Poor battery power (2) Battery wiring connection (3) Wire-harness open or short (ECU - Batt, Alt - Batt) (4) Alternator malfunction

<Diagnosis procedure>
(1) Check battery voltage.
(2) Check alternator out put voltage.
(3) Check battery wiring.

(19) P0605/12 (EEPROM Error)

DTC	**P0605/12**	**EEPROM Error**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P0605/12	1. Key on. 2. ECU detects EEP ROM device error. 3. - 4. "CHECK ENGINE" on TELEFLEX display	ECU

Fail Mode	
Limited Operation	*No limited operation*
Fail Release	No.
Remarks	Other DTC and some of engine information can not be indicated while this DTC is occurring. Ex. "Engine Run Hours" ***Require key off to reset fail mode.***

<Content of trouble>

DTC / FMI	Probable cause
P0605/12	(1) ECU device malfunction.

<Diagnosis procedure>
(1) Replace ECU.

(20) P1202/0, 1 (Rack Position Sensor)

DTC	P1202/0, 1	Rack Position Sensor

<Electrical circuit chart>
*Refer to other wiring diagram ”Rack Position Sensor”.

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1202/0, 1	1. Key SW ON. 2. Rack position sensor failure logic. (Rack current - rack position response.) Rack mechanical stick or bad response. 3. 0.32 / 0.16s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Injection pump Rack position sensor Rack actuator Wire-harness

Fail Mode	Engine keeps running with fail mode of rack control. Injection timing is controlled as rack-fail mode. *"Target rack position" and "actual rack position" will be indicated 0 by "YANMAR Service Tool". *"Engine load" is indicated 0% on monitor.
Limited Operation	**Maximum engine speed is limited to 1800min^{-1}.**
Fail Release	No.
Remarks	White smoke or black smoke may increase than usual because of Fail mode of injection timing control. This DTC also can be detected by "rack mechanical" or "rack actuator" malfunction, so check also rack actuator performance.

<Content of trouble>

DTC / FMI	Probable cause
P1202/0, 1	(1) Rack position sensor related wire-harness open or short. (2) Rack mechanical malfunction.

<Diagnosis procedure>
(1) Check wire-harness and connector of rack position sensor. (short or open)
(2) Check rack actuator wire-harness including rack actuator relay.

(21) P1210/4 (Rack Actuator)

DTC	P1210/4	Rack Actuator

<Electrical circuit chart>
*Refer to wiring diagram “Rack actuator, Rack Actuator RL”, also “Rack Position Sensor”.

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1210/4	1. Key on. 2. ECU diagnostic logic for rack actuator input. 3. 0.1s. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness Rack actuator

Fail Mode	Engine stop by rack position to be set at stop position. *Break rack actuator relay.
Limited Operation	**Engine Stop**
Fail Release	No.
Remarks	***Require key off to reset fail mode.*** FFD (Freeze Frame Data) is recorded and can be monitor by “YANMAR Service Tool”.

<Content of trouble>

DTC / FMI	Probable cause
P1210/4	(1) Rack actuator related wire-harness open or short.

<Diagnosis procedure>
(1) Check wire-harness and connector of rack actuator and actuator relay.
(2) Check rack actuator hysteresis performance.
(2a) If NG, replace fuel injection pump.

(22) P1211/7 (Rack Actuator Mechanical Malfunction)

DTC	P1211/7	Rack Actuator Mechanical Malfunction

<Electrical circuit chart>
*Refer to wiring diagram “Rack Actuator, Rack Actuator RL”, also “Rack Position Sensor”.

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1211/7	1. Key on. 2. Abnormal acceleration of engine speed caused by rack actuator malfunction. 3. 1s. 4. "CHECK ENGINE" on TELEFLEX display.	Rack actuator Fuel injection pump Wire-harness

Fail Mode	Engine stop by rack position to be set at stop position. *Break rack actuator relay.
Limited Operation	**Engine Stop**
Fail Release	No.
Remarks	***Require key off to reset fail mode.*** FFD (Freeze Frame Data) is recorded and can be monitor by “YANMAR Service Too”.

<Content of trouble>

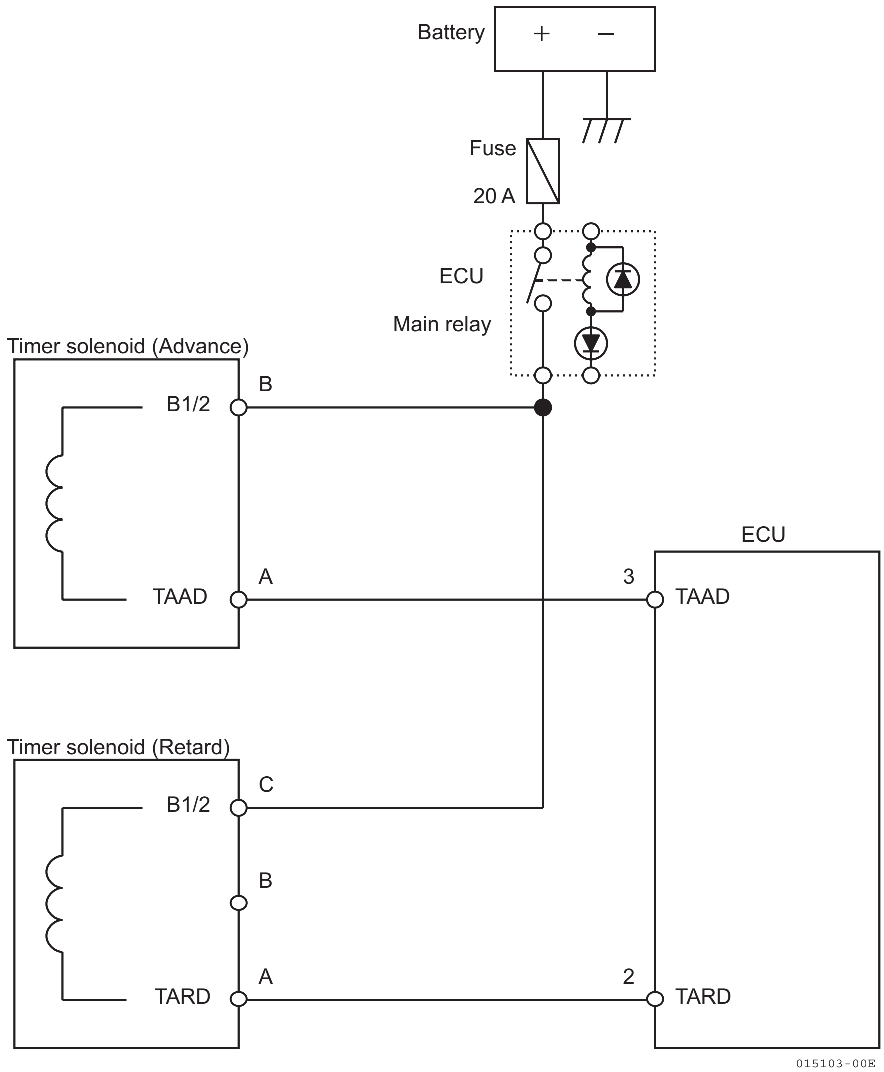
DTC / FMI	Probable cause
P1211/7	(1) Wire harness (2) Rack actuator, fuel injection pump

<Diagnosis procedure>
(1) Check wire-harness and connector of rack actuator and actuator relay.
(2) Check rack actuator hysteresis performance.
  (2a) If NG, replace fuel injection pump

(23) P1220/7, P1225/7 (Advance / Retard Timer Solenoid)

DTC		
DTC	**P1220/7**	**Advance Timer Solenoid**
	P1225/7	**Retard Timer Solenoid**

<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1220/7 P1225/7	1. Key on. 2. ECU diagnosis open or short status of advanced / retard timer output circuit. 3. - 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Wire-harness Timer solenoid

Fail Mode	Engine can not control Injection timer and have fail mode of injection timer control which injection timing will be fully retarded.
Limited Operation	**Maximum engine speed is limited to 1800min^{-1}.**
Fail Release	No.
Remarks	***Require key off to reset fail mode.*** White smoke or black smoke may increase than usual because of fail mode of injection timing control. This DTC is for open or short status of wire harness and timer solenoid. Timer device malfunction is detected by other DTC.

<Content of trouble>

DTC / FMI	Probable cause
P1220/7 P1225/7	(1) Timer actuator connector disconnected. (2) Timer actuator related wire-harness open or short.

<Diagnosis procedure>
(1) Check injection timer solenoid and solenoid wire-harness.

(24) P1230/0, 1 (Sensor 5V Voltage)

DTC	**P1230/0, 1**	**Sensor 5V Voltage**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1230/0	1. Key on. 2. Sensor 5V voltage above 5.5V. 3. 0.5s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Wire-harness (ECU)
P1230/1	1. Key on. 2. Sensor 5V voltage below 4.5V. 3. 0.5s. 4. "PWR REDUCTION", "CHECK ENGINE" on TELEFLEX display.	Wire-harness Sensor (ECU)

Fail Mode	ECU can not get boost pressure value and, so, goes to limited operation condition.
Limited Operation	***Maximum engine speed is limited to 1800min^{-1}.***
Fail Release	Yes. When sensor voltage goes to normal range (4.5 - 5.5 V).
Remarks	Sensor 5V affects to all pressure sensor and sub-throttle. P1230/0 or 1 does not take open of sensor 5V wire-harness. Only short of wire-harness may lead. Sensor supply voltage must be kept below 6 V. Once sensor supply voltage exceeded 6V, sensor have been damaged in a large possibility and strongly recommend to replace all pressure sensor. To check if exceeded voltage is supplied, check the status of DTC 1230/0.

<Content of trouble>

DTC / FMI	Probable cause
P1230/0	(1) Sensor 5V wire-harness short to battery voltage.
P1230/1	(1) Sensor 5V wire-harness short to GND.

<Diagnosis procedure>
(1) Check sensor 5V wire-harness. (short condition)
(2) Check sub-throttle sensor wire harness.
(3) Check pressure sensor (boost, LO) wire harness and pressure sensor malfunction.

(25) P1240/0 (ECU Power Supply Voltage Open)

DTC	**P1240/0**	**ECU Power Supply Voltage Open**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1240/0	1. Key on. 2. ECU diagnostic logic for ECU supply voltage open. 3. Once of 2 time ignition on. 4. "CHECK ENGINE" on TELEFLEX display.	Wire-harness(battery - ECU)

Fail Mode	
Limited Operation	*No limited operation.*
Fail Release	No.
Remarks	

<Content of trouble>

DTC / FMI	Probable cause
P1240/0	(1) ECU power supply voltage open.

<Diagnosis procedure>
(1) Check ECU power supply wire-harness.

(26) P1603/0 (ECU Temperature Too High)

DTC	**P1603/0**	**ECU Temperature Too High**

<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
P1603/0	1. Key on. 2. ECU temperature exceed to 85 deg C. 3. 0.5s. 4. "CHECK ENGINE" on TELEFLEX display.	• Cooling Fresh water / seawater system • Environment around ECU (Engine room temperature due to exhaust gas)

Fail Mode	
Limited Operation	*No limited operation*
Fail Release	Yes. After fail released and also ECU temperature below 80 deg C.
Remarks	From the experience of field test, around 50 deg C will be usual temperature at hot condition.

<Content of trouble>

DTC / FMI	Probable cause
P1603/0	(1) Poor ventilation in engine room.

<Diagnosis procedure / improvements>

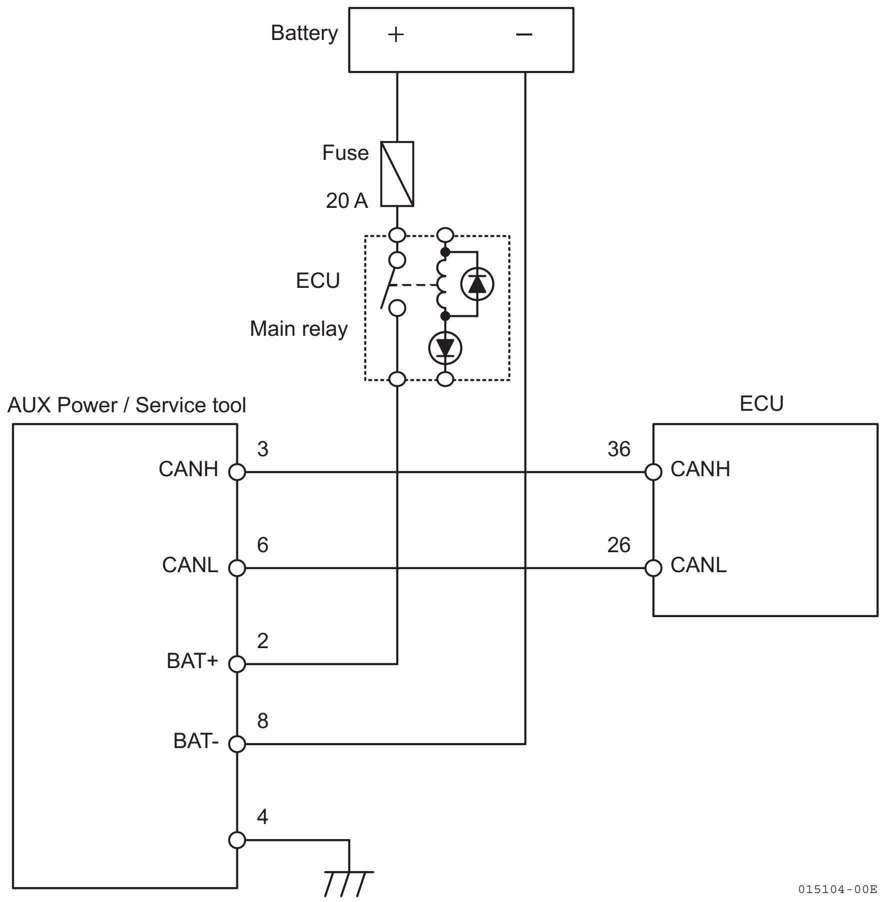
(1) If DTC gets active often, please keep the engine room temperature below 60 deg C at any time by any means.
Ex. Improve ventilation performance of the engine room.

(27) U0146/12 (i2 module (i832X) Communication Error)

Format

DTC	U0146/12	i8320 Communication Error i2 module Communication Error

<Electrical circuit chart>



<DTC detect condition>

DTC / FMI	1. Detection, 2. Judgement, 3. time to detect, 4. etc	Check Point
U0146/12	1. Key on. 2. No throttle position data transmitted from i2 module (i832X). 3. 1s. 4. "ENG COM ERROR" on TELEFLEX display.	Wire-harness (CAN communication cable) I2 Module Wire-harness

Fail Mode	ECU receives throttle position data from i2 module (i832X) and then goes to throttle fail mode if lost i2 module communication. Target engine speed ramp down to low idle speed and stay until sub-throttle get activated. Sub-throttle will be selectable with sub-throttle lamp blinking. If sub-throttle is selected, lamp tunes on. Once sub-throttle is selected, sub-throttle keeps working even if i2 module communication would get back to normal.
Limited Operation	*Main throttle fail mode.*
Fail Release	Yes. (i2 module Communication error)
Limited Operation Release	<Main throttle fail release> (1) If sub-throttle is active: No. (2) If sub-throttle is inactive: Yes. After U0146 fail released.
Remarks	This DTC comes from only communication between i2 module and ECU. TELEFLEX control head malfunction will detected as “Main Throttle Position Sensor Error”. Marine gear transmission control (shift) function is independent from throttle function. This means that shifting function should be controlled as i2 module function. (If i2 module is not powered, then U0146 occur and shift function may get inactive.) Back to normal communication after receiving data from i2 module. If sub-throttle is selected before communication get back to normal, main throttle will stay inactive.

<Content of trouble>

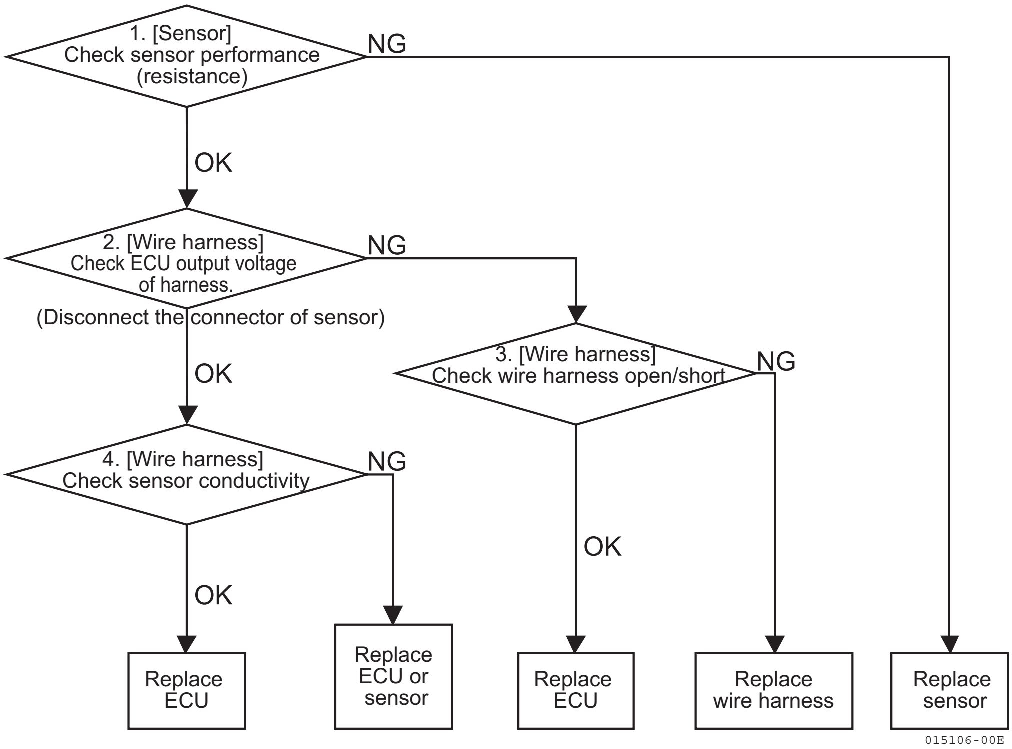
DTC / FMI	Probable cause
U0146/12	(1) Communication wire-harness (CAN) between ECU and Teleflex i2 module open or connector not connected properly. (2) i2 module powered off or malfunction

Diagnosis procedure:
(1) Check if i2 module unit working.
(2) Check CAN communication cable between ECU and i2 module.
(3) Check if 8320 is installed proper software and software setting.

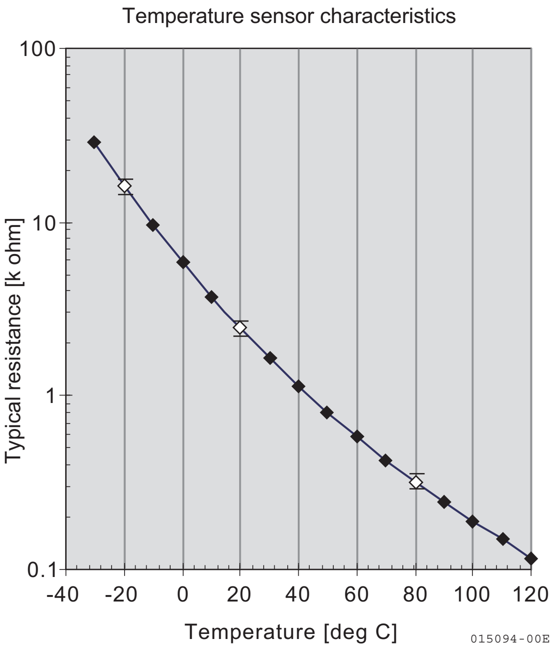
3.3.2 Temperature / Pressure Sensor Diagnosis

(1) Diagnosis Procedure (Temperature Sensor):

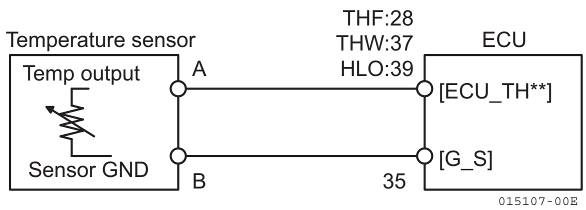
DTC	FMI	CONTENT	PIN# of [ECU_TH*]	PIN# of [ECU_G_S]
P0115	3/4	Water Temperature Sensor	37 (THW)	35 (G_S)
P0180	3/4	Fuel Oil Temperature Sensor	28 (THF)	35 (G_S)
P0195	3/4	Lubricant Temperature Sensor	39 (THLO)	35 (G_S)



<Sensor Characteristic>



<Wiring Diagram of Temperature Sensor>



Case1: When DTC is ACTIVE.
To distinguish (classify) the cause (wire-harness, sensor failure or connector).

1. Checking sensor performance:
   (a) Measure resistance between both terminals of temperature sensor with electrical tester. Check if resistance is in normal range. (*Refer to sensor specification chart.)

NG	Replace sensor
OK	Check ECU / wire harness output voltage

   (b) *This procedure is available If normal sensor is available to use, such as extra / spare sensor or other installed normal sensor.
   Unplug the connector from the sensor which indicating DTC active and re-connect to the normal sensor. See if alarm goes off or not.

Alarm goes off ?	Contents
Yes	Sensor failure. Replace sensor
No	Check ECU / wire harness output voltage

   *The value of temperature is recommended to monitor by service tool.

2. Checking ECU / wire harness output voltage:
   *Unplug connector from temperature sensor and ECU connector is remained to be connected to ECU.
   *Key on and supply power to ECU.
   *Use electric tester to measure the voltage.
   Check the voltage between terminals of wire harness connector.

Terminals	Expected value
Wire harness connector A - B	5V

NG	Check engine wire harness
OK	Check sensor voltage output

3. Checking wire harness open / short circuit.
   *Disconnect ECU connector from ECU and unplug sensor connector.
   *Use electric tester to check open / sort circuit of wire harness. (Conductivity check)
   C: Sensor 5V Supply

Terminals	Conductivity	Expected status
[ECU_TH*] - A	Good	OK: Normal
	Poor	***Failure:*** *Open circuit of wire harness*
[ECU_G_S] - B	Good	OK: Normal
	Poor	***Failure:*** *Open circuit of wire harness*
[ECU_TH*] - other terminal / earth	Poor	OK: Normal
	Good	***Failure:*** *Short circuit of wire harness*
[ECU_G_S] - earth /11/33/34	Good	OK: Normal
	Poor	***Failure:*** *Short circuit of wire harness*
[ECU_G_S] - other terminal	Poor	OK: Normal
	Good	***Failure:*** *Short circuit of wire harness*

Failure	(1) Check wire harness if there is any damage or miss-wiring. (2) Replace wire harness
OK	Check Sensor output voltage → (4)

4. Sensor Output Voltage
*Use electric tester to check open / short circuit of wire harness.
*Make sure that all connectors (sensor and ECU) are connected.
Measure voltage between sensor signal and GND. ([ECU_TH*] - [ECU_G_S])

Voltage	Status	Action
[ECU_TH*] <= 0.2V	NG	(1) Replace wire harness. *Wire harness [ECU_TH*] short to ground / earth (2) Replace temperature sensor. *Sensor failure
0.2V < [ECU_TH*] < 4.8V	Normal condition	Replace ECU if DTC is still active. (Refer to "Sensor specification chart".)
[ECU_TH*] >= 4.8V	NG	(1) Replace wire harness. *Wire harness [ECU_TH*] open or short to "Sensor 5V" / "battery+" (2) Replace temperature sensor. *Sensor failure

Failure	(1) Check wire harness if there is any damage or miss wiring. (2) Replace wire harness
OK	Replace ECU

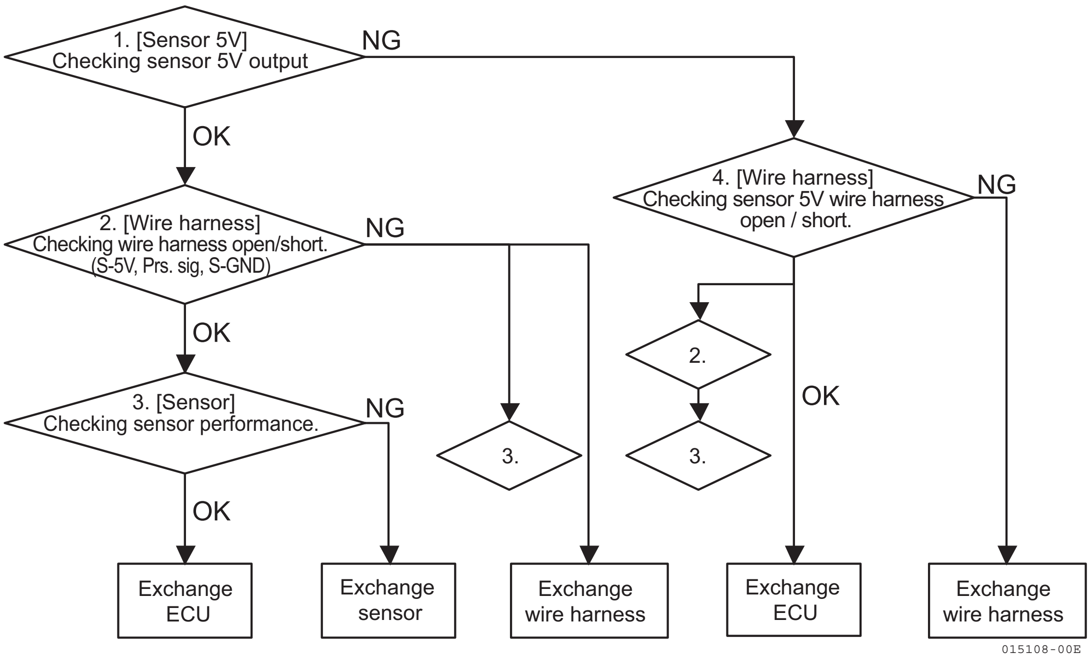
Case2: When DTC is not active (logged status).
*ECU stores the past DTC information and service tool indicate as logged DTC. If there is a possibility to have had failure situation such as disconnecting the connector, it may be the reason of logged DTC.

(1). Checking wire harness.
Sway wire harness along the wire harness between sensor and ECU. See if alarm turn on or not.
*Recommendation: Before start this, it may be easier to clear DTC information by service tool, because the occurrence counter goes 0 and easily can identify when alarm occurred.

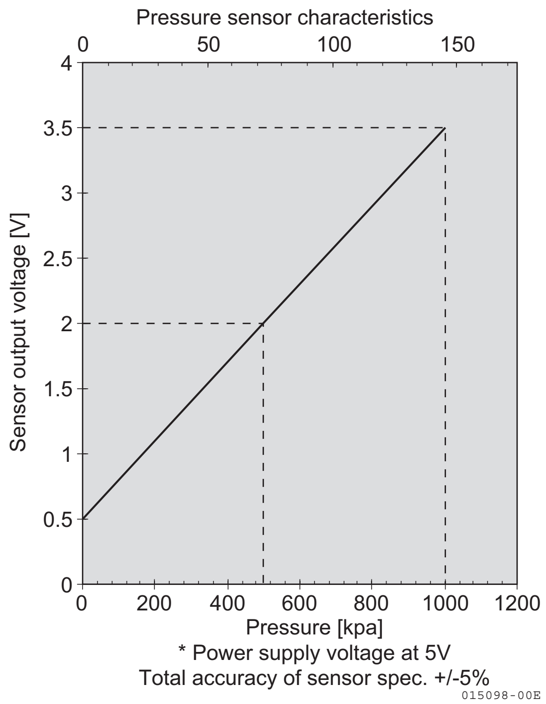
DTC	Contents
Appeared	Check connector terminal.Change wire harness.
Not appeared	No action

(2) Diagnosis Procedure (Pressure Sensor):

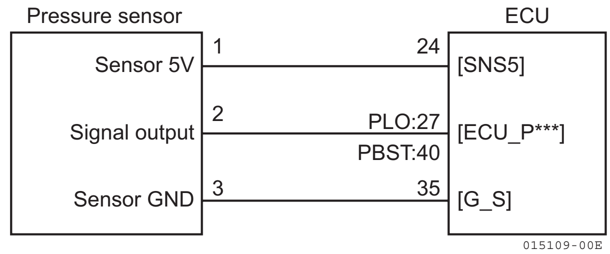
DTC	FMI	CONTENT	PIN# of [ECU_VSEN]	PIN# of [ECU_PRS*]	PIN# of [ECU_G_S]
P0235	3/4	Boost Pressure Sensor	24 (SNS5)	40 (PBST)	35 (G_S)
P0520	3/4	Lubricant Oil Pressure Sensor	24 (SNS5)	27 (PLO)	35 (G_S)

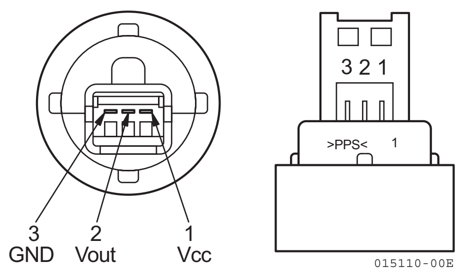


<Performance>



<Wiring Diagram >





****NOTE: THIS PRESSURE SENSOR GET DAMAGED IF SUPPLIED VOLTAGE OF SIGNAL OR SENSOR POWER EXCEEDED 6V. IN THIS CASE, SENSOR MAY GET OUT OF TUNE, AND HAS TO BE REPLACED. SENSOR POWER LINE IS COMMON TO ALL PRESSURE SENSOR, THUS REPLACEMENT SHOULD HAPPEN TO ALL PRESSURE SENSOR AT A TIME.***

****Before replacing wire harness, check also connectors of wire harness and ECU.***

Case1: When DTC is ACTIVE.
To distinguish (classify) the cause (wire-harness, sensor failure, connector).

1. Checking sensor 5V output voltage.
   *Unplug connector from sensor.
   *Measure the voltage between terminals A and C of wire harness connector by electric tester.

Terminals	Voltage	Expected status
Wire harness connector A - C	5V	OK: Normal → Go to 2 “Check wire harness open / short”.
	not 5V	***Failure:*** → Go to 4 “Check sensor 5V wire harness open / short”.

NOTE:
[ECU_SNS5] short to GND shall be detected by P1230/1.
[ECU_SNS5] short to battery shall be detected by P1230/0.

2. Checking wire harness open / short.
   *Disconnect ECU connector from ECU and unplug sensor connector.
   *Use electric tester to check open / sort circuit of wire harness. (Conductivity check)

Terminals	Conductivity	Expected status
[ECU_P***] - B	Good	OK: Normal
	Poor	***Failure:*** *Open circuit of wire harness*
[ECU_SNS5] - C	Good	OK: Normal
	Poor	***Failure:*** *Open circuit of wire harness*
[ECU_G_S] - A / earth /11/33/34	Good	OK: Normal
	Poor	***Failure:*** *Open circuit of wire harness*
[ECU_P***] - A / C / other terminal / earth / Battery +	Poor	OK: Normal
	Good	***Failure:*** *Short circuit of wire harness*
[ECU_SNS5] - A / B / other terminal / earth / Battery +	Poor	OK: Normal
	Good	***Failure:*** *Short circuit of wire harness*
[ECU_S_G] - B / C / other terminal / earth / Battery +	Poor	OK: Normal
	Good	***Failure:*** *Short circuit of wire harness*

Failure	→ Replace wire harness. *Take a look on wiring harness if there is any damage on harness or wrong-wiring.
OK	Go to 3 “Check Sensor performance”.

3. Checking sensor performance.
   *Connect ECU connector to ECU and plug in sensor.
   *Key on and supply battery voltage to ECU.
   *Use electrical tester to measure voltage.

Check sensor signal out put and sensor 5V voltage.

Terminals	Expected value
A - B (Pressure sensor connector of wire harness)	0.5V (at engine stopped)
A - C (Pressure sensor connector of wire harness)	5V * Wire harness is already checked at 1.

NG	Replace pressure sensor. *Replace ECU if pressure sensor replacement does not make different.
OK	Replace ECU

Comment: Sensor signal out put range.

Terminals	Voltage	Expected status
Wire harnes sconnector A - B	below 0.5V *just below 0.5V may be an error.	***Failure:*** *(1) Open circuit of wire harness B- [ECU_P***]* *(2) Open circuit of wire harness C- [ECU_SNS5]* *(3) Short to GND circuit of wire harness B- [ECU_P***]*
	0.5V < [ECU_P***] V < 3.6V	OK: Normal
	above 3.6V	***Failure:*** *(1) Short to battery of wire harness C- [ECU_SNS5]* *(2) Short to battery of wire harness B- [ECU_P***]*

4. Checking sensor 5V wire harness.
   *Disconnect ECU connector from ECU and unplug sensor connector.
   *Use electric tester to check open / sort circuit of wire harness. (Conductivity check)

Terminals	Conductivity	Expected status
[ECU_SNS5] - C	Good	OK: Normal
	Poor	***Failure:*** *Open circuit of wire harness*
[ECU_SNS5] - A / B / other terminal / earth / Battery +	Poor	OK: Normal
	Good	***Failure:*** *Short circuit of wire harness*

Case2: When DTC is not active (logged status).

*ECU store the past DTC information and service tool indicate as logged DTC. If there is a possibility to have had disconnected the wire harness of sensor and turn on ECU, it may be the reason to have logged DTC.

*Clear DTC information first, then it become easy to identify when DTC comes on and also engine condition.

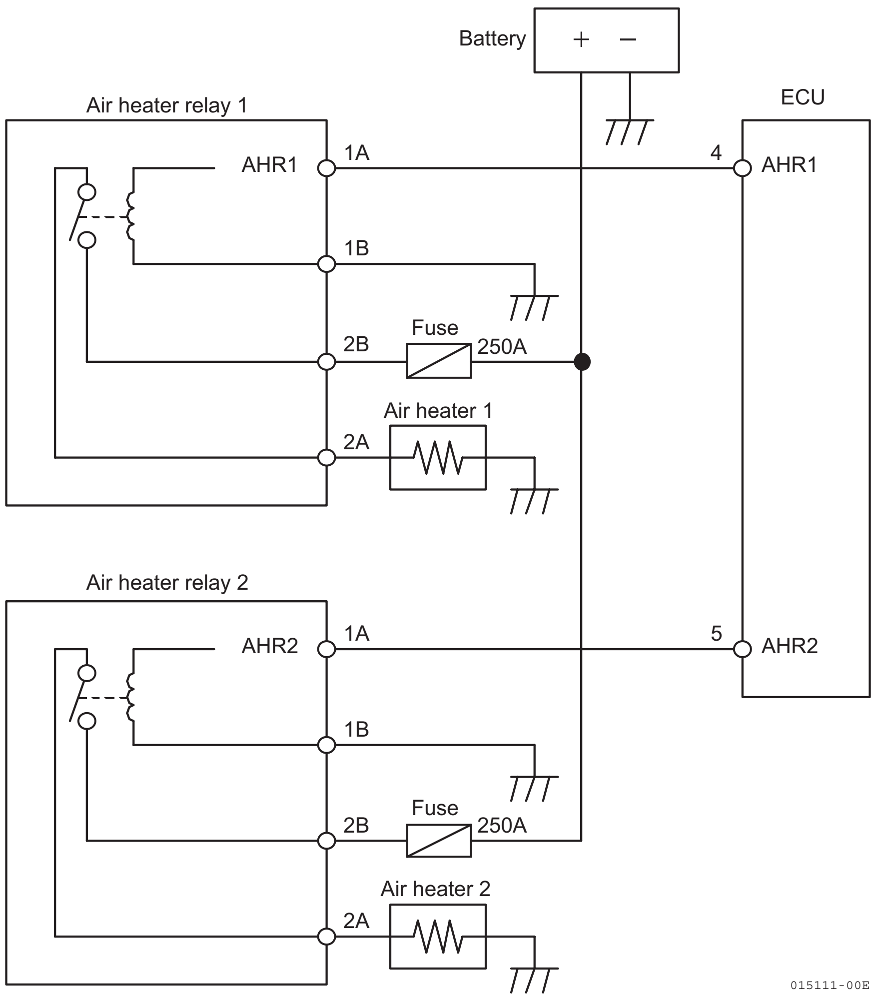
*Sway wire harness around the pressure sensor and ECU. Check if DTC comes again.

DTC	Contents
Appeared	*Check the condition that DTC comes on. Check connector terminal and wire harness. Change wire harness.
Not appeared	No action at this time. *Wait and see if same DTC will come.

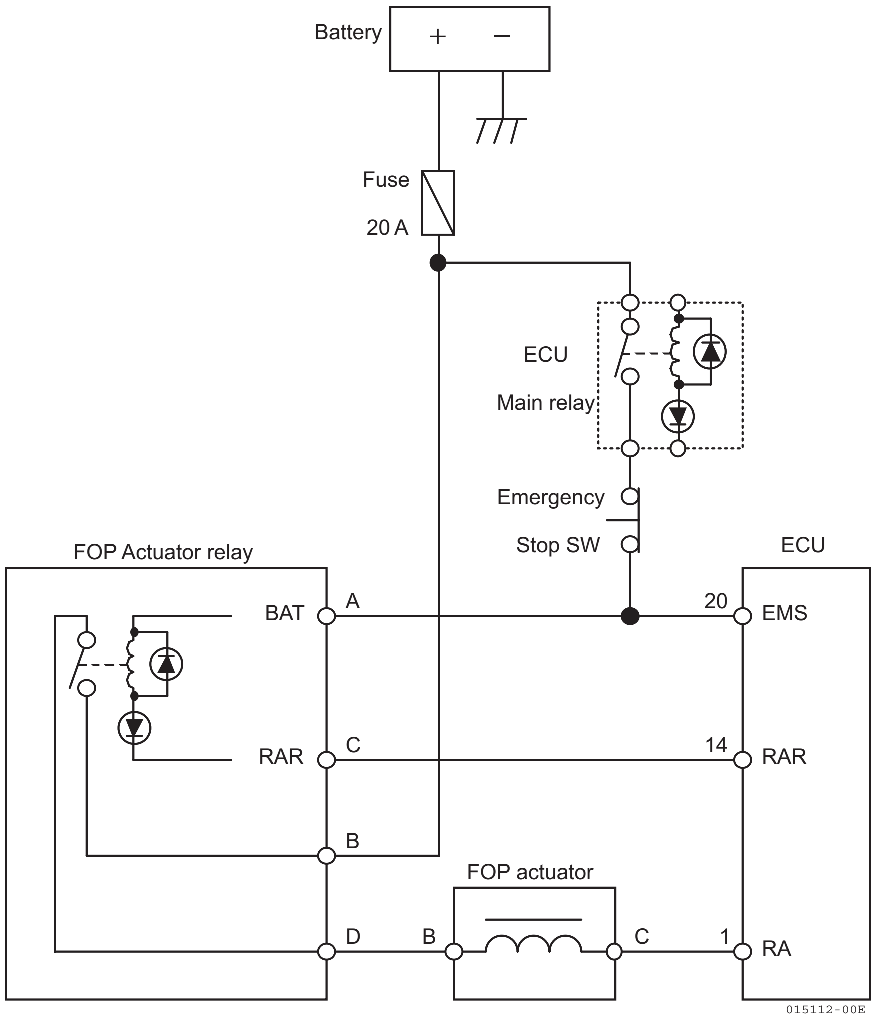
3.3.3 Other Wiring Diagram

*The following wiring diagram is listed
1. Air Heater
2. Rack Actuator, Rack Actuator Relay, Emergency SW
3. Rack Position Sensor
4. Sub-Throttle Indicator, Emergency Throttle Position Sensor
5. Starter Interlock RL, Starter, Alternator
6. Main RL, 1st Station RL, 2nd Station RL
7. NEUTRAL SW

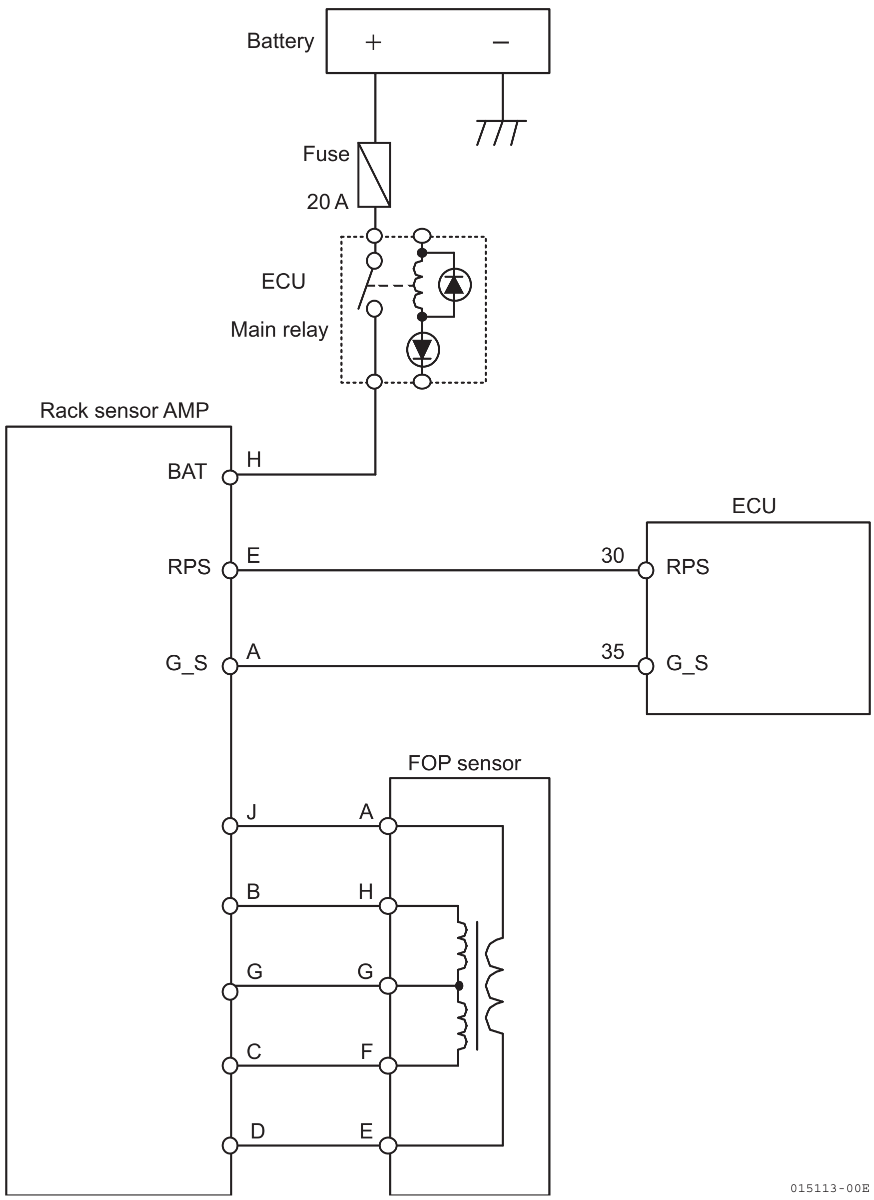
(1) Air Heater



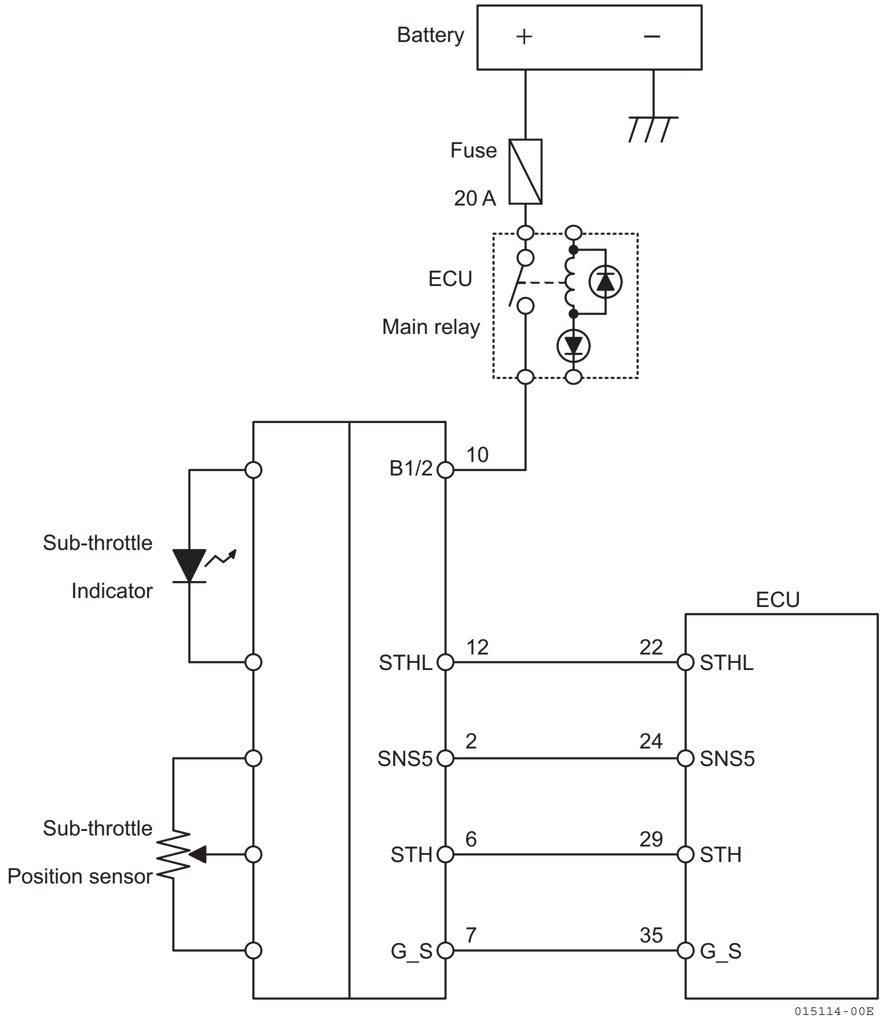
(2) Rack Actuator, Rack Actuator Relay, Emergency SW



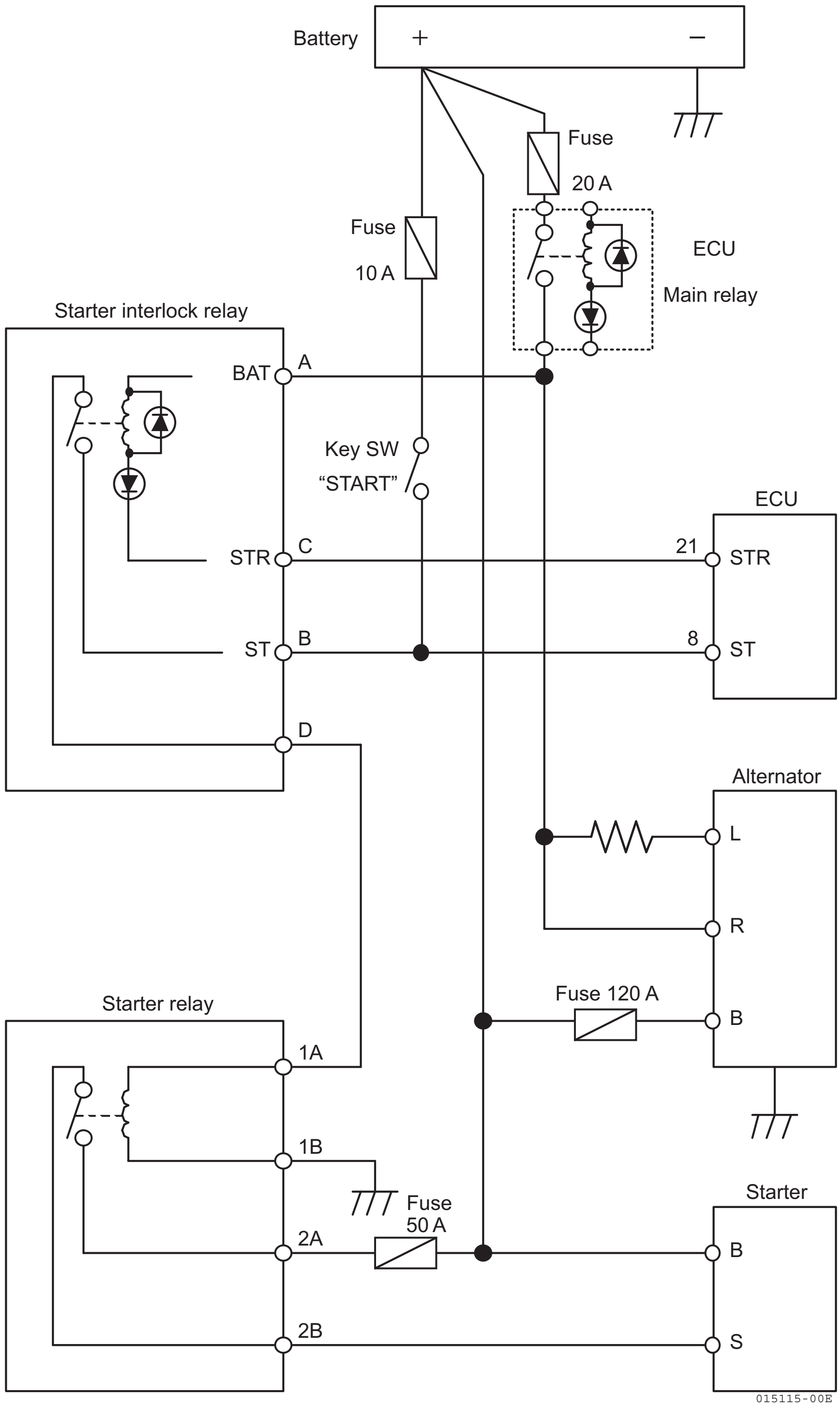
(3) Rack Position Sensor



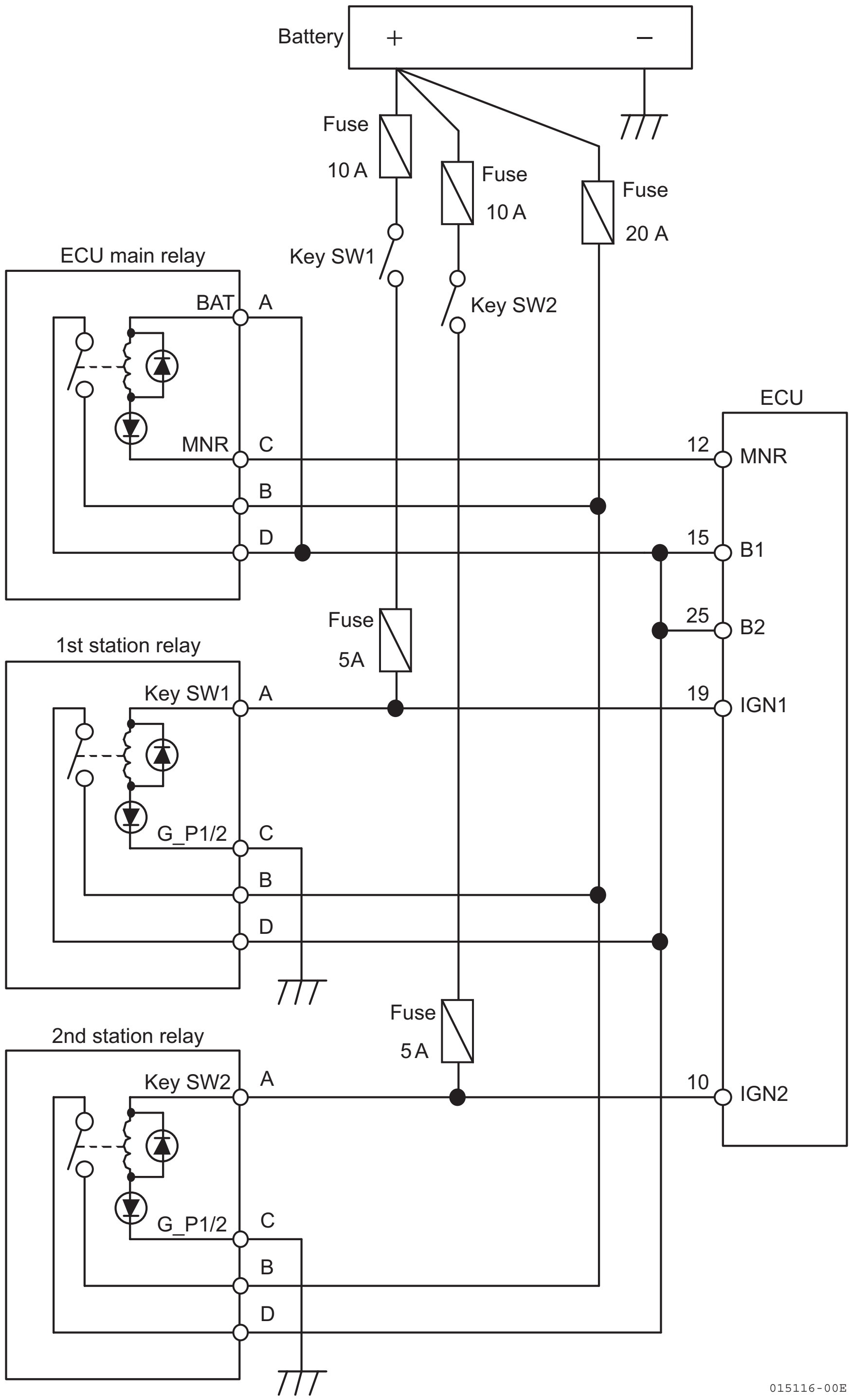
(4) Sub-Throttle Indicator, Emergency Throttle Position Sensor



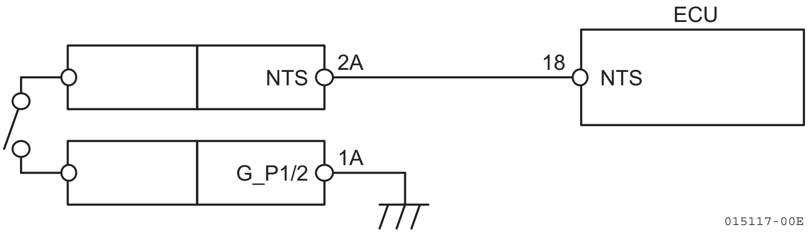
(5) Starter Interlock RL, Starter, Alternator



(6) Main RL, 1st Station RL, 2nd Station RL



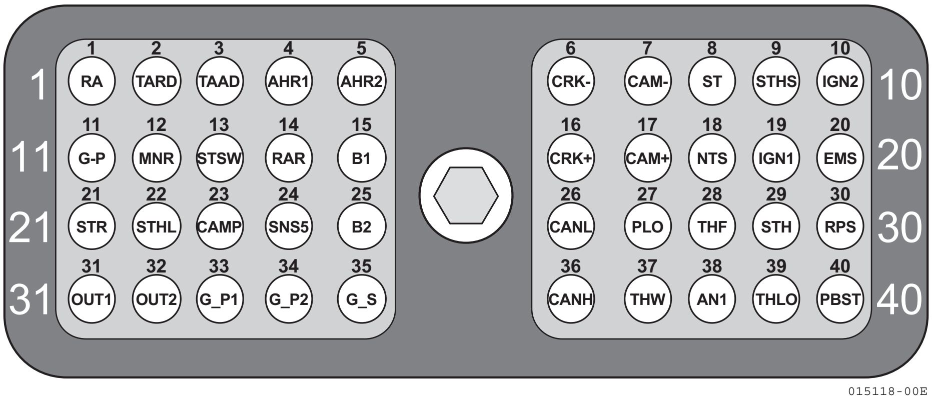
(7) NEUTRAL SW



3.3.4 TELEFLEX i5501E Display "Alarm Screen Information"

HOT ENGINE	CHECK ENGINE
OVER REV	EMERGENCY STOP
OIL PRESSURE	LOW VOLTAGE
TURBO BOOST	ALTERNATOR
GEAR OIL	SEA WATER FLOW
ENG COM ERROR	LOW COOLANT
MAINENANCE	WATER IN FUEL
NET WORK	MAIN THROTTLE
PWR REDUCTION	SEC THROTTLE
NEUTRAL PROTECTION	SHUTTING DOWN

3.3.5 ECU Connector Pin Configuration



3.3.6 Abbreviation

DTC: Diagnostic Trouble Code
FMI: Failure Mode Identifier

4. Disassembly and reassembly

4.1 Disassembly and reassembly precautions

(1) Disassembly

- Take sufficient time to accurately pin-point the cause of the trouble, and disassemble only those parts which are necessary.
- Be careful to keep all disassembled parts in order.
- Prepare disassembly tools.
- Prepare a cleaner and a cleaning can.
- Clear an adequate area for parts and prepare a container(s)
- Drain cooling water (sea water, fresh water) and lube oil.
- Close the seacock

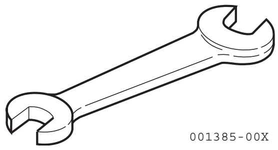
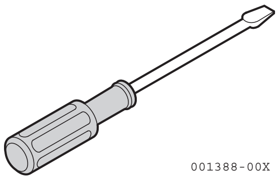
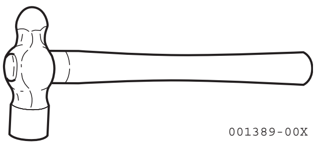
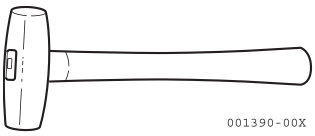
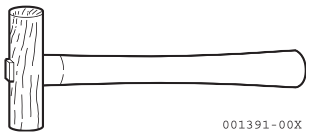
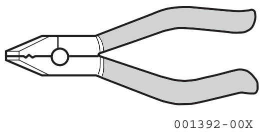
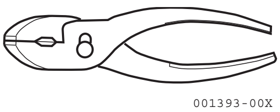
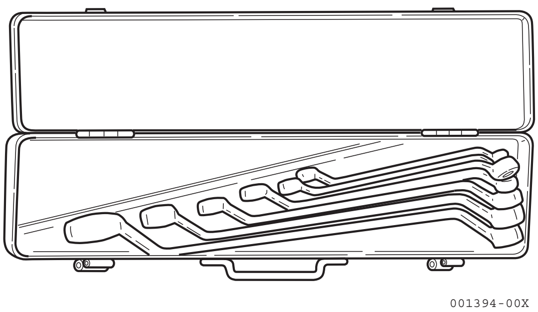
(2) Reassembly

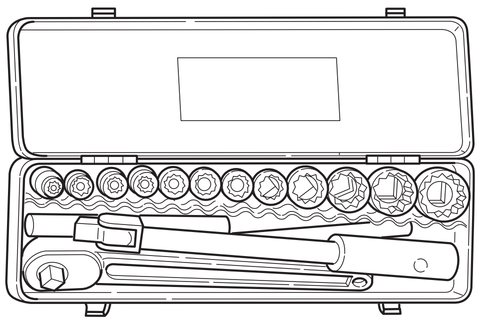
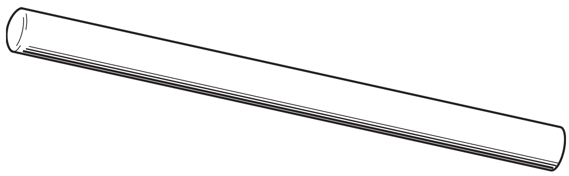
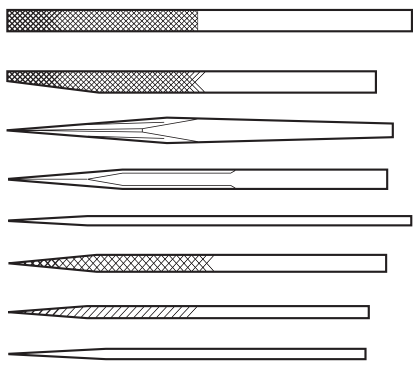
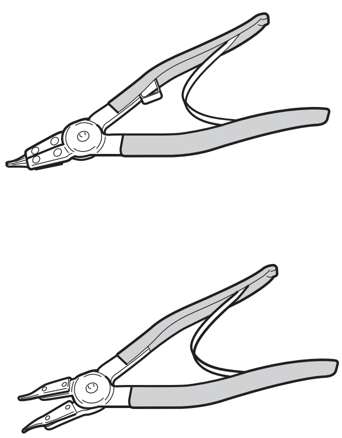
- Sufficiently clean and inspect all parts to be assembled.
- Coat sliding and rotating parts with new engine oil when assembling.
- Replace all gaskets and O-rings.
- Use a liquid packing agent as necessary to prevent oil / water leaks.
- Check the oil and thrust clearances. etc. of parts when assembling
- Make sure you use the correct bolt / nut / washer.
- Tighten main bolts / nuts to the specified torque. Be especially careful not to over tighten the aluminum alloy part mounting bolts.
- Align match marks (if any) when assembling. Make sure that the correct sets of parts are used for bearings, pistons, and other parts where required.

4.2 Disassembly and reassembly tools

The following tools are required when disassembling and reassembling the engine.
Please use them as instructed.

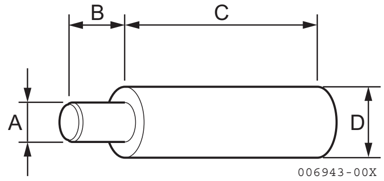
4.2.1 General hand tools

Name of tool	Illustration	Remarks
Wrench		Size: 10 x 13 12 x 14 17 x 19 22 x 24
Screwdriver		
Steel hammer		Local supply
Copper hammer		Local supply
Mallet		Local supply
Nippers		Local supply
Pliers		Local supply
Offset wrench		Local supply 1 set

Name of tool	Illustration	Remarks
Box spanner	 001395-00X	Local supply 1 set
Scraper	 001396-00X	Local supply
Lead rod	 001397-00X	Local supply
File	 001398-00X	Local supply 1 set
Rod spanner for hexagon socket head screws	 001399-00X	Local supply Size: 6 mm 8 mm 10 mm
Stariing pliers Hole type Shaft type	 S - 0 H4 - H8 S = Hole type H = Shaft type 001400-00E	Local supply

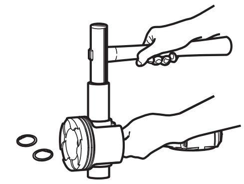
4.2.2 Special hand tools

<table>
<tr><th>Name of tool</th><th>Illustration</th><th>Remarks</th></tr>
<tr><td>Piston pin insertion / extraction tool</td><td>

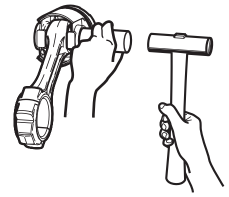


<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>11</td><td>20</td><td>80</td><td>35</td></tr>
</table>

</td><td>



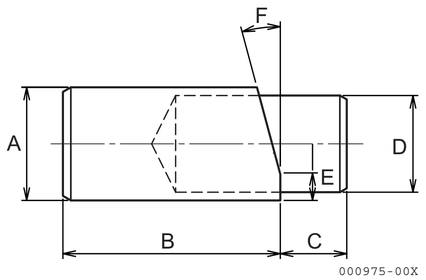
(Extraction of piston pin)



(Insertion of piston pin)

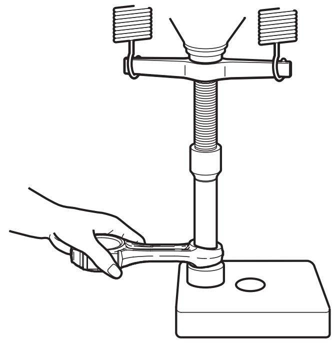
001402-00E

</td></tr>
<tr><td>Connecting rod small end bushing insertion / extraction tool</td><td>



<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>$40^{-0.2}_{-0.5}$</td><td>86</td><td>24</td><td>$37^{-0.45}_{-0.48}$</td><td>5.8±0.5</td><td>10°±30°</td></tr>
</table>

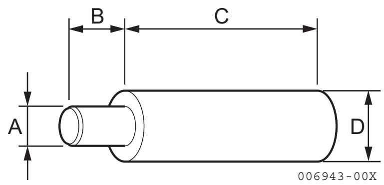
</td><td>



(Extraction)

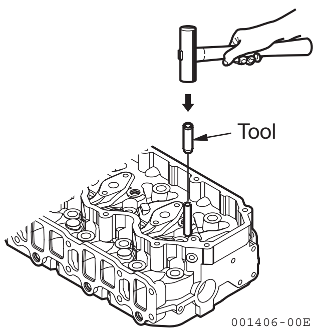
001404-00E

</td></tr>
<tr><td>Intake and exhaust valve guide insertion / extraction tool</td><td>

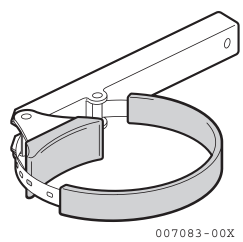


<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th></tr>
<tr><td>7.5</td><td>20</td><td>75</td><td>11</td></tr>
</table>

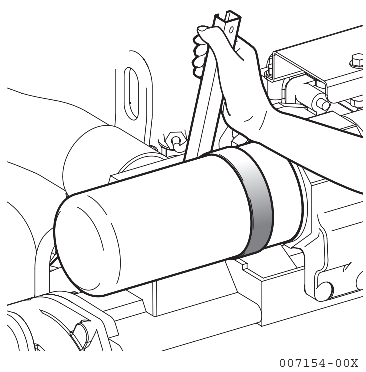
</td><td>



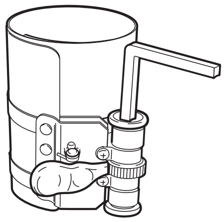
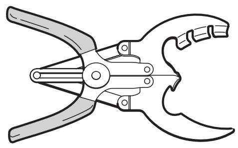
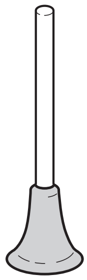
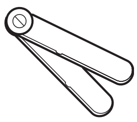
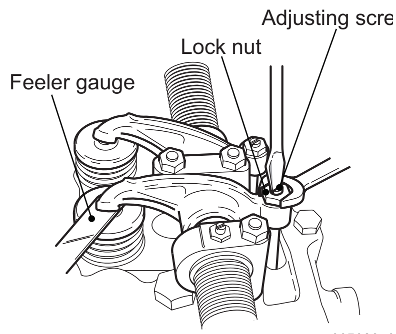
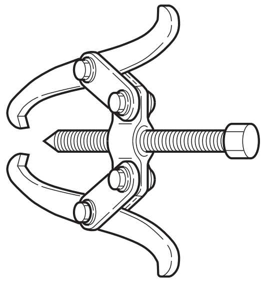
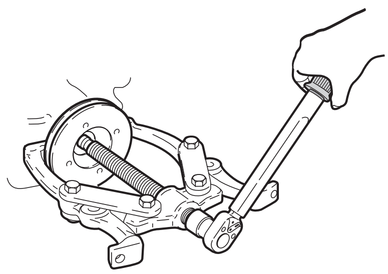
</td></tr>
<tr><td>Lube oil filter case remover</td><td>



</td><td>

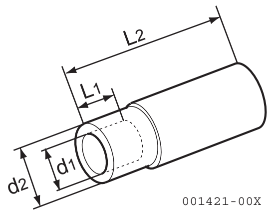


</td></tr>
</table>

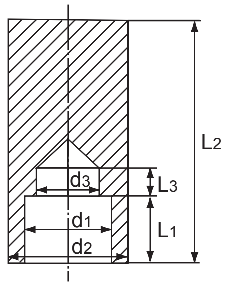
Name of tool	Illustration	Remarks
Piston ring compressor	 007236-00X	
Piston ring replacer (for removal / insertion of piston ring)	 001411-00X	
Valve lapping tool (Rubber cap type)	 001412-00X	
Valve lapping powder	 001413-00X	
Feeler gauge	 001414-00X	 007089-C
Pulley puller	 (Local supply) 001416-01E	 (Removing the coupling) 001417-00E

<table>
<tr><th>Name of tool</th><th>Illustration</th><th>Remarks</th></tr>
<tr><td>Stem seal insertion (for inserting stem seal)</td><td>
mm

	d_1	d_2	d_3	L_1	L_2	L_3
Intake	16.2	22	13.5	11.5	65	4
Exhaust	16.2	22	13.5	9.5	65	4



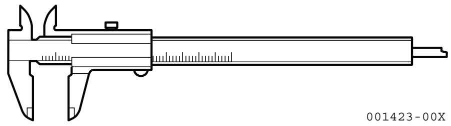
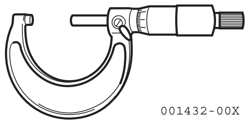
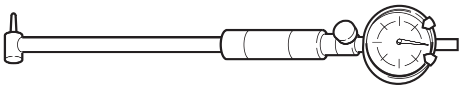
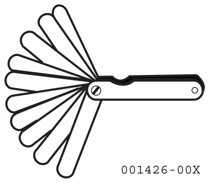
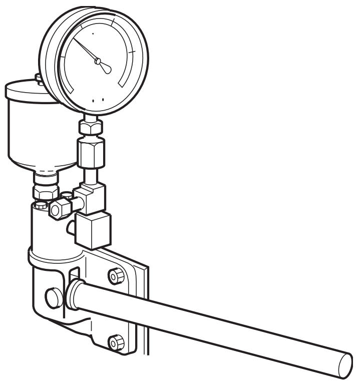
001421-00X



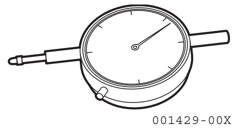
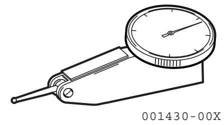
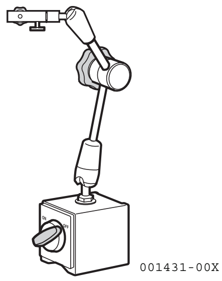
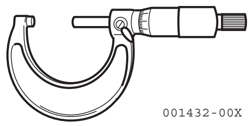
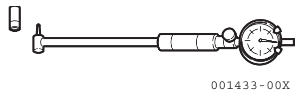
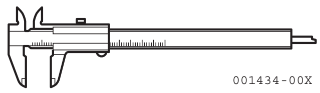
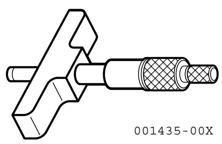
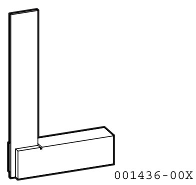
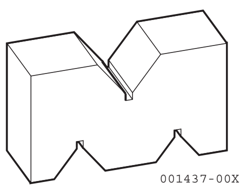
001422-00X
</td><td></td></tr>
</table>

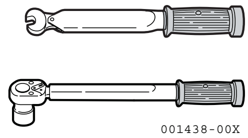
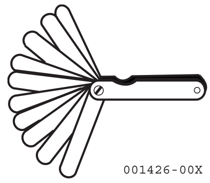
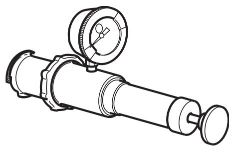
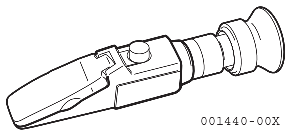
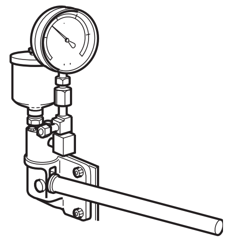
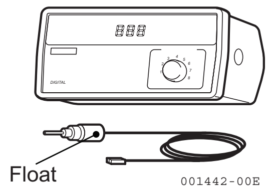
4.2.3 Measuring instruments

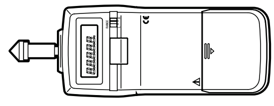
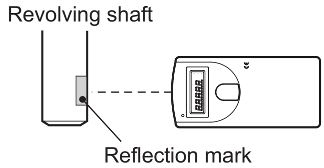
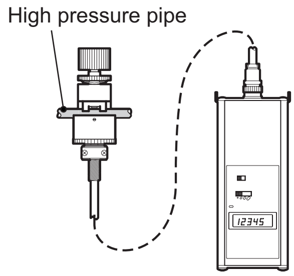
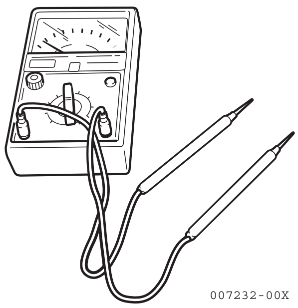
(1) Application of tools

Name of tool	Illustration	Application
Vernier calipers		0.05 mm 0-150 mm
Micrometer		0.01 mm 0-25 mm 25-50 mm 50-75 mm 75-100 mm 100-125 mm 125-150 mm
Cylinder gauge		0.01 mm 18-35 mm 35-60 mm 50-100 mm
Thickness gauge		0.05-2 mm
Torque wrench		0-343 N•m (0-35 kgf•m)
Nozzle tester		0-49 MPa (0-500 kgf / cm^2)

(2) Use of tools

No.	Name of tool	Use	Illustration
1	Dial gauge	Measures shaft bending, distortions of levelness, and gaps.	
2	Test indicator	Measures narrow and deep places, which cannot be measured with dial gauge.	
3	Magnetic stand	Keeps the dial gauge firmly in position, thereby permitting it to be used at various angles.	
4	Micrometer	Measures the outer diameter of the crank shaft, piston, piston pin, etc.	
5	Cylinder gauge	Measure the inner diameter of the cylinder liner and rod metal.	
6	Vernier calipers	Measures various outer diameter, thickness, and width.	
7	Depth micrometer	Measures sinking of valves.	
8	Square	Measures distortion in position of springs and perpendicularity of parts.	
9	V Block	Measures shaft distortion.	

No.	Name of tool	Use	Illustration
10	Torque wrench	Used to tighten bolts and nuts to standard torque.	
11	Thickness gauge	Measures the distance between the ring and ring groove, and between the shaft and shaft joint at time of assembling.	
12	Cap tester	Check for leakage in the fresh water system.	
13	Battery current tester	Checks density of antifreeze and charging condition of battery fluid.	
14	Nozzle tester	Checks the shape and pressure of spray emitted from the fuel injection valve at the time of injection.	
15	Digital thermostat	Measures temperature of various parts.	

No.	Name of tool		Use	Illustration
16	Rotation gauge	Contact type	Measures rotation speed by using a reflector seal which is placed on the exterior of the revolving shaft.	 001443-00X
		Photoelectric type	Measures rotation speed by using a reflector seal which is placed on the exterior of the revolving shaft.	 001444-00E
		High pressure fuel pipe clamp type	Measures rotation speed without reference to revolving shaft center or the exterior of the revolving shaft.	 001445-00E
17	Circuit tester		Measure the resistance, voltage, and continuity of the electric circuit.	 007232-00X

4.2.4 Other material

Items		Usual contents	Features and application
Liquid gasket	Three Bond No.1 TB1101	200 g (1 kg also available)	Non-drying liquid gasket; solvent less type, easy to remove, superior in seawater resistance, applicable to various mating surfaces.
	Three Bond No.2 TB1102	200 g (1 kg also available)	Non-drying liquid gasket; easy to apply, superior in water resistance and oil resistance, especially superior in gasoline resistance.
	Three Bond No.3 TB1103	150 g	Drying film, low viscosity and forming of thin film, appropriate for mating surface of precision parts.
	Three Bond No.4 TB1104	200 g (1 kg also available)	Semi-drying viscoelastic material, applicable to non-flat surface having many indentations and protrusions, superior in heat resistance, water resistance, and oil resistance.
	Three Bond No.10 TB1211	100 g	Solvent-less type silicone-base sealant, applicable to high temperature areas. (-50 °C to 250)
	Three Bond TB1212	100 g	Silicone-base, non-fluid type, thick application possible.
Adhesive	Three Bond TB1401	200 g	Prevention of loose bolts, gas leakage, and corrosion. Torque required to loosen bolt: 10 to 20% larger than tightening torque.
	Lock tight SUPER TB1324	50 g	Excellent adhesive strength locks bolt semi-permanently.
Seal Tape		5 m round tape	Sealing material for threaded parts of various pipes. Ambient temperature range: -150 °C to 200 °C
O-ring kit		Ø1.9 x 2 m: 1 Ø2.4 x 2 m: 1 Ø3.1 x 2 m: 1 Ø3.5 x 2 m: 1 Ø5.7 x 2 m: 1	O-ring of any size can be prepared, whenever required. (Including adhesive, release agent, cutter, and jig)
EP lubricant (molybdenum disulfate)	Brand name (LOWCOL PASTE)	50 g	For assembly of engine cylinders, pistons, metals shafts, etc. Spray type facilitates application work.
	Brand name (PASTE SPRAY)	330 g	
	Brand name (MOLYPASTE)	50 g	Prevention of seizure of threaded parts at high temperature. Applicable to intake and exhaust valves. (stem, guide, face)

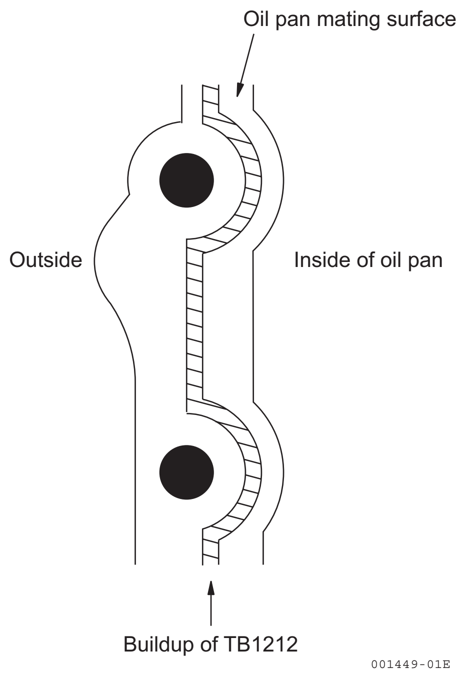
Items		Usual contents	Features and application
Scale solvent	Scale solvent	1 box (4 kg x 4 removers)	• The scale solvent removes scale in a short time. (1 to 10 hours) • Prepare water (seawater is possible) in an amount that is about 10 times the weight of the solvent. Mix the solvent with water. • Just dipping disassembled part into removes scale. To shorten removal time, stir remover mixture. • If cleaning performance drops, replace remover mixture with new remover mixture. • Neutralize used mixture, and then dispose of it. To judge cleaning performance of mixture, put pH test paper into mixture. If test paper turns red, remover mixture is still effective.
	Neutralizer (caustic soda)	1 box (2 kg x 4 neutralizers)	
	pH test paper		
Anti freeze			Add antirust to fresh water system at the cold area to engine operate.
Cleaning agent			• The cleaning agent removes even carbon adhering to disassembled parts. • If a cleaning machine is used, prepare 4 to 6% mixture of 60° to 80° to ensure more effective cleaning.
Cleaning agent for turbocharger		4ℓ x 4	Special cleaning agent that requires no water, specially designed for blower of turbocharger and intercooler.
		18ℓ x 1	
		15sets: 1, 500cc x 6	

[NOTICE]

It is recommended that the liquid gasket of Three Bond TB1212 should be used for service work.

Before providing service, observe the cautions below:

1) Build up each gasket equally.
2) For a bolt hole, apply liquid gasket to the inside surface of the hole.
3) Conventionally, Three Bond TB1104(gray) or Three Bond TB1102(yellow) is used for paper packing though single use of one of these bounds is not effective.
4) If conventional packing is used, do not use liquid packing.



4.3 Disassembly and reassembly

4.3.1 Disassembly

• Preparation on a boat

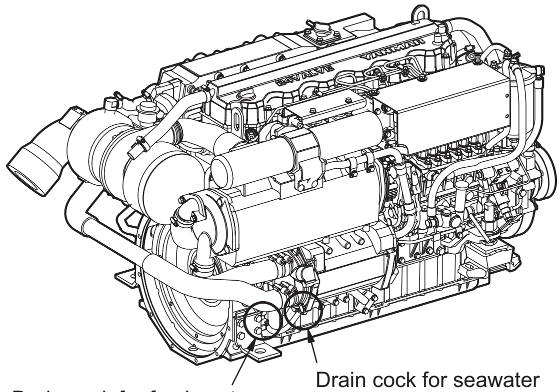
For engines mounted in an engine room of a ship, remove the piping and wiring connecting them to the ship.

1) Remove the electric wiring connecting the electronic control system and the engine.
2) Remove the wiring between the starting motor and the battery.
3) Remove the exhaust rubber hose from the mixing elbow.
4) Remove the rubber hose connecting the coolant recovery tank to the filler cap.
5) Remove the seawater inlet hose for the sea water pump (after making sure the seacock is closed).
6) Remove the fuel oil inlet rubber hose from the fuel feed pump.
7) Remove the body fit (reamer) bolts and disassemble the propeller shaft coupling and thrust shaft coupling.
8) If a driven coupling is mounted to the front drive coupling, disassemble.
9) Remove the flexible mount nut, lift the engine, and remove it from the engine base. (Leave the flexible mount attached to the engine base.)

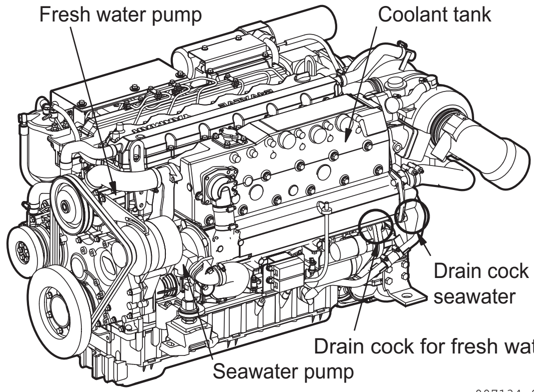
• Disassembling an engine in a workshop

(1) Drain cooling water

1) Open two drain cocks to drain seawater.
2) Open two drain cocks to drain fresh water.



007133-00E



007134-00E

(2) Drain lube oil

Remove the pipe coupling bolt, which holds the lube oil dipstick guide, and drain the lube oil from the engine.

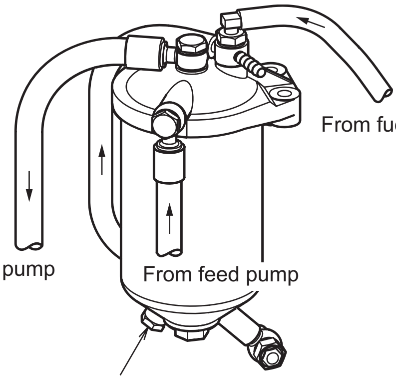
Note:
If a lube oil supply / discharge pump is used for the engine, the intake hose is placed in the dipstick guide.

(3) Removing electrical wiring

Remove the wiring from the engine.

(4) Removing the fuel filter & fuel pipe

1) Remove the fuel pipes (fuel filter- feed pump, fuel filter-fuel pump and fuel nozzle-fuel filter).
2) Remove the fuel filter from the engine.

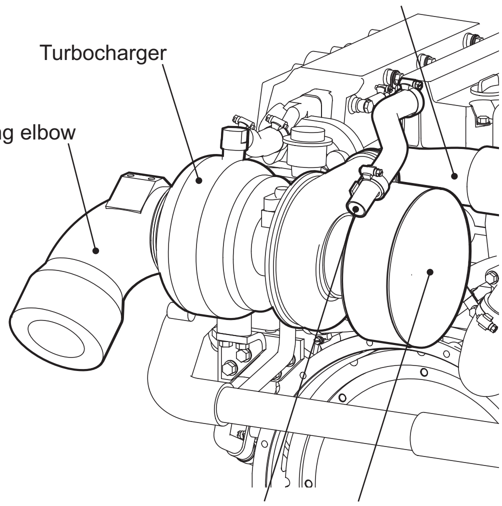


(Fuel filter)

007126-00E

(5) Removing the air silencer

1) Remove the breather hose from the air silencer.
2) Remove the air silencer from the turbocharger



(6) Removing the mixing elbow

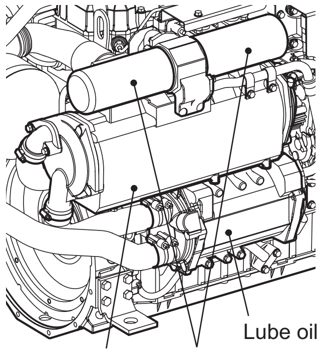
1) Remove the seawater rubber hose connecting to the mixing elbow.
2) Remove the mixing elbow from the turbocharger.

(7) Removing the turbocharger

1) Remove the intake pipe (turbine-intake manifold).
2) Remove the oil pan side rubber hose for the turbine lube oil return pipe from the oil pan.
3) Remove the turbine lube oil pipe (lube oil cooler-turbine).
4) Remove the turbine.

(8) Removing the intercooler

1) Remove the intake air hose.
2) Remove the seawater rubber hoses.
   (Heat exchanger→intercooler→Lube oil cooler)
3) Remove the intercooler

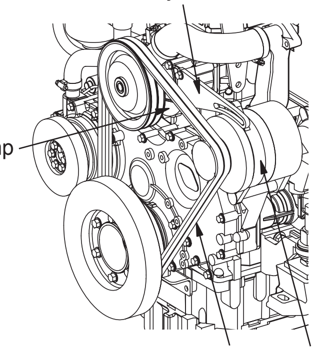


(9) Removing the starting motor

Remove the starting motor from the flywheel housing.

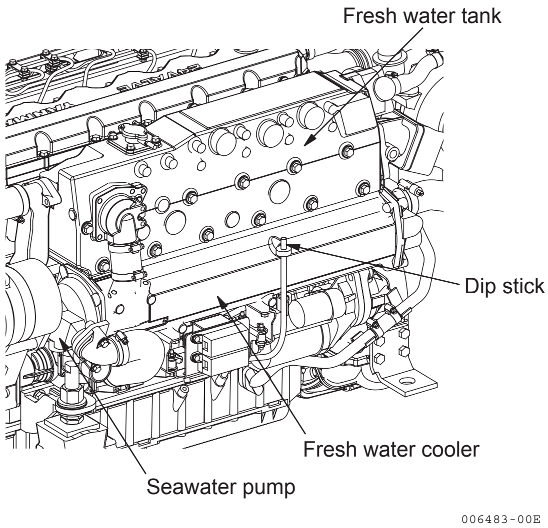
(10)Removing the alternator

1) Loosen the alternator adjuster bolt and remove the V-belt.
2) Removing the adjuster from the fresh water pump, and remove the alternator from the gear case (with distance piece).



(11)Removing the cooling water pipe (seawater / fresh water)

1) Remove the seawater pipe (seawater pump-fresh water cooler).
2) Remove the fresh water pipe (fresh water pump-fresh water cooler, exhaust manifold-fresh water pump).
3) Remove the fresh water pipe (cylinder block-lube oil cooler, lube oil cooler-fresh water pump).



(12)Removing the fresh water tank (exhaust manifold), fresh water cooler and fresh water pump.

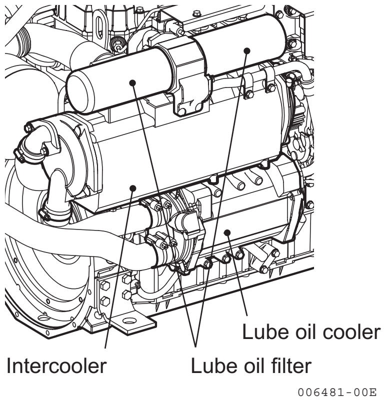
1) Remove the fresh water tank and gasket packing.
2) Remove the fresh water cooler.
3) Remove the fresh water pump and gasket.

(13)Removing the seawater pump

Remove the seawater pump.

(14)Removing the lube oil filter and lube oil cooler

1) Remove the lube oil filter.
2) Remove the lube oil cooler.
3) Remove the lube oil dipstick and guide.



(15)Removing the electronic control devices

Remove the cover and remove the electronic control unit, amplifier and fuse.

(16)Removing the fuel injection pipe

1) Remove the fuel injection pipe retainer.
2) Loosen the cap nuts on both ends of the fuel injection pipe and remove the fuel injection pipe.

(17)Removing the fuel injection nozzles

Note:
If the fuel nozzle seat stays in the cylinder head, make a note of the cylinder number and be sure to remove it when disassembling the cylinder head.

(18)Removing the fuel injection pump

Refer to 6.1.5 for the procedure.

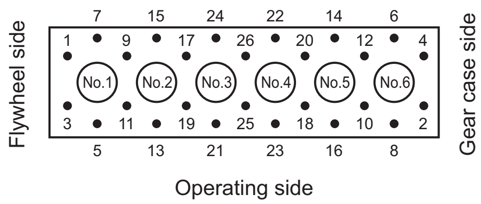
(19)Removing the rocker arm shaft assembly

1) Remove the rocker arm cover.
2) Remove the bolts (s) for the rocker arm shaft support, and remove the entire rocker arm shaft assembly.

3) Pull out the push rods.

(20)Removing the cylinder head

1) Loosen the cylinder head bolts in two steps in the illustrated order. Remove the cylinder head.
2) Remove the cylinder head gasket.



(Order of loosening cylinder head bolts)

006485-00E

(21)Removing the marine gearbox

Loosen the bolts for the clutch case flange, and remove the gearbox assembly.

(22)Removing the crankshaft damper and pulley

Remove the crankshaft damper and the V-pulley.

(23) Removing the gear case cover

Loosen the gear case cover bolts, and remove the gear case cover from the gear case.

(24) Removing the flywheel and flywheel housing

1) Loosen the flywheel bolts and remove the flywheel.
2) Remove the flywheel housing.

Note:
Be careful not to scratch the ring gear.

(25)Turning the engine over

Place a wood block on the floor, and lay the cylinder block upside down on it.

Note:
Make sure that the positioning pins on the cylinder block do not come in contact with the wood block.

(26)Removing the oil pan and spacer

Remove the oil pan and spacer.

(27)Removing the connection rod big end cap

1) Loosen the rod bolts and remove the big end cap.
2) Turn the crankshaft and remove the big end cap for each cylinder.

(28)Remove the lube oil pump

(29) Loosening the main bearing bolts

1) Loosen the main bearing bolts and remove the main bearing bolts.
2) Remove the main bearing cap and lower main bearing metal.

Note:
The thrust metal (lower) is mounted to the base main bearing cap.

(30)Removing the crankshaft

Remove the crankshaft

Note:

1. The thrust metal (upper) is mounted to the standard main bearing.
2. Remove the main bearing metal (upper) from the cylinder block.

(31) Removing the connecting rod & piston assy

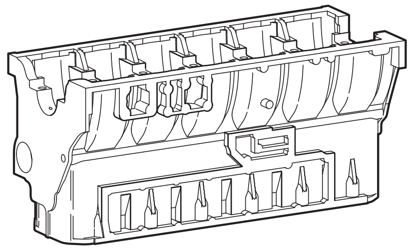
4.3.2 Reassembly

- Clean all parts
  Clean all parts using by the cloth and diesel oil (or cleaning agent) before reassembly.

Note:
1. If the dust remain with the parts, engine may cause the seizing or damage.
2. The cleaning agent removes even carbon adhering to disassembled parts.

(1) Cylinder block

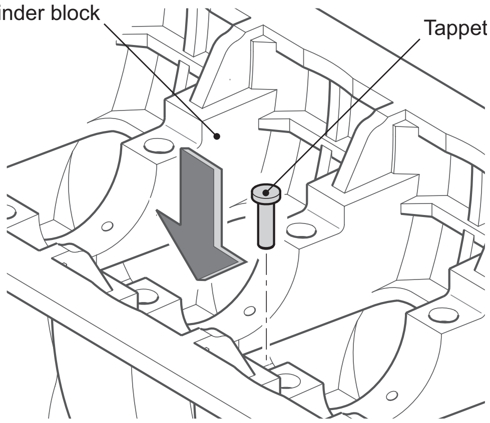
Completely clean each oil hole. After cleaning, check that no scaling remains on cylinder block.
Place a wood block on the floor and put the cylinder block upside down (with the cylinder head mounting surface facing down).



(Cylinder block)
006486-00E

(2) Inserting the tappets

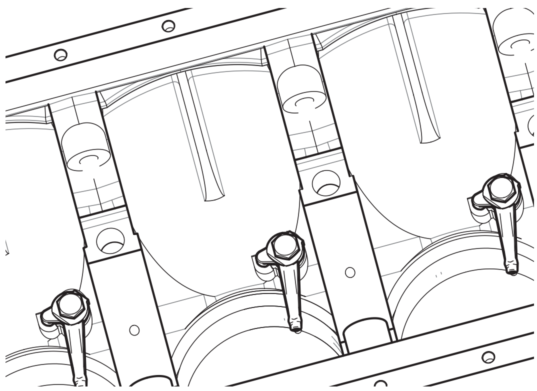
Check that each tappet is fitted to appropriate cylinder and valve (exhaust or intake).
Before fitting, apply engine oil to each tappet. After fitting, check that each tappet operates smoothly.



(Tappet fitting)
006487-00E

(3) Fitting piston cooling nozzle

Fit each piston cooling nozzle.
Check that nozzle end is positioned on piston head side.
Also check that nozzle does not touch cylinder block.
Tightening torque: 19.6N•m (2.0kgf•m)



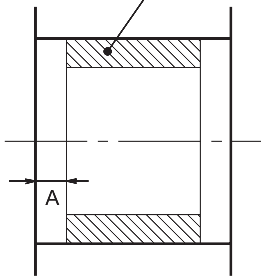
(Piston cooling nozzle)
006488-00E

(4) Fitting cam shaft bearing

1) Fit each cam shaft bearing as follows:

a) Apply lube oil to outer surface of each bearing and fitting area of cylinder block, and then press-fit metal into its position using driving tool. Check the position of each oil hole. More than 2/3 area of a hole should be aligned.

Anti-flywheel side: A=2
Intermediate position: A=1.5
Flywheel side: A=0.5



b) After press-fitting, check each bearing for distortion by measuring inner diameter of bearing.

mm

Inner diameter after press-fitting	57+0.05/-0.02

Note:
To remove cam shaft bearing

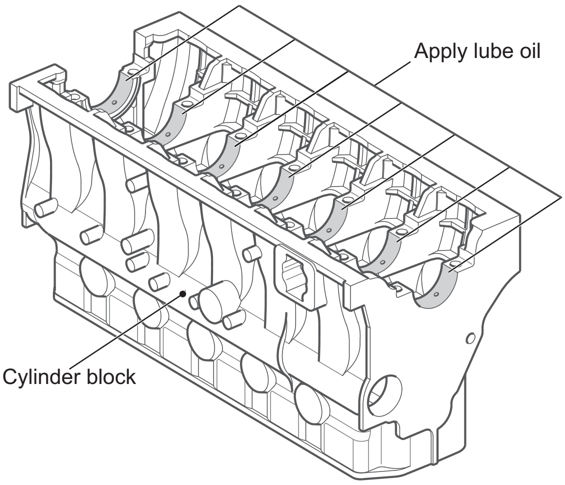
1) Attach plate to cam shaft bearing, and tap off bearing using copper hammer.
2) Completely clean each bearing hole on cylinder block before press-fitting each bearing.

(5) Mounting the crankshaft

1) Apply engine oil to each crank journal hole of cylinder block and each block side main bearing.
Bearings having an oil groove should be positioned on upper side (block side).
Fit thrust metal so that oil grooves are respectively positioned outside.
2) Apply engine oil to each crank pin and crank journal, and fit each journal to main bearing.
3) Fitting bearing caps

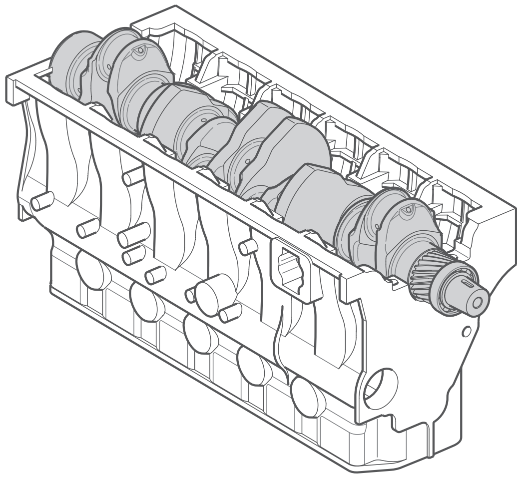
a) Apply engine oil to both surfaces of each cap side main bearing, and then fit each main bearing to the cap.

b) Apply lube oil to bolt holes of each bearing cap.
Fit each bearing cap to each journal of crankshaft, and apply the specified torque to tighten each bearing cap bolt. Check that each bolt is equally tightened.

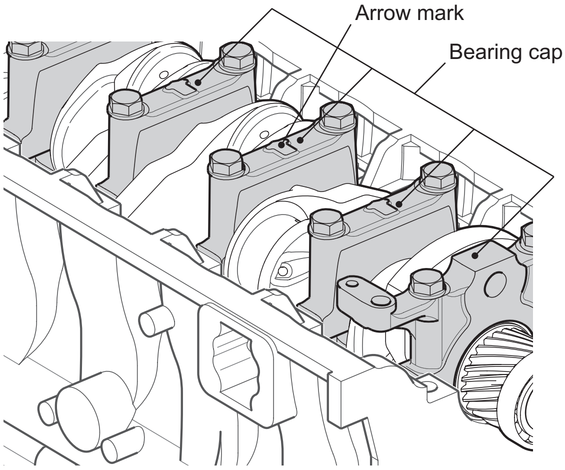


(Fitting of upper bearings)

Bearing cap bolt (M15, 14 bolts) tightening torque	235±10N•m (24±1kgf•m)



(Fitting of crankshaft) 006491-00E



(Fitting of bearing cap) 006492-00E

Note:

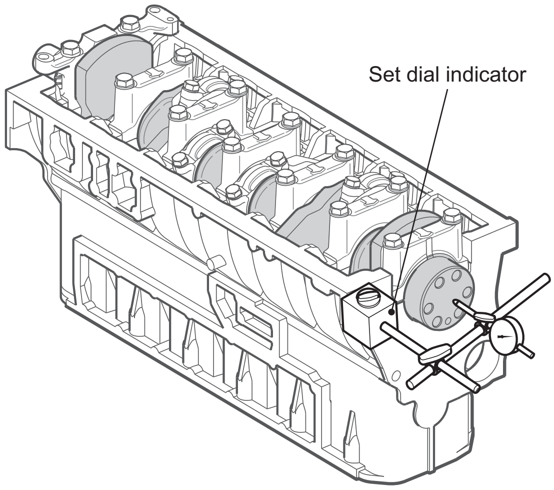
Check that the arrow marked on each bearing cap faces flywheel direction, and the match mark on each cylinder is correctly aligned.

c) Check that crankshaft rotates smoothly.

d) Set a dial indicator on the cylinder block and measure side clearance of crankshaft.

mm

Side clearance of crankshaft	0.132-0.223

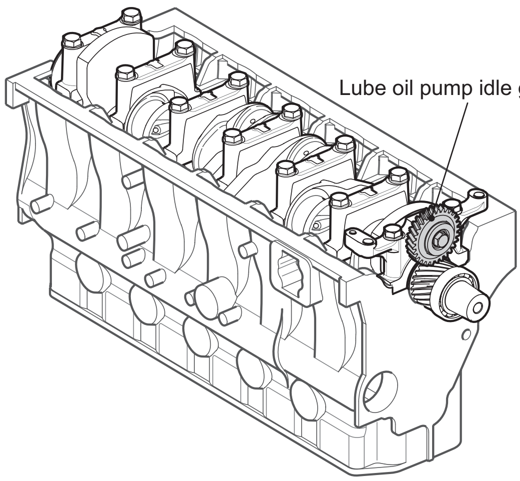


(Measurement of side clearance) 006614-00E

(6) Fitting lube oil pump

1) Fit lube oil pump idle gear and shaft to main bearing cap.

Side clearance	0.10 - 0.30 mm
Tightening torque	64 ± 2 N•m (6.5 ± 0.2 kgf•m)

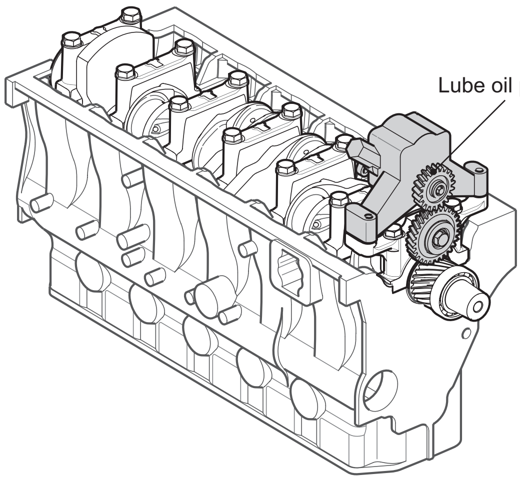


(Fitting of lube oil pump idle gear) 006615-00E

2) Fit lube oil pump while adjusting the position of positioning pin. Secure pump by tightening 3 bolts of M10 x 55 mm.

3) Measure gear backlash between lube oil pump and idle gear, and check that backlash satisfies value specified below:

Gear backlash	0.12 ± 0.04 mm

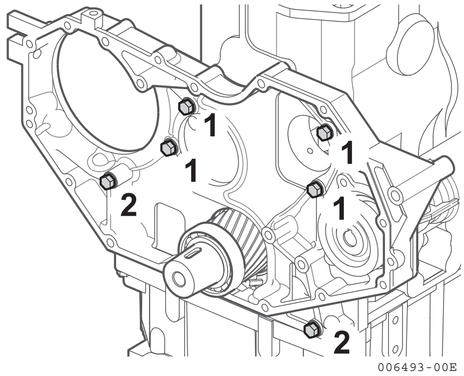


(Fitting of lube oil pump) 006616-00E

(7) Gear case

Apply liquid gasket to gear case, and then fit gear case to cylinder body while adjusting position of dowel pin.
Secure gear case by tightening bolt listed below:

1. M8 x 45 mm bolts...... 4 pcs.
2. M8 x 80 mm bolts...... 2 pcs.



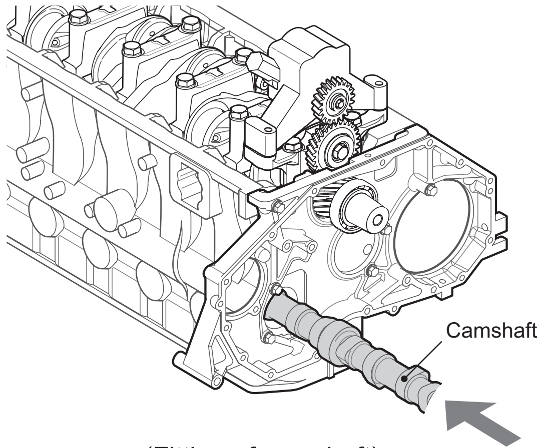
(8) Camshaft

1) Apply lube oil to bearing of camshaft, and then fit camshaft.
2) Fit thrust plate, and secure it by tightening 2 bolts of M8 x 16 mm

mm

Side clearance	0.05-0.20

Note:
If cam gear is removed from camshaft, fit thrust metal before fitting gear.
Heat cam gear to between 180 °C and 200 °C, and then press-fit it.
Interference: 0.023 to 0.060 mm

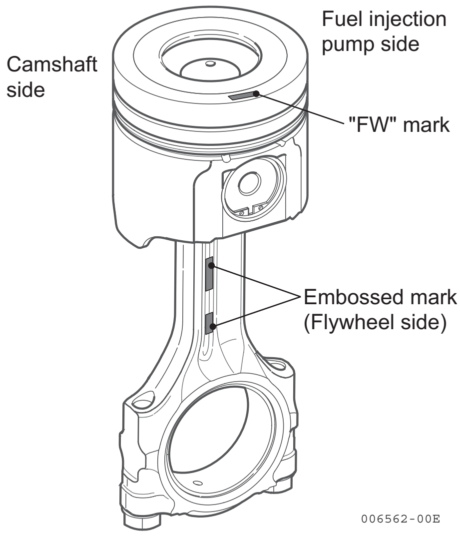


(Fitting of camshaft)

(9) Piston assembly

1) Fit connecting rod to each piston while checking direction of piston. (See the right figure.)

Note:
Coat engine lube oil on piston pin and insert it into piston if it is hard to insert piston pin into piston.

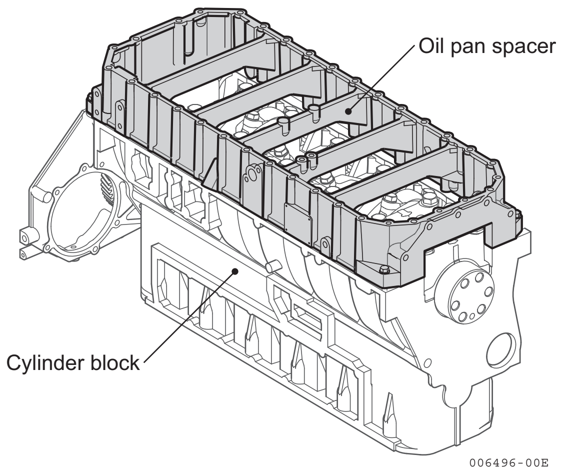


2) Fit piston rings and oil ring to each piston while checking that cutouts of rings are offset 120° from each other.
3) Apply engine oil to sleeve, outer surface of piston, and rod metal.
4) Adjust crankshaft pin of corresponding piston to top position.
5) Check direction of piston.
6) Insert piston into cylinder using piston insertion tool.
7) After insertion, remove tool.
Then rotate crankshaft by pressing piston edge using hammer until piston reaches bottom dead center.
8) Install cap on big end while checking match marks, and then tighten rod bolts.
Before tightening rod bolts, apply lube oil to bolt bearing surface.

Note:
Selectively fit each piston and sleeve.

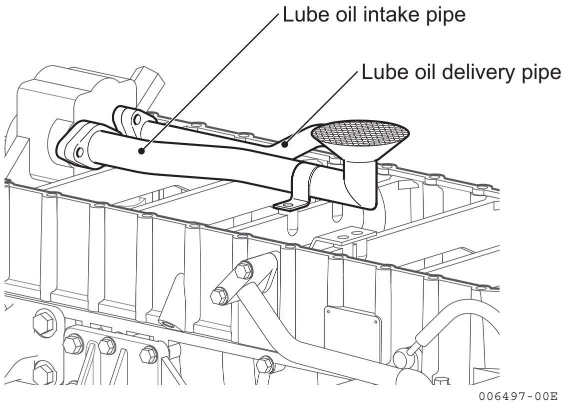
(10) Oil pan spacer

Apply liquid gasket to oil pan spacer, and then fit spacer.
Secure spacer by tightening 2 bolts of M8 x 35mm and 2 bolts of M8 x 30mm.



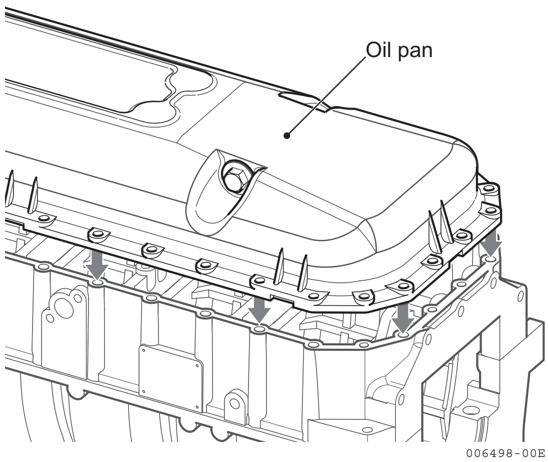
(11) Lube oil intake pipe and delivery pipe

1) Fit lube oil delivery pipe first, and then intake pipe.
   Secure delivery and intake pipes by tightening bolts listed below:
   M8 x 25 mm, 2 bolts
   M8 x 16 mm, 2 bolts
2) Insert other end of lube oil delivery pipe into oil pan spacer.
   Secure pipe by tightening bolts of M8 x 25 mm.



(12) Oil pan

Apply liquid gasket to oil pan, and then fit oil pan.
Secure oil pan by tightening bolts listed below:
M8 x 25 mm, 4 bolts
M8 x 120 mm, 26 bolts
M8 x 190 mm, 2 bolts
M8 x 90 mm, 2 bolts

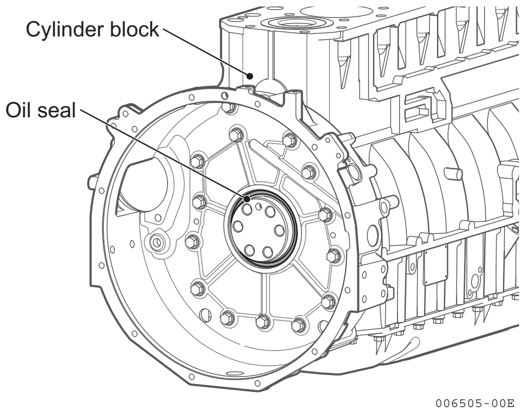


(13) Oil seal (Flywheel housing)

Insert the oil seal into the flywheel housing. (Use the special tool for insertion.)
Grease the outer circumference of the lip portion of the oil seal.

mm

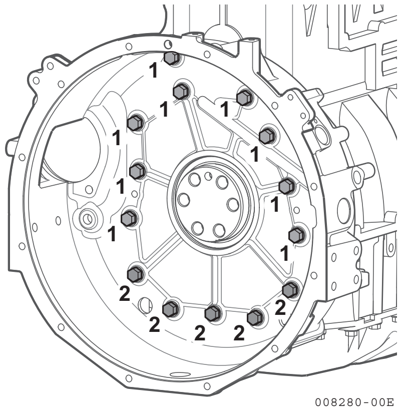
Spigot joint runout of flywheel housing	0.25



(14) Flywheel housing

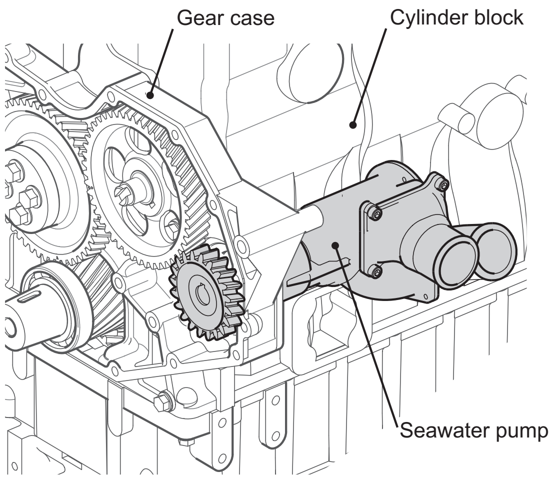
Fit flywheel housing while adjusting position of 2 parallel pins.
Secure housing by tightening bolts listed below:

1. M10 x 30 mm, 9 bolts
2. M10 x 35 mm, 5 bolts



(15) Seawater pump

Fit seawater pump to gear case. Secure pump by tightening bolts and nuts listed below:
M8 x 20 mm, 2 bolts
M8, 2 nuts



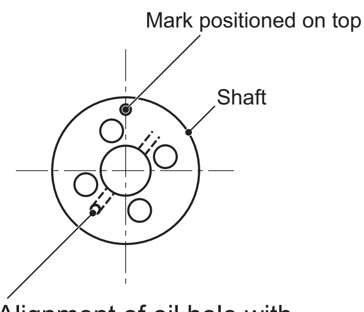
(Fitting of seawater pump)

(16) Idle gear

1) Fit idle gear and shaft, and secure them by tightening 2 bolts of M8 x 25 mm.
2) Measure side clearance of idle gear, and check that clearance satisfies value specified below:

Side clearance	0.12 - 0.22 mm

Note:
Align oil hole with that of cylinder block (see figure).

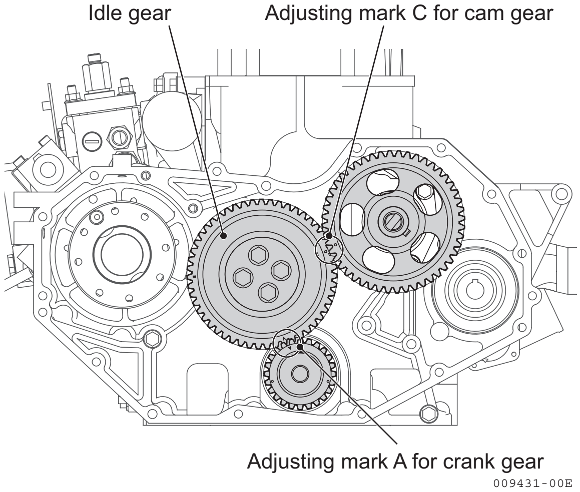


Alignment of oil hole with that of cylinder block

3) When assembling an idle gear, keep the crankshaft at top dead center (T.D.C.) of No.6 cylinder (gear case side) and adjust the adjusting mark A of idle gear for crankshaft gear and the mark C for camshaft gear with "0" marks of each gear.
   Fasten the idle gear. (with lube oil)

Tightening torque: N•m (kgf•m)	M10 bolt	64.0±2(6.5±0.2)

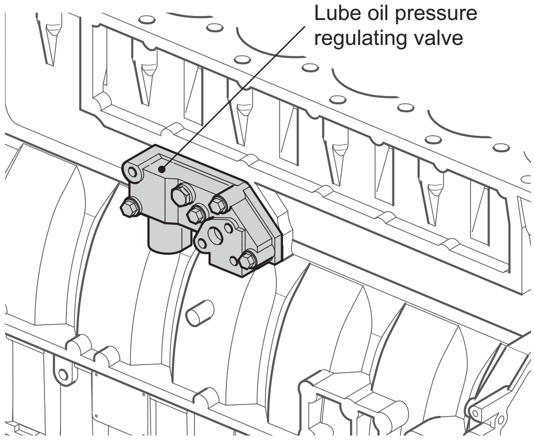
At top dead center



(17) Lube oil pressure regulating valve

Fit lube oil pressure regulating valve assembly, and secure it by tightening bolts listed below:
M8 x 45 mm, 3 bolts
M8 x 50 mm, 1 bolt

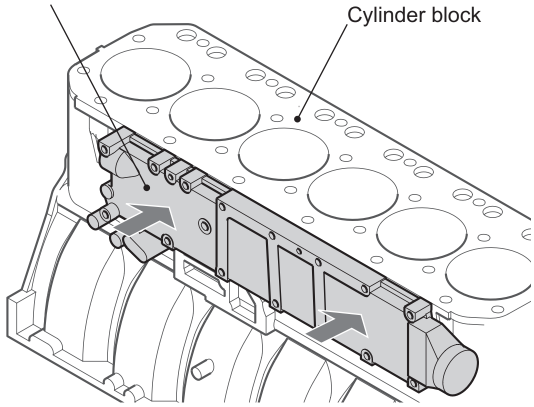
Lube oil pressure (at 3300min^{-1})	0.45 $\pm$ 0.050 MPa (4.6 $\pm$ 0.5 kgf•cm^2)



(Fitting of regulating valve) 006502-00E

(18) Cooling water passage cover

Apply liquid gasket to cooling water passage cover, and then fit cover.

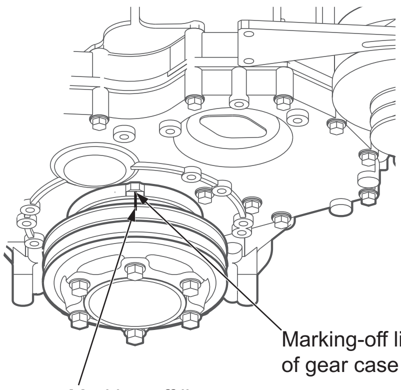


(Fitting of cooling water passage cover)
006503-00E

(19) Fuel injection pump

1) Before assembling a fuel injection pump gear, keep the crankshaft at 29° before compression top dead center of the No.6 cylinder.

[NOTICE]
Be careful not to adjust a crankshaft to exhaust stroke.
The exhaust and intake valves don't move during compression stroke.

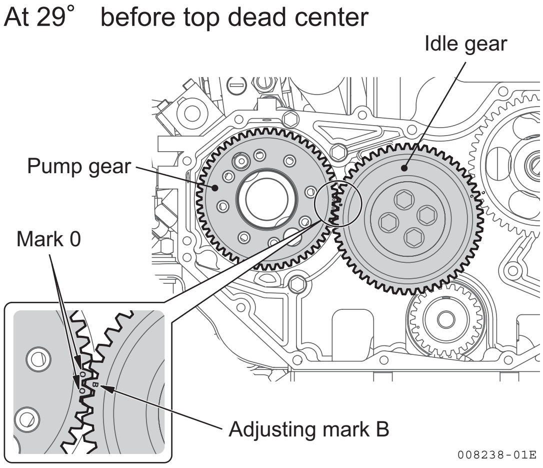


009440-00E

2) While adjusting the mark (0) of the fuel injection pump gear and mark (B) of the idle gear, insert the pump gear to the timer flange.

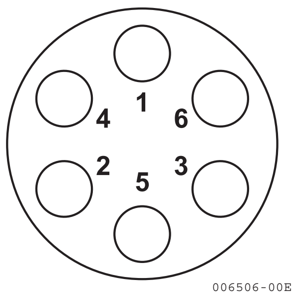
Refer to 6.1.5.

At 29° before top dead center



(20) Flywheel

Fit the flywheel while adjusting the position of dowel pin. It is convenient to use 2 bolts of M10 x 1.5 for lifting the flywheel. Apply engine oil to thread and flange of bolt.
Secure flywheel by tightening 6 bolts of M16 x 47 mm. The tightening order of 6 bolts is shown in right figure.



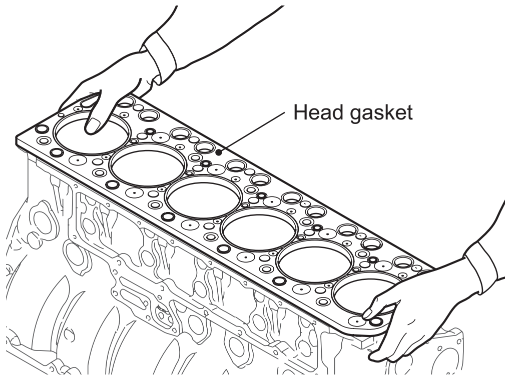
Tightening torque	294 ± 10N•m (30 ± 1 kgf•m)

(21) Cylinder head assembly

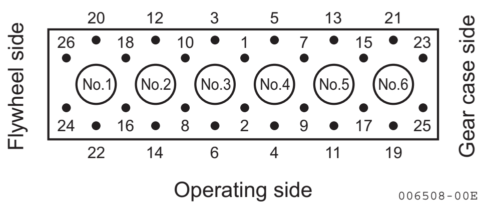
1) Correctly fit head gasket.
   Thickness t = 1.3 mm
   Check that each positioning pin is properly inserted into pin hole.
2) Fit cylinder head, into which intake / exhaust valves were assembled, to cylinder block while checking that each positioning pin is properly inserted into pin hole.
3) Apply lube oil to thread and flange of bolt.

- Sequentially tighten bolts in order of ascending number.
- Loosely tighten bolts twice, and then finally tighten them.

Note:
1. The total length of the head bolts for operation side is different from those for non operation side.
   M14-139mm (13 pcs.)...... Operation side
   M14-149mm (13 pcs.)...... Non operation side
2. Be careful because the tightening torque differs in the new bolts and the used bolts.



(Fitting of head gasket) 006507-00E

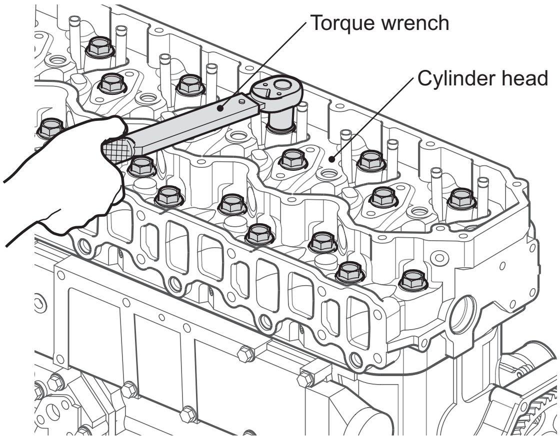


N•m (kgf•m)

	1st time	2nd time	3rd time
Used bolts	108 (11)	167 (17)	206 ± 10 (21 ± 1)
New bolts	118 (12.0)	177 (18.0)	226 ± 10 (23 ± 1)

4) Measure the top clearance by using fuse wire. Refer to 5.2.7.

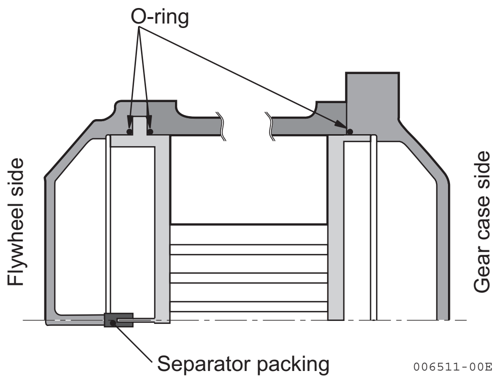
   Note:
   1. Check that cylinder head surface fitting on cylinder block is clean. Also check inside of each cylinder for dust, dirt, and so on.
   2. Head identification No. is marked on upper surface on flywheel side.



(Tightening of cylinder head) 006510-00E

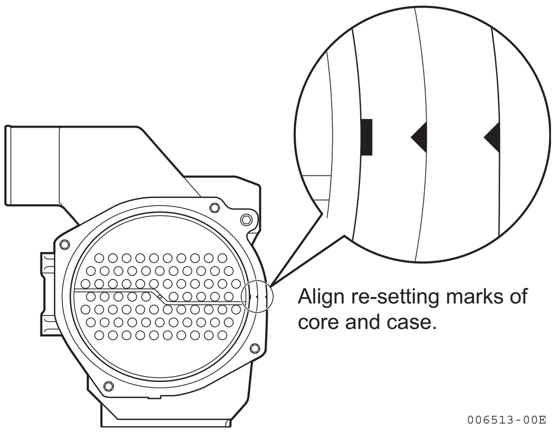
(22) Intercooler

1) Apply silicone grease to O-ring and fit the O-ring to flywheel side of cooler core and insert the core into cooler body.



Note:
Align re-setting marks of core and case (see the below figure).

2) Apply silicone grease to O-rings and fit two O-rings to both sides of cooler core then fit side covers to cooler.
3) Fit intercooler to engine.



(23) Intake manifold

Fit intake manifold assembly, and secure it by tightening bolts.

(24) Marine gear

Install marine gear to flywheel housing.
Refer to service manual of each marine gear.

(25) Push rod and rocker arm shaft assembly

1) Check condition of each push rod. If there is no abnormality, properly fit push rod to tappet.
2) Fit rocker arm shaft assembly. Do not forget to fit valve cap.
   Secure rocker arm shaft assembly by tightening bolts and nuts:

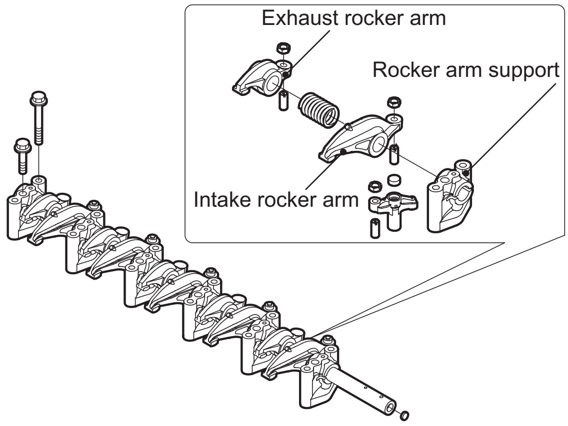
Rocker arm shaft support tightening torque (M8)	26 ± 3 N•m (2.6 ± 0.3 kgf•m)

3) Measure valve clearances, and check that they satisfy values specified below: (at normal temperature)
   Refer to 2.2.4(2) for the procedure.

Valve clearance	Intake valve	0.2 ± 0.05 mm
	Exhaust valve	0.5 ± 0.05mm

After adjusting valve clearances, apply lube oil to each rocker arm (both sides of valve and push rod), and then fit rocker arm cover.

4) Fit rocker arm cover, and secure it by tightening 10 bolts of M8 x 25 mm.
5) Fit lifting eye bolts to gear and flywheel sides of rocker arm cover.



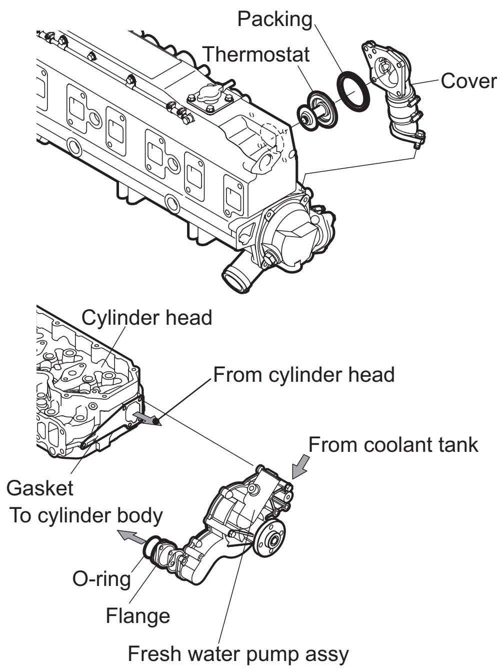
(Rocker arm shaft assembly)

006515-00E

(26) Fresh water pump

1) Apply liquid gasket to both sides of gasket.
2) Fit fresh water pump to fitting surface on cylinder head.
   Then secure pump by tightening bolts.

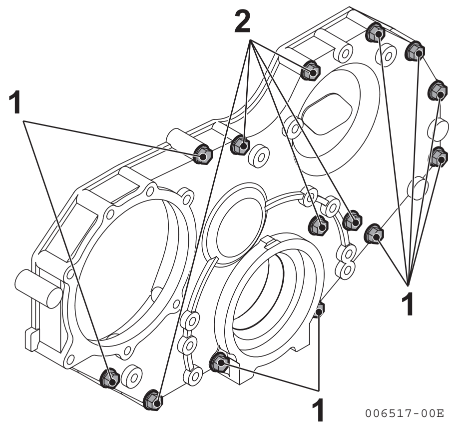
Note:
Before tightening bolts, attach O-ring to area connected to cooling water passage cover.



008281-00E

(27) Gear case cover

1) Apply liquid gasket to gear case, and then fit gear case cover to gear case while adjusting position of 2 parallel pins.
2) Tighten gear case cover with bolts listed below.
   1. M8 x 45 mm (washer based bolt)... 9 pcs.
   2. M8 x 80mm (washer based bolt).... 5 pcs.

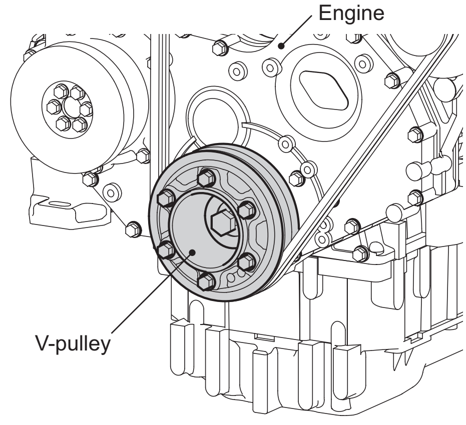


(28) Crank V-pulley and damper

1) Fit crank V-pulley, and secure it by tightening crank pulley bolt.

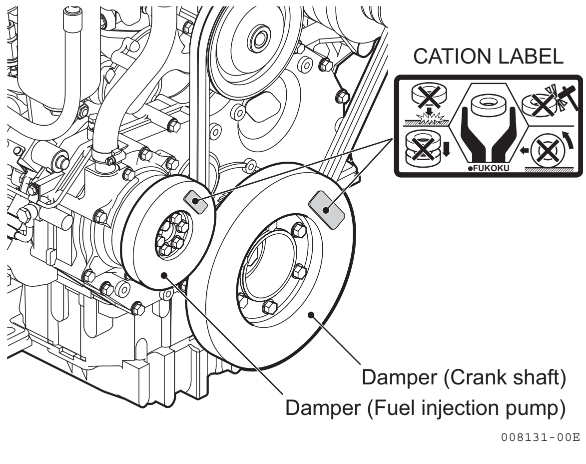
Crank pulley bolt (M16) tightening torque	226 ± 10 N•m (23 ± 1kgf•m)

Note:
While fitting crank pulley, take care not to attach dust or dirt to tapered area of crankshaft and tapered hole of V-pulley.



(Crank V-pulley)

2) When fitting viscous-type dampers for crank shaft and fuel injection pump, position the caution labels on the viscous dampers outside.
   Tighten bolts for dampers.



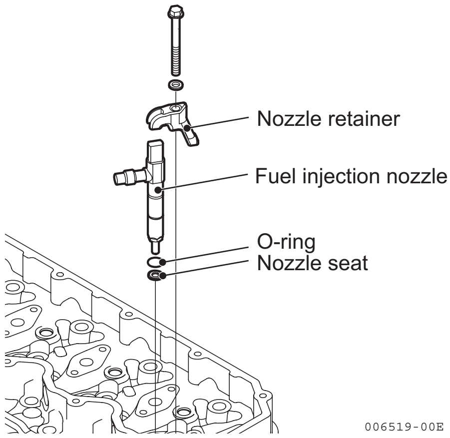
(29) Fuel injection nozzle

1) Fit O-ring to fuel injection nozzle, and apply lube oil to outside of O-ring.

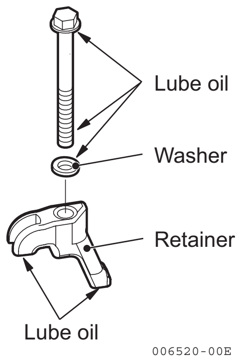
Note:
Replace O-ring with new one every time when fuel injection nozzle is disassembled.

2) Insert nozzle seats into cylinder head and fit fuel injection nozzles to cylinder head.

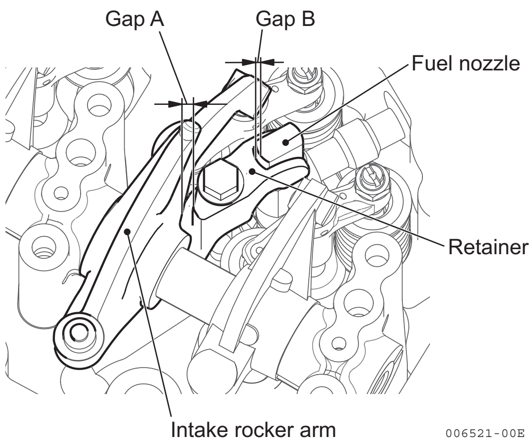
Note:
Replace nozzle seal with new one every time when fuel injection nozzle is disassembled.



3) Apply lube oil to fuel nozzle retainer and fuel nozzle bolt (see the right figure).
Fit retainer and bolt to fuel injection nozzle.
Fasten the bolt by hand while shaking the retainer back and forth and making the position of the retainer be stable.

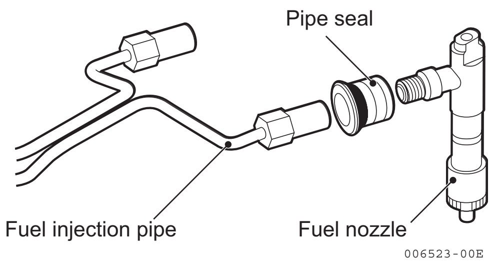


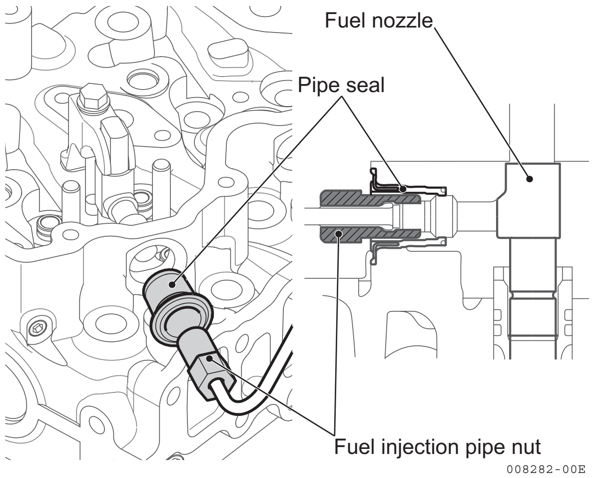
Note:
When fixing retainer to cylinder head, be careful to take the gap A in more than 1.5mm between retainer and intake rocker arm and the gap B in more than 1mm between fuel nozzle and retainer.



4) Insert pipe seal for fuel injection pipe into cylinder head and connect fuel injection pipe to fuel nozzle.
   Tighten the fuel injection pipe nut.

Tightening torque (nozzle & pump sides)	24.5 ± 2 N•m (2.5 ± 0.2kgf•m)



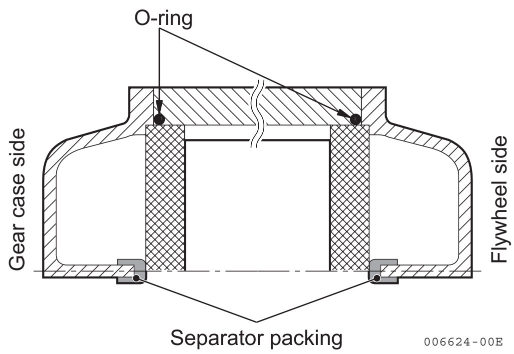


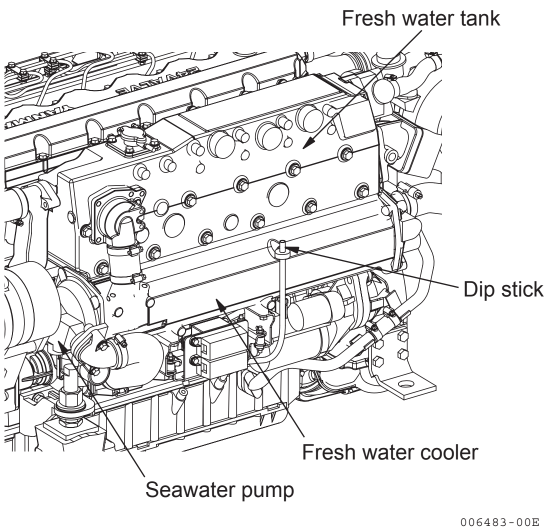
5) Finally tighten the retainer bolt for fuel injection nozzle to the specified torque.

Tightening torque	31.4 ± 2 N•m (3.2 ± 0.2 kgf•m)

(30) Fresh water cooler

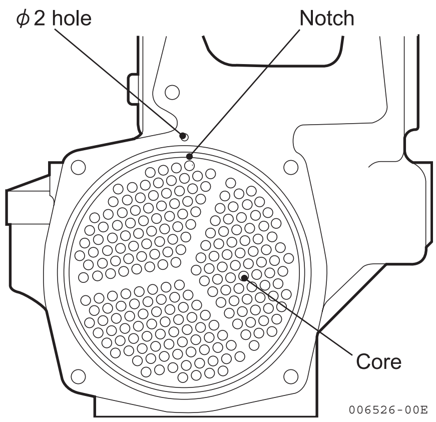
1) Apply silicone grease to two O-rings and fit the O-rings to both sides of cooler core and insert the core into cooler body.





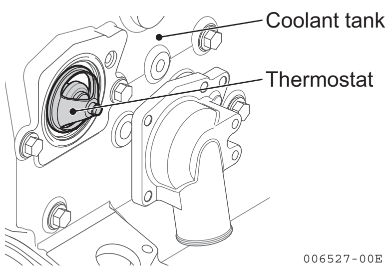
Note:
Align the cooler core notch with ø2 hole of cooler body (see the right figure).

2) Fit separator packing to both side covers (gear case side & flywheel sides). (See the above figure.)
   Fit side covers to fresh water cooler.

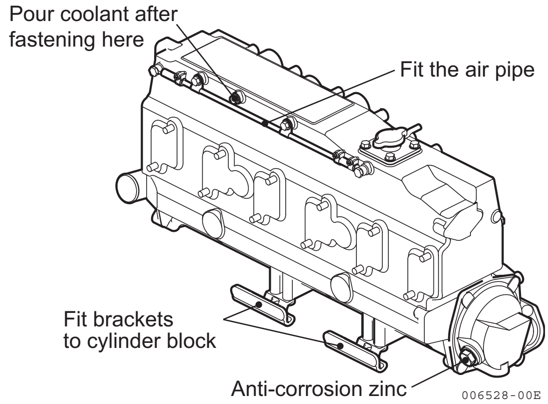


(31) Coolant tank (fresh water)

1) Fit rubber packing to thermostat and insert the thermostat to coolant tank.



2) Secure the coolant tank securely with bolts.



006528-00E

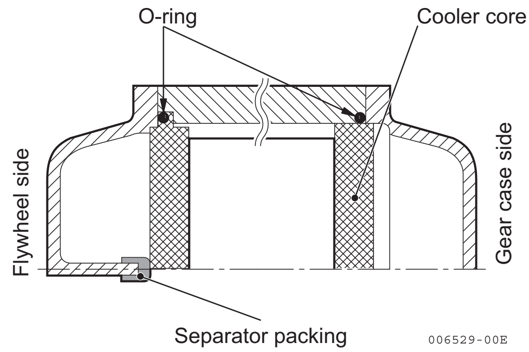
(32) Lube oil cooler

1) Apply silicone grease to two O-rings and fit the O-rings to both sides of cooler core and insert the core into cooler body.

Note:
Align re-setting marks of cooler core and case.

2) Fit separator packing to side cover of flywheel side. (See the right figure.)
Fit side covers to lube oil cooler.
3) Fit lube oil cooler to engine.

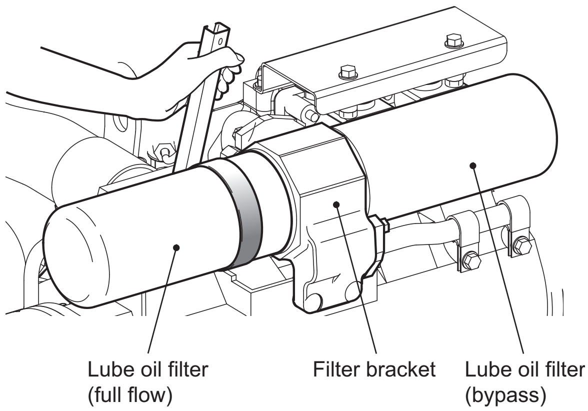
Note:
After fitting intercooler and filter bracket to engine and tightening lube oil tube, fit lube oil cooler.



006529-00E

(33) Lube oil filter

1) Apply lube oil to rubber packing of lube oil filters.
2) Install lube oil filter of full flow manually to filter bracket by turning it clockwise until its rubber packing comes into contact with mounting surface, and tighten it further to 3/4 of a turn with filter wrench.
Install lube oil filter of bypass manually to filter bracket by turning it clockwise until its rubber packing comes into contact with mounting surface, and tighten it further to one turn with filter wrench.

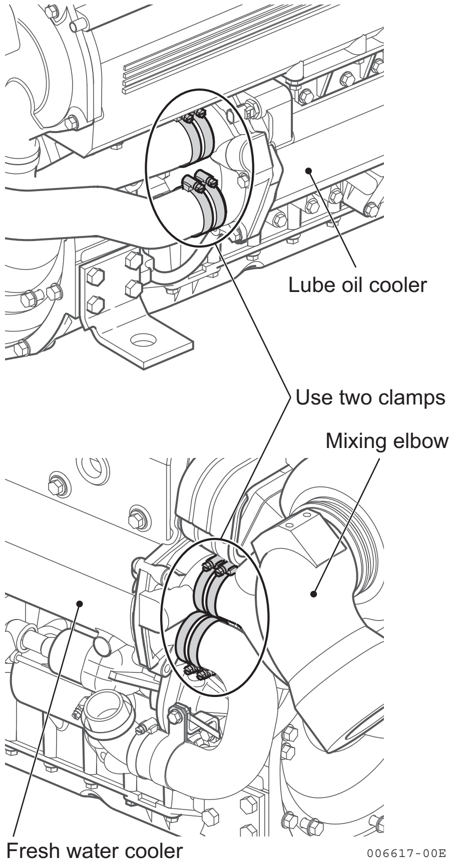


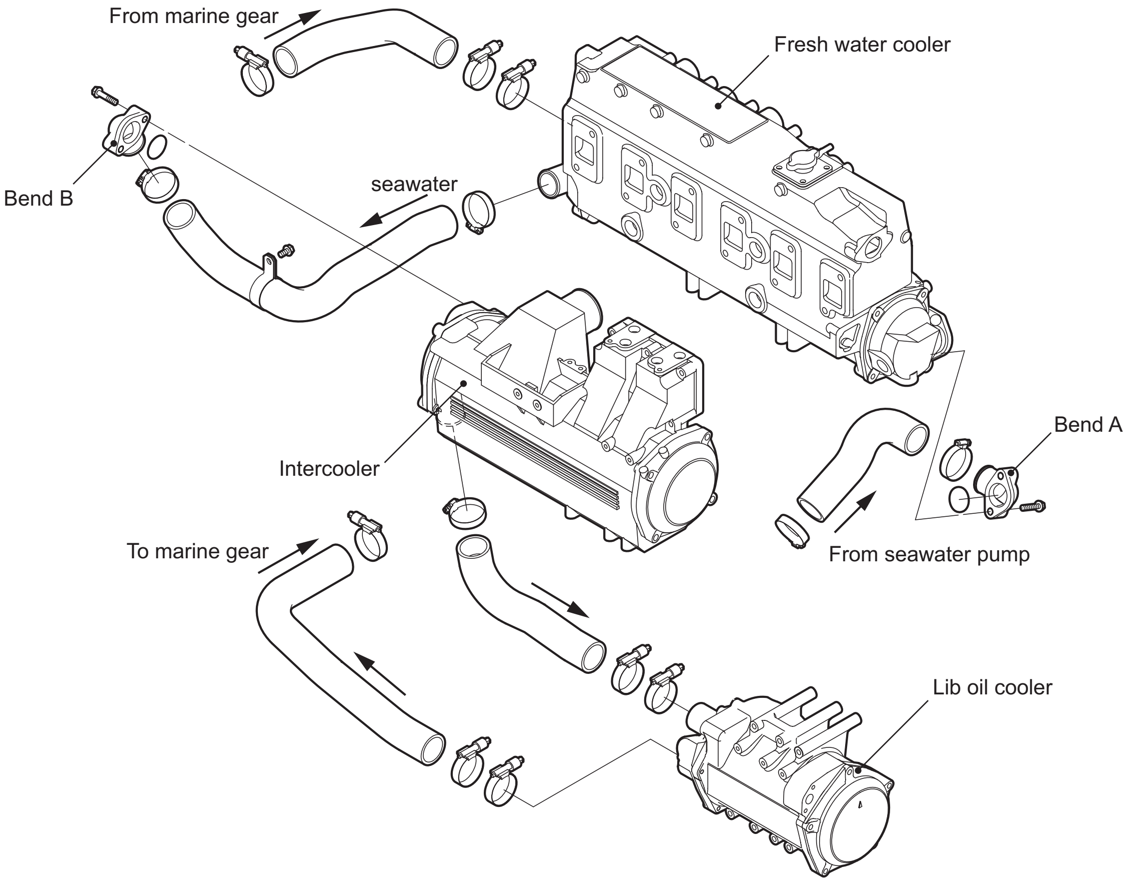
008227-00E

(34) Cooling water pipes

1) Fit bend A to fresh water cooler and joint the bend and seawater pump with hose.
2) Fit bend B to intercooler and joint intercooler and fresh water cooler with hose.
3) Apply hose clamps to seawater inlet & outlet of fresh water cooler and seawater inlet & outlet of lube oil cooler.

Note:
Apply two hose clamps to each four places shown in the right and below figures to prevent the pulling-out of hoses.



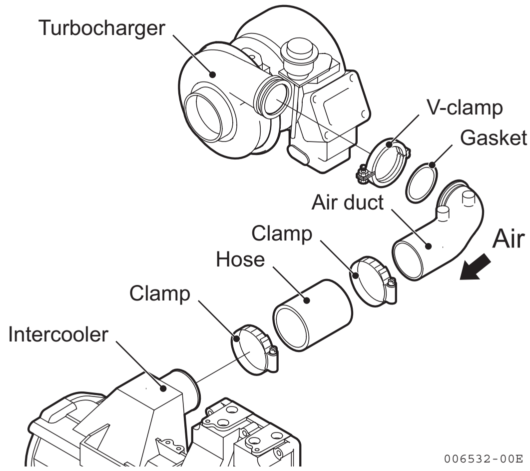


(Seawater line)

006618-00E

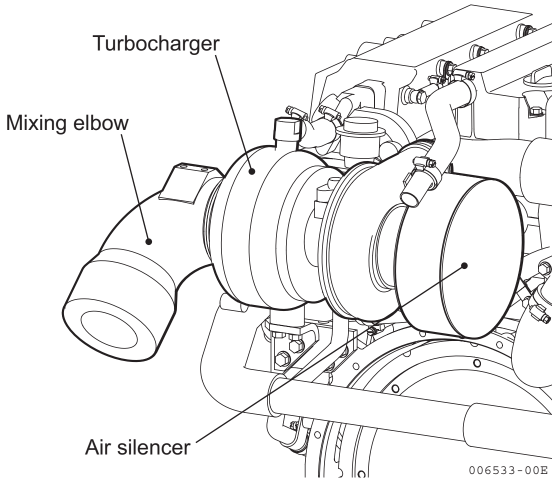
(35) Air duct

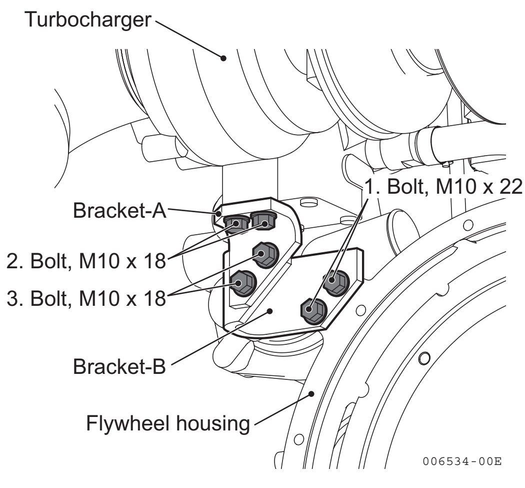
1) Fit air duct to outlet of turbine by V-clamp.
2) Fit air duct to inlet of intercooler by hose and clamps.



(36) Turbocharger

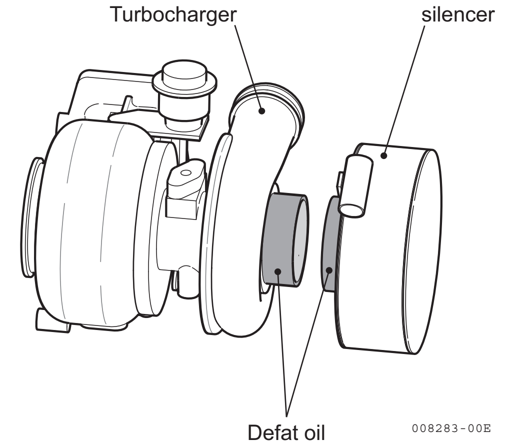
1) Install the turbocharger and the attached lube oil pipe.
2) Fit bracket A & bracket B (bridging) and fasten bolts lightly.
   Tighten bolts in order of 1,2,3 shown in the below figure.





3) Defat the silencer, turbocharger and inside of hose sufficiently. If oil is stuck on those parts, they may come off during engine running.
Install the silencer and hose to the turbocharger and tighten hose bands to the specified torque.

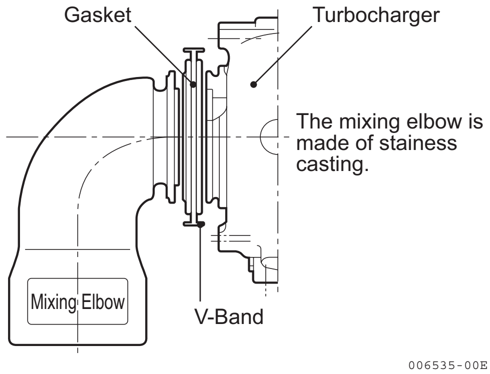
Tightening torque	3±0.5 N•m (0.3±0.05kgf•m)



(37) Mixing elbow

Install the mixing elbow to turbocharger.

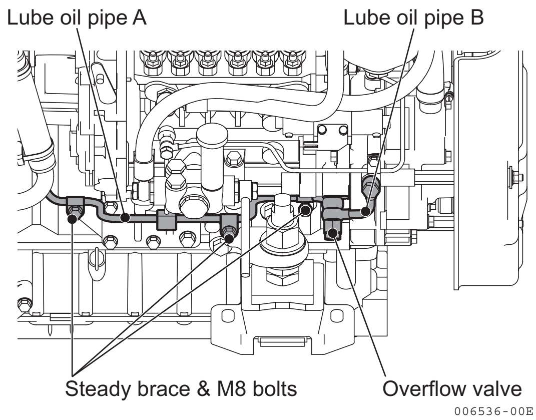
- Structure of exhaust outlet and V-Band (right figure)



(38) Lube oil pipes for fuel injection pump

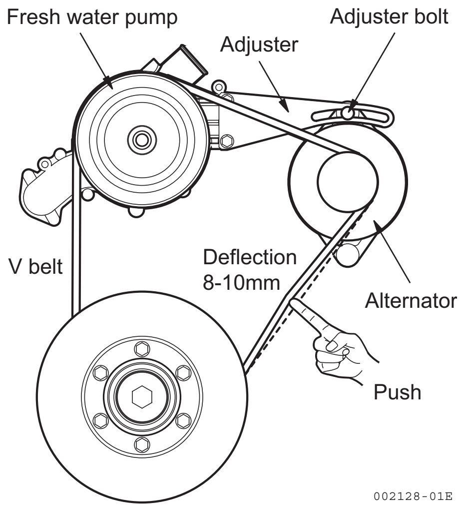
Connect lube oil pipe to fuel injection pump.

- Fit lube oil pipe A connected between pressure regulating valve, timer and fuel injection pump.
  Fit three steady braces to the places shown in the right figure.
- Tighten overflow valve for both lube oil pipe A & B at timer inlet.
- Apply seal washers to pipe joint bolts.



(39) Alternator

1) Mount adjuster on the fresh water pump and install alternator.
2) Adjust V-belt tension with the adjuster, and tighten the adjuster bolt.



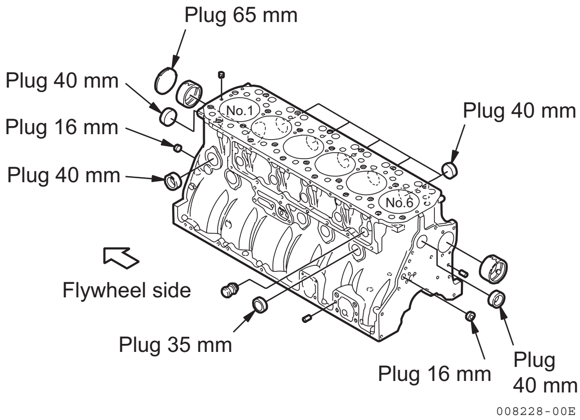
(40) Starting motor

Fit starting motor to flywheel housing.

5. Inspection and servicing of basic engine parts

5.1 Cylinder block

The cylinder block is a thin-skinned, (low-weight), short skirt type with rationally placed ribs. The side walls are shaped to maximize rigidity for strength and low noise.



5.1.1 Inspection of parts

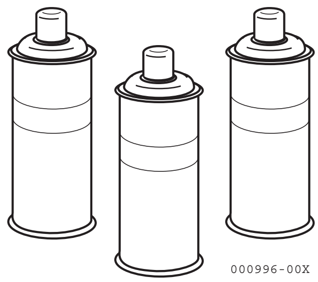
Make a visual inspection to check for cracks on engines that have frozen up, overturned or otherwise been subjected to undue stress. Perform a color check on any portions that appear to be cracked, and replace the cylinder block if the crack is not repairable.

5.1.2 Cleaning of oil holes

Clean all oil holes, making sure that none are clogged up and the blind plugs do not come off.

Color check kit

	Quantity
Penetrant	1
Developer	2
Cleaner	3



5.1.3 Color check procedure

(1) Clean the area to be inspected.

(2) Color check kit

The color check test kit consists of an aerosol cleaner, penetrant and developer.

(3) Clean the area to be inspected with the cleaner.

Either spray the cleaner on directly and wipe, or wipe the area with a cloth moistened with cleaner.

(4) Spray on red penetrant

After cleaning, spray on the red penetrant and allow 5~10 minutes for penetration. Spray on more red penetrant if it dries before it has been able to penetrate.

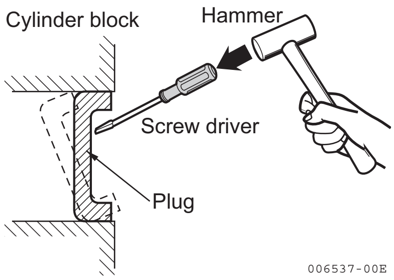
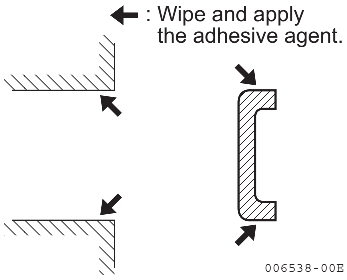
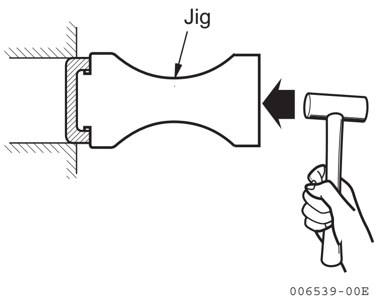
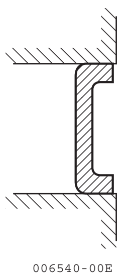
(5) Spray on developer

Remove any residual penetrant on the surface after the penetrant has penetrated, and spray on the surface after the penetrant has penetrated, and spray on the developer. If there are any cracks in the surface, red dots or a red line will appear several minutes after the developer dries.
Hold the developer 300~400mm away from the area the surface uniformly.

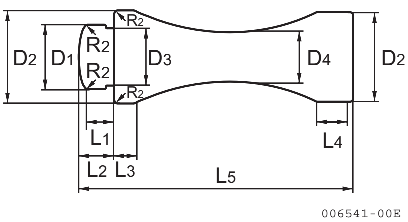
(6) Clean the surface with the cleaner.

Note:
Without fail, read the instructions for the color check kit before use.

5.1.4 Replacement of plugs

Step No.	Description	Procedure	Tool or material used
1		Remove the plug using by a screw driver and hammer. Hit the plug by screw driver and hammer tap lightly obliquely from the upper side.	• Screw driver • Hammer
2		Wipe the cylinder block and plug fitting portion clean. Apply an adhesive agent (acrylic) on the periphery of the plug and the cylinder block inside.	• Thinner • Adhesive agent (or Three bond 1386B)
3		Insert the plug using by the jig and hammer. (Set the jig straightly.)	• Jig • Hammer
4		Do not supply water into the cylinder block for two hours after the plug are set.	

Note: Design of jig



mm

Plug dia.	D1	D2	D3	D4	L1	L2	L3	L4	L5
ø16	12.0	20.0	10.0	10.0	2.5	4.0	20.0	30.0	150.0
ø40	36.0	48.0	34.0	28.0	8.5	10.0	20.0	30.0	150.0

5.1.5 Cylinder bore measurement

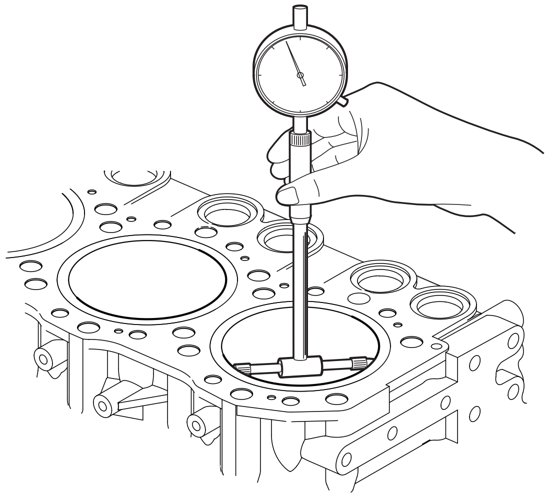
Especially clean head surface, cylinder bores and oil holes, and check the below items after removing any carbon deposit and bonding agent.

(1) Appearance inspection

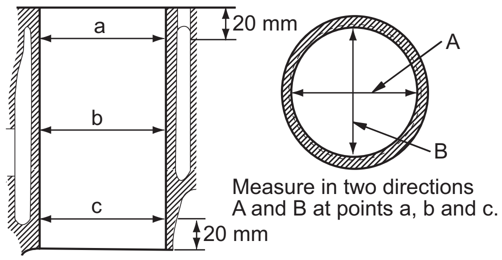
Check if there is any discoloration or crack. If crack is suspected, perform color check. Sufficiently clean the oil holes and check they are not clogged.

(2) Cylinder bore and distortion

Measure at 20 mm below the crest of the liner, at 20 mm from the bottom end and at the center in two directions A and B as shown in the below figure. Direction A means crank shaft center line.



(Cylinder bore) 007086-00E



(Cylinder bore measurement positions)

001495-01E

Roundness:

Roundness is found as follows though it is the simple method. Measure cylinder diameters of the A direction and the B direction on each section of a, b and c.

Roundness is the maximum value among those difference values.

Cylindricity:

Cylindricity is found as follows though it is the simple method.

Measure cylinder diameters of a, b and c sections in the A direction, and calculate the difference in maximum value and minimum value of the measured diameters.

In the same way measure and calculate the difference in the B direction.

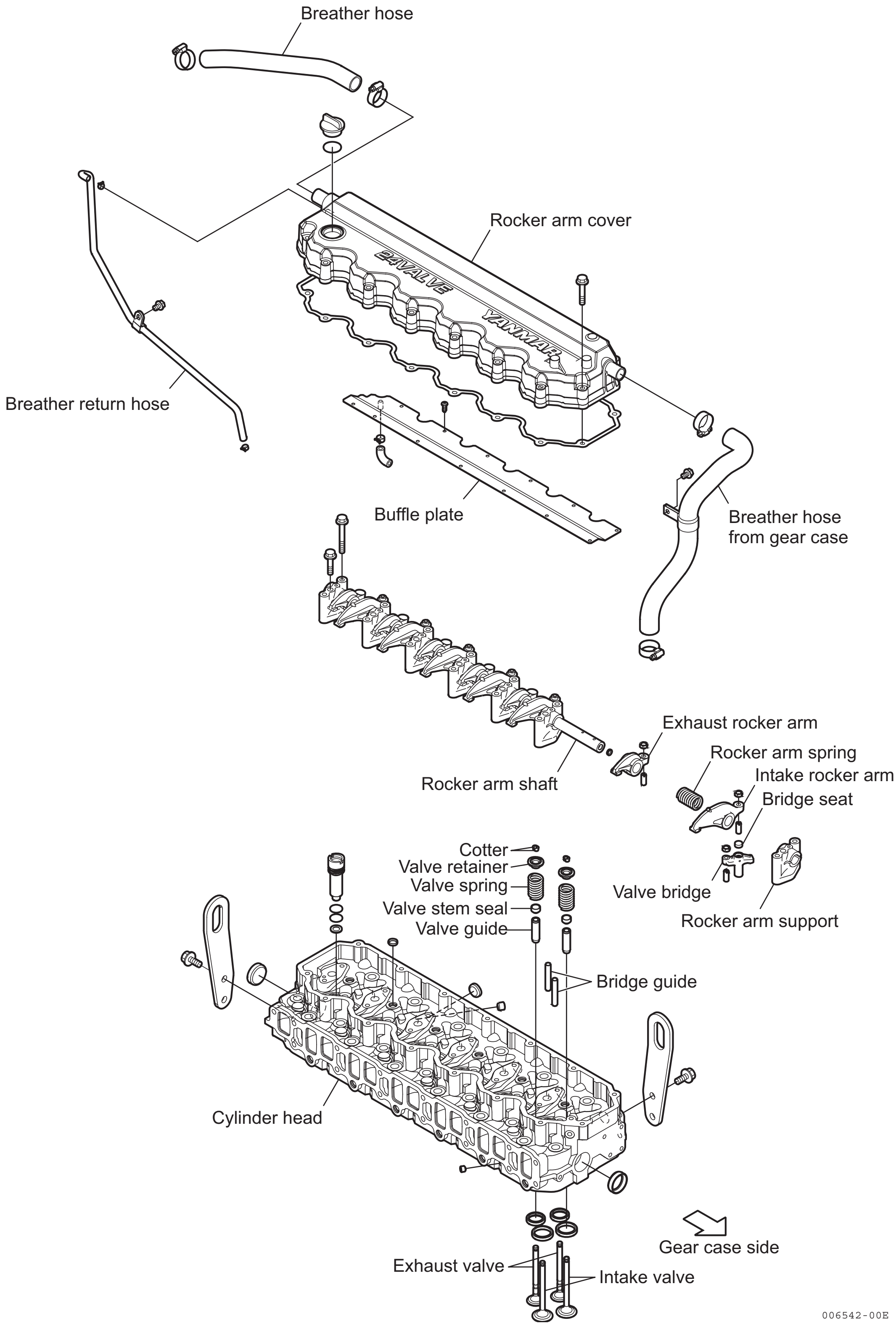
Cylindricity is the maximum value between those difference values.

mm

Item	Standard	Limit
Cylinder bore diameter	105.900-105.930	105.950
Cylinder roundness	0.03 or less	-
Cylindricity	0.02 or less	-

5.2 Cylinder head

The cylinder head is of 6-cylinder integral construction, mounted with 26 bolts. Special alloy stellite with superior resistance to heat and wear is fitted on the seats, and the area between the valves is cooled by the water jet.



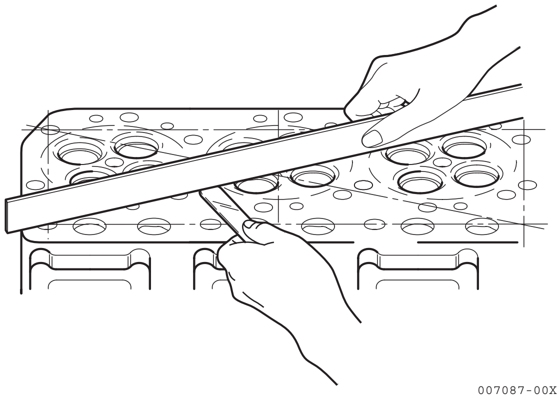
5.2.1 Inspecting the cylinder head

The cylinder head is subjected to very severe operating conditions with repeated high pressure, high temperature and cooling. Thoroughly remove all the carbon and dirt after disassembly and carefully inspect all parts.

(1) Distortion of the combustion surface

Carefully check for cylinder head distortion as this leads to gasket damage and compression leaks.

1) Clean the cylinder head surface.
2) Place a straight-edge along each of the four sides and each diagonal. Measure the clearance between the straight-edge and combustion surface with a feeler gauge.

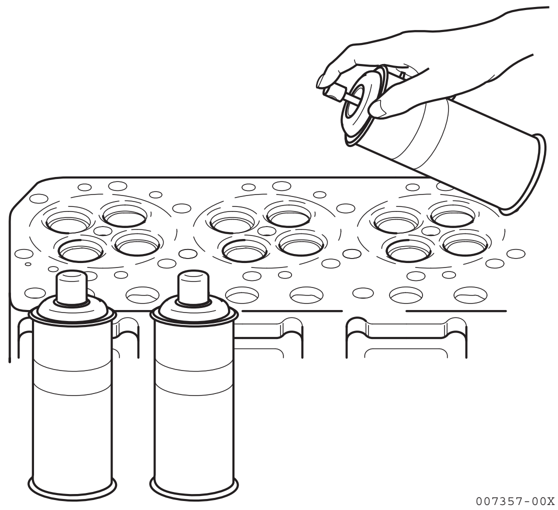


mm

	Standard	Wear limit
Cylinder head distortion	0.05 or less	0.20

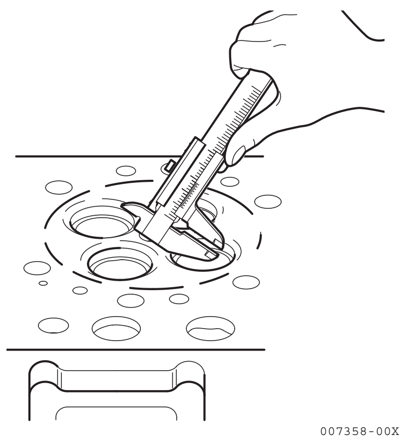
(2) Checking for cracks in the combustion surface

Remove the fuel injection nozzle, intake and exhaust valve and clean the combustion surface. Check for discoloration or distortion and conduct a color check test to check for any cracks.



(3) Checking the intake and exhaust valve seats

Check the surface and width of the valve seats.
If seat width is too wide, or if the surface is rough, correct to the following standards:

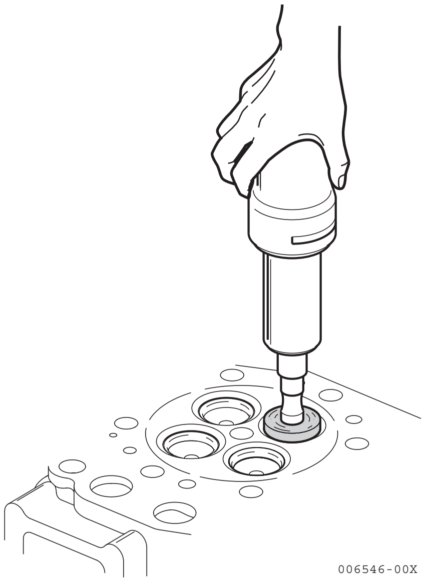


Seat angle	Intake	90°
	Exhaust	90°

Seat width	Standard	Limit
Intake	1.07~1.24	1.74
Exhaust	1.24~1.45	1.94

5.2.2 Valve seat correction procedure

The most common method for correcting unevenness of the seat surface with a seat grinder is as follows:

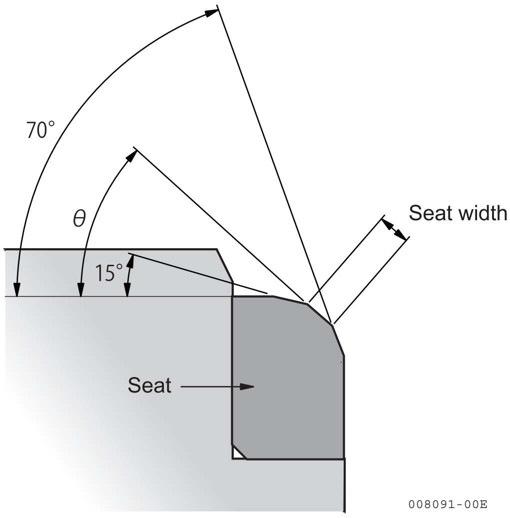


(1) Use a seat grinder to make the surface even.

As the valve seat width will be enlarged, first use a 70° grinder, then grind the seat to the standard dimension 45° by using the seat grinder with a 15° chanfer.

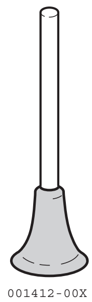
Seat angle θ	Intake valve	45 deg.
	Exhaust valve	45 deg.

Note:
When seat adjustment is necessary, be sure to check the valve and valve guide. If the clearance exceeds the tolerance, replace the valve or the valve guide, and then grind the seat.

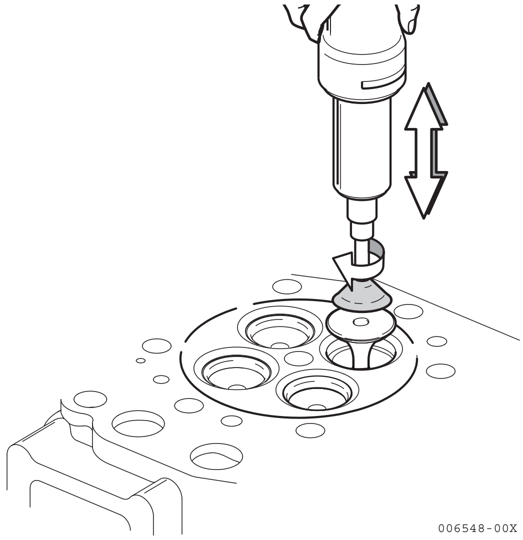


(2) Knead valve compound with oil and finish the valve seat with a lapping tool.

Lapping tool
Use a rubber cap type lapping tool for valves without a lapping tool groove slit.



(3) Final finishing should be done with oil only.



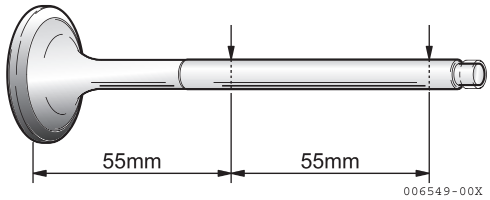
Note:

1. Clean the valve and cylinder head with light oil or the equivalent after valve seat finishing is completed and make sure that there are no grindings remaining.
2. Measure valve distortion after valve seat refinishing has been completed, and replace the valve and valve seat if it exceeds the tolerance.

5.2.3 Intake / exhaust valves, valve guides

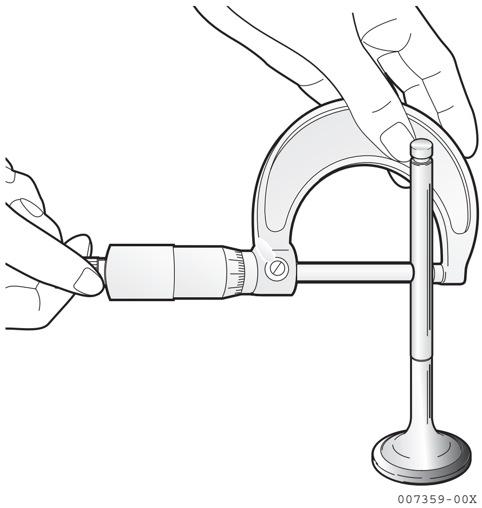
(1) Wearing and corrosion of valve stem

Measure the outside diameter of valve stem.
Replace the valve, if the stem is excessively worn or corroded.



mm

Valve stem outside diameter	Standard	Limit
Intake	7.960-7.975	7.90
Exhaust	7.955-7.970	7.90



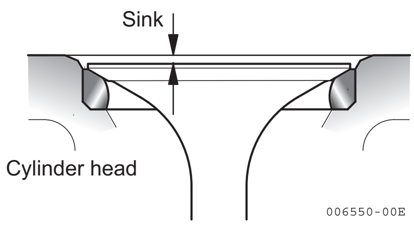
(2) Inspection of valve seat wear and contact surface

Inspect for valve seat scratches and excessive wear. Check to make sure the contact surface is normal. The seat angle must be checked and adjusted if the valve seat contact surface is much smaller than the width of the valve seat.

Note:
Keep in mind the fact that the intake and discharge valve have different diameters.

(3) Valve sink

Over long periods of use and repeated lapping, combustion efficiency may drop.
Measure the sinking distance by depth gauge. Replace the valve and valve seat if the valve sink exceeds the tolerance.



mm

Valve sink	Standard	Limit
Intake	0.7~0.9	1.2
Exhaust	1.2~1.4	1.7

(4) Valve guide

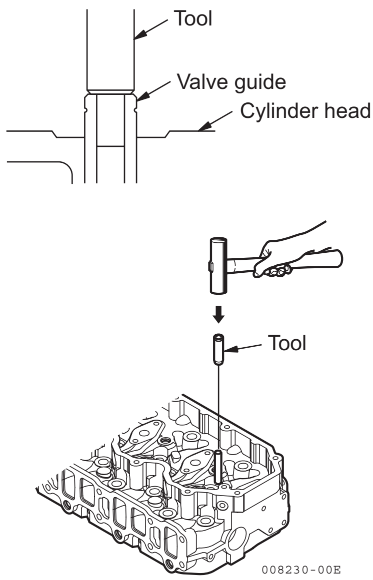
1) Measuring inside diameter of valve guide.
Measure the inside diameter of the valve guide and replace it if it exceeds the wear limit.

mm

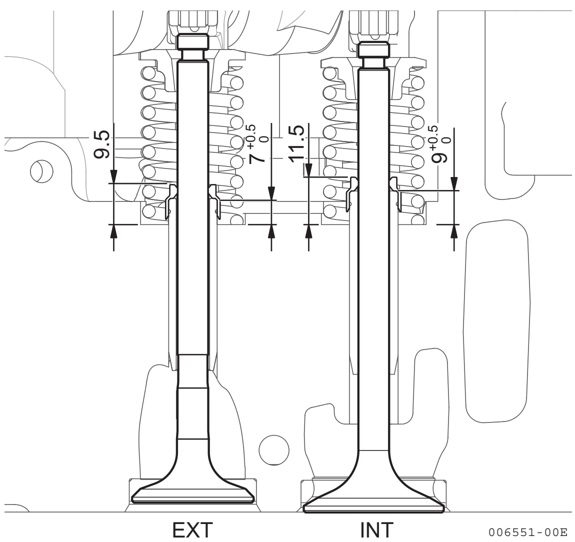
		Standard	Limit
Valve guide inside diameter	Intake	8.010~8.025	8.1
	Exhaust	8.015~8.030	8.1
Clearance	Intake	0.035-0.065	0.18
	Exhaust	0.045-0.075	0.18

Note:
The inside diameter standard dimensions are measured after insertion.

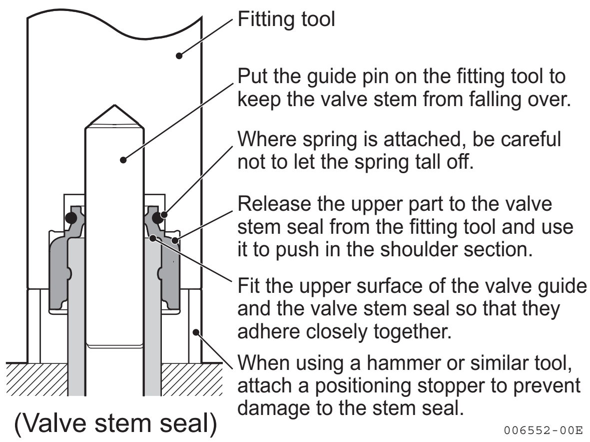
2) Replacing the valve guide
Use the insertion tool and tap valve guide with a mallet.



Valve guide projection:
The valve guide should project the specified value from the top of the cylinder head. (See the below figure.)



3) Valve stem seal:
   The valve stem seals on the intake / exhaust valve guides cannot be re-used once they are removed. Be sure to replace them with new ones.
   When assembling the intake / exhaust valves, apply an adequate quantity of lube oil on the valve stem before inserting.
   Exhaust stem seal is marked by yellow. Intake stem seal is not marked.

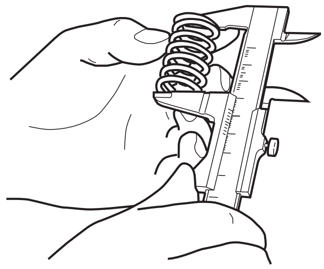


(Valve stem seal)

5.2.4 Valve springs

(1) Checking valve springs

1) Check the spring for scratches or corrosion.
2) Measure the free length of the spring.

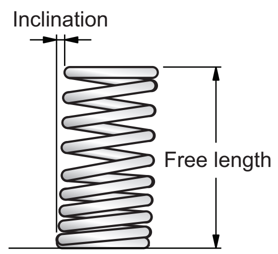


001509-01X

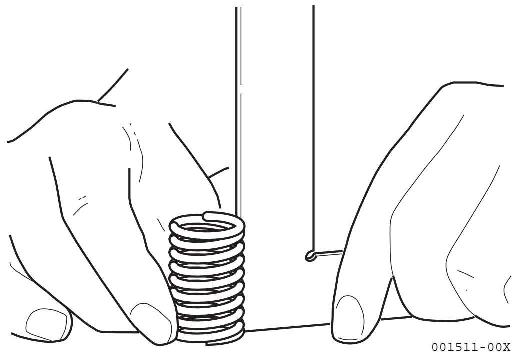
3) Measure inclination.

mm

	Limit
Inclination	1.2



001510-00E

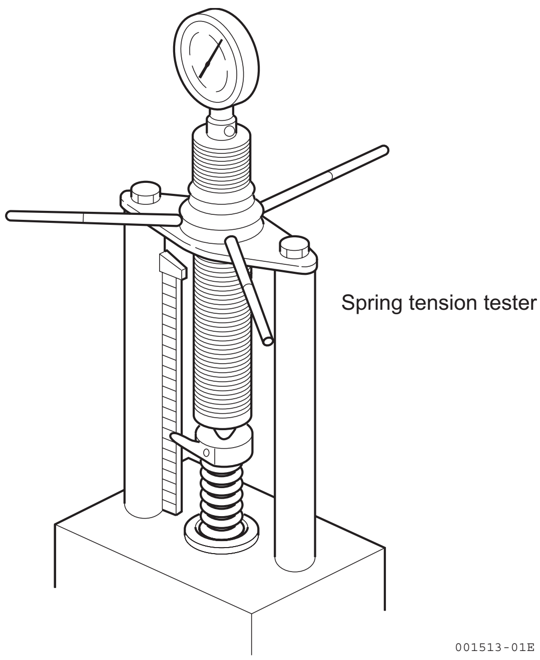


001511-00X

4) Measure spring tension.

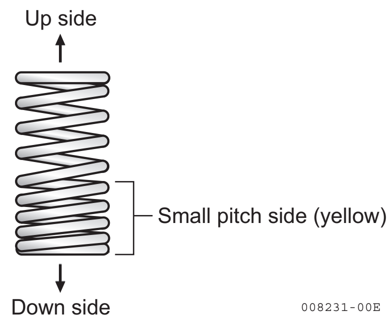
Valve spring	Unit	Standard	Limit
Free length A	mm	53.0	51.5
Tension (1mm pressure)	N / mm (kgf / mm)	K1=17.5 (1.78)	–
		K2=22.9 (2.33)	–

- Assembling valve springs.
  The side with the smaller pitch (painted yellow) should face down (cylinder head).



001513-01E

Note:
The pitch of this valve spring is not even. Pay attention to the up-down direction of the spring when assembling.



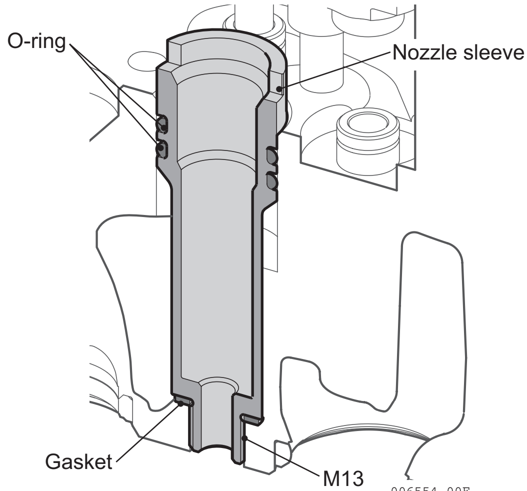
5) Spring retainer and spring cotter
Inspect the inside face of the spring retainer, the outside surface of the spring cotter, the contact area of the spring cotter inside surface and the notch in the head of the valve stem. Replace the spring retainer and spring cotter when the contact area is less than 70%, or when the spring cotter has been recessed because of wear.

5.2.5 Nozzle sleeve

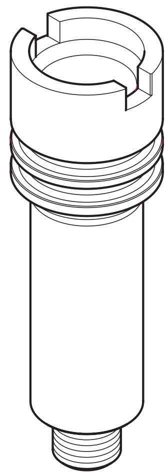
1) When assembling, apply lube oil to O-ring.
2) Fit the sleeve to cylinder head and tighten it.

Tightening torque	57.8±4.9N•m (5.89±0.50kgf•m)

Part name	Part code
Nozzle sleeve	119578-11820
O-ring (1AP22A)	24311-350220
Nozzle sleeve gasket	119578-11960



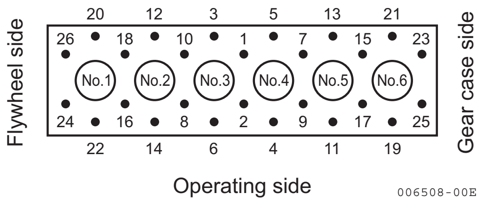
006554-00E



(Nozzle sleeve)

006553-00E

5.2.6 Assembling the cylinder head



(1) Clean out the cylinder head bolt holes.

(2) Check for dust and dirt on the cylinder head surface where it comes in contact with the block.

(3) Coat thread and flange surface of the head bolt with lube oil.

(4) Use the positioning pins to line up the head gasket with the cylinder block.

(5) Match up the cylinder head with the head gasket and mount.

(6) Partially tighten the bolts in the specified order and then tighten to the specified torque, being careful that the head does not get distorted.

N•m (kgf•m)

		1st	2nd	3rd
Tightening torque	Used bolt	108 (11.0)	167 (17.0)	196-216 (20.0-22.0)
	New bolt	118 (12.0)	177 (18.0)	216-236 (22.0-24.1)

5.2.7 Measuring top clearance

(1) Place a high quality fuse (ø1.2mm, 10mm long) in four positions on the flat part of the piston head.

(2) Assemble the cylinder head gasket and the cylinder block and tighten the bolts in the specified order to the specified torque.

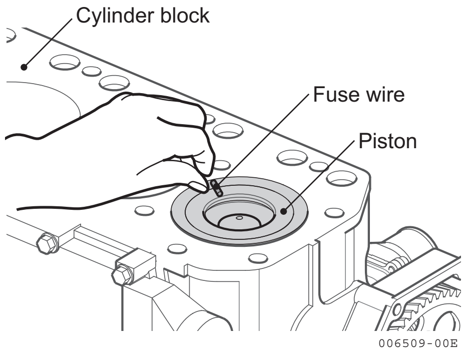
(3) Turn the crank, (in the direction of engine revolution), and press the fuse against the piston until it breaks.

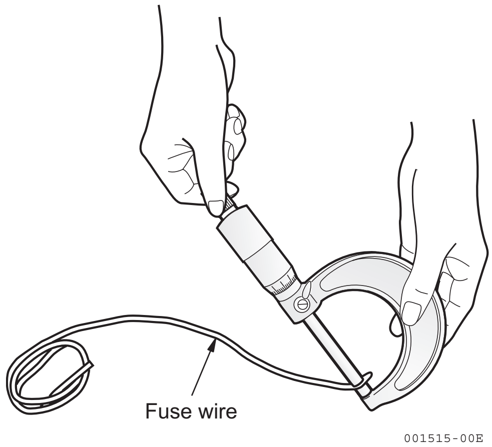
(4) Remove the head and take out the broken fuse.

(5) Measure thickness of broken fuse at four positions and calculate the average.

mm

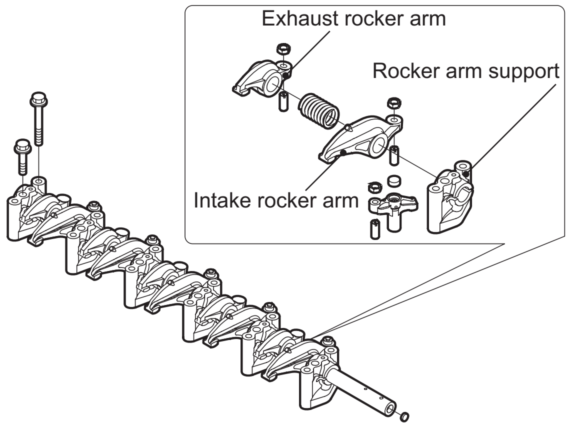
Top clearance	0.78-0.98





5.2.8 Intake and exhaust rocker arms

The wear of rocker arm and rocker arm bushing may change opening / closing timing of the valve, and may in turn affect the engine performance according to the extent of the change.



(Rocker arm shaft assembly)

006515-00E

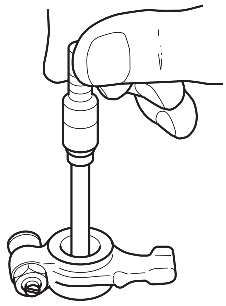
(1) Rocker arm shaft and rocker arm bushing

Measure the outer diameter of the shaft and the inner-diameter of the bushing, and replace if wear exceeds the limit.

mm

	Standard	Limit
Inside dia. of intake and exhaust rocker arm bushing	20.000~20.020	20.090
Outside dia of intake and exhaust rocker arm shaft.	19.970~19.990	19.955
Clearance of rocker arm shaft and bushing at assembly	0.010~0.050	0.140

Replace rocker arm bushing if it moves. Replace entire rocker arm if there is no tightening clearance.



(Rocker arm hole diameter)

001516-01E

(2) Rocker arm spring

Check the rocker arm spring and replace it if it is corroded or worn.

(3) Rocker arm and valve top retainer wear

Inspect the contact surface of rocker arm and replace it if there is abnormal wear or flaking.

(4) Adjusting bolt

Inspect the contact surface of adjusting bolt and push rod. Replace if there is abnormal wear or flaking.

5.2.9 Adjustment of valve clearance

(1) Make adjustments when the engine is cool. (Refer to 2.2.4(2).)

Standard valve clearance (mm)

Intake valve	0.15-0.25
Exhaust valve	0.45-0.55

(2) Be sure that the opening and closing angles for both intake and exhaust valves are checked when timing gear is disassembled.

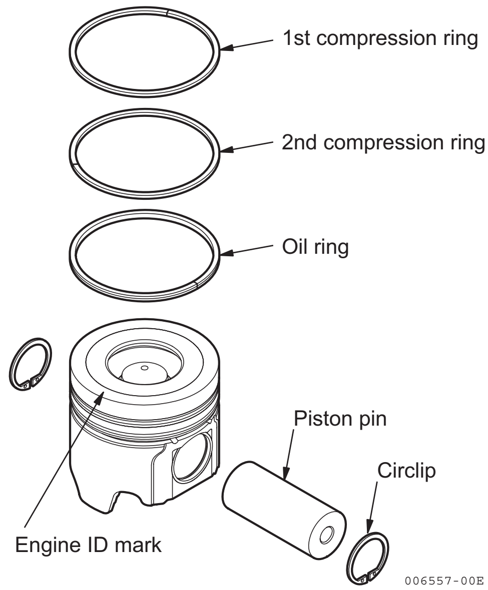
deg.

Intake valve open	b.TDC.	26°±5°
Intake valve closed	a.BDC.	56°±5°
Exhaust valve open	b.BDC.	67°±5°
Exhaust valve closed	a.TDC.	29°±5°

5.3 Piston and piston pins

Pistons are made of a special light alloy with superior thermal expansion characteristics, and the top of the piston forms a swirl type combustion chamber. The opposite face of the piston combustion surface is oil-jet cooled.

IMPORTANT:
Piston shape differs among engine models. If any incorrect piston is installed, combustion performance will drop. Be sure to check the applicable engine model identification mark "LY3" on the piston for 6LY3 engines to insure use of the correct part.



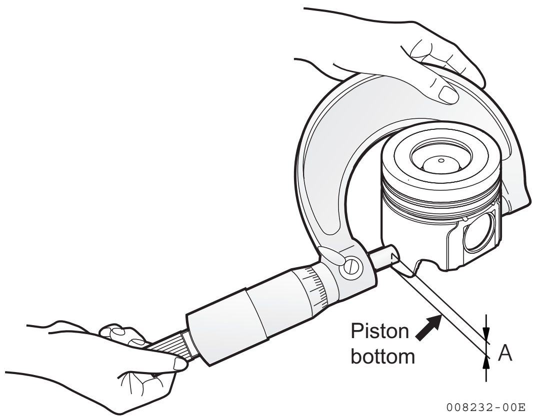
5.3.1 Piston

(1) Piston head and combustion surface

Remove the carbon that has accumulated on the piston head and combustion surface, taking care not to scratch the piston. Check the combustion surface for any damage.

(2) Measurement of piston outside diameter / inspection

1) Replace the piston if the outsides of the piston or ring grooves are worn.
2) Measure the outside diameter in the position of A from the piston bottom in the direction vertical to the piston pin.
   If the piston outside diameter exceeds the limit, replace the piston with new one.



A	22 mm

Piston outside diameter

Piston ID mark	Standard	Limit	Clearance between piston and cylinder
L	105.799-105.809	105.780	0.111-0.131
ML	105.794-105.799		
MS	105.789-105.794		
S	105.779-105.789		

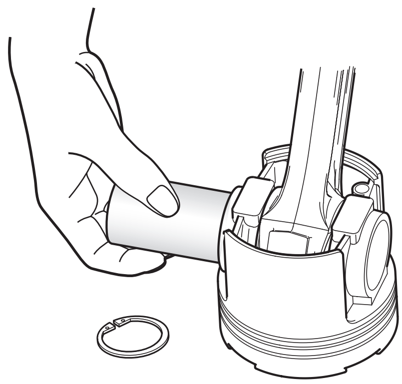
Selective pairing of cylinder liner and piston
Piston must be paired with cylinder liner according to the below table. The size mark of a piston is shown on the top surface of the piston and the size mark of a cylinder liner is shown on the non-operating side of the cylinder block. The service parts of pistons are provided.

			Piston outside diameter. D2	
	Tolerance		below+0.005 0 min.	below 0 -0.005 min.
		Size mark	ML	MS
Cylinder liner inside diameter D1	+0.030 max. +0.020 min.	L	○	×
	below +0.020 +0.010 min.	M	○	○
	below +0.010 0 min.	S	×	○

Cylinder liner inside diameter D1 (mm)	Piston outside diameter. D2 (mm)
105.900	105.794

(3) Removing the piston

A floating type piston pin is used in this engine. The piston pin can be pressed into the piston pin hole at room temperature (coat with oil to make it slide easily).

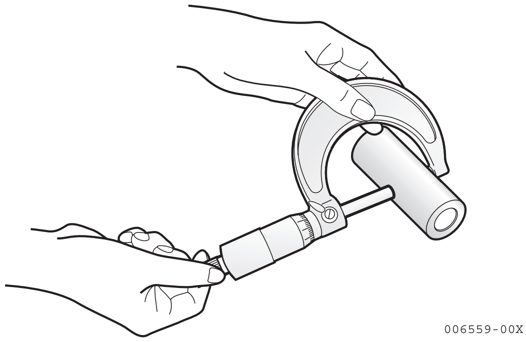


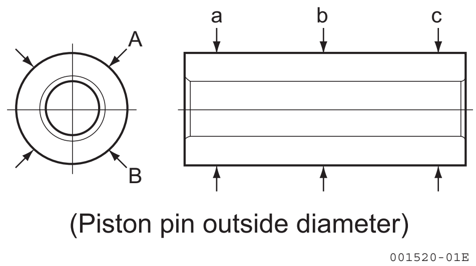
006558-00X

5.3.2 Piston pin

Measure the outer diameter and replace the pin if it is excessively worn.

	Standard	Limit
Piston pin hole inside dia.	37.025-37.040	37.100
Piston pin outside dia.	36.994-37.000	36.964
Clearance	0.025-0.046	0.110

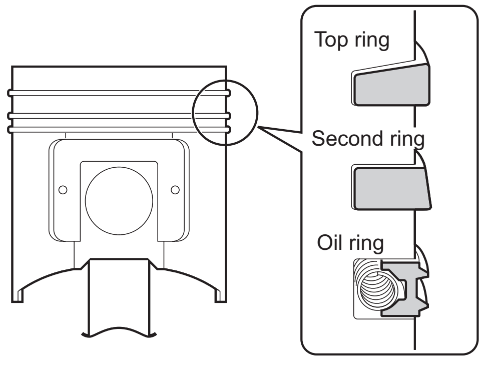




(Piston pin outside diameter)

5.3.3 Piston rings

There are 2 compression rings and 1 oil ring.

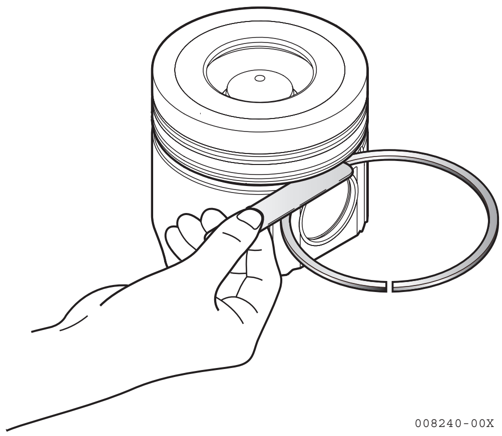


(Ring components)

001522-01E

(1) Measuring the rings.

Measure the thickness and width of the rings, and the ring-to-groove clearance after installation. Replace if wear exceeds the limit.



008240-00X

mm

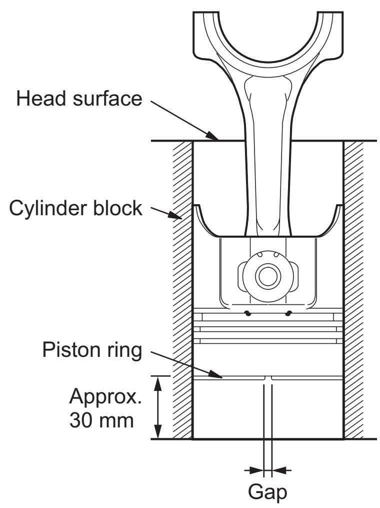
		Standard	Limit
Top ring	Groove width	2. 626-2.646	2.746
	Ring width	2.470-2.490	2.450
	Clearance	-	-
Second ring	Groove width	2.570-2.585	2.140
	Ring width	2.470-2.490	1.950
	Clearance	0.080-0.115	0.200
Oil ring	Groove width	4.010-4.025	4.130
	Ring width	3.970-3.990	3.950
	Clearance	0.020-0.055	0.150

(2) Measuring piston ring gap

Press the piston ring onto a piston liner and measure the piston ring gap with a gauge. Press on the ring about 30mm from the bottom of the liner.

mm

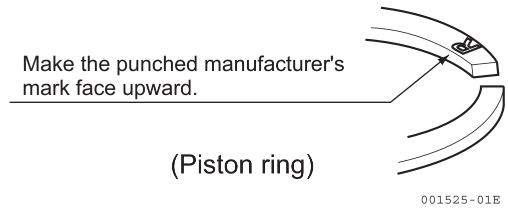
	Standard	Limit
Top ring gap	0.30-0.50	1.5
Second ring gap	0.50-0.70	1.5
Oil ring gap	0.25-0.45	1.5

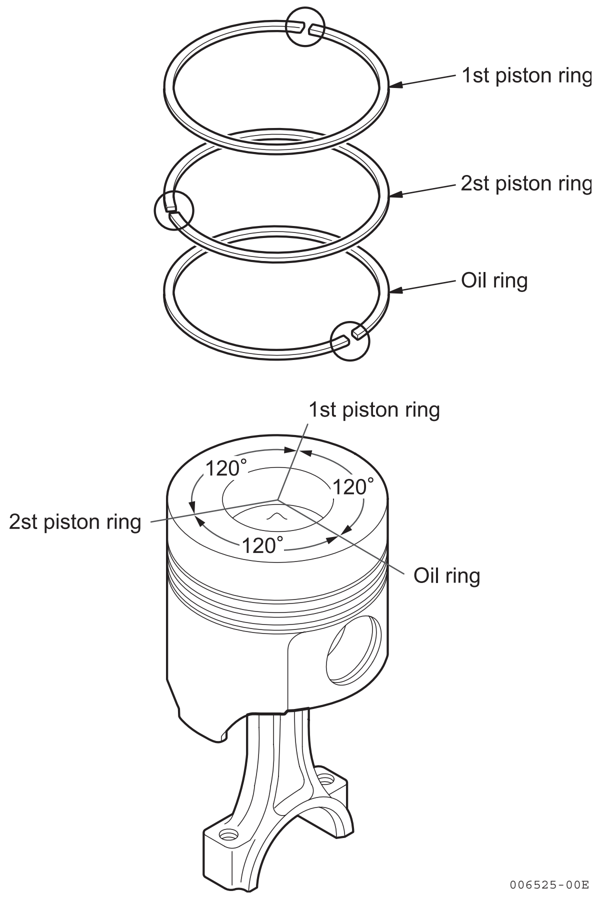


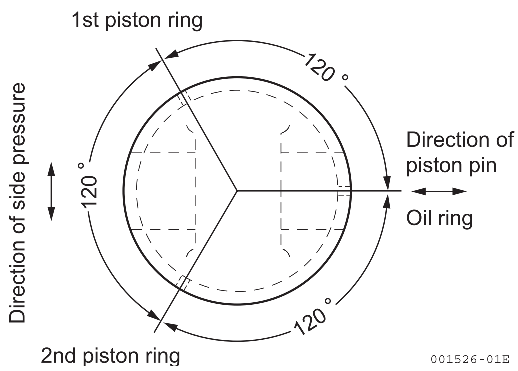
001524-01E

(3) Replacing the piston rings

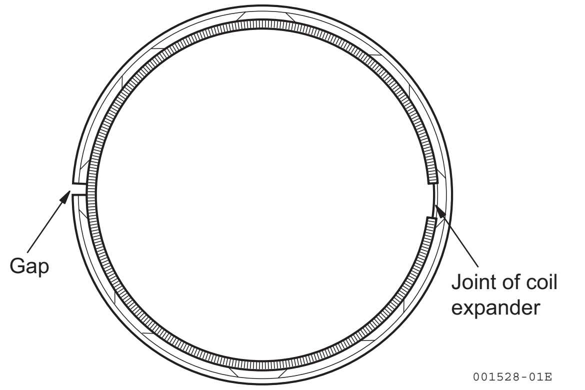
1) Thoroughly clean the ring grooves when replacing piston rings.
2) The side with the manufacturer's mark should face up.
3) After fitting the piston ring, make sure it moves easily and smoothly.
4) Stagger the piston rings at 120° intervals, making sure none of them line up with the piston.





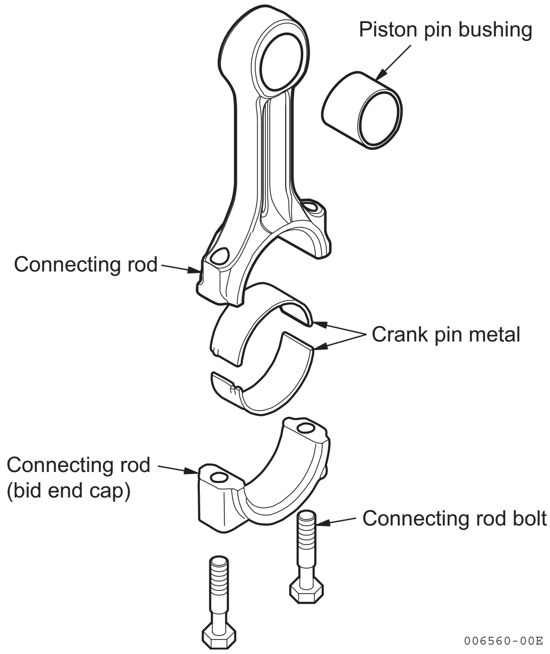


5) The oil ring is provided with a coil expander. The coil expander joint should be opposite (staggered 180°) the oil ring gap.



5.4 Connecting rod

The connecting rod is made of high-strength forged carbon steel.
The large end with the aluminum metal can be separated into two and the small end has a 2-layer copper alloy coil bushing.

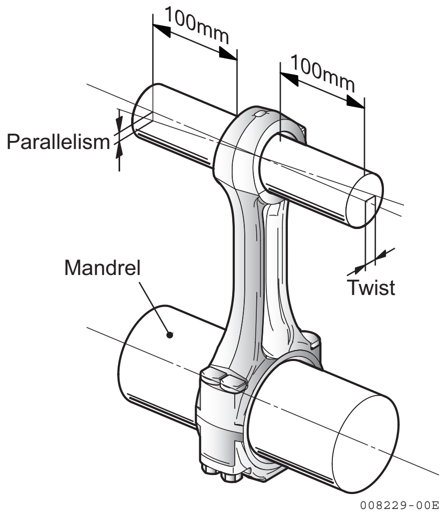


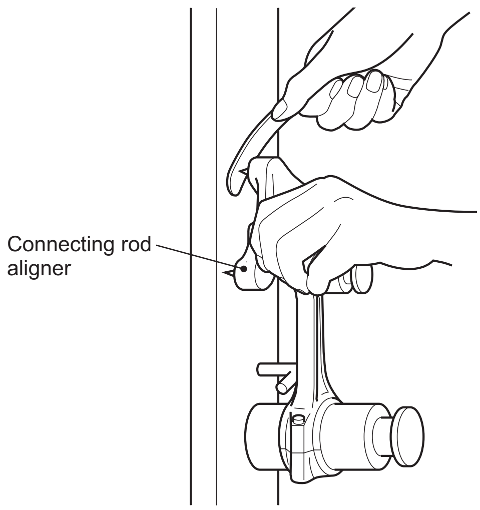
5.4.1 Inspecting the connection rod

(1) Twist and parallelism of the large and small ends. Insert the measuring tool into the large and small ends of the connecting rod. Measure the extent of twist and parallelism and replace if they exceed the tolerance.

mm

	Standard	Limit
Connecting rod twist and plurality	Less than 0.05 (at 100 mm)	0.07



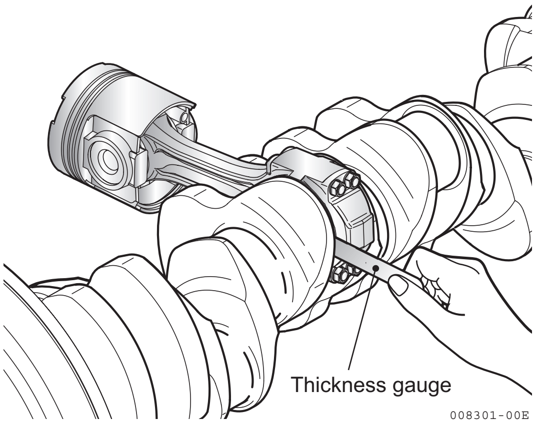


(Twist measurement using a connecting rod aligner)

(2) Checking side clearance of a connecting rod

Fit the respective crank pins to the connecting rod and check to make sure that the side clearance in the crankshaft direction is correct.

	Standard	Limit
Connecting rod side clearance	0.20~0.40	0.45



5.4.2 Crank pin metal

(1) Checking crank pin metal

Check for flaking, melting or seizure on the contact surface of the crank pin metal.

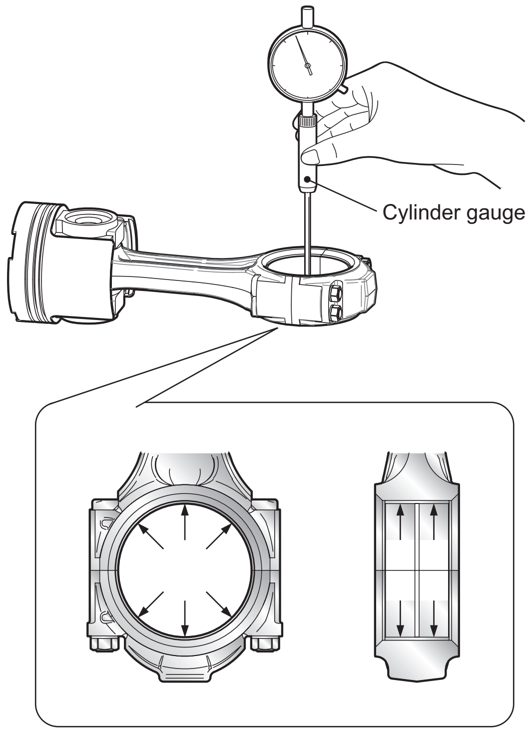
(2) Measuring crank pin oil clearance

Measure the crank pin outside diameter and the crank pin metal inside diameter. Calculate the oil clearance from the measured values.

(Refer to 5.5.1(3) for measuring the crank pin outside diameter.)

Replace the crank pin metal if the oil clearance becomes about the limit dimension of the below table.

Correct by grinding if unevenly wear, roundness exceeding the limit or insufficient outside diameter is found. Also use an undersized metal if necessary.



008302-00E

[NOTICE]

When measuring the inside diameter of the rod big end, install the crank pin metal in the rod big end not to mistake the top and bottom of the metals and tighten the rod bolts by the standard torque.

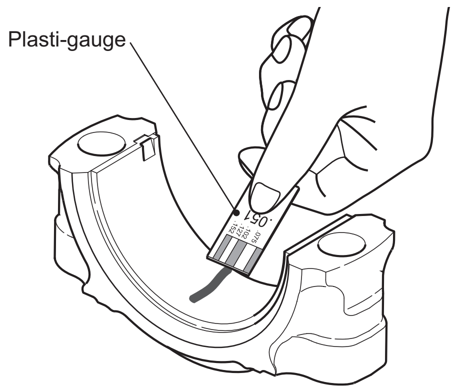
N•m (kgf•m)

Rod bolt tightening torque	132.1-141.9 (13.5-14.5)

mm

Item	Standard	Limit
Rod metal I.D.	65.000-65.045	65.100
Crank pin O.D.	64.952-64.964	64.902
Metal thickness	1.987-2.000	-
Clearance	0.036-0.093	0.160

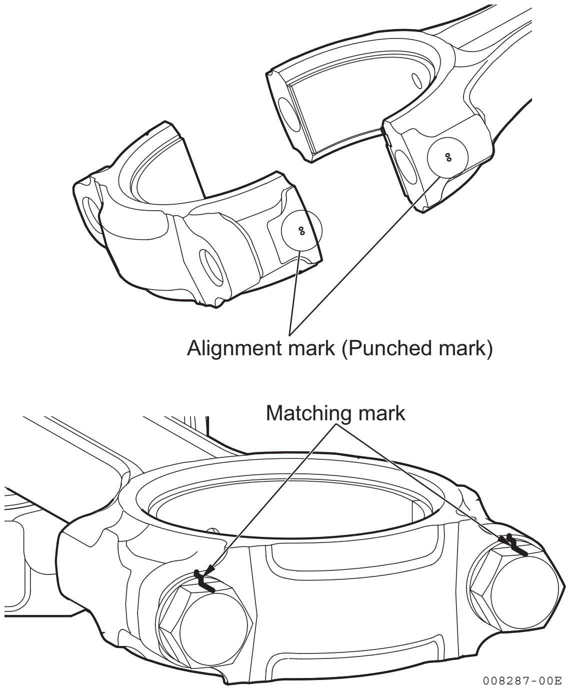
- Other procedure of measuring crank pin oil clearance
  1) Use the press gauge (plasti-gauge) for measuring the oil clearance of the crank pin.
  2) Mount the connecting rod on the crank pin and tighten to specified torque.
  3) Remove the connecting rod and measure the broken plasti-gauge with measuring paper.



008286-00E

(3) Precautions on replacement of crank pin metal

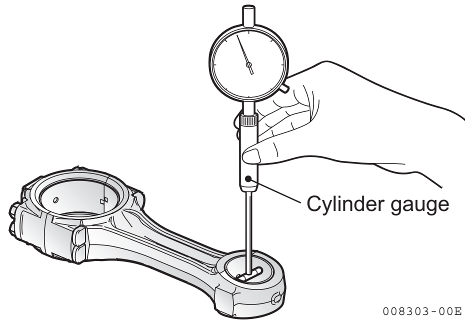
1) Wash the crank pin metal.
2) Wash the large end cap, mount the crank pin metal and make sure that it fits tightly on the large end cap.
3) When assembling the connecting rod, match up the large end and large end cap number. Coat the bolts with engine oil and gradually tighten them alternately to the specified torque.
   If a torque wrench is not available, make match marks on the bolt heads and large end cap (to indicate the proper torque position) and retighten the bolts to those positions.
4) Make sure there is no sand, metal cuttings or other dust in the lube oil, and that the crankshaft is not scratched. Take special care in cleaning the oil holes.



5.4.3 Piston pin bushing

(1) Measuring piston pin clearance

Excessive piston pin bushing wear may result in damage to the piston pin or the piston itself. Measure the piston pin bushing inside diameter and the piston pin outside diameter. Calculate the oil clearance from the measured values. (Refer to 5.3.2 for the piston pin.)



mm

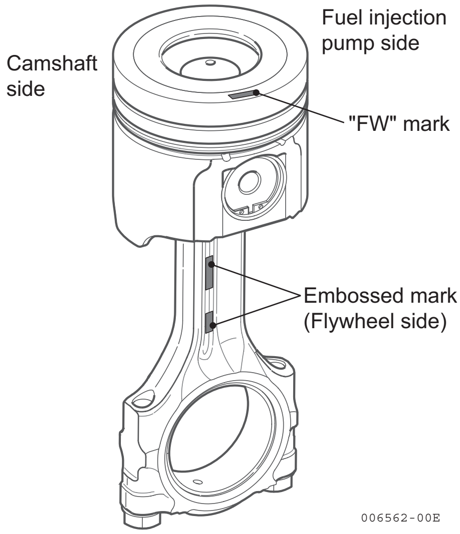
	Standard	Limit
Piston pin bushing inside dia.	37.025-37.040	37.100
Oil clearance	0.025-0.046	0.110

Note:

Since the rod small end is tapered, bush insertion is extremely difficult. Any minor mistake will cause abnormalities such as twist and bite. Do not insert the bush on-site.
(No piston pin bush spare part is available. It is included in the connecting rod assembly supplied as a spare part.)

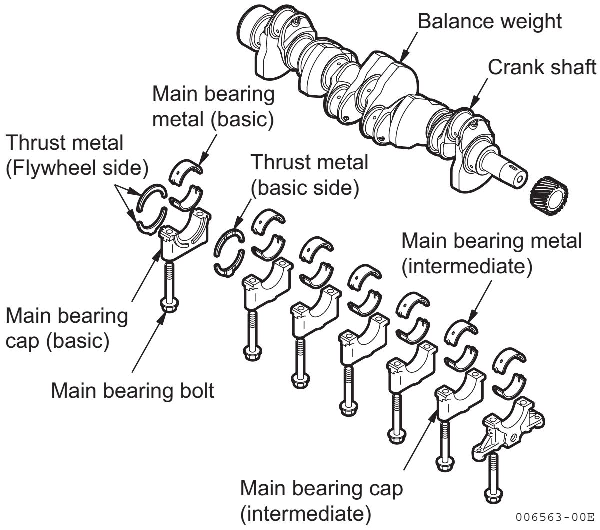
5.4.4 Assembling piston and connecting rod

The piston and connecting rod should be assembled so that the emboss mark on the connecting rod and the "FW" mark on the piston top face the same direction. Install the piston and connecting rod assembly with those marks facing flywheel side.



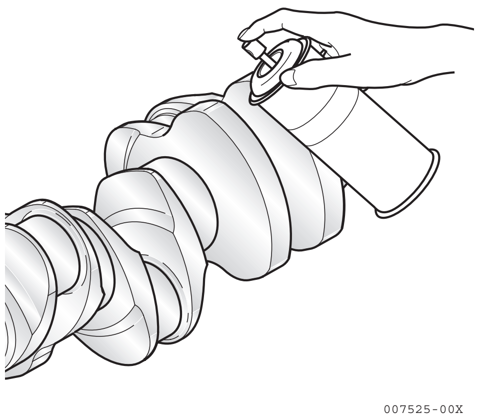
5.5 Crankshaft and main bearing

The crank pin and crank journal have been induction hardened for superior durability, and the crankshaft is provided with for balance weights for optional balance. The crankshaft main veering is of the hanger type. The upper metal (cylinder block side) is provided with an oil groove. There is no oil groove on the lower metal (bearing cap side). The veering cap (location cap) of the flywheel side has a thrust metal, which supports the thrust load.



5.5.1 Crankshaft

(1) Color check after cleaning the crankshaft, and replace the crank shaft if there is any cracking or considerable damage.

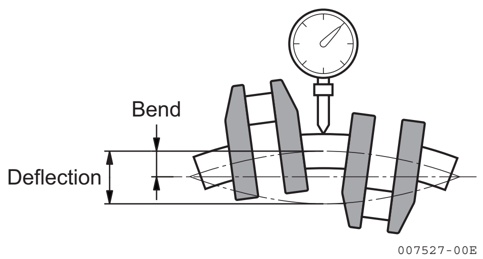


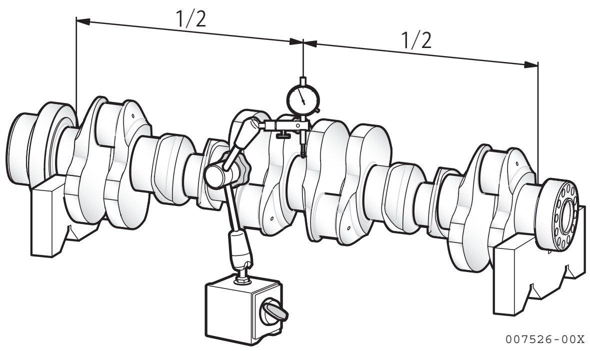
(2) Bending of the crankshaft

Support the crankshaft with V-blocks at both ends of the journals. Measure the deflection of the center journal with a dial gauge while rotating the crankshaft to check the extent of crankshaft bending.

mm

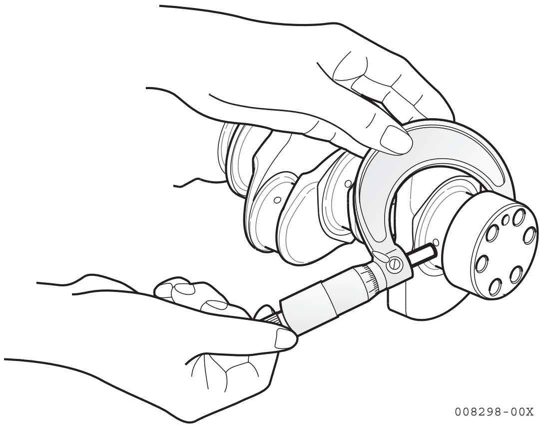
Crankshaft bend limit (1/2 the dial gauge reading)	0.03





(3) Measuring the crank pin and journal

Measure the outside diameter, roundness and taper at each crank pin and journal.
Correct by grinding if unevenly wear, roundness exceeding the limit or insufficient outside diameter is found. Replace if the defect is excessive.

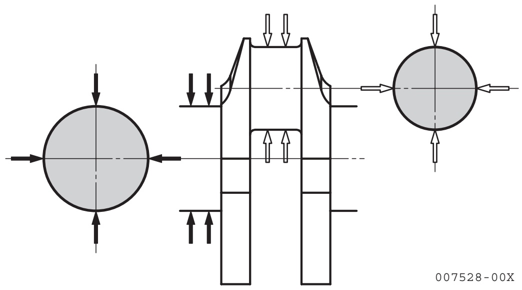


008298-00X

mm

Item	Limit (Diameter)
Roundness Taper	0.01

To look for the oil clearance of crank pin, measure the inside diameter of crank pin metal. (Refer to 5.4.2(2).)



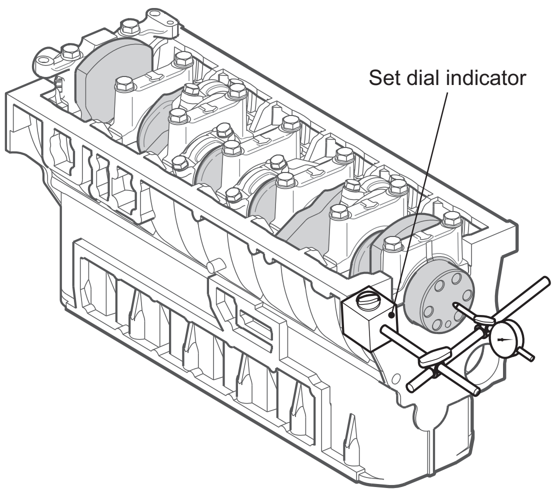
007528-00X

mm

		Standard	Limit
Crank pin	Outside dia.	64.952~64.964	64.90
	Oil clearance	0.036~0.093	0.160
Crank journal	Outside dia.	74.952~74.964	74.90
	Oil clearance	0.036~0.093	0.15

(4) Checking the side clearance of a crankshaft

After assembling the crankshaft, tighten the main bearing cap to the specified toque, and move the crankshaft to one side, placing a dial gauge on one end of the shaft to measure thrust clearance.
Replace the thrust bearing if it is worn beyond the limit.



(Measurement of side clearance) 006614-00E

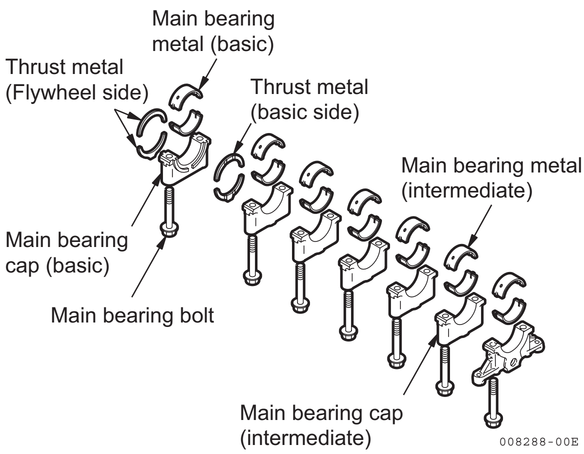
mm

	Standard	Limit
Crankshaft side clearance	0.132~0.223	0.29

5.5.2 Main bearing

(1) Inspecting the main bearing

Check for flaking, seizure or burning of the contact surface and replace if necessary.



(2) Measuring the inner diameter of metal

Tighten the cap to the specified torque and measure the inner diameter of the metal.

N•m (kgf•m)

Tightening torque	New bolt	245-265 (25.0-27.0)
	Used bolt	225-245 (23.0-25.0)

mm

	Standard	Limit
Metal inside diameter	75.000-75.045	-
Metal thickness	2.487-2.500	-

Note:

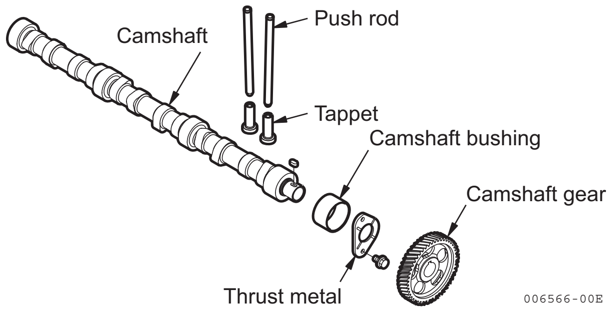
When assembling the bearing cap, keep the following in mind.

1) The lower metal (cap side) has no oil groove.
2) The upper metal (block side) has an oil groove.
3) Check the cylinder block alignment number.
4) The "FW" on the cap lies on the flywheel side.

5.6 Camshaft and Tappets

5.6.1 Camshaft

The camshaft is normalized and the cam and bearing surfaces are surface hardened and ground. The cams have a curve that minimized the repeated shocks on the valve seats and maximizes valve seat life.

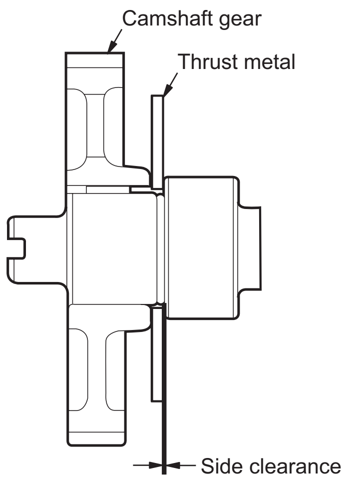


(1) Checking the camshaft side clearance

Measure the thrust clearance before disassembly. As the cam gear is shrink-fitted to the cam, be careful when replacing the thrust bearing.

mm

	Standard	Limit
Camshaft side clearance	0.05-0.20	0.29



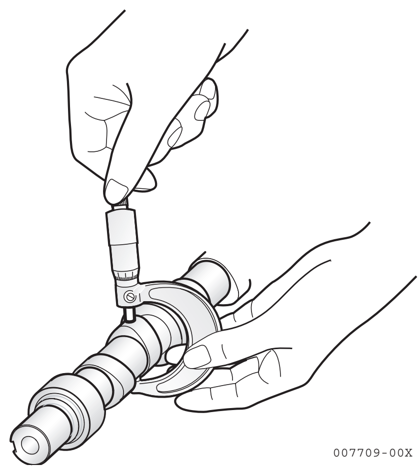
(Camshaft side clearance)

009311-01E

(2) Measure the camshaft height, and replace the cam if it is worn beyond the limit.

mm

		Standard	Limit
Cam height	Intake	49.435-49.565	49.185
	Exhaust	48.135-48.265	48.110



(3) Camshaft and bearing hole measurement

Measure the camshaft outside diameter with a micrometer. The oil clearance shall be calculated by subtracting the measured camshaft outside diameter from the inside diameter of the camshaft bearing or bushing. The camshaft bushing at gear case side is measured with a cylinder gage after insertion to the cylinder.
Replace if they exceed the limit or are damaged.

mm

Item	Standard	Limit
Bushing I.D.	56.980-57.050	57.130
Camshaft O.D.	56.910-59.940	56.880
Oil clearance	0.040-0.140	0.250

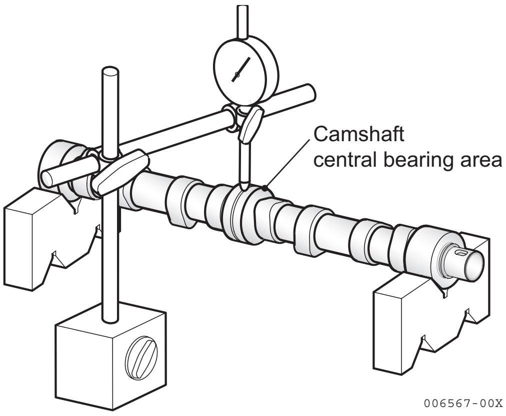
(4) Bending of the camshaft

Support both ends of the camshaft with V-blocks, place a dial gauge at the central bearing areas and measure bending. Replace if excessive.

Note:
The reading on the dial gauge is divided by two to obtain the camshaft bend.

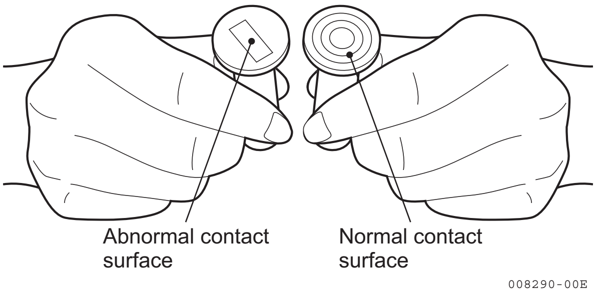
mm

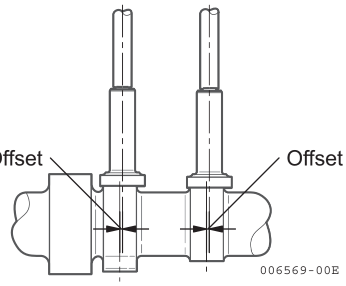
	Limit
Camshaft bend	0.02



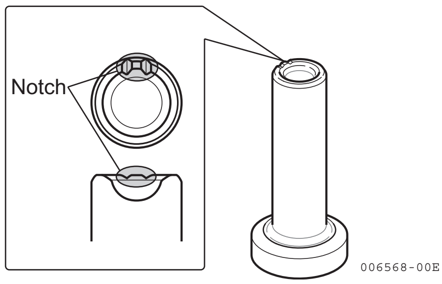
5.6.2 Tappets

(1) The tappets are offset to rotate during operation and thereby prevent uneven wearing. Check the contact of each tappet and replace if excessively or unevenly worn.





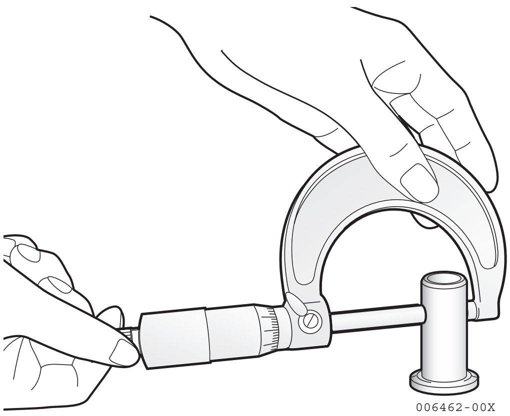
Note:
When removing tappets, be sure to keep them separate for each cylinder and intake / exhaust valve.
The tappet of exhaust side has the identifying mark of two notch on the top of tappet and the one of intake side has no notch.



(2) Measure the outer diameter of the tappet, and replace if worn beyond the limit.

mm

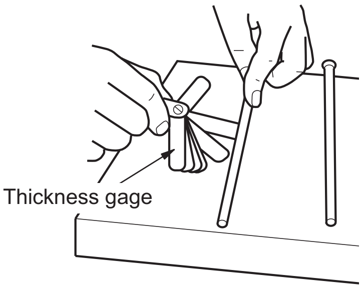
	Standard	Limit
Tappet stem outside dia.	14.218-14.233	14.17
Tappet guide hole inside dia. (cylinder block)	14.249-14.270	14.30
Oil clearance	0.016-0.052	0.10



(3) Measuring push rods.

Measure the length and bending of the push rods.

	Standard	Limit
Push rod bend	Less than 0.03	0.3
Push rod dia.	10	-



(Push rod bend)

001554-01E

5.7 Timing gear

The timing gear is helical type for minimum noise and specially treated for high durability.

5.7.1 Inspecting the gears

(1) Inspect the gears and replace if the teeth are damaged or worn.

(2) Measure the backlash of all gears that mesh, and replace the meshing gears as a set if wear exceeds the limit.

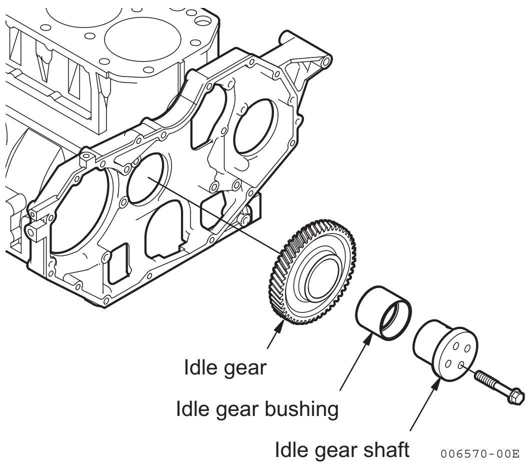
Note:
If backlash is excessive, it will not only result in excessive noise and gear damage, but also lead to bad valve and fuel injection timing and a decrease in engine performance.

mm

	Standard	Limit
Backlash	0.08-0.16	0.25

(3) Idling gear

The bushing is pressure fitted into the idling gear. Measure the bushing inner diameter and the outer diameter of the shaft, and replace the bushing or idling gear shaft if the oil clearance exceeds the wear limit.
A,B and C are inscribed on the end of the idling gear.
When assembling, these marks should align with those on the cylinder block.

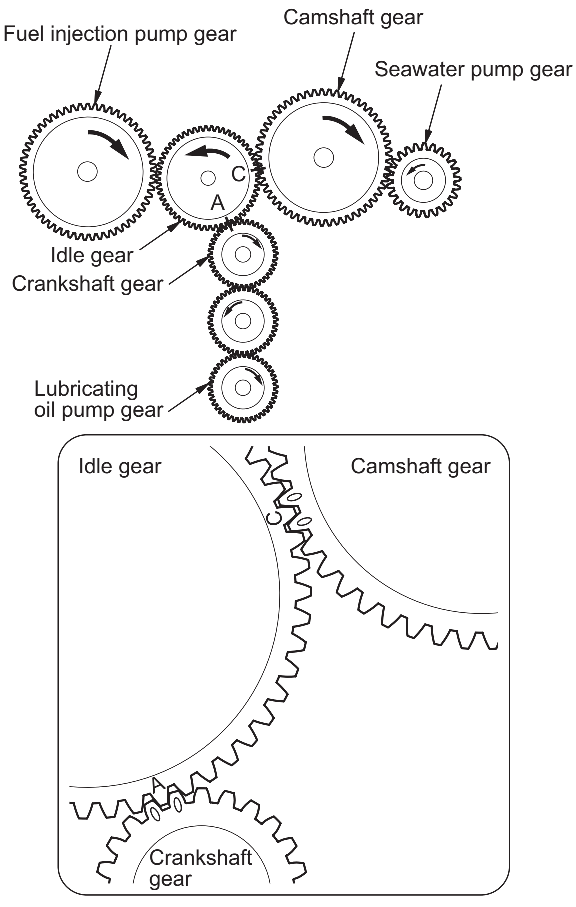


mm

	Standard	Limit
Idle shaft dia.	53.950-53.975	53.88
Idle gear bushing inside dia.	54.000-54.025	54.08
Oil clearance	0.025-0.075	0.15

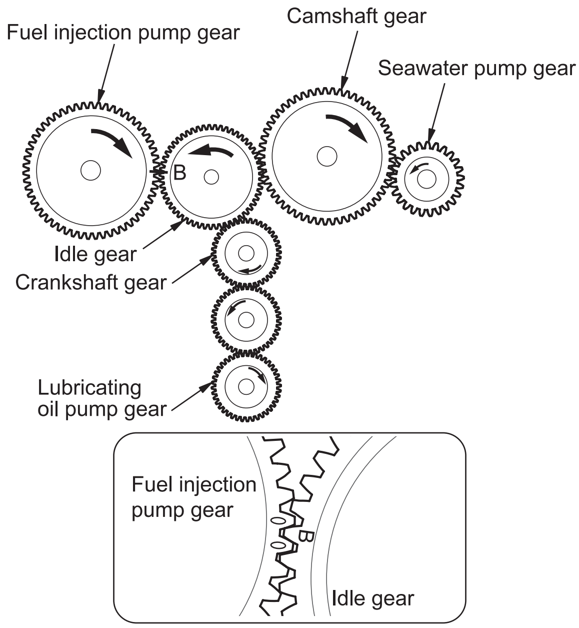
5.7.2 Gear timing marks

Match up the timing marks on each gear when assembling (A, B and C).



At T.D.C. of No.6 cylinder

006571-00E



At 29° before T.D.C. of No.6 cylinder

009439-00E

5.8 Flywheel and housing

The function of the flywheel is through inertia, to rotate the crankshaft in a uniform and smooth manner by absorbing the turning force created during the combustion stroke of the engine, and by compensating for the decrease in turning force during the other strokes.

The flywheel is mounted and secured by 6 bolts on the crankshaft end at the opposite end to the gear case; it is covered by the mounting flange (flywheel housing) which is bolted to the cylinder block.

The fitting surface for the damper disc is on the crankshaft side of the flywheel. The rotation of the crankshaft is transmitted through this disc to the input shaft of the reduction and reversing gear. The reduction and reversing gear is fitted to the mounting flange.

The flywheel's unbalanced force on the shaft center must be kept below the specified value for the crankshaft as the flywheel rotates with the crankshaft at high speed.

To achieve this, the valance is adjusted by drilling holes in the side of the flywheel, and the unbalanced momentum is adjusted by drilling holes in the circumference.

The ring gear is shrink fitted onto the circumference of the flywheel, and this ring gear serves to start the engine by meshing with the starter motor pinion.

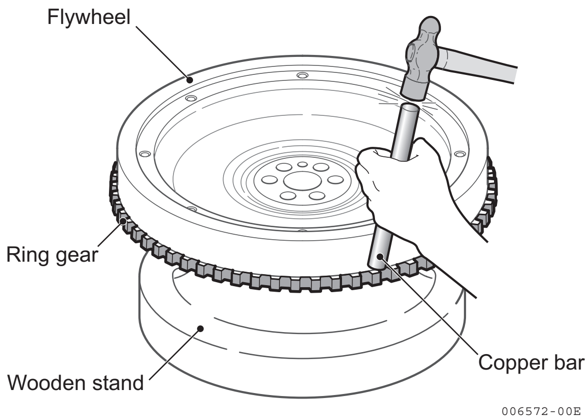
The stamped letter and line which show top dead center of each cylinder are positioned on the flywheel circumference, and by matching these marks with the arrow mark at the hole of the flywheel housing, the rotary position of the crankshaft can be ascertained in order to adjust tappet clearance or fuel injection timing.

5.8.1 Specifications of flywheel

<table>
<tr><td colspan="2">Outside dia. of flywheel</td><td>mm</td><td>392</td></tr>
<tr><td colspan="2">Width of flywheel</td><td>mm</td><td>73.9</td></tr>
<tr><td colspan="2">GD^2 value</td><td>$kgf \cdot m^2$</td><td>2.95</td></tr>
<tr><td rowspan="3">Fixing part of crankshaft</td><td>Pitch circle dia. of bolts</td><td>mm</td><td>70</td></tr>
<tr><td>No. of thread holes</td><td></td><td>6-ø16.5</td></tr>
<tr><td>Fit joint dia.</td><td>mm</td><td>$95^{+0.035}_{0}$</td></tr>
<tr><td rowspan="2">Ring gear</td><td>Center dia.</td><td>mm</td><td>387</td></tr>
<tr><td>No. of teeth</td><td></td><td>129</td></tr>
</table>

5.8.2 Ring gear

When replacing the ring gear due to excessive wear or damaged teeth, heat the ring gear evenly at its circumference, and after it has expanded drive it gradually off the flywheel by tapping it with a hammer, a copper bar or something similar around the whole circumference.

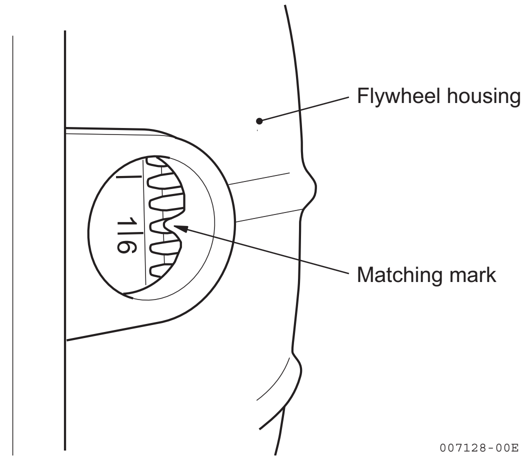


mm

Shrink range of ring gear	0.21-0.45

5.8.3 Position of top dead center

The top dead center is set with the matching marks of hole of flywheel housing and of flywheel.

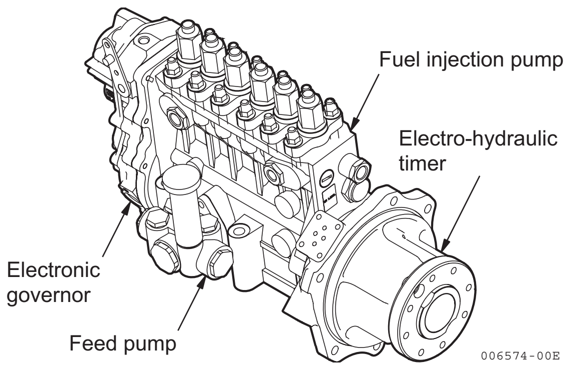


6. Fuel injection equipment

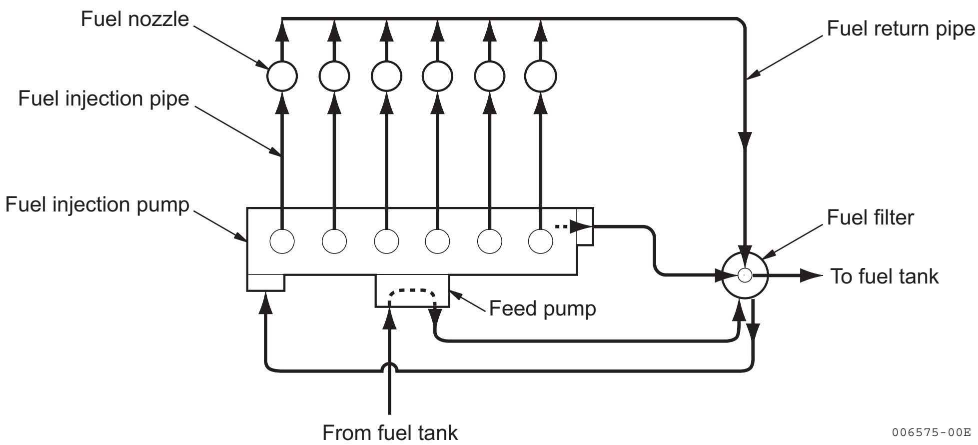
6.1 Fuel Injection pump / governor / timer

The YPES-AL II fuel injection pump with an electronic governor and electro-hydraulic timer is applied to this engine.
Refer to the service manual of separate volume for the disassembly, assembly and adjustment procedures of the fuel injection pump, governor and timer for 6LY3 engines.

Note:
Don't disassemble the fuel injection pump assembly at Yanmar workshop. Ask the maintenance to the authorized FIE service shops (Association of Diesel Specialists etc). In that case both the fuel injection pump assembly and the rack position sensor amplifier must be sent to the FIE service shop (Refer to 13.7(2) for the location of rack position sensor amplifier).



6.1.1 Fuel system diagram



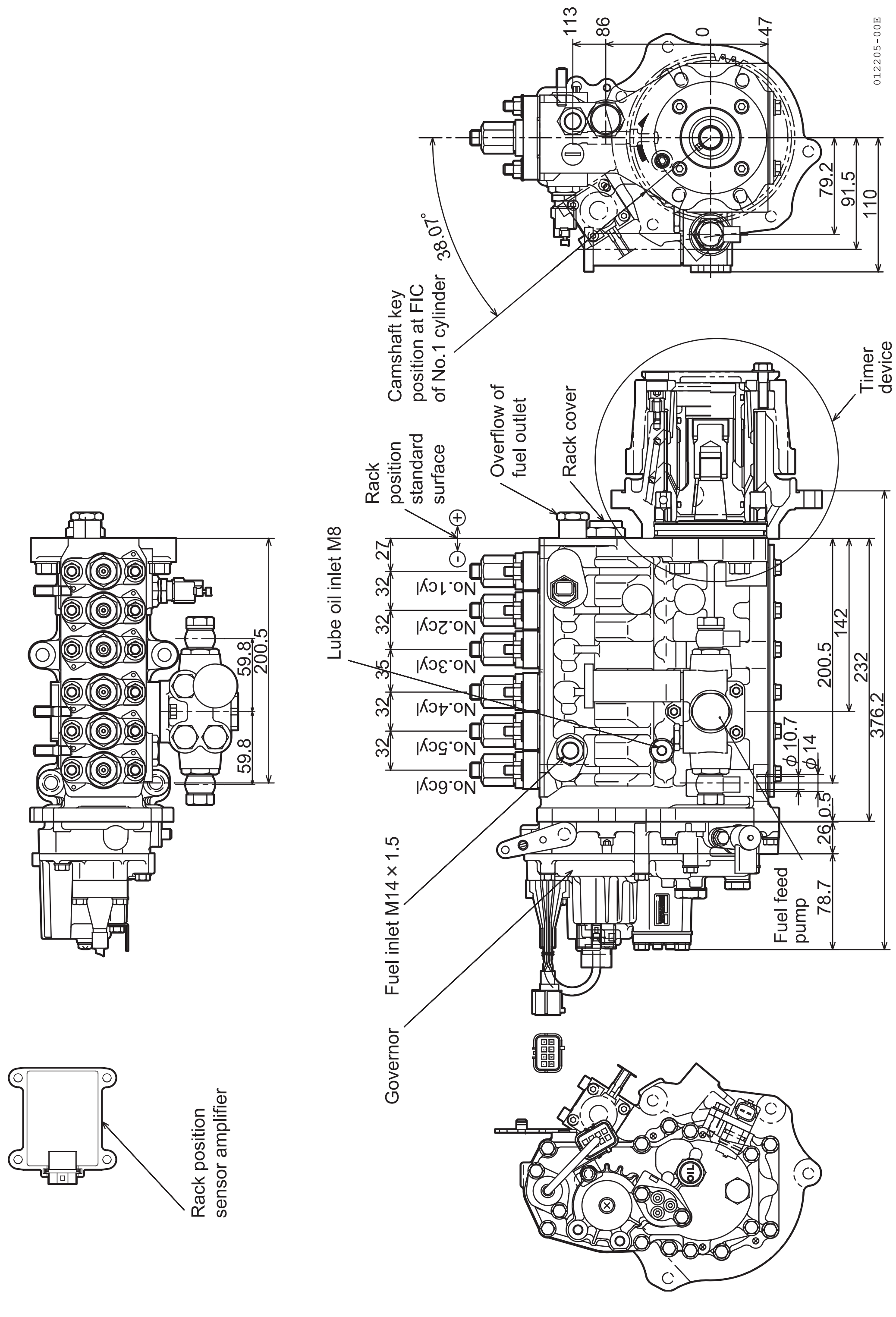
6.1.2 Fuel injection pump specifications

(1) Specifications

Injection system specifications

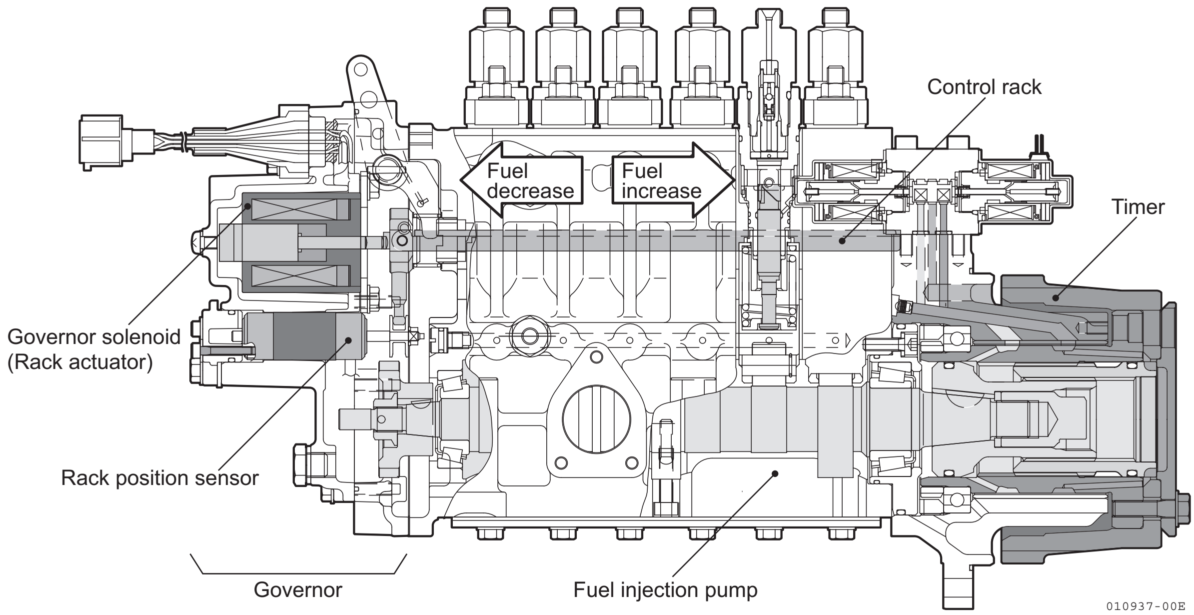
General	a	Rotation direction		Clockwise viewed from drive side
	b	Injection order		1-4-2-6-3-5-1
	c	Interval	deg.	60 ± 0.5
	d	Drive system		Gear
	e	Lubrication system		Forced lubrication
	f	Fuel cut method		Cutting by stop solenoid
Fuel injection pump	a	Cam profile for plunger		AL12V220
	b	Plunger dia. / helix. lead degree	mm / deg.	ø11.0/55.35°
	c	Lift to port close (No.1 plunger)	mm	2.5 ± 0.05
	d	Delivery valve retraction volume	mm^3 / st	0 (CPV)
	e	Angleich cutting	mm	0
	f	Delivery valve opening pressure	MPa (kgf / cm^2)	1.1(11.2)
	g	Delivery valve spring constant	N/mm (kgf/mm)	24.8(2.525)
	h	Damping valve		-
	i	Allowable max. pump speed	min^{-1}	1850
	j	Overflow pressure	MPa (kgf/cm^2)	0.2(2.0)
	k	Allowable pipe inside pressure	MPa (kgf/cm^2)	100(1020)
Governor	a	Governor type		Electronic control (PGS)
Feed pump	a	Cam profile type		AL50DFP39
	b	Fuel delivery	cm^3/rev.	7.6
	c	Delivery pressure	MPa (kgf/cm^2)	0.23 - 0.37(2.3 - 3.8)
	d	Suction head	mAq	1.0

(2) Structure


113
86
0
47
012205-00E
79.2
91.5
110
38.07°
Camshaft key position at FIC of No.1 cylinder
Timer device
Overflow of fuel outlet
Rack cover
Rack position standard surface
Lube oil inlet M8
27
32
32
35
32
32
No.1cyl
No.2cyl
No.3cyl
No.4cyl
No.5cyl
No.6cyl
59.8
59.8
200.5
142
232
376.2
φ10.7
φ14
0.5
26
78.7
Fuel feed pump
Fuel inlet M14 × 1.5
Governor
Rack position sensor amplifier

6.1.3 Governor structure and function

The electronic governor controls fuel injection quantity and engine speed electronically. The rack position sensor and governor solenoid are built-in in the governor.
The rack position sensor is linked to the control rack and detects the rack position. The governor solenoid is linked to the control rack and actuates it according to the rack position which be calculated by the ECU (Electronic Control Unit).
This governor has a function of iso-chronous control. Actual engine speed is feedback-controlled to the target speed. Engine speed depends on only throttle position.



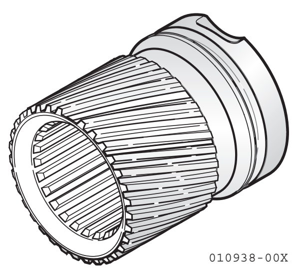
6.1.4 Timer structure and function

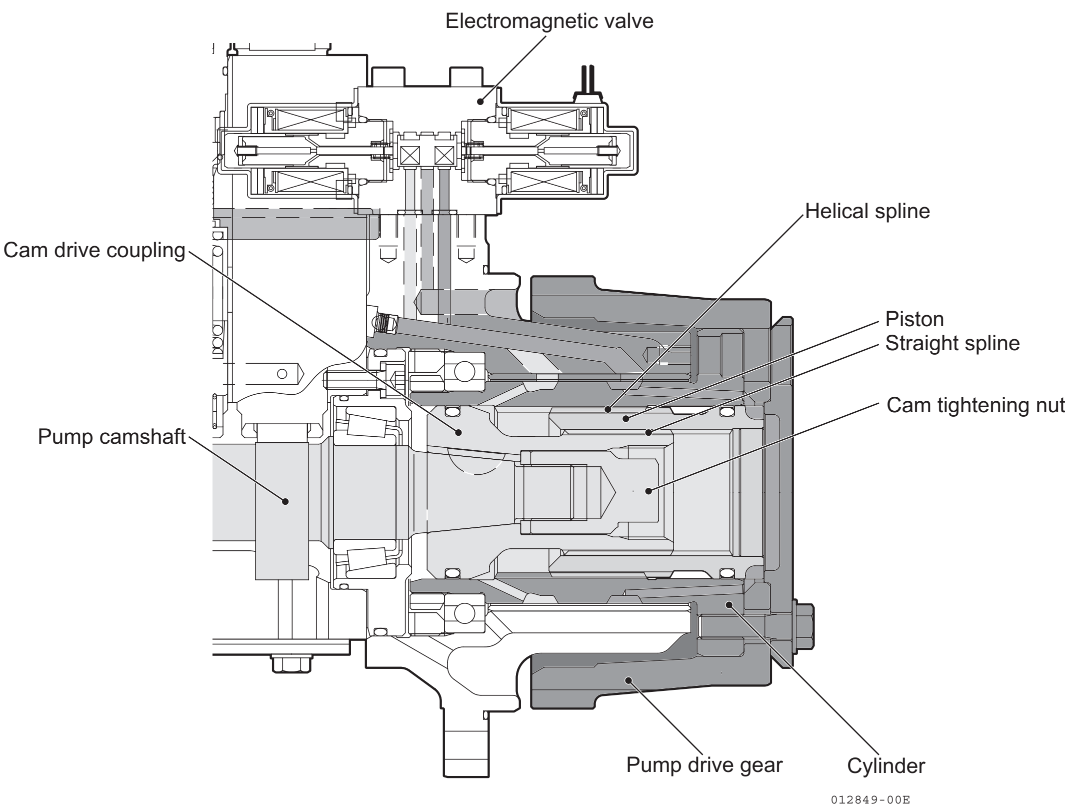
(1) Structure

The 6LY3 series engine applies the electro-hydraulic timer. The timer consists of piston, cylinder, cam drive coupling etc. The piston has helical spline outside and straight spline inside. The cylinder has helical spline inside and oil passages to move the piston.

The cam drive coupling has straight spline outside and drives pump camshaft.

Piston





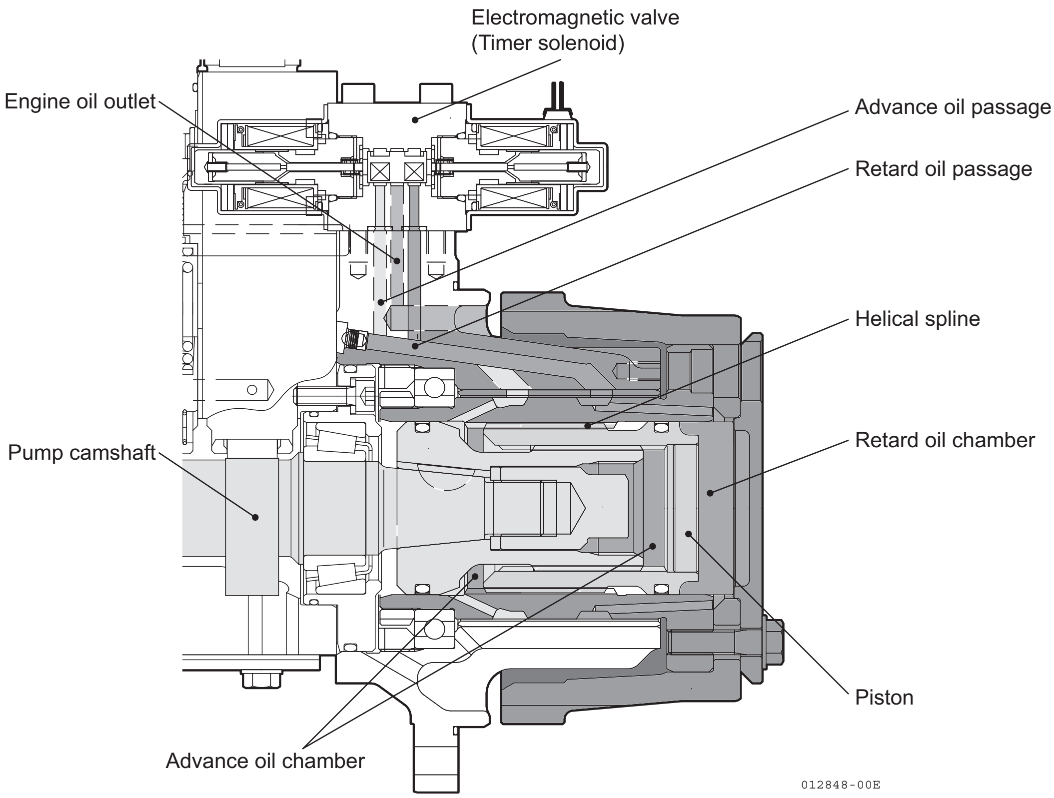
(2) Function

The electro-hydraulic timer advances or retards the fuel injection timing according to the timer phase control calculation by the ECU. The ECU calculates the optimum fuel injection timing depending on engine speed, load and coolant temperature.

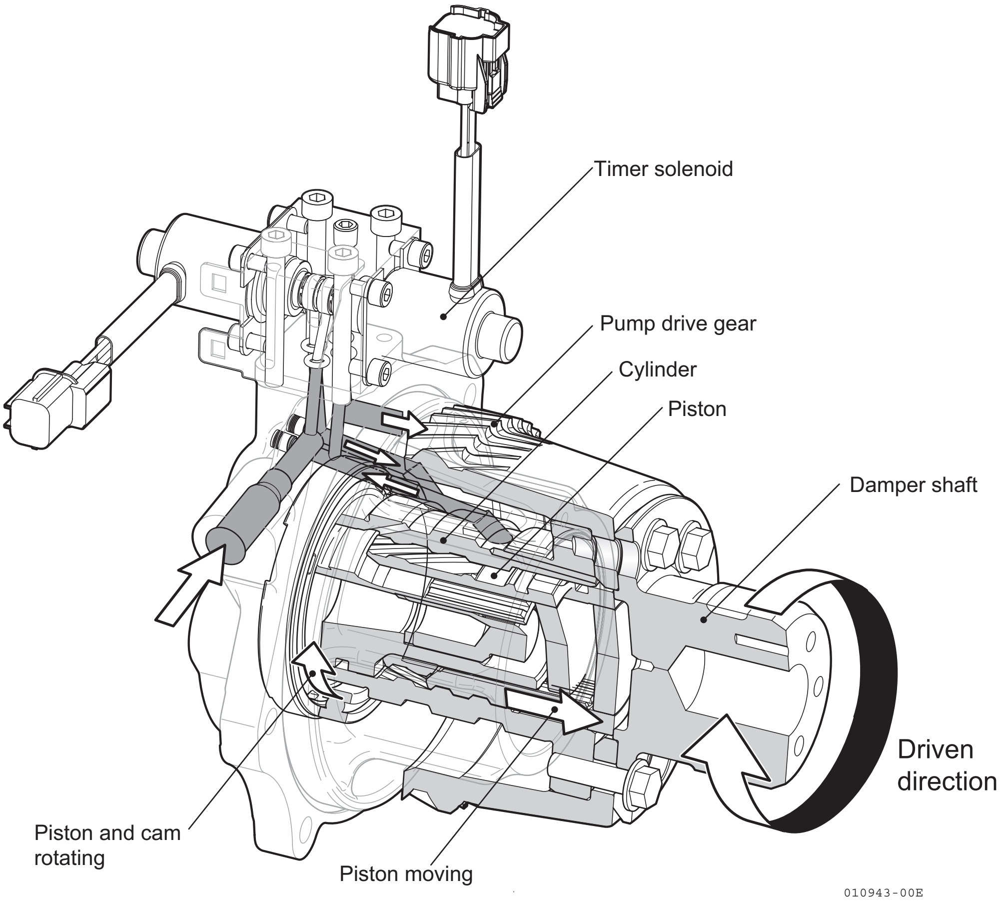
The engine oil is fed to the electromagnetic valve (timer solenoid), which controls the advance oil passage, retard oil passage and engine oil inlet / outlet according to the ECU indication.

When advancing, the timer solenoid opens the advance port to the oil inlet side and opens the retard port to the oil outlet side. The advance chamber is filled with oil and the oil in the retard chamber is pumped out to oil outlet. Then the timer piston moves by the oil differential pressure and rotates to the advance direction by the helical spline.

When retarding, that is reverse.



Advanced position

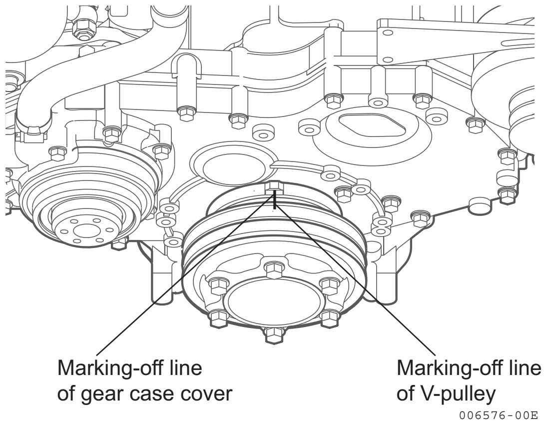


6.1.5 Removing a fuel injection pump assembly

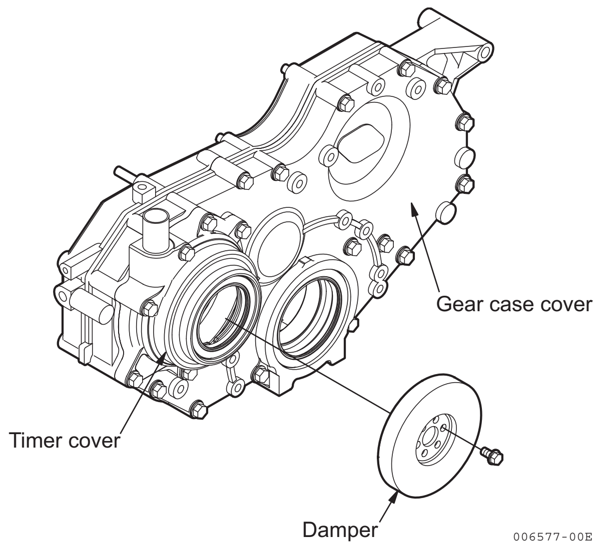
The procedure to remove a fuel injection pump assembly from the gear case is shown as follows.

1) Adjust the marking-off lines of the gear case cover and the V-pulley and the crankshaft is kept at 29° before compression top dead center of the No.6 cylinder (gear case side).

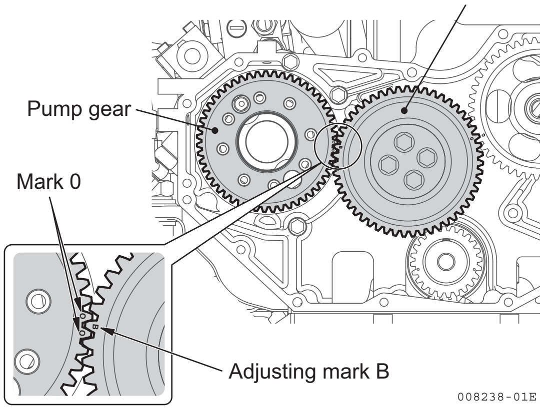
Note:
Set the crankshaft at 29° before compression top dead center while looking at the movement of suction / exhaust valves. The suction / exhaust valves are close at compression top dead center.



2) Remove fuel injection pipes and fuel pipes. Block the entrance with tape so that dust may not enter the fuel injection pipes and the fuel injection pump.
3) Remove the damper for fuel injection pump.
4) Remove the timer cover from the gear case cover.



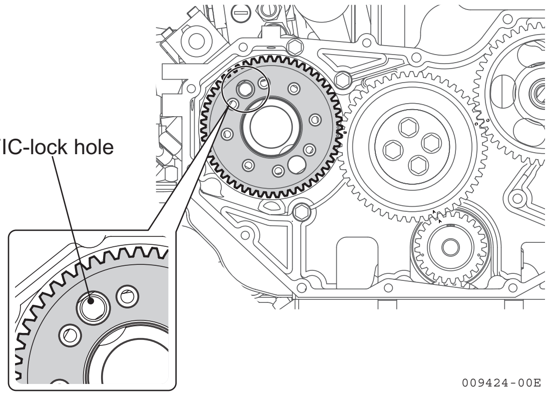
5) When the pump gear is removed without meeting the 0 marks and B mark, paint the re-setting marks to both pump gear and idle gear before removing both gears.
Don't turn the gear train and don't disassemble the idle gear. When installing the pump gear, while adjusting the re-setting marks of both gears, insert the pump gear to the timer flange.



Note:

(1) Before removing the pump gear, fasten a FIC-lock bolt and a collar through the FIC-lock hole of the pump gear to lock the camshaft of fuel injection pump.
(The camshaft angle of this pump is in the same as pump factory default.)

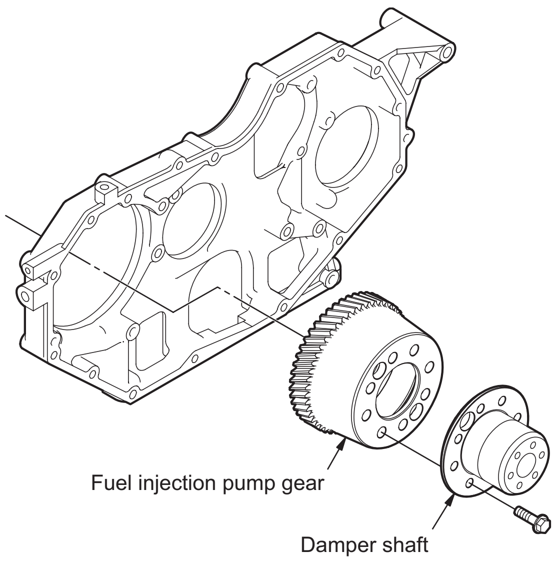
Note:
If the fuel injection pump is removed without fastening a FIC-lock bolt, the pump camshaft angle may change and the adjustment of the fuel injection timing will become difficult. In that case make sure to ask the authorized FIE service shop to adjust the FIC-lock.



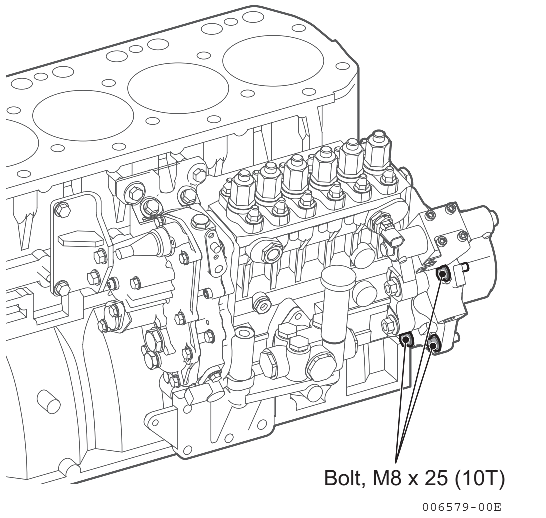
(2) In case that the idle gear was disassembled, confirm that the mark 0 of the pump gear is in the right viewed from gear case side. If not, turn the crankshaft clockwise at 360° to meet the pump gear 0 marks with the mark B of the idle gear.

6) Remove the damper shaft.

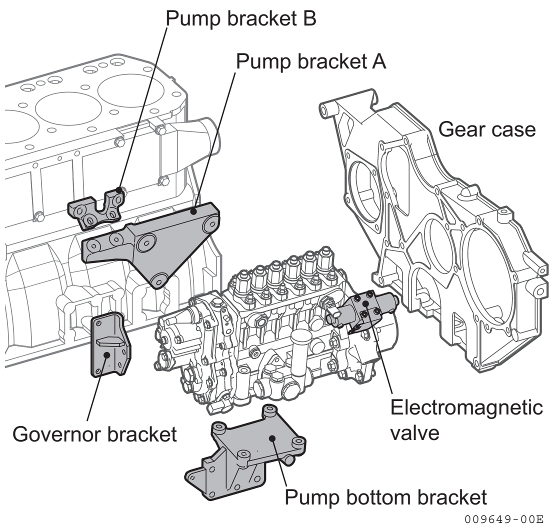
7) Remove the fuel injection pump gear from electro-hydraulic timer.



8) Loosen three tightening bolts for timer housing (fuel injection pump) from gear case. (Don't remove the bolts from gear case.)



9) Remove the bolts for governor bracket.
10) Remove the bolts for pump bracket B.
11) Remove the bolts for pump bottom bracket.



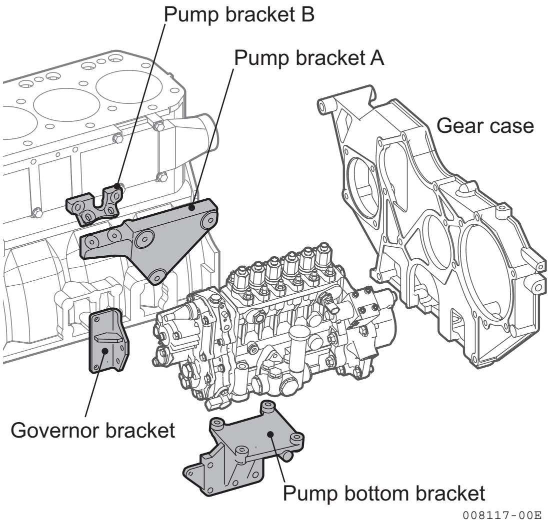
12) Remove the bolts for timer housing and remove the fuel injection pump assembly from gear case.

[NOTICE]

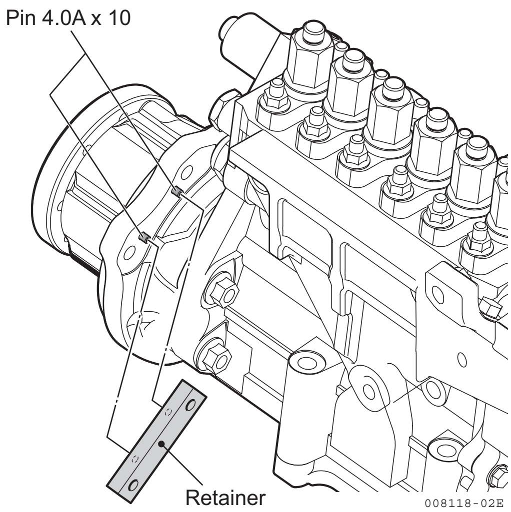
1. Be careful for the electromagnetic valve not to hit on the gear case and not to damage when removing a fuel injection pump assembly from the gear case.
2. The timer may not move properly when dust puts on the timer piston. After removing timer housing (fuel injection pump assembly) from gear case, cover the timer (piston part) and keep it until re-assembling.

6.1.6 Installing a fuel injection pump assembly

To keep the durability of electronic control parts, a fuel injection pump assembly is fixed with more than one bracket (bridging) to the engine and they protect the vibration of the electronic control parts for fuel injection pump. The composition of the fuel injection pump bridging is as in the right figure.
However, when a way of installing these brackets is improper and the fuel injection pump is warped, it may cause a malfunction of the fuel injection pump itself.
Therefore install pump brackets (bridging) for the following procedure.



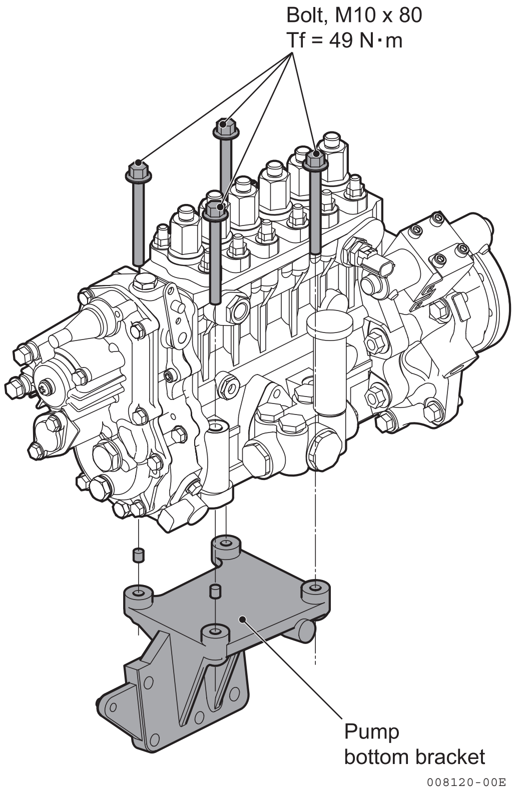
1) Insert two spring-pins in the flange of the timer housing of fuel injection pump assembly and install the retainer while adjusting knocking holes.



2) Install the pump bottom bracket.

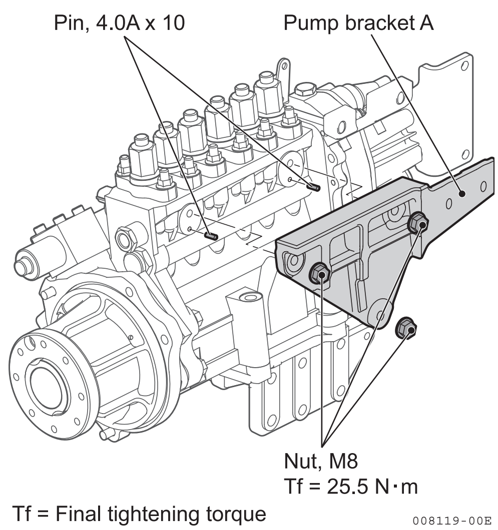
N•m (kgf•m)

Tightening torque	49±5 (5.0±0.5)

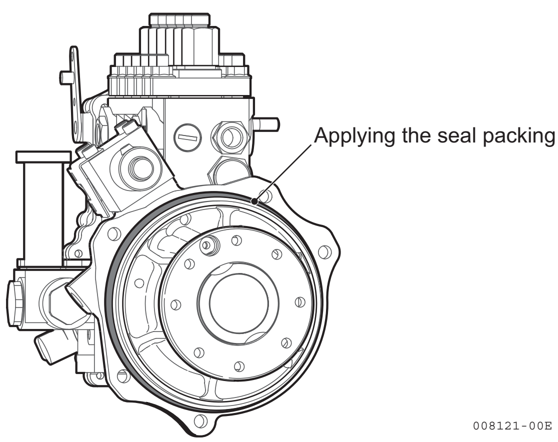


3) Tighten the pump bracket A with nuts while positioning by spring pins.

Tightening torque	25.5±3 (2.6 ± 0.3)

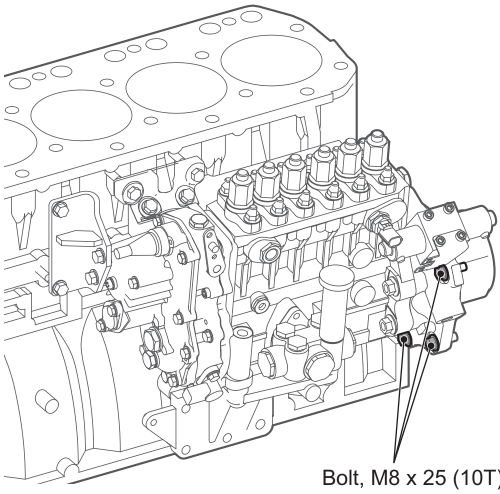


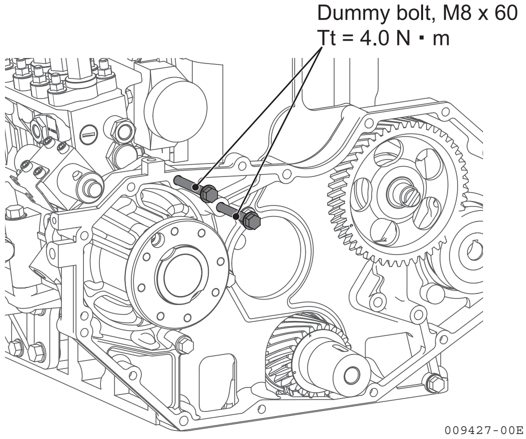
4) Apply a seal packing (liquid-packing Three Bond 1207 C) to the gear case mounting surface of the timer housing.



5) Install fuel pump assembly in the gear case and temporarily tighten the bolts (M8 - 3 pcs.) for timer housing and the dummy bolts (M8 - 2 pcs.).

Tightening torque	4.0±1 (0.4±0.1)

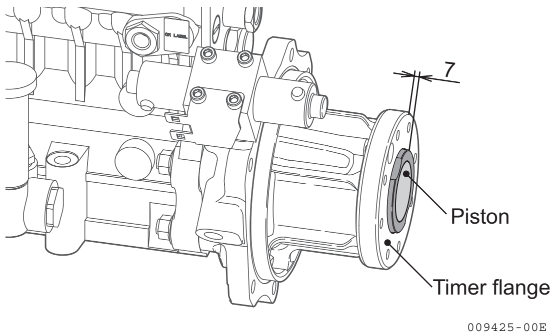




[NOTICE]

(1) Be careful for the electromagnetic valve not to hit on the gear case and not to damage when installing a fuel injection pump assembly to the gear case.

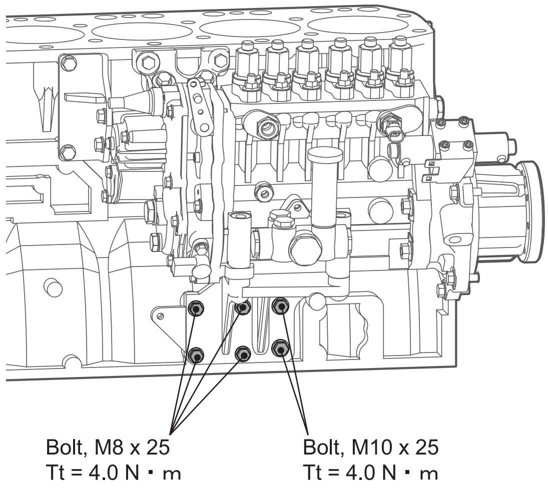
(2) Confirm that the timer of fuel pump assembly is in the most advanced condition. At the most advanced condition, the piston of the timer is overhung by 7 mm from the flange face.



6) Temporarily tighten bolts for pump bottom bracket to cylinder block. (without lube oil)

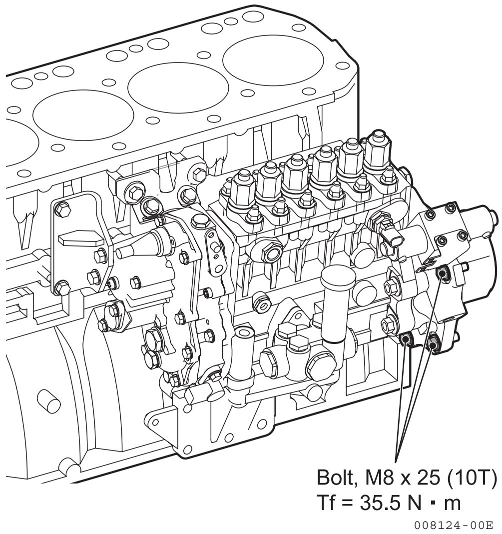
Tightening torque: N•m (kgf•m)	M8 bolt	4.0±1 (0.4±0.1)
	M10 bolt	4.0±1 (0.4±0.1)

Note:
Confirm that there is no clearance between bracket and cylinder block.



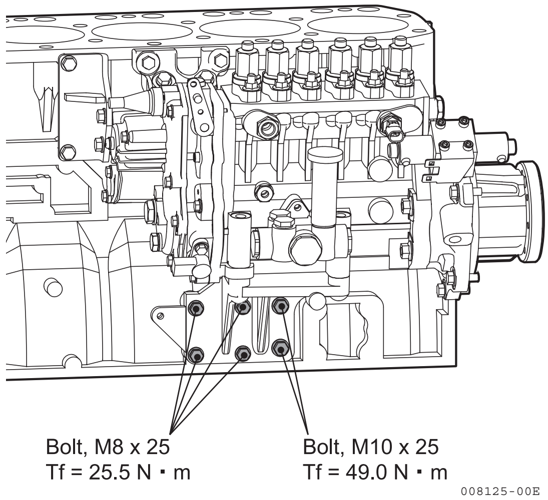
7) Tighten timer housing (fuel pump assembly) bolts to gear case. (without lube oil)

Tightening torque: N•m (kgf•m)	M8 bolt	35.3±2(3.6±0.2)

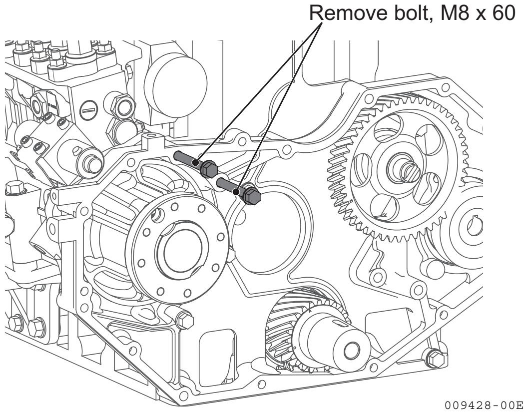


8) Tighten the bolts for pump bottom bracket.

Tightening torque: N•m (kgf•m)	M8 bolt	25.5±3(2.60±0.31)
	M10 bolt	49.0±5(4.99±0.51)

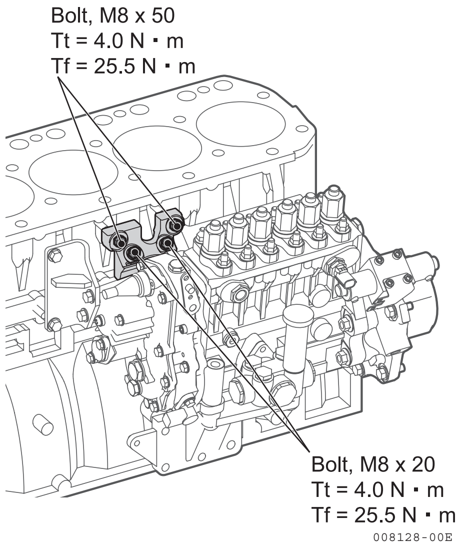


9) Remove the dummy bolts.



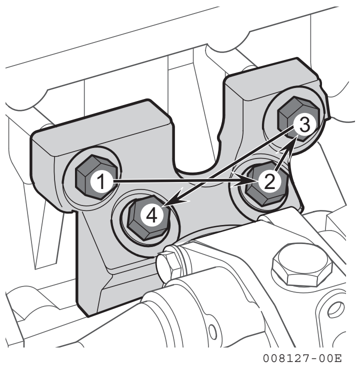
10) Install pump bracket B as shown in the right figure.
Temporarily fasten bolts for pump bracket B in the order shown in the below figure.

Tightening torque: N•m (kgf•m)	M8 bolt	4.0±1 (0.4±0.1)



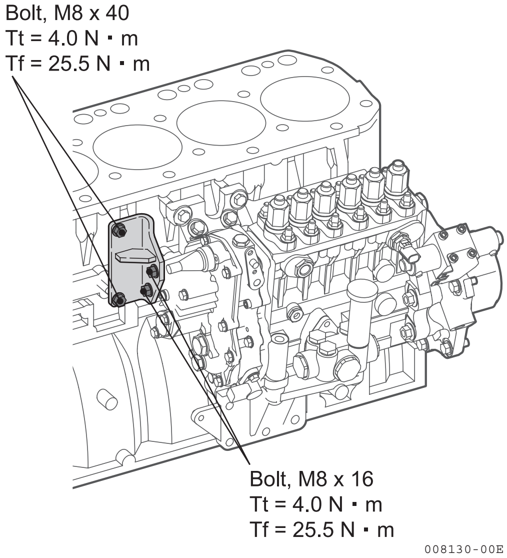
Finally tighten the bolts to the specified torque in the same order.

Tightening torque: N•m (kgf•m)	M8 bolt	25.5±3(2.60±0.31)



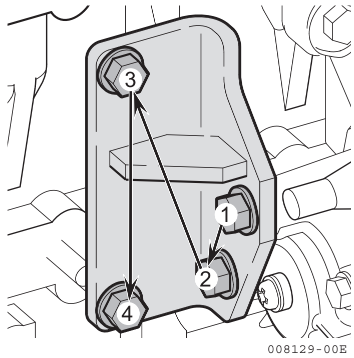
11) Install governor bracket as shown in the right figure.
Temporarily fasten bolts for governor bracket in the order shown in the below figure.

Tightening torque: N•m (kgf•m)	M8 bolt	4.0±1 (0.4±0.1)



Finally tighten the bolts to the specified torque in the same order.

Tightening torque: N•m (kgf•m)	M8 bolt	25.5±3(2.60±0.31)



12) Install fuel injection pump gear.

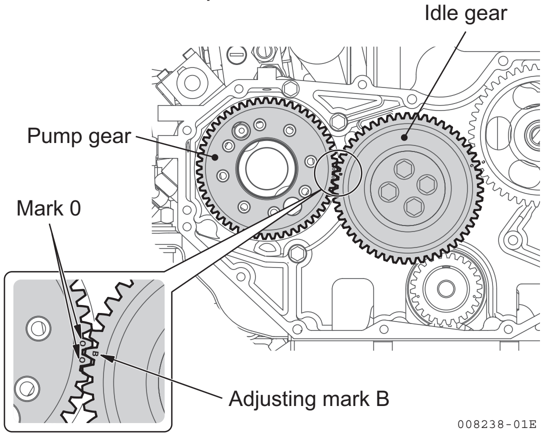
[NOTICE]

(1) When installing pump gear, meet the re-setting marks of both gears.
If the crankshaft is at 29° before T.D.C., meet the 0 marks and B mark.

(2) A fuel injection pump gear and a timer flange are assembled in tight fit. Be careful to assemble normally. When they were not assembled properly, don't hit them strongly with the hammer and so on.

(3) Be careful that trash or dust isn't attached to the timer piston.

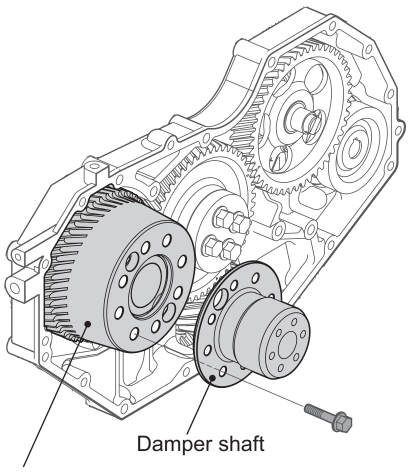
At 29° before top dead center



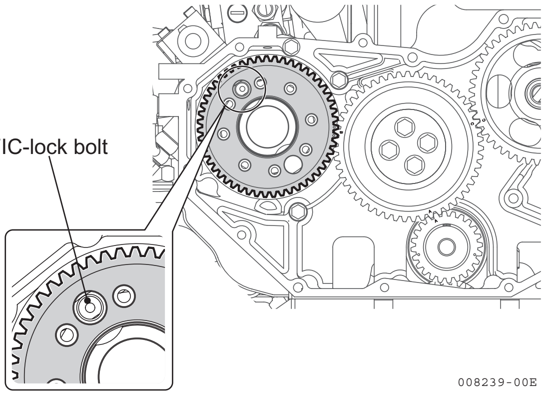
13) Insert the damper shaft, while aligning the FIC-lock bolt holes.
Tighten the damper shaft together with the pump gear while pushing the fuel injection pump gear in the counterclockwise so that both teeth of pump gear and idle gear may touch each other.

(with lube oil)

Tightening torque: N•m (kgf•m)	M8 bolt	36.8±2 (3.8±0.2)

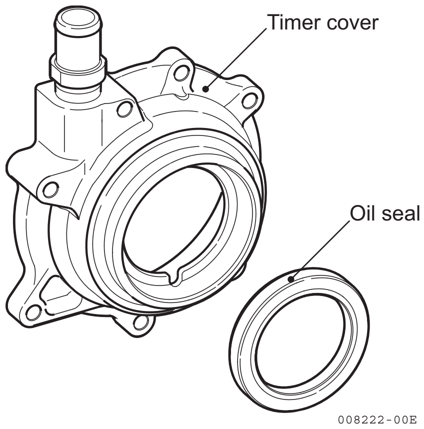


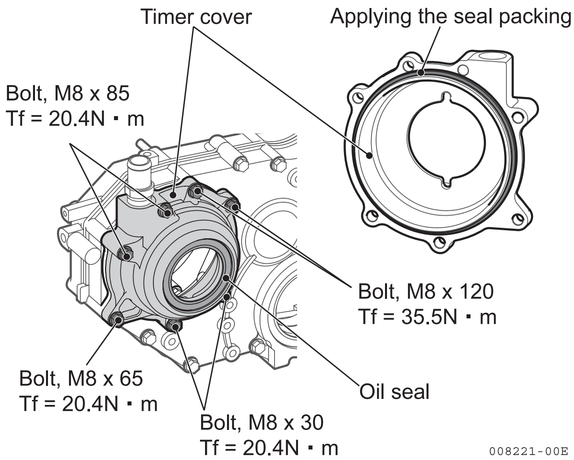
14) Remove a FIC-lock bolt and a collar.



15) Insert a new oil seal in the timer cover.

[NOTICE]
When removing an oil seal, replace it with new one.
Apply a liquid-packing (1207 C of Three Bond) to the mounting surface of the timer cover.
Install the timer cover in the gear case and tighten.





6.1.7 Troubleshooting of fuel injection pump

Complete repair means not only replacing defective parts, but finding and eliminating the cause of the trouble as well. The cause of the trouble may not necessarily be in the pump itself, but may be in the engine or the fuel system. If the pump is removed prematurely, the true cause of the trouble may never be known. Before removing the pump from the engine, at least go through the basic check points given here.
Basic checkpoints

- Check for breaks or oil leaks throughout the fuel system, from the fuel tank to the nozzle.
- Check the nozzle spray.
- Check the fuel delivery Is it in good condition? Loosen the fuel pipe connection at the injection pump inlet, and test operate the fuel feed pump.

Major faults and troubleshooting

Fault		Cause	Remedy
1. Engine won't start.	Fuel not delivered to injection pump.	(1) No fuel in the fuel tank. (2) Fuel tank cock is closed. (3) Fuel pipe system is clogged. (4) Fuel filter element is clogged. (5) Air is sucked into the fuel due to defective connections in the piping from the fuel tank to the fuel pump. (6) Defective valve contact of feed pump. (7) Piston spring of feed pump is broken. (8) Inter-spindle or tappets of feed pump are stuck.	Re-supply. Open. Clean. Disassemble and clean, or replace element. Repair. Repair or replace. Replace. Repair or replace.
	Fuel delivered to injection pump.	(1) Plunger is worn out or stuck. (2) Delivery valve is stuck. (3) Control rack doesn't move.	Repair or replace. Repair or replace. Repair or replace.
	Nozzle doesn't work.	(1) Nozzle valve doesn't open or close normally. (2) Nozzle seat is defective. (3) Injection nozzle starting pressure is too low. (4) Nozzle spring is broken. (5) Fuel oil filter is clogged. (6) Excessive oil leaks from the nozzle sliding area.	Repair or replace. Repair or replace. Adjust. Replace. Repair or replace. Replace the nozzle assembly.
	Injection timing is defective.	(1) Camshaft is excessively worn. (2) Roller guide incorrectly adjusted or excessively worn. (3) Plunger is excessively worn.	Replace camshaft. Adjust or replace. Replace plunger assembly.

Fault		Cause	Remedy
2. Engine starts, but immediately stops.		(1) Fuel pipe is clogged. (2) Fuel filter is clogged. (3) Improper air-tightness of the fuel pipe connection or pipe is broken and air is being sucked in. (4) Insufficient fuel delivery from the feed pump.	Clean. Disassemble and clean, or replace the element. Replace packing repair pipe. Repair or replace.
3. Engine output is insufficient.	Defective injection timing and other failures.	(1) Knocking sounds caused by improper (too advanced) injection timing. (2) Engine overheats or emits large amount of smoke due to improper (too delayed) injection timing. (3) Insufficient fuel delivery from feed pump.	Check trouble code. Check trouble code. Repair or replace.
	Nozzle movements is defective.	(1) Defective injection nozzle performance. (2) Nozzle spring is broken. (3) Excessive oil leaks from nozzle.	Repair or replace nozzle. Replace. Replace nozzle assembly.
	Injection pump is defective.	(1) Plunger is worn. (2) Injection amount is not uniform. (3) Injection timings of each cylinder are not even. (4) Delivery packing is defective. (5) Delivery spring is broken.	Replace. Adjust. Adjust. Replace packing. Replace.
4. Idling is rough.		(1) Movement of control rack is defective. Stiff plunger movement or sticking. (2) Uneven injection volume. (3) Injection timing is defective. (4) Plunger is worn and fuel injection adjustment is difficult. (5) Feed pump can't feed oil at low speeds. (6) Fuel supply is insufficient at low speeds due to clogging of fuel filter.	Repair or replace. Adjust. Check trouble code. Replace. Repair or replace. Disassemble and clean, or replace element.
5. Engine runs at high speeds, but cuts out at low speeds.		(1) The electric control system is defective. (2) Control rack is caught and can't be moved.	Inspect and repair. Inspect and repair.
6. Engine doesn't reach max. rpm.		(1) Governor is defective. (2) Injection performance or nozzle is poor.	Check trouble code. Repair or replace.
7. Loud knocking.		(1) Injection timing is too fast. (2) Injection from nozzle is improper. Fuel drips after each injection. (3) Uneven injection. (4) Engine overheats, or insufficient compression.	Check trouble code. Repair or replace nozzle. Adjust. Repair.
8. Engine exhausts too much smoke.	When exhaust smoke is black:	(1) Injection timing is too slow. (2) The amount of injection is uneven. (3) Injection from nozzle is improper.	Check trouble code. Adjust. Repair or replace.
	When exhaust smoke is white:	(1) Injection timing is too fast. (2) Water is mixed in fuel.	Check trouble code. Inspect fuel system.

6.2 Fuel Injection nozzle

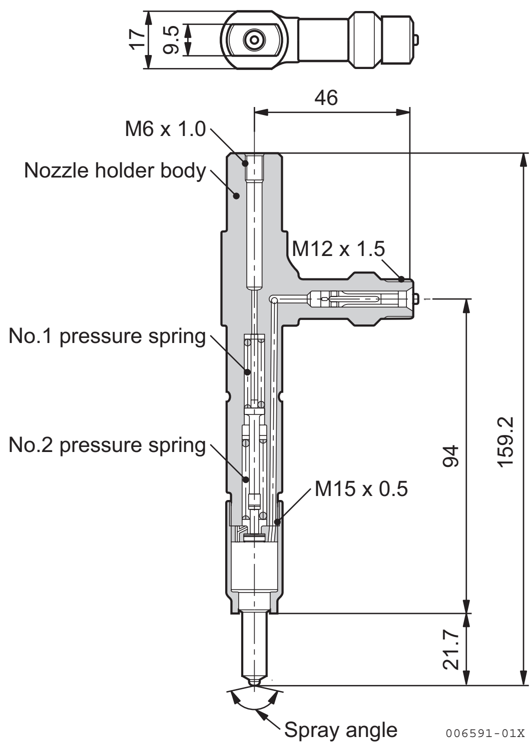
When the high pressure fuel oil reaches the injection nozzle, it pushes up the nozzle valve (held down by spring), and is injected into the combustion chamber at high pressure.
The fuel is atomized by the nozzle to mix uniformly with the air in the combustion chamber. How well the fuel is mixed with high temperature air directly affects combustion efficiency, engine performance and fuel economy.
Accordingly, the fuel injection nozzles must be kept in top condition to maintain performance and operating efficiency.
This engine applies double spring nozzles manufactured by DENSO.

Note:

Don't disassemble the nozzle holder retaining nut at Yanmar workshop. Ask the maintenance to the authorized FIE service shops (Association of Diesel Specialists etc.), which can maintain the DENSO fuel nozzles.

6.2.1 Functioning of fuel injection nozzle

Double spring type fuel nozzle is applied to this engine. Therefore the fuel injection nozzle can injects fuel at the pressures of two step.
Fuel from the fuel injection pump passes through the oil port in the nozzle holder, and enters the nozzle body reservoir.
When fuel oil reaches the specified No.1 pressure (lower), it pushes the nozzle valve up to the pre-lift (held by the nozzle No.1 spring), and is injected through the small holes on the tip of the nozzle body.
When fuel oil reaches the specified No.2 pressure (higher), it pushes the nozzle valve up to the full lift (held by the nozzle No.2 spring), and more fuel is injected in the higher pressure through the small holes.
After fuel is injected, the nozzle valve is automatically pushed down by the nozzle spring and closed.
Fuel oil leaking between the nozzle valve and nozzle body goes to the hole on top of the nozzle holder body and goes back through return pipe to the fuel tank.



Specifications

<table>
<tr><td colspan="2">Engine model</td><td>-</td><td>6LY3-ETP</td><td>6LY3-STP
6LY3-UTP</td></tr>
<tr><td colspan="2">Nozzle I.D. mark</td><td>-</td><td><u>D</u> DLLA155P913</td><td><u>D</u> DLLA155P954</td></tr>
<tr><td colspan="2">Spay angle</td><td>degree</td><td colspan="2">155</td></tr>
<tr><td colspan="2">No. of injection hole and dia.</td><td>mm</td><td colspan="2">7-ø0.26</td></tr>
<tr><td rowspan="2">Nozzle opening pressure</td><td>No.1 pressure</td><td rowspan="2">MPa (kgf/cm^2)</td><td colspan="2">24.00-24.98 (245-255)</td></tr>
<tr><td>No.2 pressure</td><td colspan="2">36.96-38.34 (377-391)</td></tr>
<tr><td rowspan="2">Nozzle lift</td><td>Pre-lift</td><td rowspan="2">mm</td><td colspan="2">0.24-0.30</td></tr>
<tr><td>Full lift</td><td colspan="2">0.33-0.38</td></tr>
<tr><td colspan="2">Body mark</td><td>-</td><td><u>D</u> 8000</td><td><u>D</u> 8090</td></tr>
<tr><td rowspan="3">Tightening torque</td><td>Nozzle holder retaining nut M15</td><td rowspan="3">N•m (kgf•cm)</td><td colspan="2">39.2-49.0 (400-500)</td></tr>
<tr><td>High pressure pipe joint M12</td><td colspan="2">22.5-26.5 (229-270)</td></tr>
<tr><td>Fuel return pipe joint M6</td><td colspan="2">7.0-9.0 (71-92)</td></tr>
</table>

Note:
The fuel injection nozzle for 6LY3-ETP is different in suck volume from that for 6LY3-STP / -UTP.

6.3 Fuel feed pump

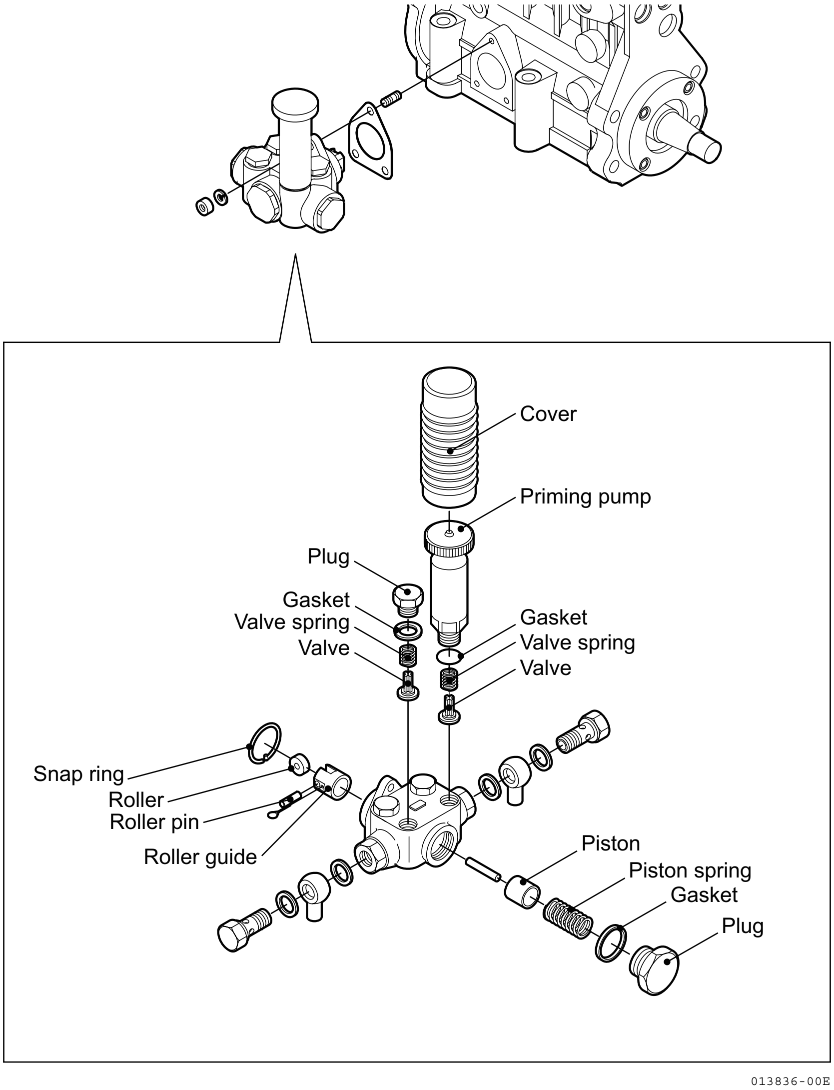
Fuel feed pump design and function

The fuel feed pump consists of a priming pump, which bleeds air from the fuel system and is used manually to feed fuel while the engine is stopped, and a feed pump, which supplies fuel while the engine is running.

The fuel feed pump is driven by an eccentric cam on the fuel camshaft.

When the cam pushes on the piston via the roller guide, the fuel in the piston chamber passes through the discharge valve and flows behind the piston. The suction valve closes under pressure and prevents the fuel from flowing back to the tank.

When the cam is lowered, the piston is pushed back by the piston spring and the fuel behind the piston chamber is forced to the fuel pump. The negative pressure which develops in the piston chamber makes the suction valve open and fills the piston chamber with fuel.



6.3.1 Fuel feed pump specifications

Item	Unit	Standard
Max. suction head of fuel feed pump	m	1.0
Max. discharge volume of fuel feed pump	ℓ/min.	11.4 at camshaft speed 1500 min^{-1}, engine speed 3000 min^{-1}
Max. discharge pressure of fuel feed pump	kPa (kgf/cm^2)	230-370 (2.3-3.8) at camshaft speed 1500 min^{-1}, engine speed 3000 min^{-1}

6.3.2 Fuel feed pump disassembly

Follow the procedure below to disassemble the fuel feed pump.

(1) Remove the piston spring stopper plug, and pull out the piston and piston spring.

(2) Remove the snap ring, and pull out the tappet assembly.

(3) Pull out the inter-spindle.

(4) Remove the priming pump.

(5) Remove the discharge valve spring stopper, and remove the valve and spring from inside.

(6) Remove the O-ring.

6.3.3 Fuel feed pump inspection

(1) Block the priming pump with your finger and check whether the pressed-in piston returns by spring force.

(2) If the piston returns, the piston does not have enough negative pressure. Always replace the priming pump as a set.

(3) Check the piston spring for cuts, cracks, uneven wear and rust.

(4) If the piston, inter-spindle, or tappet assembly are extremely worn, replace the part.

(5) Check the contact surface of the valve and valve seat for defects.

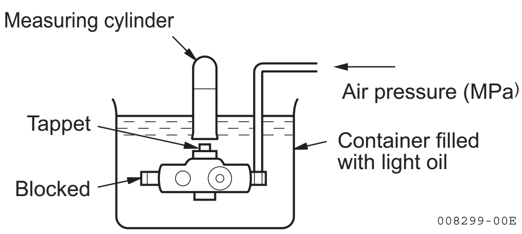
(6) When there is play in a valve seat which has been calked into the feed pump body, the whole fuel pump body must be replaced.

Note:
Play in the valve seat hinders the opening and closing of the valve, causing insufficient fuel supply and abnormal wear of the tappets and camshaft.

6.3.4 Fuel feed pump reassembly

(1) To reassemble the fuel feed pump, follow the assembly procedure in reverse order.

(2) When the pump has been reassembled, perform the air-tightness test.
Apply 0.3MPa (3kg/cm^2) of air pressure to the discharge outlet of the pump, and check for air leaks from the O-ring. If air is leaking, replace the O-ring.

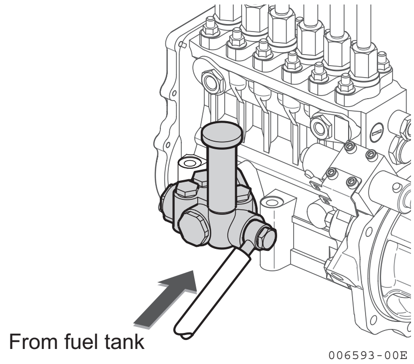


6.3.5 Fuel feed pump adjustment

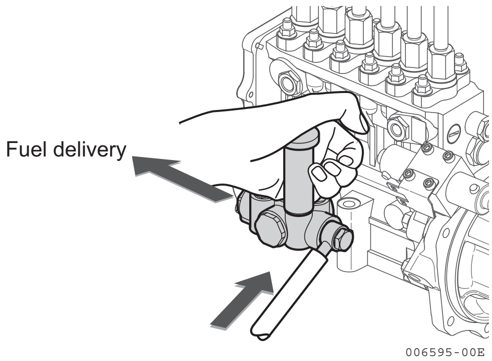
(1) Testing procedures for the fuel feed pump

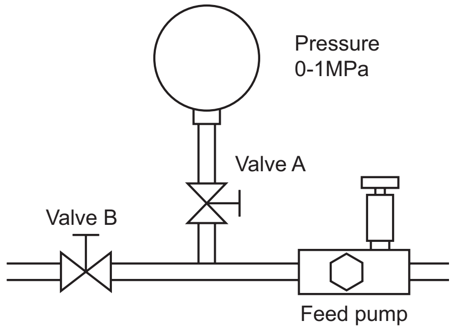
Set the fuel feed pump on the injection pump, and operate the assembled unit on the pump tester.
Fuel piping should be provided directly from the tank, not through the delivery pump for tester.

1) Suction test for the priming pump
Loosen the handle of the priming pump, and push the handle at 60 - 100 strokes / minute. If fuel comes out of the delivery side of the feed pump after about 30 strokes, the priming pump is normal.
If it takes longer, replace the priming pump as a set.



Suction head	1m	Within 30 strokes
Suction pipe dia.	ø8	



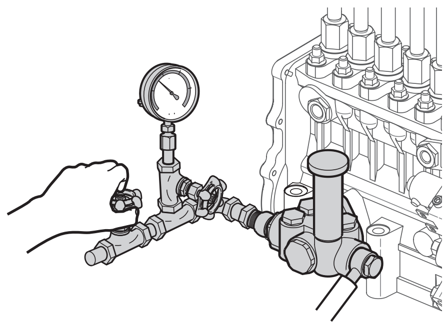


(Equipment for feed pump test)

006596-00E

2) Max. delivery feed volume test
You will need the special equipment for conducting max. delivery pressure and delivery volume tests.

Note:
1. Do not run the equipment for more than 5 minutes since the fuel injection pump may be damaged if operated in noninjection condition.
2. Operate the injection pump at the specified min^{-1}, and read the pressure gauge indicator when valve B is tightened completely. Tighten valve A so that the pressure gauge indicator does not move when the pressure is applied.



(Max. delivery pressure test)

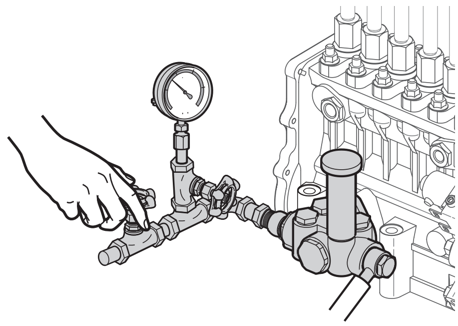
006594-00E

- Volume pressure: 0.22-0.31 MPa
  (2.2-3.2 kg/cm^2)
- min^{-1}: 600

Replace the piston spring if it is defective.

3) Delivery test
Operate the fuel injection pump at the specified min^{-1}, open valve B until the pressure gauge indicator shows 0.1MPa (1kg/cm^2), and measure the delivery rate for one minute.

- Volume (ℓ/min.): over 1.8
- Back pressure: 0.1MPa (1 kg/cm^2)
- min^{-1}: 1000

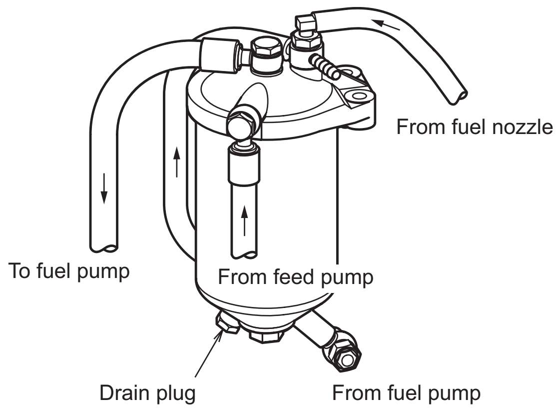


(Delivery test)

006597-00E

6.4 Fuel filter

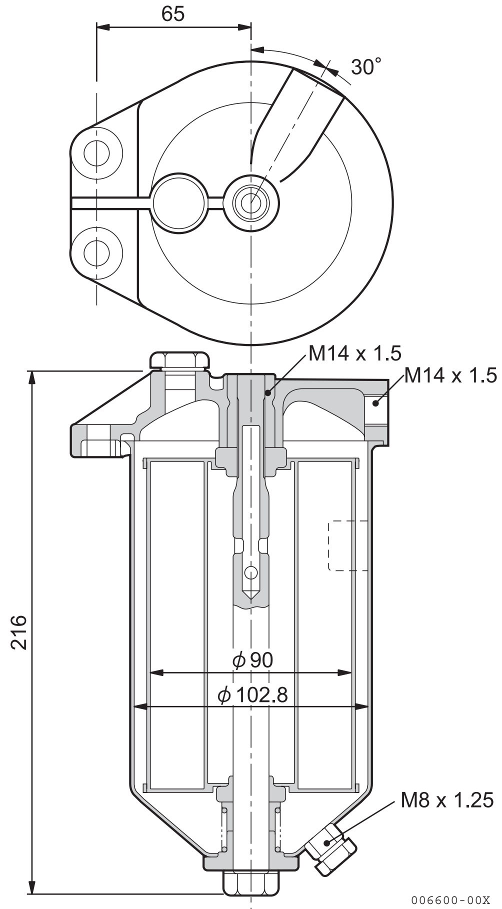
The fuel filter is installed between the fuel feed pump and fuel injection pump, and removes dirt / foreign matter from the fuel pumped from the fuel tank.
The filter element must be changed periodically. The fuel goes around the filter element. The fuel is fed through the pores in the filter and discharged from the center of the cover. Dirt and foreign matter in the fuel are deposited in the filter element.



(Fuel filter)

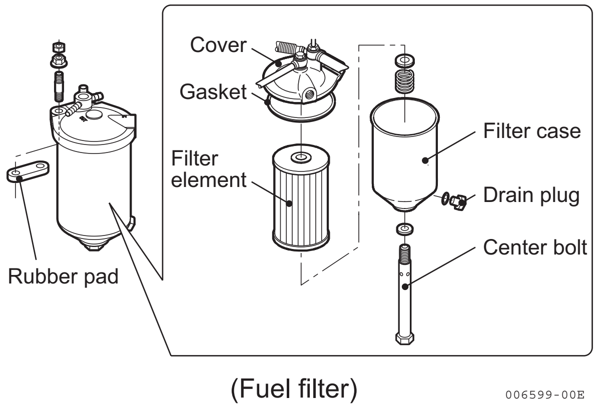
6.4.1 Fuel filter specifications

Part No.	41650-550310
Filtering method	Filter paper element
Filtering area	4000cm^2
Element pore size	Max.45μ, average 35μ



6.4.2 Fuel filter inspection

The fuel strainer must be cleaned occasionally. If there is water or foreign matter in the strainer bowl, disassemble the strainer and wash with clean fuel oil to completely remove foreign matter. Replace the element every periodically.
Replace the filter prior to the periodical maintenance if the filter is very dirty, deformed or damaged.



(Fuel filter)

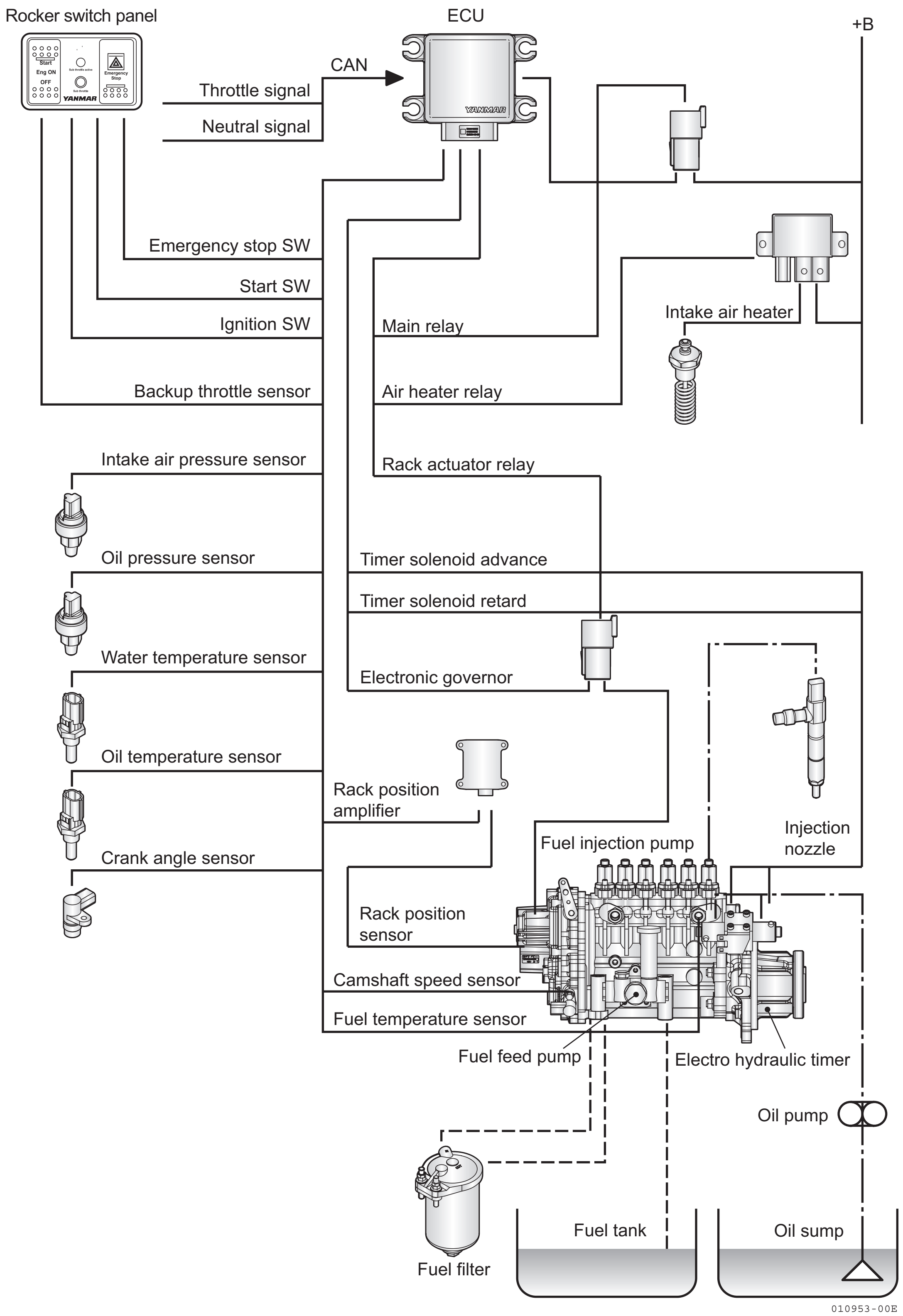
6.5 Electronic Control System

The Electronic Control System (ECS) is applied to the 6LY3 series engines. To work out the ECU the electronic governor and electro-hydraulic timer are attached to the fuel injection pump. Also the ECU (Engine Control Unit, engine interface module), the electronic control equipment, etc. are applied to this engine. The ECU controls the fuel injection quantity and injection timing electronically.

(1) Engine control system diagram

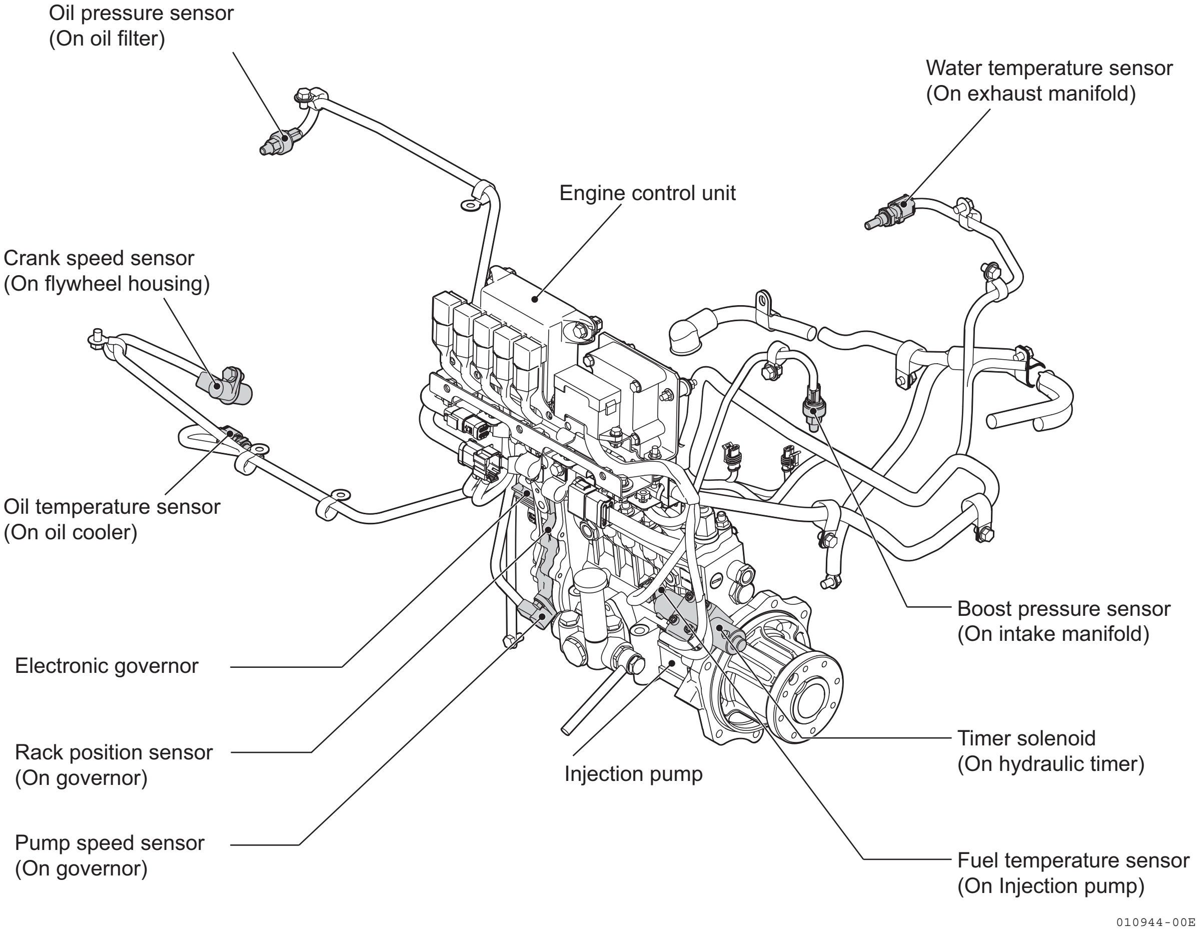
The engine control system diagram is shown below. The ECU (Engine Control Unit) controls the fuel injection quantity and injection timing base on the information such as engine operation (throttle, gear shift, control panel), and engine condition (temperature, pressure etc.).

Engine control system diagram



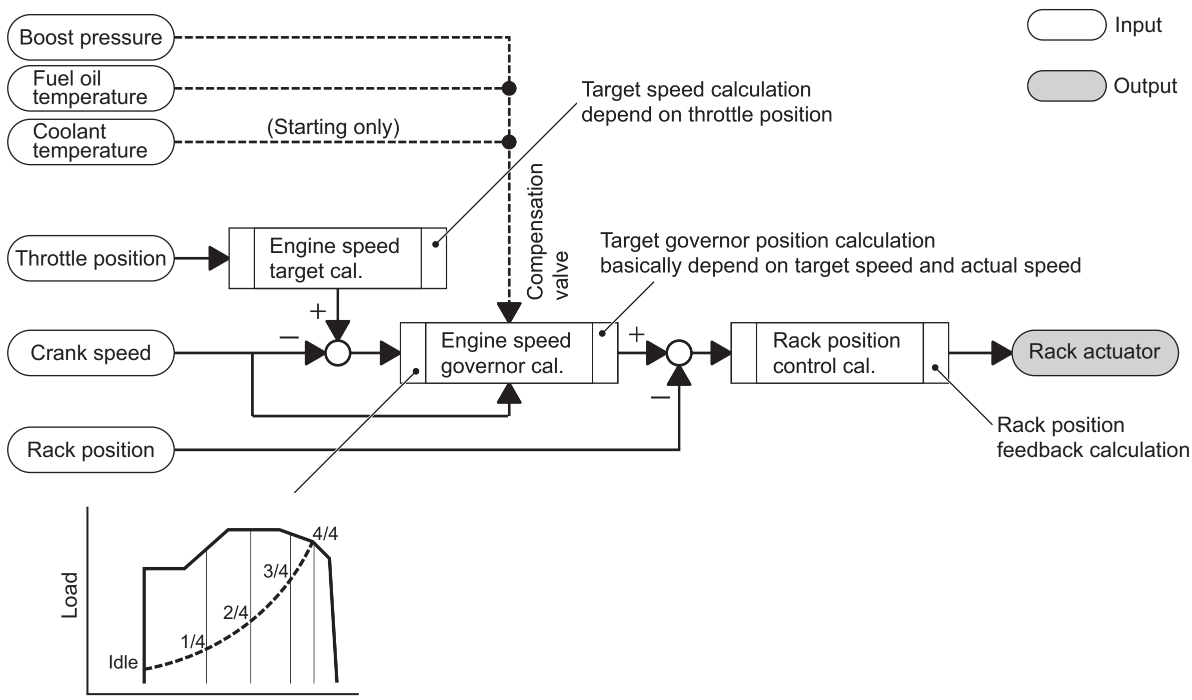
(2) Sensors and actuators

Sensors and actuators are the devices for engine control and monitoring and are laid out to the engine as shown below. The sensors of oil pressure and oil temperature are installed for the purpose of monitoring and warning to vessel owners.



(3) Injection quantity control diagram

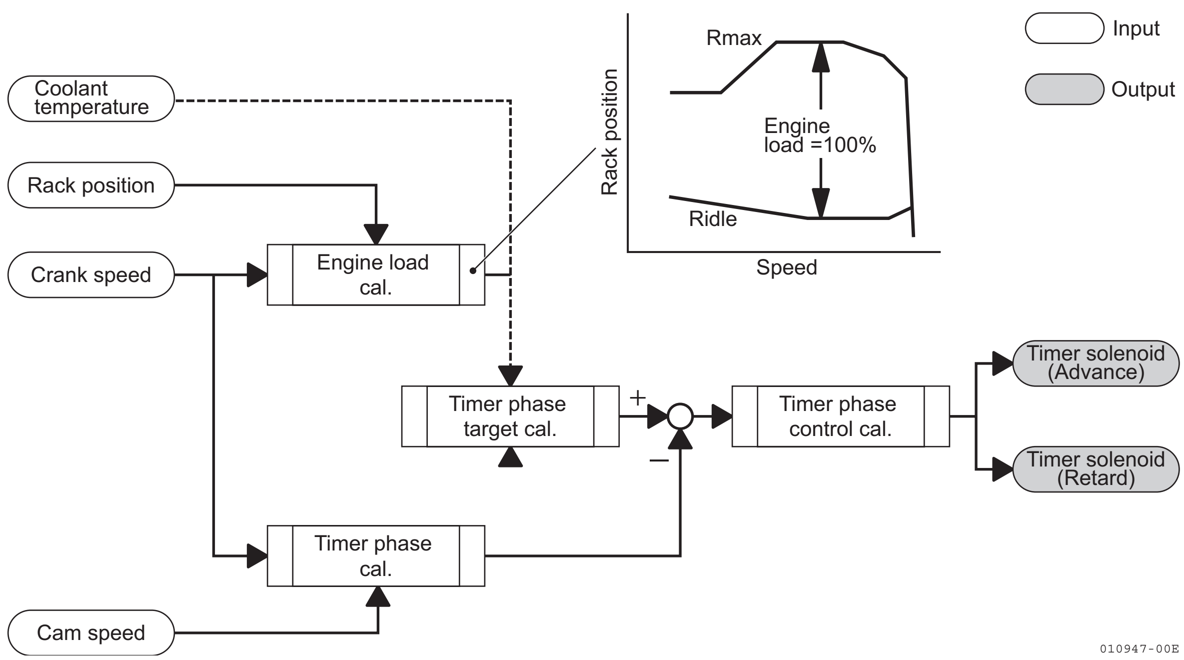
The ECU (Engine Control Unit) controls the fuel injection quantity and injection timing. Injection quantity control is done through rack position control of the fuel injection pump. The injection quantity control diagram by ECU is shown below.



010945-00E

(4) Injection timing control diagram

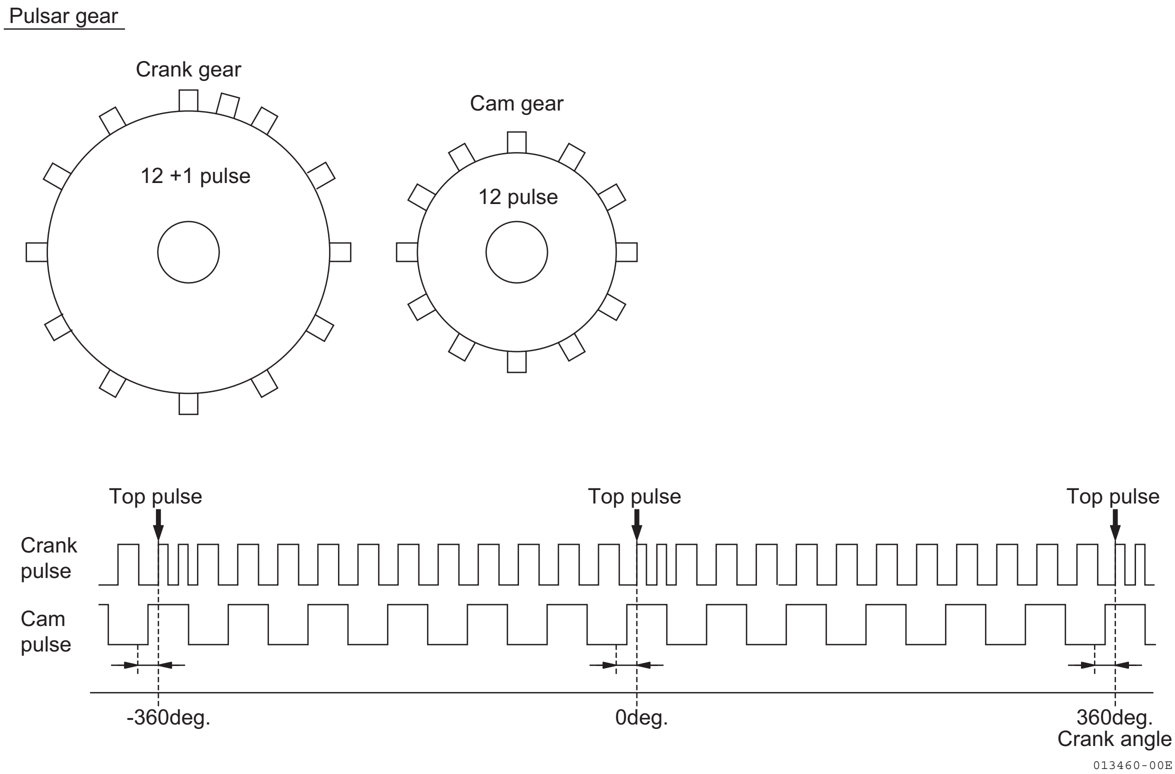
Injection timing is controlled as a timer phase, which is the torsion angle between the pump camshaft and pump drive gear. The injection timing control diagram by ECU is shown below.



010947-00E

The timer phase is detected by two pulsar gears and is calculated by ECU from the deviation of two pulses.
Pulsar gear of crankshaft is on the flywheel.

Timer phase detection

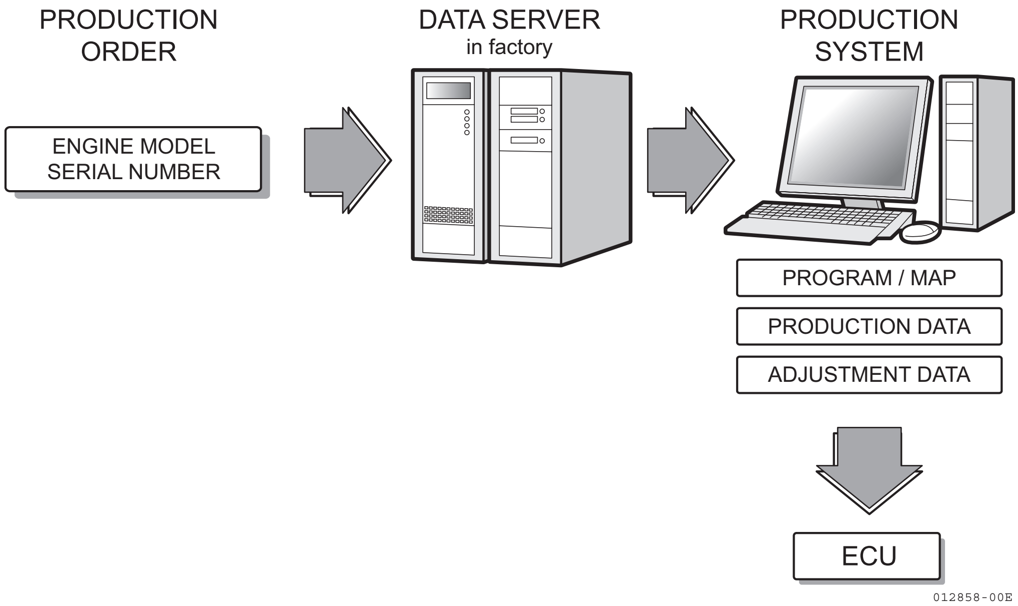


(5) ECU control data management

In order to prevent the misuse or illegal operation of an engine's control system, the control program and data are managed by a production system. In addition, Yanmar's production data management system can provide the correct data for replacing an ECU and / or an fuel injection pump when it is necessary.

1) ECU control data management in factory

The flow of ECU control data management in factory is shown below. Control program, data map, and data are assigned to a part number for each engine model. Engine production data and adjustment data are specific for each engine and injection pump. The ECU control data for each engine is stored in the factory server after running test in factory.



2) ECU control data management in service shop
Figure below shows the ECU control data flow within a service shop when **injection pump replacement** is required. In case of replacing a fuel injection pump, the ECU of the engine must be rewritten by the Pump Adjustment Data by using a service tool. The rewriting of the ECU control data is performed by Yanmar authorized personnel when replacement of an ECU or its components is necessary.

Note:
1. Data rewriting is permitted only by authorized persons who Yanmar decided.
2. Data rewriting is performed by using service tool, which is originally developed by Yanmar. Service tool consists of pc-software, engine-interface and connections.
3. Service tool requires password to handle these data.

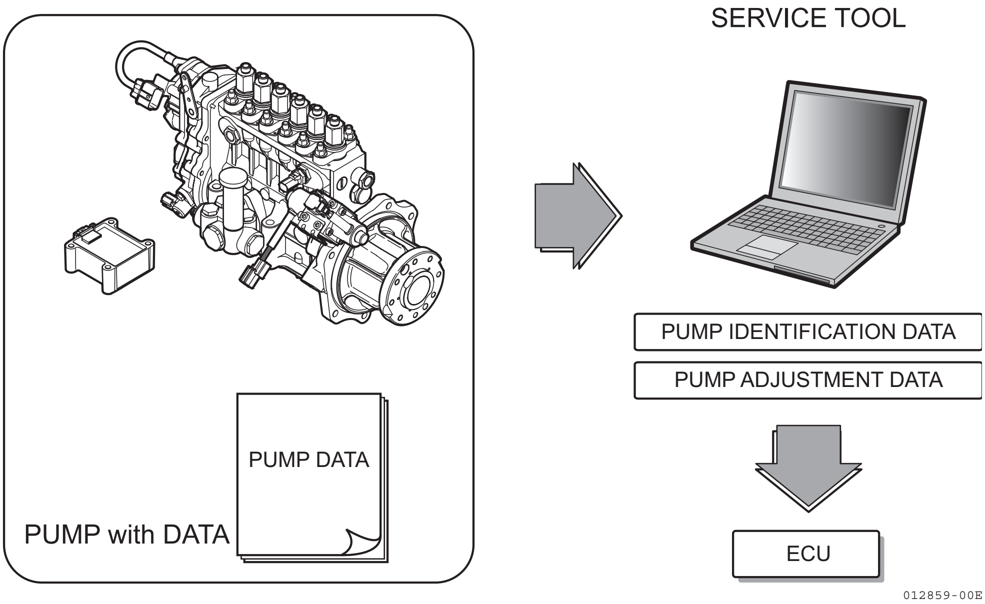
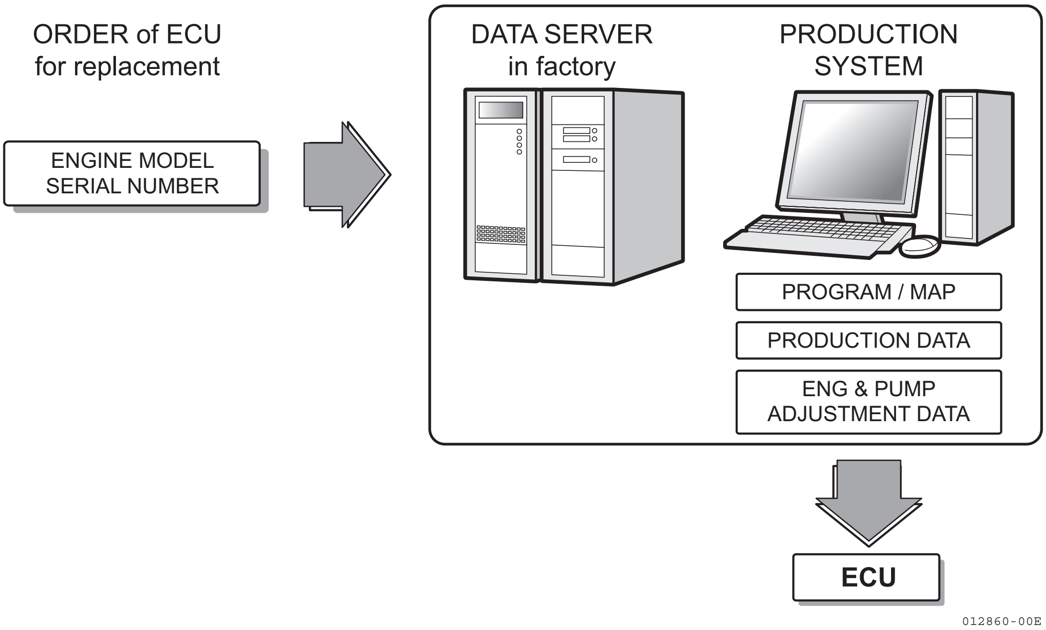


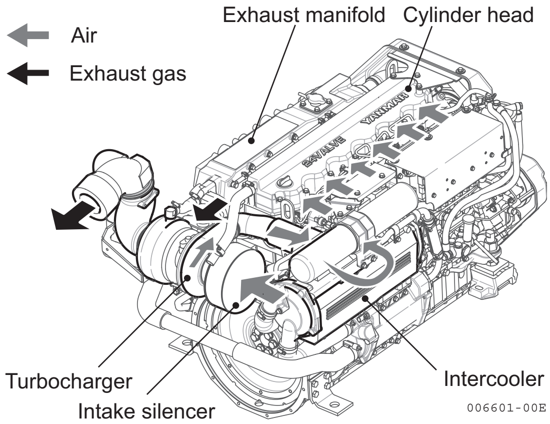
Figure below shows the ECU control data flow when **ECU replacement** is required. When an ECU is ordered to the factory, the ECU control data is selected according to the engine identification information such as engine serial number, pump serial number, etc. Then an ECU is provided directly by the factory. The data is stored into the production system network.



7. Intake and exhaust system

7.1 Intake system

Air enters in intake silencer mounted at turbocharger. It is fed to intake manifold through turbocharger and intercooler and then on to each cylinder.
When the inside of the intake manifold becomes dirty, intake air resistance increases and reduces engine power. Periodically check the inside of intake manifold. In the same way, the net portion of intake air silencer should be checked for dirt periodically and cleaned.
When installing intake manifold to cylinder head, the attachment surfaces should be checked for dirt and cleaned. Care should also be taken to insure there is no air leakage.
Do not operate with intake air silencer removed.



7.2 Exhaust system

Exhaust gas goes into turbocharger through exhaust manifold (in coolant tank) mounted on cylinder head. The exhaust gas enters the mixing elbow, which is connected with turbocharger, and is discharged from the ship along with seawater.

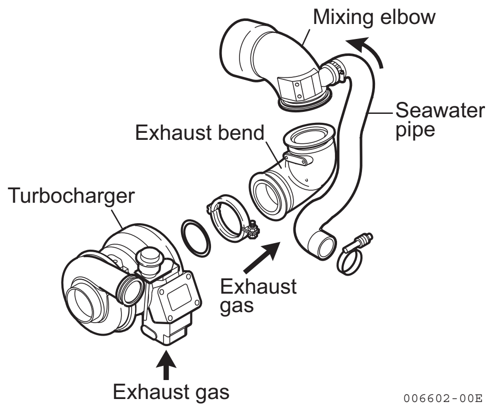
7.2.1 Mixing elbow inspection

The mixing elbow is attached to the exhaust outlet of turbocharger. After long time use, check and clean the mixing elbow with the following procedures.

(1) Clean dirt and scale out of the gas and seawater lines.

(2) Repair crack or damage to welded part, or replace.

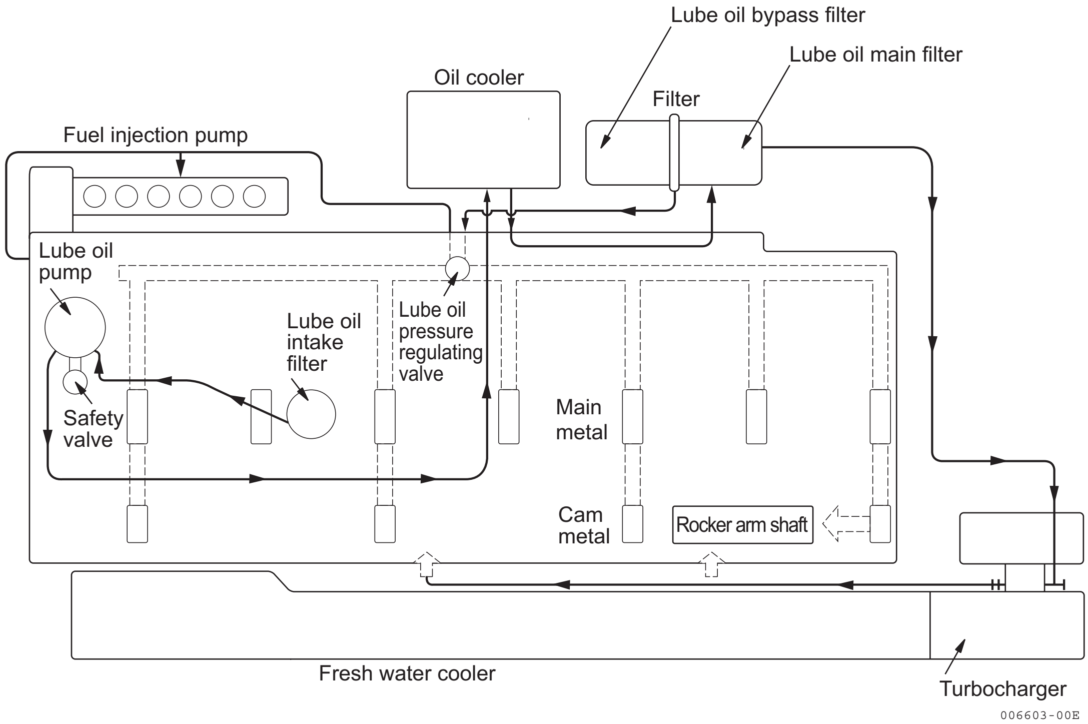
(3) Inspect the gasket and replace as necessary.



8. Lubrication system

8.1 Lubrication system

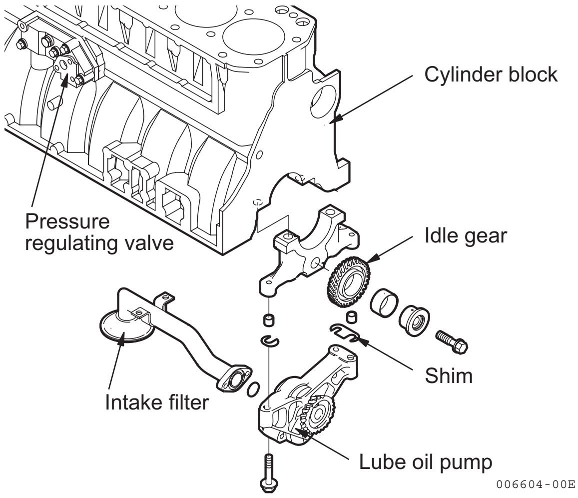
The lube oil in the oil pan is pumped up through the intake filter and intake piping by the lube oil pump. The lube oil is sent to the oil cooler and the lube oil filter. The lube oil is sent to the pressure regulating valve, which controls the lube oil pressure. Then it goes through the holes in the cylinder body and on to the parts to be lubricated. The lube oil pressure is regulated by safety valve first, then by pressure regulating valve.
The lube oil, which flows in the main gallery, goes to the crankshaft journal and lubricates the crank pin from the crankshaft journal.
Lube oil for the fuel injection pump is sent by pipe from the main gallery to the fuel injection pump.
Lube oil for the turbocharger is sent by pipe from the lube oil filter to the turbocharger.



8.2 Lube oil pump

8.2.1 Lube oil pump construction

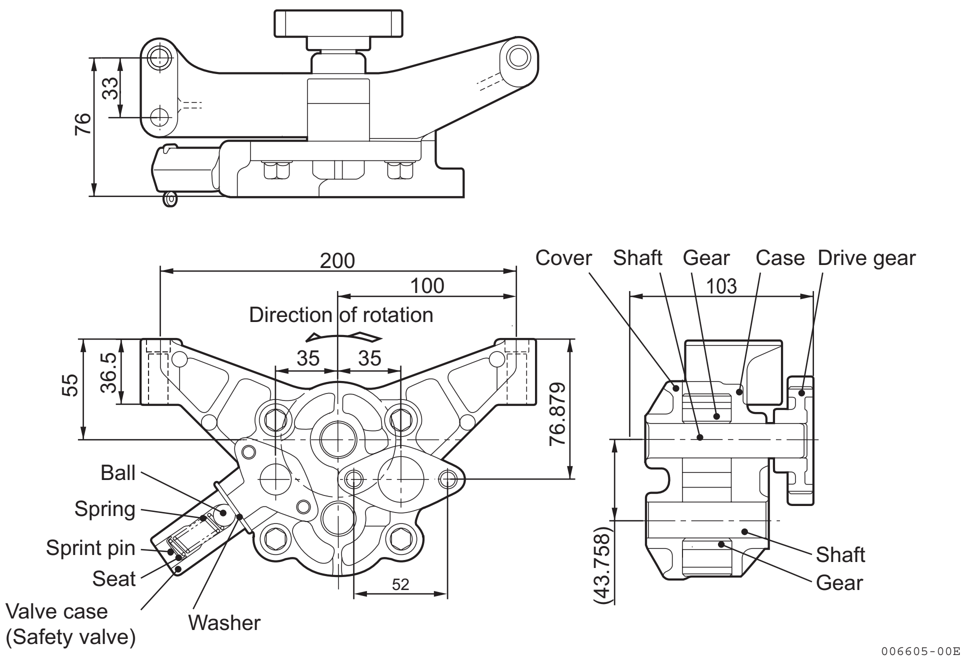
The gear-type lube oil pump is mounted on the cylinder block, and the pump is driven by the crankshaft gear through idle gear. A pressure regulating valve is located on cylinder block behind lube oil cooler.



8.2.2 Specifications of lube oil pump

Pump test performance	
Theoretical delivery	32.8 cc/rev
Delivery	94.5 L/min or more
Delivery pressure (Safety valve)	0.8MPa (8 kg/cm^2)
Pump speed	3200 min^{-1}
Engine speed	3200 min^{-1}

Specification of drive gear	
Module	2.5
Angle of pressure	20°
Number of teeth	24
Standard pitch dia.	66.203 mm



8.2.3 Lube oil pump disassembly and reassembly

Removal

(1) Drain the engine oil.

(2) Remove the oil pan.

(3) Remove the oil inlet and outlet pipes.

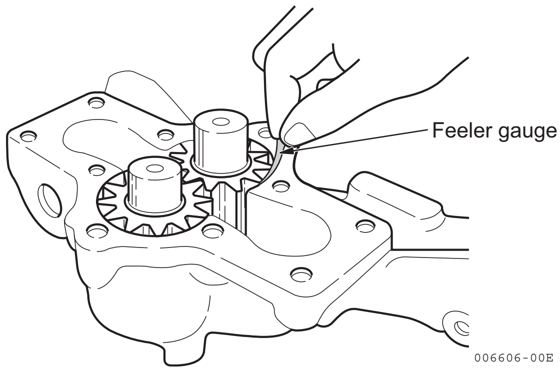
(4) Remove the oil pump.

Inspection

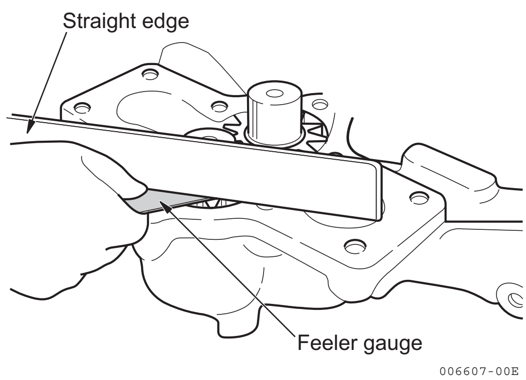
Remove the oil pump cover and measure the oil pump gear-to-oil pump body and the gear-to-cover clearances.
If the measured value exceeds the service limit or if there is local wear, replace the oil pump assembly.

Gear-to-pump clearance
Service limit: 0.098 mm
Gear-to-cover clearance
Service limit: 0.093 mm

Measuring the oil pump gear-to-pump body clearance.



Measuring the oil pump gear-to-pump cover clearance.



Note:
1. The oil pump should be disassembled only when oil pressure does not rise sufficiently even after adjusting with the pressure regulator valve.
2. When assembling, make sure that the drive shaft (gear) rotates smoothly.

Installation

(1) Install the oil pump on the main bearing cap.

Note:

1. Get the surface of the oil pump drive gear and the surface of the idle gear flush and tighten the pump bolts temporarily. Rotate the crankshaft so that the engagement of the teeth is parallel. Then tighten the pump bolts.
2. Check the backlash of the drive gear.
   Backlash: 0.08-0.26 mm.

(2) Use new O-rings and attach the oil inlet and outlet pipes.

(3) Apply liquid sealant and install the oil pan.

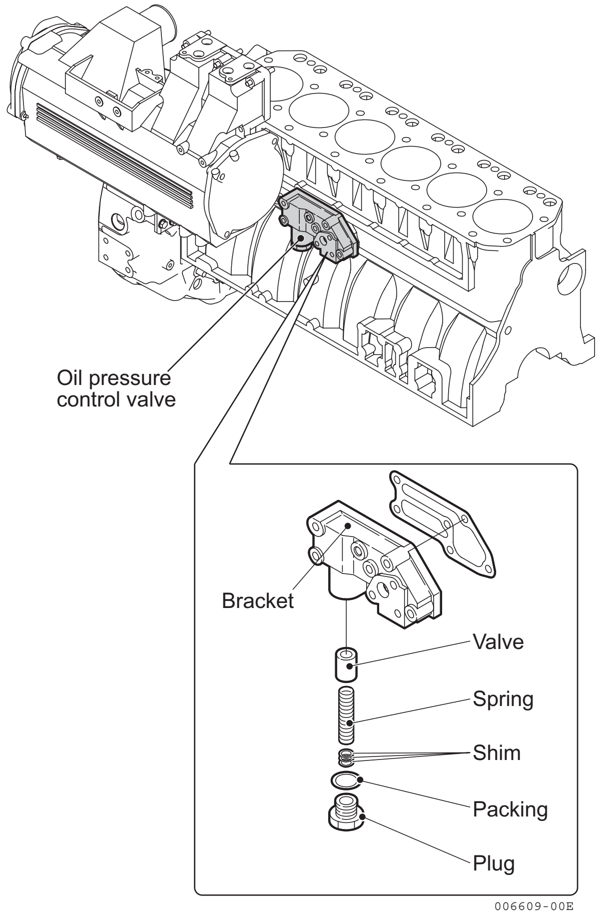
Note:

1. Coat the three faced matching corner with liquid sealant.
2. Tighten after securely matching with the surface of the cylinder block.

(4) Install all drain plugs and pour in the recommended oil to the upper level.

8.2.4 Oil pressure control valve construction

Lube oil travels from the lube oil cooler to the oil filter and sent on to the main gallery of the cylinder body. Adjust the pressure of the valve located just before the entrance to the main gallery.
When the pressure of the lube oil entering the main gallery of the cylinder body exceeds the standard, the pressure control valve piston opens an escape outlet and allows excess oil to drain into the oil pan.



(1) Regulating pressure

MPa (kgf/cm^2)

Regulating pressure (at 3300 min^{-1})	0.40-0.50 (4.1-5.1)

(2) Oil pressure control valve replacement

The control valve has been adjusted and assembled at the factory, so it should not be disassembled without good reason.
If the oil pressure control valve is disassembled due to spring trouble, etc., mount a pressure gauge on the oil pressure sender unit mounting washer, and adjust the pressure with adjustment shims until it is at the specified value.

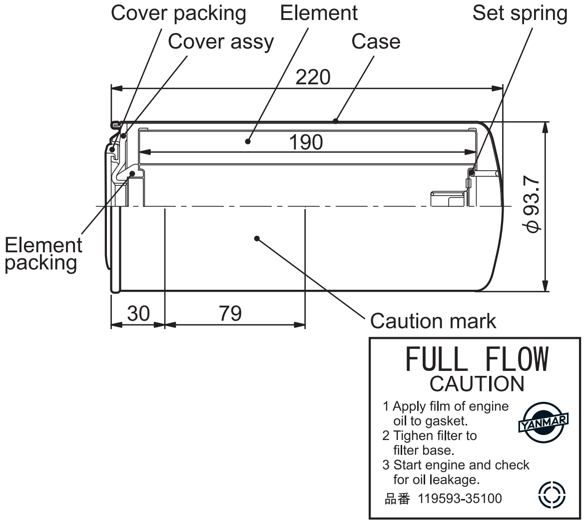
mm

Thickness of shim	0.2, 0.5, 1.0

8.3 Lube oil filter

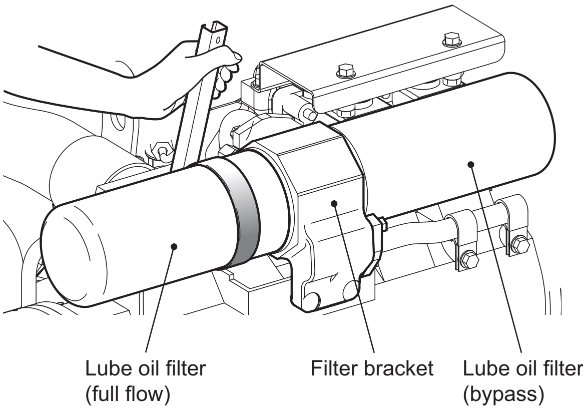
8.3.1 Lube oil filter construction

The lube oil filters are a full-flow paper element type and bypass paper element type, mounted to the top of the intercooler. The cartridge type filter is easy to remove.
To prevent seizure in the event of the filter clogging, a bypass circuit is provided.



(Full-flow lube oil filter)

006610-00E



008227-00E

Specifications

	Full-flow	Bypass
Pressure loss	0.03MPa (0.3kgf/cm^2) or less	3.4 liters/min
	(50 liters/min, SAE#30, 80°C)	Deferential press. In / out 0.44MPa(4.5kgf/cm^2), SAE#30, 80°C
Relief valve pressure (Open)	0.18 ± 0.02MPa (1.8 ± 0.2kgf/cm^2)	-
Filtration area	5800cm^2	5700cm^2
Filtration (nominal)	20μ	1μ

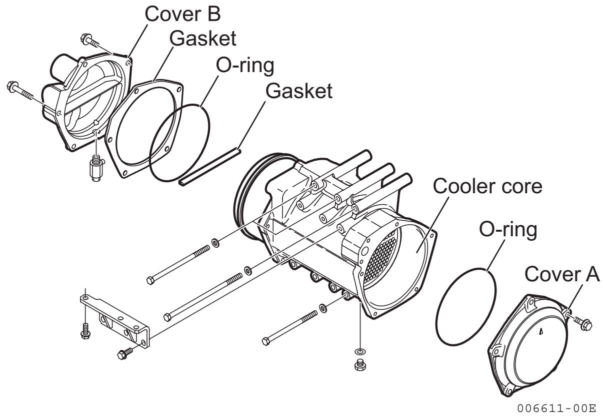
8.3.2 Lube oil filter replacement

Refer to 2.2.2(1).

8.4 Lube oil cooler

8.4.1 Lube oil cooler construction

The lube oil flows through the lube oil cooler and is cooled by the cooling water (seawater) flowing through the cooler core.



8.4.2 Inspecting the lube oil cooler

(1) Clean the inside of the seawater pipes with a wire brush to prevent the build-up of scale.

(2) If the rubber hose connection or welds are corroded, repair or replace the cooler.

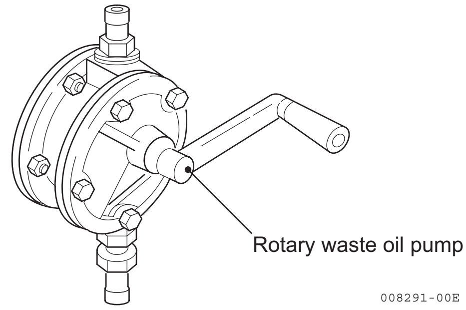
(3) Apply the following water pressures to the seawater and lube oil lines to check for any leakage. Repair or replace the cooler if there are any leaks.

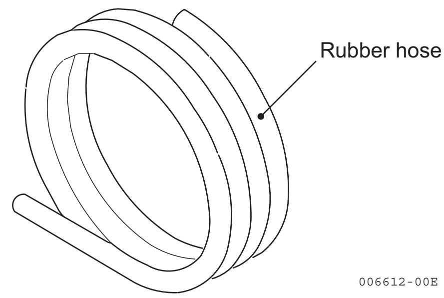
	Test pressure
Lube oil circuit	0.8MPa (8kgf/cm^2)
Seawater path	0.3MPa (3kgf/cm^2)

(4) When cleaning the inside of the tube, use a nylon brush, which will fit inside.

8.5 Rotary waste oil pump (Optional)

A rotary waste oil pump to pump out waste oil during oil changing is available as an option.
This is a vane type pump. Turning the handle rotates the vanes and pumps out lube oil.

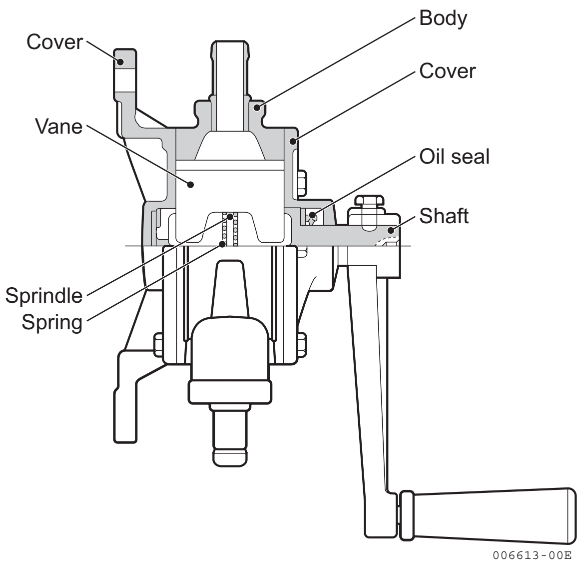




(1) Construction

Rotary waste oil pump

Delivery capacity of one stroke	0.13 L
Delivery pressure	0.15 MPa (1.5 kg/cm^2) or below
Suction head	less than 1 m



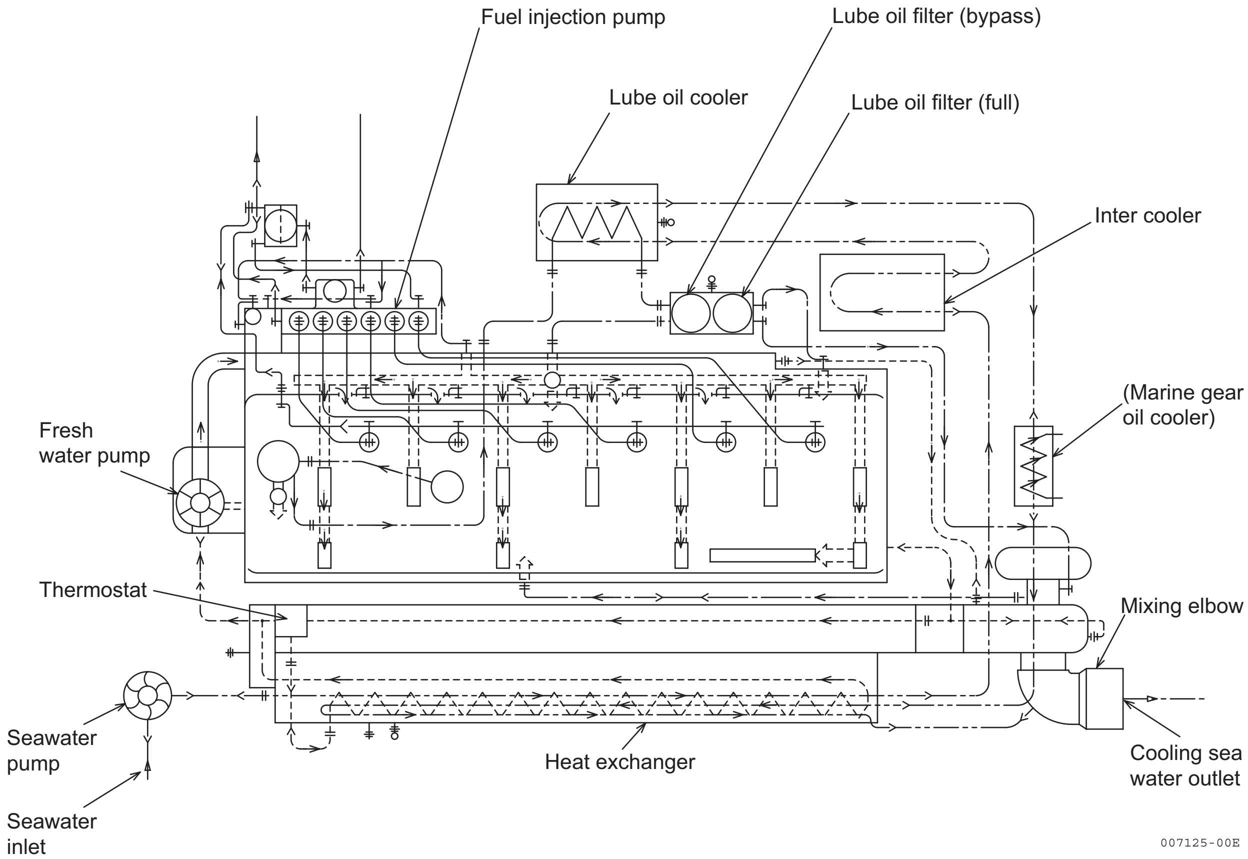
(2) Inspecting the waste oil pump

1) Disassemble the waste oil pump and check for spring breakage or vane damage when there is an extreme drop in discharge volume, and replace if necessary.
2) Replace the oil seal if there is excessive oil leakage from the handle shaft.
3) Replace the impeller if there is an excessive gap between the impeller and the covers on both sides of casing. This will cause a drop in discharge volume.
4) The hose coupling is coated with adhesive and screwed in.
   It therefore cannot be disassembled.

9. Cooling water system

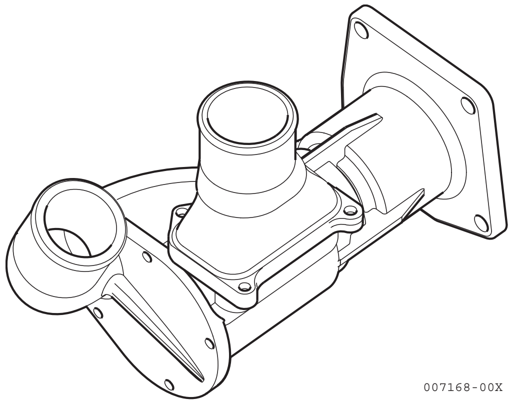
9.1 Cooling water system

The cooling water system is of the indirect seawater cooled, fresh water circulation type. The cylinders, cylinder head, turbocharger and exhaust manifold are cooled with fresh water, and fresh water cooler (heat exchanger), lube oil cooler and inter-cooler use seawater.
Seawater pumped in from the sea by the seawater pump goes to the heat exchanger, where it cools the fresh water. It is sent to inter-cooler and then lube oil cooler. After going to marine gear oil cooler, seawater is sent to the mixing elbow and is discharged from the ship together with exhaust gas.
Fresh water is pumped by the fresh water pump from fresh water / coolant tank to the cylinder jacket to cool the cylinders, turbocharger and then cylinder head. The fresh water pump body also serves as a discharge passageway (line) at the cylinder head outlet, and is fitted with a thermostat.
The thermostat is closed when the fresh water temperature is low, immediately after the engine is started and during low load operation, etc. Then the fresh water flows to the fresh water pump inlet, and is circulated inside the engine with passing through the heat exchanger.
When the temperature of the fresh water rises, the thermostat opens, fresh water flows to the heat exchanger, and it is then cooled by the seawater in the tubes as it flows through the cooling pipe. The temperature of the fresh water is thus kept within a constant range by the thermostat.



9.2 Seawater pump

The seawater pump has a rubber impeller. The seawater pump is mounted to the gear case and is driven by a gear.



9.2.1 Specifications of seawater pump

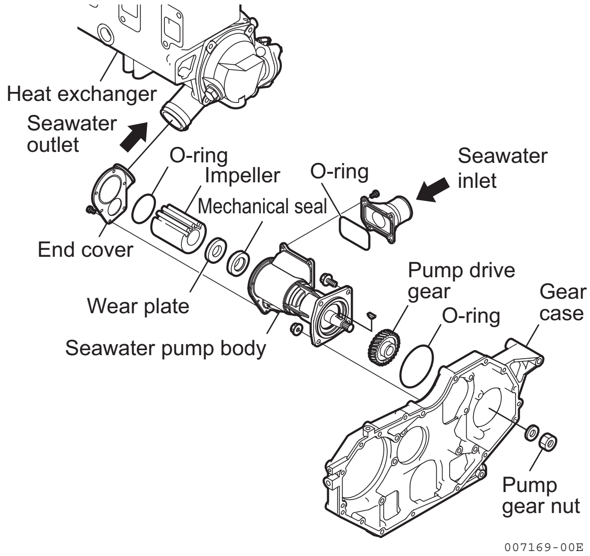
(1) Performance

Flow	Min. 215 L/min at pin = -0.4 bar pout = 1.2 bar n = 2933 min^{-1} after 100h duty
Self-priming ability	Max. 10 sec. at suction head = 0.5m length of pipe = 0.6m n = 622 min^{-1}
Tightness test	4bar water Leakage from seal: max. 0.03%

(2) Durability

• Impeller • Flow drop	Min. 1500h Max. 10% after 1000h
Lip seal, water	Min. 1000h
End cover, wear plate	Min. 1500h
Other parts	Min. 3000h

9.2.2 Seawater pump disassembly



(1) Remove the rubber hose from the seawater pump outlet and then the seawater pump assembly from the gear case.

(2) Remove the seawater pump end cover and take out the O-ring, impeller and wear plate.

(3) Remove the mechanical seal side stop ring.

(4) Insert pliers from the drive gear long hole and remove the stop ring that holds the bearings.

(5) Lightly tap the pump shaft from the impeller side and remove the pump shaft, bearings, and drive gear as a set.

(6) Remove the lip seal and mechanical seal if necessary.

9.2.3 Seawater pump Inspection

(1) Rubber impeller

If there is damage or wear on the impeller, replace it.

(2) Wear plate

Inspect the wear plate, and if the side surface is worn or if it is deformed, replace it.

(3) Pump housing

If there is excessive wear on the inner surface of the housing or on the sliding surface of the impeller, replace it.

(4) Mechanical seal

If there is a large amount of water leakage from the drain pipe replace the mechanical seal. (Cooling water leakage: less than 3cc/h)

Note:

1. Be careful not to damage each sliding surface while replacing
2. Coat the sliding surface of the mechanical seal with a small amount of high quality silicon oil to prevent early leakage due to insufficient fit.
3. Coat the seal bore with liquid sealant.

(5) Bearing

Inspect the bearing for wear or damage.

9.2.4 Seawater pump reassembly

(1) When replacing the mechanical seal, coat the sliding surface with a good quality silicon oil, taking sufficient care not to cause any scratches.

(2) When replacing the lip seal, coat with grease and insert.

(3) Mount the pump shaft, ball bearing and gear assembly to the pump unit and fit the bearing stop ring. Be sure not to forget the O-ring when doing this.

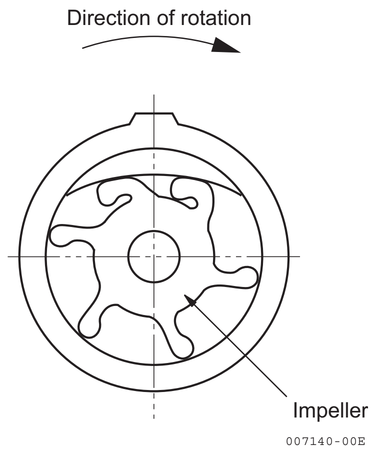
Note:
Coat the shaft with grease.

(4) When removing the pump drive gear, retighten the pump drive gear nut to the specified torque.

Tightening torque	73-83 N•m (7.4-8.5 kgf•m)

(5) After inserting the mechanical seal stop ring, mount the wear plate and impeller.

Note:
1. When inserting the impeller make sure it lies in the proper direction as shown in the right figure.
2. Coat the inside of pump body impeller housing with grease.

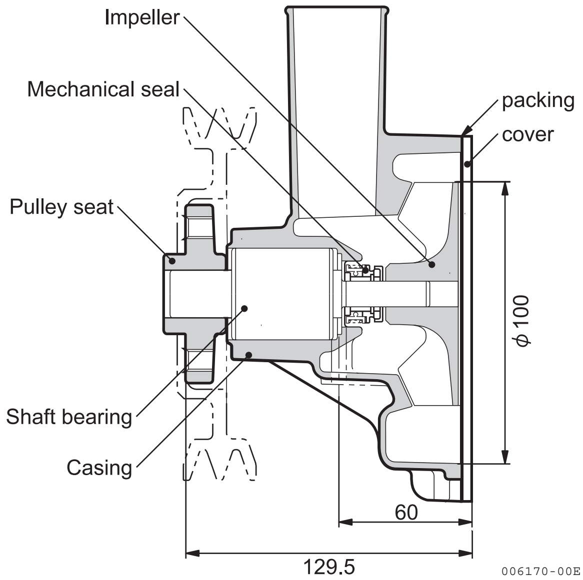


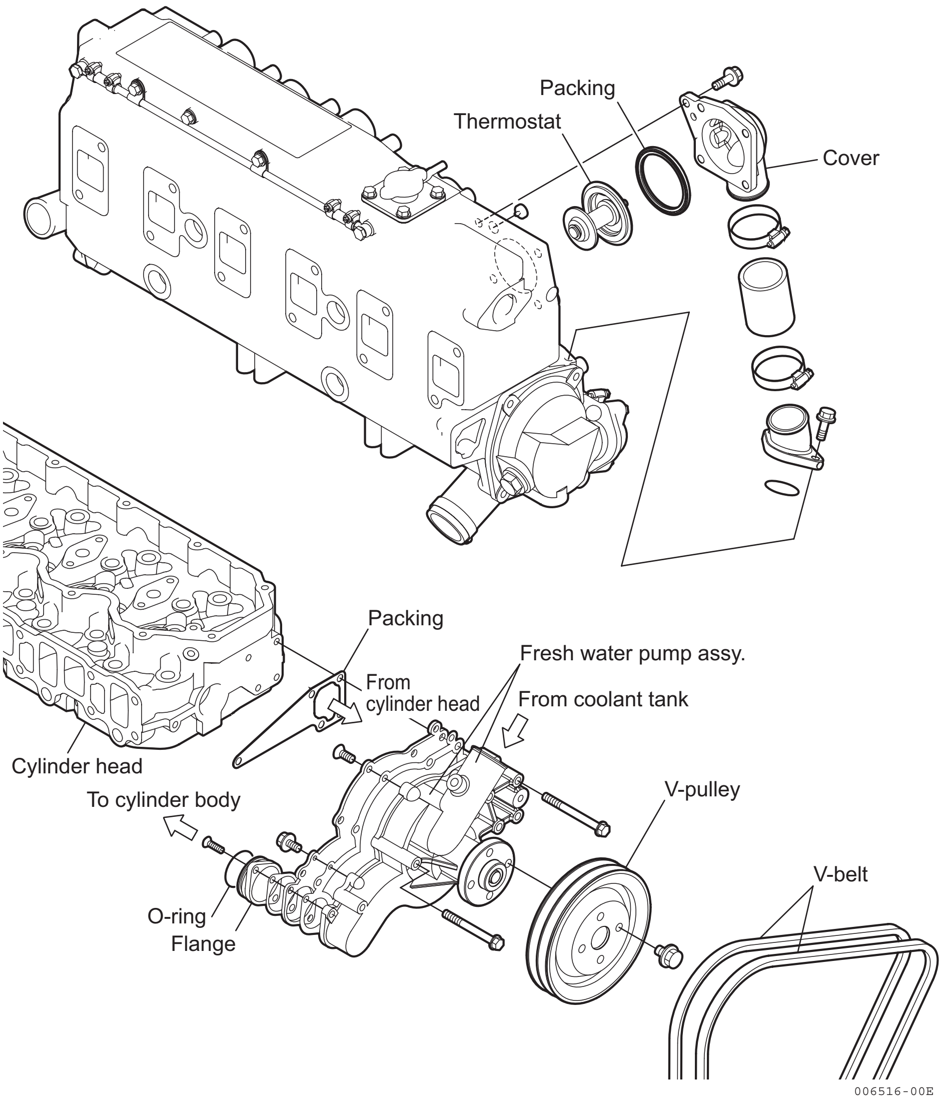
(6) Mount the O-ring between the pump body and end cover.

9.3 Fresh water pump

9.3.1 Fresh water pump construction

The fresh water pump is of the centrifugal (volute) type, and circulates water from the fresh water tank to the cylinders and cylinder head.
The fresh water pump consists of the pump body, impeller, pump shaft, bearing unit and mechanical seal. The V-pulley on the end of the pump shaft is driven by two V-belts from the crankshaft.
The bearing unit assembled in the pump shaft uses grease lubricated ball bearings and cannot be disassembled.
The totally enclosed mechanical seal spring presses the impeller seal mounted on the impeller side away from the pump body side. This prevents water from leaking along the pump shaft.
As the impeller and pulley flanges are press fit assembled, they cannot be disassembled.





9.3.2 Specifications of fresh water pump

Delivery capacity	13200 L/hr. at pump speed 3350 min^{-1}, total head 13 mAq

9.3.3 Fresh water pump disassembly

(1) Do not disassemble the fresh water pump. It is difficult to disassemble and, once disassembled, even more difficult to reassemble. Replace the pump as an assembly in the event of trouble.

(2) When removing the fresh water pump as an assembly from the cylinder and cylinder head, replace the cylinder inlet pipe O-ring.

(3) When the fresh water pump body and cylinder inlet flange and / or fresh water pump and pump plate are disassembled, retighten pump setting bolts to the specified torque.

Tightening torque for pump setting bolts	6.9-10.8 N•m (0.7-1.1 kgf•m)

9.3.4 Fresh water pump inspection

(1) Bearing unit inspection

Rotate the impeller smoothly. If the rotation is not smooth or abnormal noise is head due to excessive bearing play or contact with other parts, replace the pump as an assembly.

(2) Impeller inspection

Check the impeller blade, and replace if damaged or corroded or if the impeller blade is worn due to contact with pump body.

(3) Check the holes in the cooling water and bypass lines, clean out any dirt or other foreign matter and repair as necessary.

(4) Replace the pump as an assembly if there is excessive water leakage due to mechanical seal or impeller seal wear or damage.

(5) Inspect the fresh water pump body and flange, clean off scale and rust, and replace if corroded.

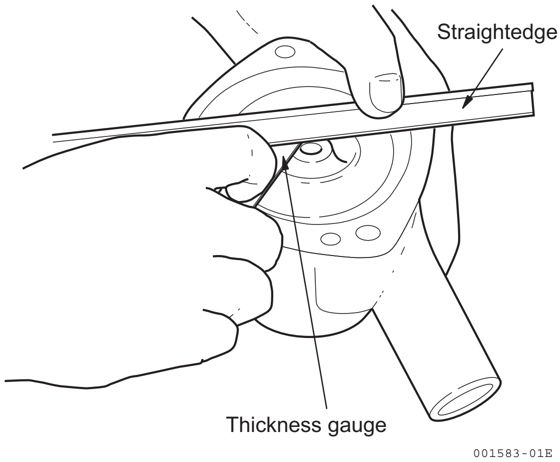
(6) Measure the clearance between the impeller and the pump body by pushing the impeller all the way towards the body, and inserting a thickness gauge diagonally between the impeller and the body.
Measure the clearance between the impeller and the plate (pump body bracket) by placing a straight-edge against the end of the pump body and inserting a thickness gauge between the impeller and the straight-edge.

Measuring clearance between impeller and pump body.

Measuring clearance between impeller and pump body bracket.

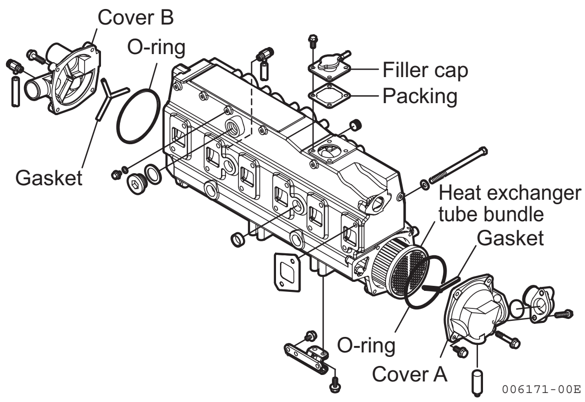
mm

	Standard	Limit
Clearance between impeller and body	0.3-1.1	1.5
Clearance between impeller and plate	1.5	-



9.4 Heat exchanger

9.4.1 Heat exchanger construction



The heat exchanger cools the hot fresh water, that has cooled the inside of the engine, with seawater. The inside of the heat exchanger consists of many small diameter tubes and baffle plates. The fresh water flows through the maze formed by the baffle plates.
There is a reservoir in the upper part of the exhaust manifold, which serves as the fresh water tank. There is an water passageway (line) in the reservoir, which forms a water cooled exhaust manifold.
The filler cap on top of the fresh water tank has a pressure valve, which lets off steam through the overflow pipe when pressure in the fresh water system exceeds the specified value. It also takes in air from the overflow pipe when pressure in the fresh water system drops below the normal value.

9.4.2 Specifications of heat exchanger

No. of tubes	-	214
Tube inner dia.	mm	5.35
Bundle length	mm	687.5
Tube surface area	m^2	2641

9.4.3 Disassembly and reassembly

(1) Remove the heat exchanger from the cylinder head.

Note:
Be careful not to get hurt with the cover A or B.

(2) Remove the cover A & B on both sides and take out the tube bundle (cooler core) and O-rings.

Note:
Replace the O-ring (s) and gasket(s) on both sides with new ones when you have removed the tube bundle.

9.4.4 Heat exchanger inspection

(1) Cooling tubes inspection

1) Inspect the inside of the tubes for rust or scale build up from seawater, and clean with a wire brush if necessary.

Note:
Disassemble and wash when the cooling water temperature reaches 85°C.

2) Check the joints at both ends of the tubes for looseness or damage, and repair if loose. Replace if damaged or corroded.
3) Check tubes and replace if leaking.
4) Clean any scale or rust off the outside of the tubes. When cleaning the inside of the tube, use a nylon brush which will fit inside.

007172-00X

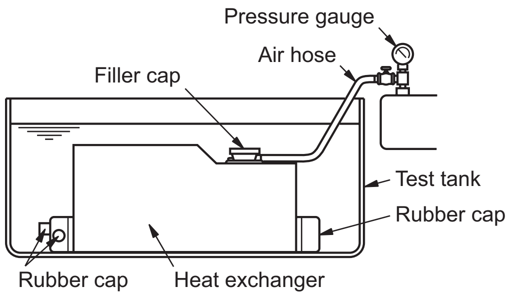
(2) Cooler body inspection

1) Check heat exchanger body and side cover for dirt and corrosion. Replace if excessively corroded, or cracked.
2) Inspect seawater and fresh water inlets and outlets, retighten any joints as necessary and clean the insides of the pipes.

(3) Water leakage test of fresh water cooler body

1) Compressed air / water tank test
Fit rubber covers on inlets and outlets of the fresh water and seawater. Place the fresh water cooler in a water tank, feed in compressed air from plug on seawater inlet(2nd) and check for any (water) leakage, (air bubbles).

Test pressure	0.2 MPa (2 kgf/cm^2)



007152-00E

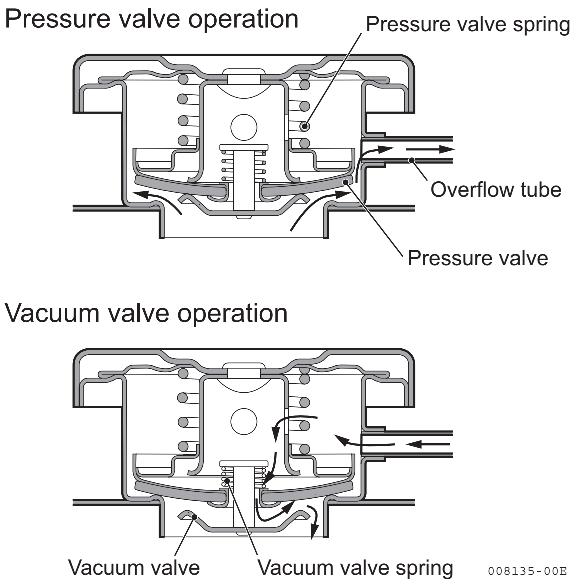
9.5 Pressure cap and coolant recovery tank

9.5.1 Pressure cap construction

The pressure cap mounted on the fresh water filler neck incorporates a pressure control valve. The cap is mounted on the filler neck by placing it on the locking tab and rotating. The top seal of the cap seals the top of the filler neck, and the pressure valve seals the lock seat.

9.5.2 Pressure cap pressure control

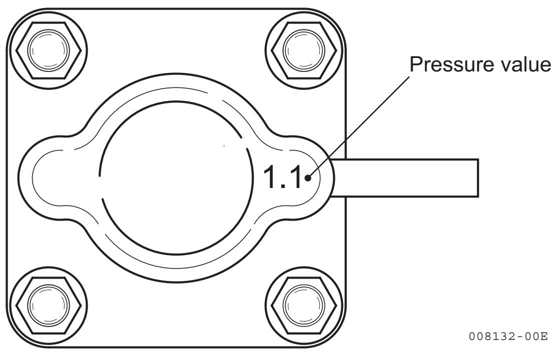
The pressure valve and vacuum seal both seal the valve seat when the pressure in the fresh water system is within the specified value of 0.11MPa(1.1kg/cm^2). This seals the fresh water system.
When the pressure within the fresh water system exceeds the specified value, the pressure valve opens, and steam is discharged through the overflow pipe. When the fresh water is cooled and the pressure within the fresh water system drops below the normal value, atmospheric pressure opens the vacuum valve, and air is drawn in through the overflow pipe.
The coolant recovery tank (which sill be described later), keeps the water level from dropping due to discharge of steam when the pressure valve opens.



Action of pressure control valve

Pressure valve	Open at 93-123 kPa (0.95-1.25 kgf/cm^2)
Vacuum valve	Open at 5 kPa (0.05 kgf/cm^2) or below

Note:
The pressure cap for 6LY3 is different from that for 6LYA and 6LY2A. The pressure value 1.1 is punched on the top of the cap for 6LY3.



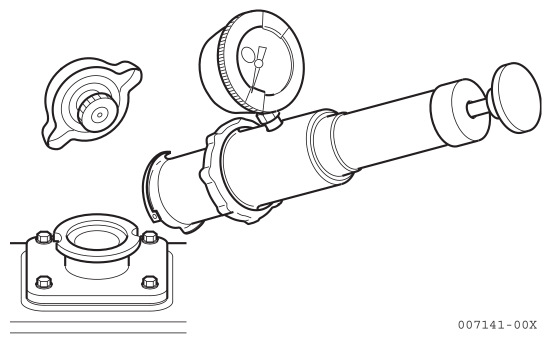
9.5.3 Pressure cap inspection

Precautions
Do not open the pressure cap while the engine is running or right after shutting down because high temperature steam will be blown out. Remove the cap only after the water has had a chance to cool down.

(1) Remove scale and rust, check the seat and seat valve, etc. for scratches or wear, and the spring for corrosion or settling. Replace if necessary.

Note:
Clean the pressure cap with fresh water as it will not close completely if it is dirty.

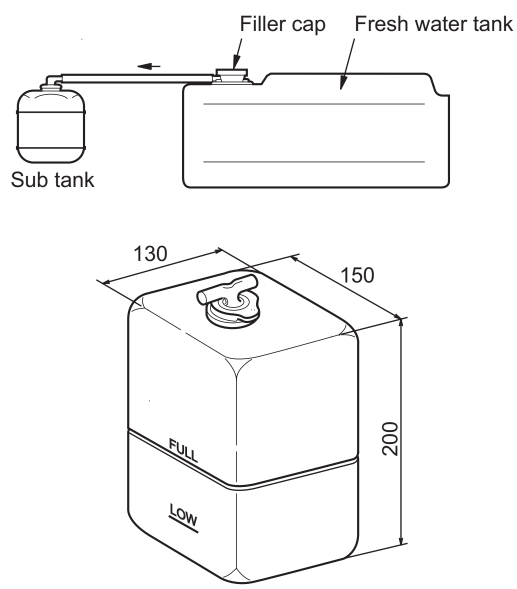
(2) Fit the adapter on the tester to the pressure cap.
Pump until the pressure gauge is within the specified pressure range 93-123kPa (0.95-1.25 kgf/cm^2) and note the gauge reading. The cap is normal if the pressure holds for six seconds. If the pressure does not rise, or drops immediately, inspect the cap and repair or replace as necessary.



007141-00X

9.5.4 Function of the coolant recovery tank

The pressure valve opens to discharge steam when the steam pressure in the fresh water tank exceeds 93-123kPa (0.95-1.25 kgf/cm^2). This consumes water. The coolant recovery tank maintains the water level by preventing this discharge of water.
The steam discharged into the coolant recovery tank condenses into watch, and the water level in the coolant recovery tank rises.
When the pressure in the fresh water system drops below the normal value, the water in the coolant recovery tank is sucked back into the fresh water tank to raise the water back to its original level.
The coolant recovery tank facilitates long hours of operation without water replacement and eliminates the possibility of burns when the steam is ejected from the filler neck because the pressure cap does not need to be removed.



008294-00E

9.5.5 Specifications of coolant recovery tank

Overall capacity	3.4 liter
Full scale capacity	1.5 liter
Low scale capacity	0.43 liter

9.5.6 Mounting the coolant recovery tank

(1) The coolant recovery tank is mounted at approximately the same height as the pressure cap on fresh water tank. (Allowable difference in height: 300mm (11.8110 in.) or less)

(2) The overflow pipe should be less than 1,000mm (39.3701in) long, and mounted so that it does not sag or bend.

Note:
Make sure that the overflow pipe of the coolant recovery tank is not submerged in bilge. If the overflow pipe is submerged in bilge, water in the bilge will be siphoned into the fresh water tank when the water is being cooled.

9.5.7 Precautions on usage of the coolant recovery tank

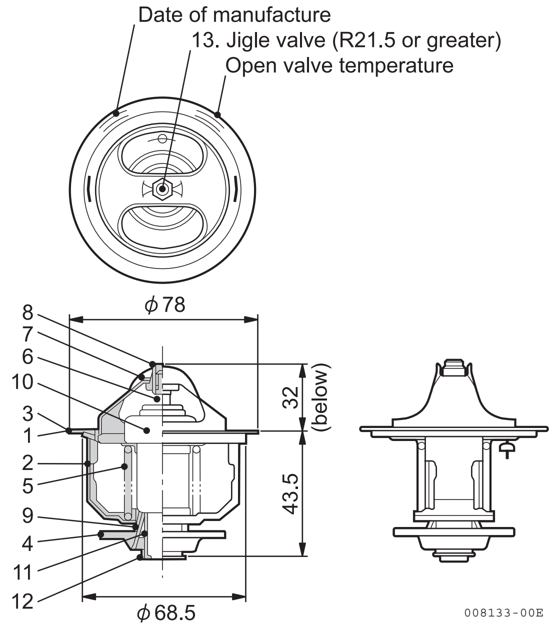
(1) Check the coolant recovery tank when the engine is cool. Refill with fresh water as necessary to bring the water level between the low and full marks.

(2) Check the overflow pipe and replace if bent or cracked. Clean out the pipe if it is clogged up.

9.6 Thermostat

9.6.1 Functioning of thermostat

The thermostat opens and closes a valve according to changes in the temperature of the fresh water inside the engine, controlling the volume of water flowing to the heat exchanger from the cylinder head, and in turn maintaining the temperature of the fresh water in the engine at a constant level.
The thermostat is bottom bypass type. It is located in a position connected with the cylinder head outlet line at the top of the top of fresh water pump unit.
When the fresh water temperature exceeds the above temperature, the thermostat opens, and a portion of the water is sent to the heat exchanger and cooled by sea water, the other portion going from the bypass line to the fresh water pump intake.
The bypass line is closed off as the thermostat valve opens and is completely closed when the fresh water temperature reaches 81.5°C (valve lifts 4mm (0.1575in)), sending all of the water to the heat exchanger.



9.6.2 Thermostat construction

The thermostat used in this engine is of the wax pellet type, with a solid wax pellet located in a small chamber.
When the temperature of the cooling water rises, the wax melts and increases in volume. This expansion and construction is used to open and close the valve.

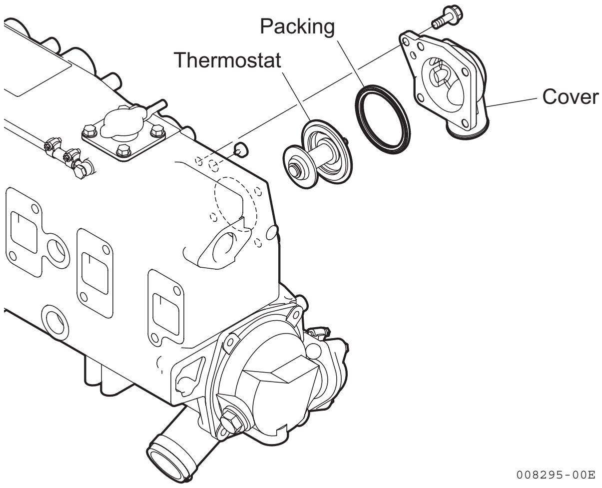
No.	Item	Measurement
1	Seat	t1
2	Attachment frame	t1
3	Valve	t0.8
4	Bypass valve	t0.6
5	Spring	ø3
6	Piston	ø6.4
7	Stopper	ø14
8	Adjustment fittings	ø8
9	Helpers spring	ø1.8
10	Pellet	-
11	Pipe	ø15, t1
12	E snap ring	E9
13	Jigle valve	ø5.3

9.6.3 Characteristics of thermostat

Opening temperature	69-73 °C
Full open temperature	85 °C
Valve lift at full open	10 mm

9.6.4 Thermostat inspection

Remove the thermostat cover on the side of the fresh water tank and take out the thermostat. Clean off scale and rust and inspect, and replace if the characteristics (performance) have changed, or if the spring is broken, deformed or corroded.



9.6.5 Testing the thermostat

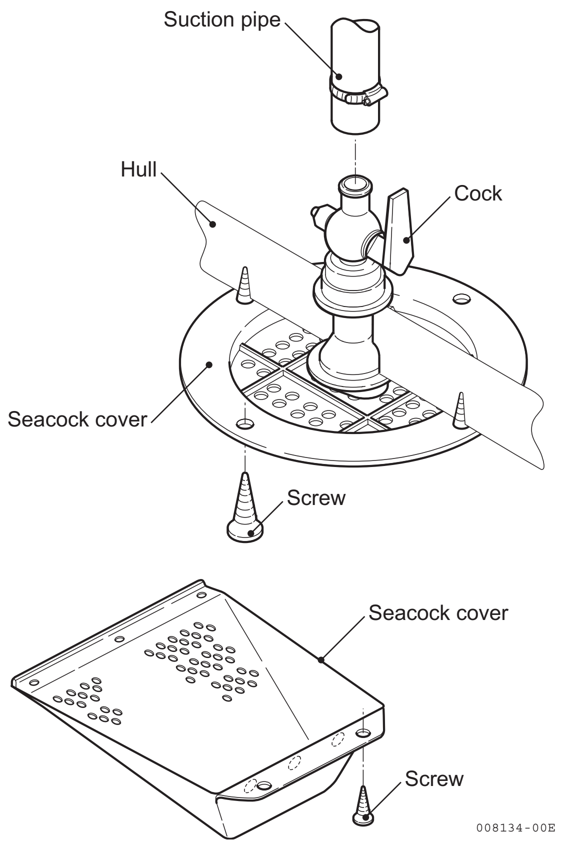
Refer to 2.4 in chapter 2.

9.7 Seacock (Optional)

Construction
The seacock, installed on the bottom of the hull, controls the intake of cooling water into the boat. The seacock serves to filter the water so that mud, sand, and other foreign matter in the water does not enter the water pump.
Numerous holes are drilled in the water side of the seacock, and a scoop strainer is installed to prevent the sucking in of vinyl, etc.

Handling precautions
Cautions the user to always close the seacock after each day of use and to confirm that it is open before beginning operation.
If the seacock is left open, water will flow in reverse and the vessel will sink if trouble occurs with the water pump.
On the other hand, if the engine is operated with the seacock closed, cooling water will not be able to get in, resulting in engine and pump trouble.

Inspection
When the cooling water volume has dropped and the pump is normal, remove the vessel from the water and check for clogging of the seacock.
It water leaks from the cock, disassemble the cock and inspect if for wear, and repair or replace it.



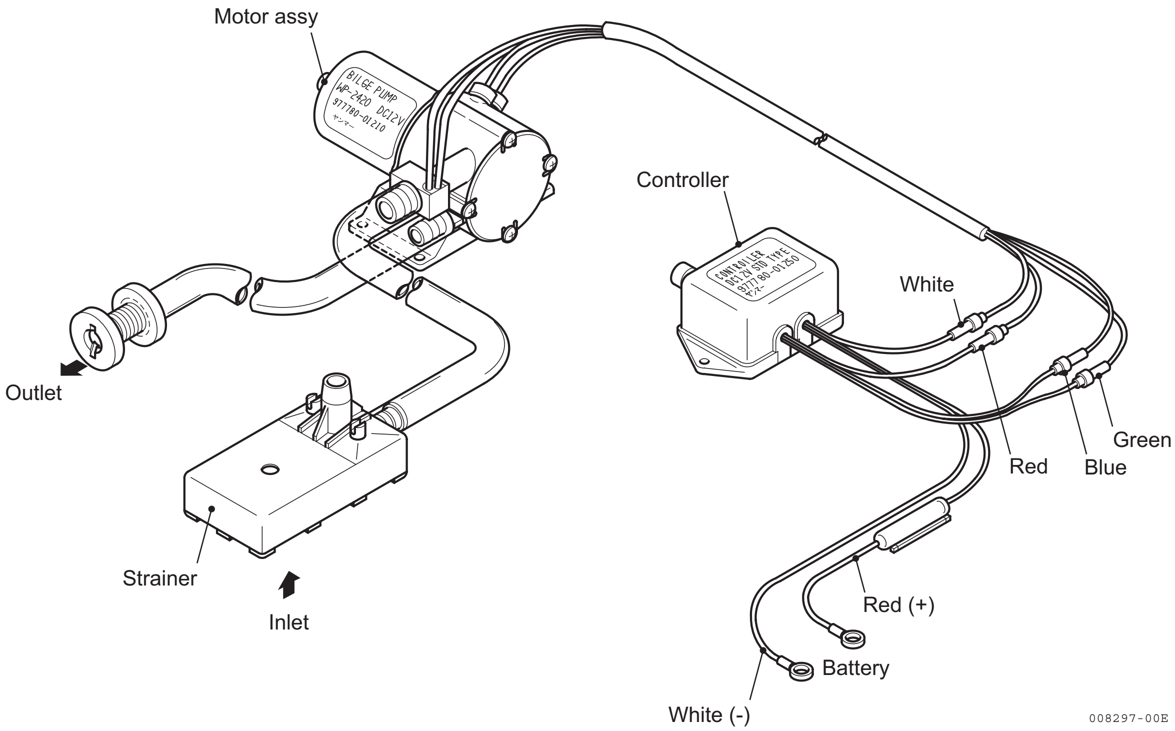
9.8 Bilge pump and bilge strainer (Optional)

9.8.1 Introduction

(1) General introduction

Name	Bilge pump
Time	10 minutes
Rotation direction	Right (viewed from the impeller side)
Negative pressure detector	Diaphragm type
Temperature	-30°C~80°C

(2) Exterior



9.8.2 Description

(1) Characteristics

1) Discharge at lift: 0 m discharge capacity: 20 liters/min. or greater.
2) Automatic feeding height: 1 m or greater (Limit for automatic feeding height: new pump with inside parts wet, approx. 2 m)
3) Automatic feeding time: 2-5secs. (Limit for automatic feeding time: new pump with inside parts wet, approx. 1 sec.)
4) Automatic stopping: Air intake causes negative pressure triggering automatic stopping.

(2) Insulation

1) Insulation resistance: 500V with a megatester when the difference between the continuity point and the body is 1MΩ or greater.
2) Insulation proof stress: AC50 between the continuity point and the body, or 60hz 500V for 1minute when impressed current leakage is 10mA or lower.

(3) Durability

Rated voltage when there is 3% salt water 60ℓ + engine oil 3%, and operation is at 1800 cycles and there are no difficulties.

(4) Vibration proof

Amplitude 0.51mm (one side of the amplitude)
Vibration frequency 10-55Hz
Sweep time 90secs.
Direction of vibration each direction 4 hours
No difficulties after test period

9.8.3 Cautions

(1) Attach at a position higher than the bilge water away from rain or other water, and 50-70cm above the bottom of the boat.

(2) Never run the pump dry. Be sure that the strainer is inserted in the drain water before pushing the switch. If no water is being drawn up after a period of 10 seconds or more, prime the pump. (Do not run the pump for longer than 10 seconds when no water is being drawn up.)

(3) When the pump has not been used for a long period of time, the inside of the pump will be dry and drawing ability will be lowered. Before reusing, clean the inside of the pump or prime it to insure that it is wet, and check to be sure that the pump is then operating correctly.

(4) When charging the diesel engine oil, wait a period of 30 minutes or longer from the time of stopping (oil temperature 20-70°C). Refrain from operation when the oil temperature is below 15°C, or above 50°C.

(5) When the bilge inside the pump or hose freezes, completely melt the water with a steaming towel before beginning operation. When the temperature inside the pump is low, it will take a longer amount of time for the pump to drain off the bilge.

(6) The impeller replacement kit includes one impeller and 3 washers for adjusting the side gap. If after replacing the impeller the pump does not drain, place side gap adjustment washers underneath the bottom plate to adjust. Select the number of washers used in accordance with the following. (When the pump is draining, the electric current load is about 5A. When there are too many washers, the electric current value will be too great and will blow a fuse.)

(7) The pump cannot be used to drain off rain water or large amounts of flood water. The pump can be run continuously for a period of 10 minutes After this time it must shut off for a period of 2 hours before reusing.

(8) Do not use the pump for showering.
If the pump outlet is deformed for showering, the increase in water pressure will increase the load on the motor and cause motor seizure.

(9) Fix the strainer so that it well not turn upside down or on its side.

(10)When sludge has built up in the bilge to be drained, position the strainer about 20mm above the sludge. When the pump is stopped, be sure there is no sludge remaining inside the pump.

(11)The specific gravity for the battery fluid is 1.25 or more.

9.8.4 Assembly procedure

When bilge is being used, assemble in accordance with the following.

(1) Assembling the bilge pump

- Select a dry place above the bilge water level.
- Select the location for the bilge pump taking into consideration the length of the switch cable (approx. 3m) and its attachment point, and the position of the battery.
- Position at a 45°C angle as shown in the illustration with the nozzle facing up, and 50-70cm from the bottom of the boat.

(2) Assembling the switch

- Attach in a place to insure easy operation away from rainwater.
- Connect the terminal to the battery.
  (When the cord will not reach the battery, and extension of no greater than 3, length stable for AV3cm^2 can be attached.)

(3) Positioning the strainer

- Attach at the place where the greatest amount of water is collected when the boat is stopped.
- It is best to place the strainer as close to the bilge pump as possible. Cut the 3m hose to a length of 1.2m-1.8m and attach allowing plenty of give.
- Check the strainer during a test operation before screwing firmly into place.
  (When the strainer is screwed in, be especially careful not to damage the bottom of the boat.)
- The strainer contains a weight, and can be used with the weight in place.
- Always keep the strainer clean.

(4) Attaching the delivery nozzle (outlet)

- Make a fixing hole of ø21 or less for attaching the nozzle. The hose attached at the nozzle should be 1.8m or less and should reach without any strain, therefore care should be taken in deciding on the best position.
- Fix the nozzle (outlet) in place and attach on the discharge side of the pump.

(5) Attaching the hose

- Attach the hose from the strainer to the pump inlet.
- Attach the delivery nozzle hose to the pump outlet.
- Make the hose as short as possible and avoid sharp bends.

(6) Test operation

- Collect water in the bottom of the boat, and check for any problems with the hose or siring. After doing this, connect the battery.
- Turn on the pump switch, and check to see that water is being taken in and discharged properly. The pump will stop automatically when there is no water left.
- If the inside of the pump is dry, or if the water is not being drawn up initially after a period of 10 seconds, lift the strainer above the water surface and stop the pump. Prime the pump before starting it up again.

(7) Fixing the strainer

- After the test operation, fix the strainer into place with screws.
  (Be careful not to damage the bottom of the boat with the screws.)

9.8.5 Cautions for Assembling

Observe the following cautions for handling.

- Do not use gasoline or solvents.
  1.gasoline 2.ester 3.benzol 4.battery fluid 5.liquids at 70°C or greater or engine oil
- Never run when there is no water in the bilge. Check to be sure that the strainer is in the water before turning on the switch.
- Keep the cord terminal away from the water. Water inside the motor or switch may lead to damage. When the insulation around the cord is damaged, water can seep in to the wires; thus, care should be taken not to scratch or nick the cord.
- When the pump has not been used for a long period of time, the inside of the pump will be dry and it may not operate properly at first. If after 10 seconds the pump is not working, turn off the switch and prime the pump before trying again.
  (Never run the pump dry for period of greater than 10 seconds.)
- Replace the diesel engine oil only after the engine has been stopped for a period of 30 minutes (oil temp. 20~70°C). Whenever possible refrain from operation when the oil temperature is below 15°C or above 50°C.
- Bilge water left in the hose or inside the pump can freeze, and care should be taken to see that any excess bilge is completely discharged. If bilge water should freeze, and care should be taken to see that any excess bilge is completely discharged. If bilge water should freeze inside the hose or pump, it should be completely melted before starting up the pump. When the temperature inside the pump is low, it will take a longer time for the pump to operate. (0°C, 5-10secs)
- Keep the pump in a dry place away from rain or other water.
- Use the regulation hose; do no use thin vinyl hose or hose which is not heat-resistant.
- The pump cannot be used to drain off rainwater or large quantities of flood water. This pump can be operated continuously for a period of 10 minutes.
- Do not use the pump for showering.
  If the pump outlet is deformed for showering, the increase in water pressure will increase the load on the motor and cause motor seizure.

- When sludge has built up in the bilge to be drained, position the strainer about 20cm above the sludge. When the pump is stopped, be sure there is sludge remaining inside the pump housing.
- The specific gravity for the battery fluid is 1.25.
- Refer to your local dealer for impeller replacement.
  The local dealer will perform the following.
  The impeller replacement kit includes one impeller and 3 films for adjusting the side gap. If after replacing the impeller the pump does not drain, place side gap adjustment washers underneath the bottom plate to adjust. Select the number of films used in accordance with the following. (When the pump is draining, the electric current load is about 10A for 12V and 5A for 24V. The pump operates efficiently at these electric current loads.)

Steps for replacement

1) Remove the impeller plate by taking out the M4 screws (4) and opening the top of the diaphragm switch.
   (Screw lock has been applied to the screw, and a dryer should be used to heat the screw before removing it.)
2) Clean the inside of the pump.
3) Grease the plate, impeller, and film for side gap adjustment, and then reassemble the pump by inserting first the film plate and then the impeller.

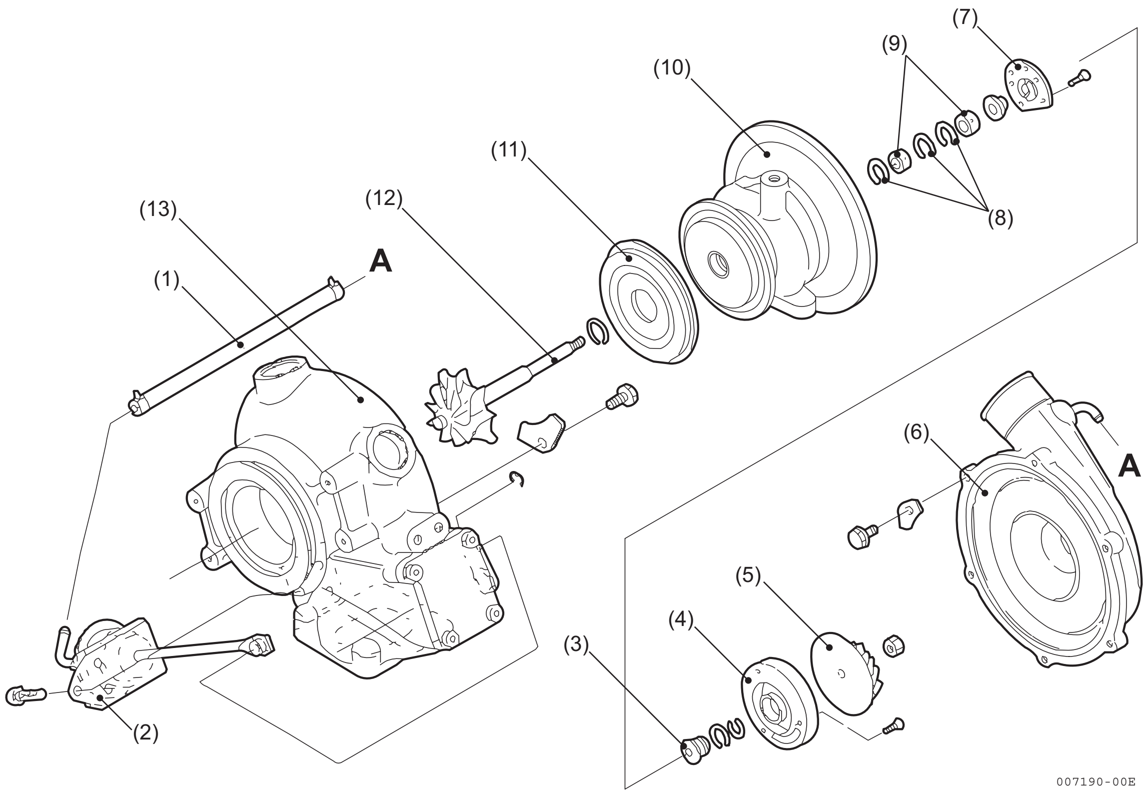
9.8.6 Troubleshooting

Refer to the following countermeasures for difficulties that arise.

Problem	Cause	Countermeasure
1. Pump does not turn.	Faulty wiring.	Check the wiring between the motor and battery.
	Faulty battery.	Check to see if the specific gravity of the battery fluid is greater than 1.25. Recharge or replace the battery.
	Faulty starter switch.	Consult your local dealer.
	Faulty pump.	Consult your local dealer.
2. Pump turns but does not draw up water.	Draws up air.	Check hose connections. Retighten pump screws.
	Low voltage in battery.	Check to see if the specific grabity of the battery fluid is greater than 1.25. Recharge or replace the battery.
	The distance between the pump and the surface of the water is too great.	Lower the pump. (Position the pump so that it is closer to the surface of the water.)
	The pump is too high.	Lower the pump. (Position the pump so that it is 50~70cm above the bottom of the boat.)
	Pump intake is weak.	If intake is still faulty after priming, consult your local dealer.
3. Pump turns, but the amount of discharge is low.	Clogged strainer.	Clean strainer.
	Hose is broken or damaged.	Check for damage and repair. If incorrect hose has been used, replace with the regulation type of hose.
4. Water leakage from pump.	Water leakage from packing.	Retighten pump screws.
	Faulty pump seal.	Consult your local dealer.
5. Pump draws up bilge, but motor stops when hand is removed from starter switch.	Faulty diaphragm switch.	Check for loose wiring in diaphragm switch and correct.
	Damaged diaphragm switch.	Consult your local dealer.
6. Motor does not stop, when there is no bilge water left.	Clogged strainer or hose.	Clean strainer or hose.
	Damaged diaphragm switch.	Check for continuity of diaphragm switch terminal. Consult your local dealer if there is continuity.

10. Turbocharger

The turbocharger of type RHC7W is adopted to this engine as well as 6LY2 series engines.
The main difference of the turbocharger for 6LY3 is the compressor for high-power.



(1)	Boost hose	(5)	Compressor	(9)	Floating metal	(13)	Turbine housing
(2)	Actuator	(6)	Compressor housing	(10)	Bearing housing		
(3)	Oil thrower	(7)	Thurust bearing	(11)	Insulation plate		
(4)	Seal plate	(8)	Retainer ring	(12)	Turbine shaft		

10.1 Construction and function

10.1.1 Outline

(1) Turbine

Exhaust gas coming out of the engine is accelerated of its flowing speed through the nozzle of the turbine wheel chamber and blown against the turbine wheel to give a torque to the turbine shaft.
This us called a turbine, in which seal rings and shrouds are assembled for protection of bearings from gas.

(2) Blower

The blower impeller mounted on the turbine shaft receives the torque force of the turbine shaft, sucks in the air and compresses it to be sent into the air feed pipe.
This is called a blower.

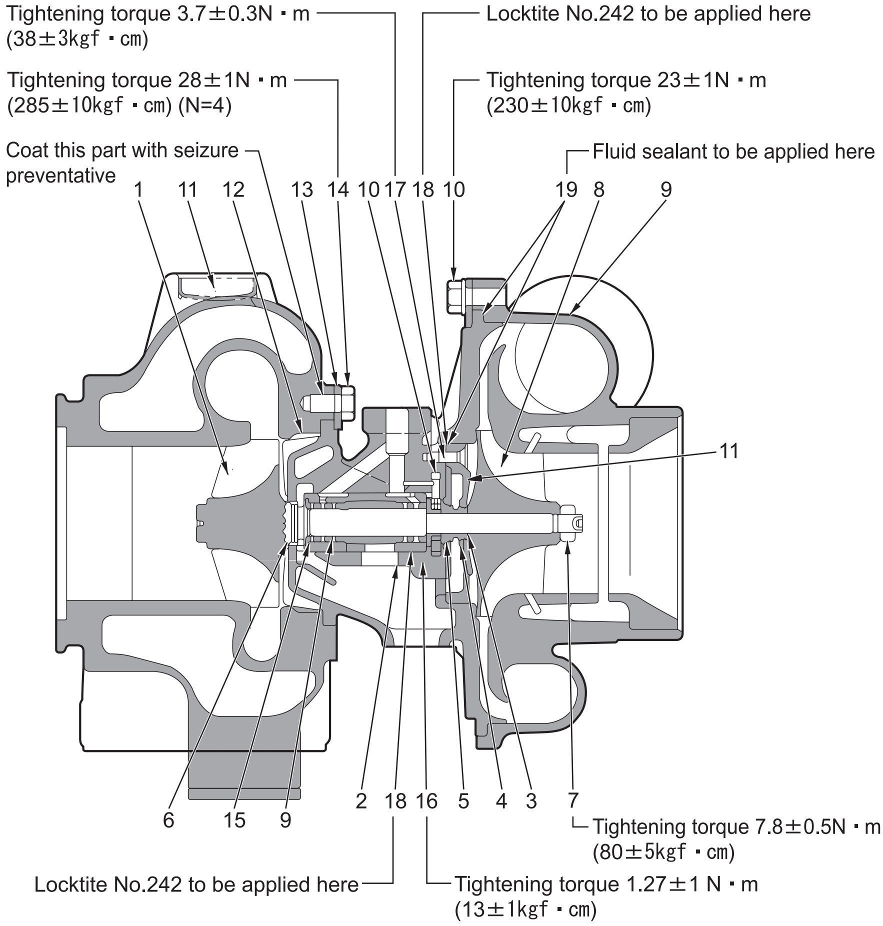
(3) Bearings

1) Thrust metal
   Thrusting force is applied to the turbine shaft at all times. The thrust metal prevents the shaft from being shifted by this thrusting force.
2) Radial metal
   Unlike an ordinary fixed type metal, the floating metal has double oil films at the inside and outside faces of the bearing which follows the metal rotation. Accordingly, the sliding speed on the bearing face becomes lower than the turbine shaft rotating speed, thus heightening the effect of dynamic stability.

(4) Sealing mechanism at blower side

For prevention of air and oil leakage, the back side of the blower impeller is lined with double wall and provided with a seal ring and oil defensive plate.

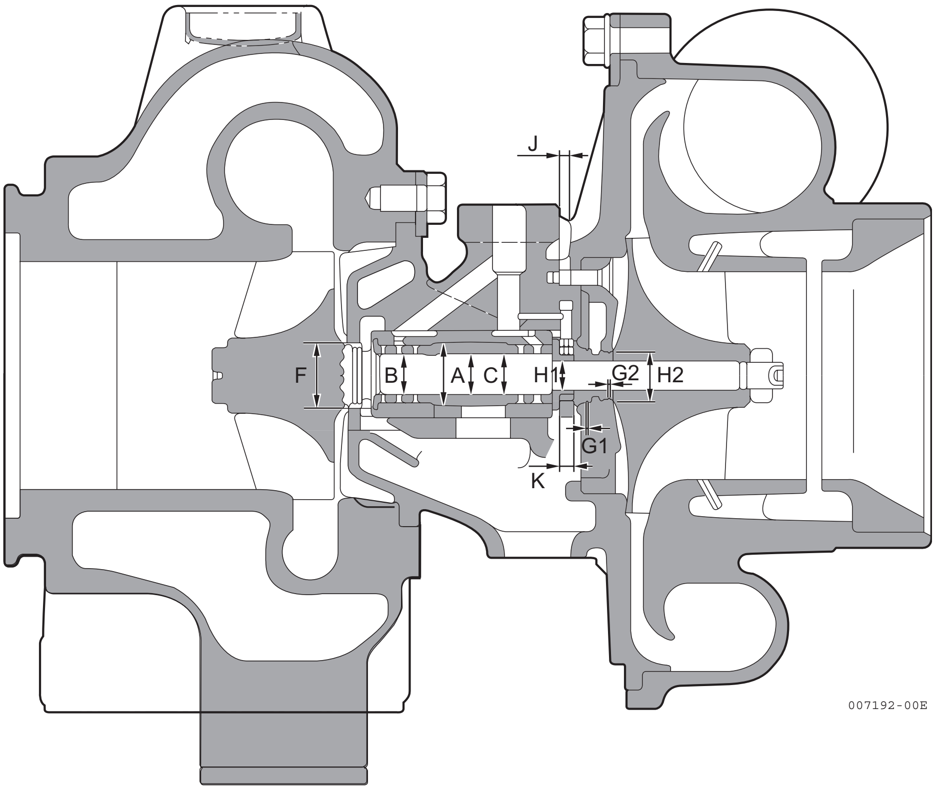
No.	Name	Q'ty
1	Turbine shaft	1
2	Thrust bush	1
3	Oil thrower	1
4	Compressor-side seal ring (small)	1
5	Compressor-side seal ring (large)	1
6	Turbine-side seal ring	1
7	Shaft end nut	1
8	Compressor impeller	1
9	Floating metal	2
10	Thrust bearing	1
11	Compressor housing	1
12	Flange hexagon bolt (M8)	6
13	Turbine housing	1
14	Shroud	1
15	Turbine-side pressure plate	8
16	Hexagon bolt (M8)	8
17	Retaining ring	3
18	TORX T across-head machine screw 54 (M3)	3
19	TORX T across-head machine screw 54 (M4)	4
20	Adhesive (Locktite)	—
21	Fluid sealant	—



Sectional view (RHC7W turbocharger)

10.2 Standards for maintenance and check

10.2.1 Standards for maintenance and check



(Unit: mm)

	Check Item	Limit of use	Remarks
Turbine Shaft	Turbine shaft journal O.D. (A) Turbine-side seal ring groove width (E) Blower-side seal ring groove width (G1) Blower-side seal ring groove width (G2) Turbine shaft runout	12.280 1.630 1.750 1.520 0.011	
Bearings	Floating metal I.D. (C) Floating metal O.D. (D) Bearing base I.D. (B)	12.360 16.980 17.110	
Thrust metal bearing	Thrust metal width (J) Thrust bush groove-to-groove dimension (K)	4.480 4.680	
Seal ring inserting parts	Turbine side (Bearing wheel chamber) (F) Blower side (seal plate)(H1) (H2)	18.550 16.050 14.050	
Play in rotor axial direction		0.110	Maintenance standard 0.06 - 0.09
Play in rotor radial direction		0.215	Maintenance standard 0.11 - 0.18

10.2.2 Tightening torque

Item	Tightening torque (kgf/cm)	N•m
Turbine shaft runout (M8)	285±10	28±1
Blower wheel chamber set bolt (M8)	230±10	23±1
Thrust metal setscrew (M3)	13±1	1.27±0.1
Sealing plate setscrew (M4)	38±3	3.7±0.3
Blower impeller set nut (M8)	80±5	7.8±0.5
Actuator set bolt (M8)	285±10	28±1
Valve case cover set bolt (M8)	285±10	28±1

10.3 Periodical checking procedure

10.3.1 Periodical checking interval

Check the entire status and contamination of turbocharger at regular intervals.
The checking intervals vary depending on the conditions of use. Perform checking work at the intervals as shown below according to individual purposes of use.

Purpose of use	Checking intervals		
For marine use Check item	Every 6 months or 1,500 operating hrs.	Every 12 months or 3,000 operating hrs.	Every 24 months or 6,000 operating hrs.
Rotation of rotor	○		
Play of rotor		○	
Disassembly, cleaning and checking of entire supercharger			○

10.3.2 Checking procedure

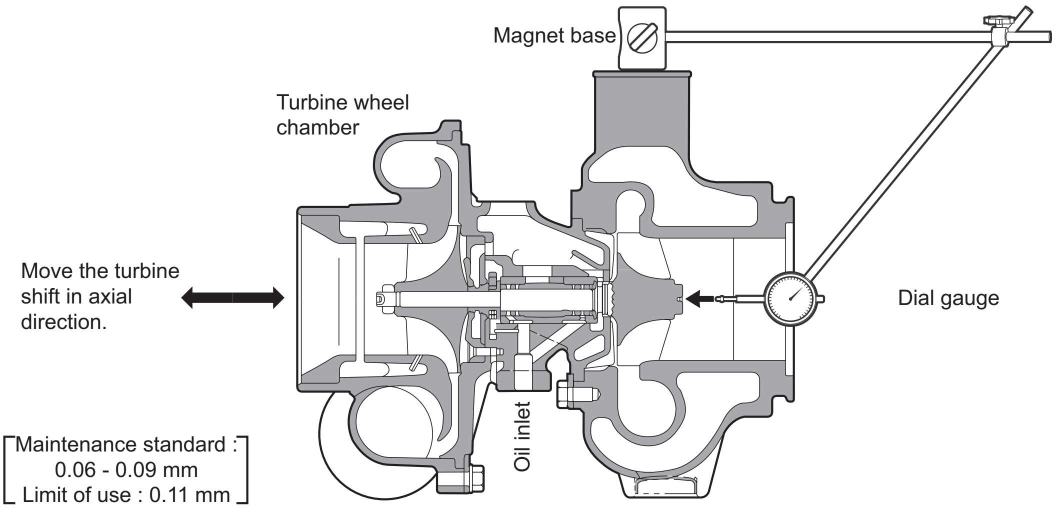
(1) Checking of rotation of rotor

Check the rotation of the rotor by hearing whether it produces an abnormal sound or not during rotation.
When using a listening rod, tap the tip of it closely to the turbocharger case and pick up the engine speed gradually.
If a high-pitched sound is heard successively every 2-3 seconds, it means that the rotation of rotor is abnormal.
When such a symptom is observed, the metal and rotor may be in trouble. In such case, the turbocharger should be replaced or disassembled and repaired.

(2) Checking of play of rotor

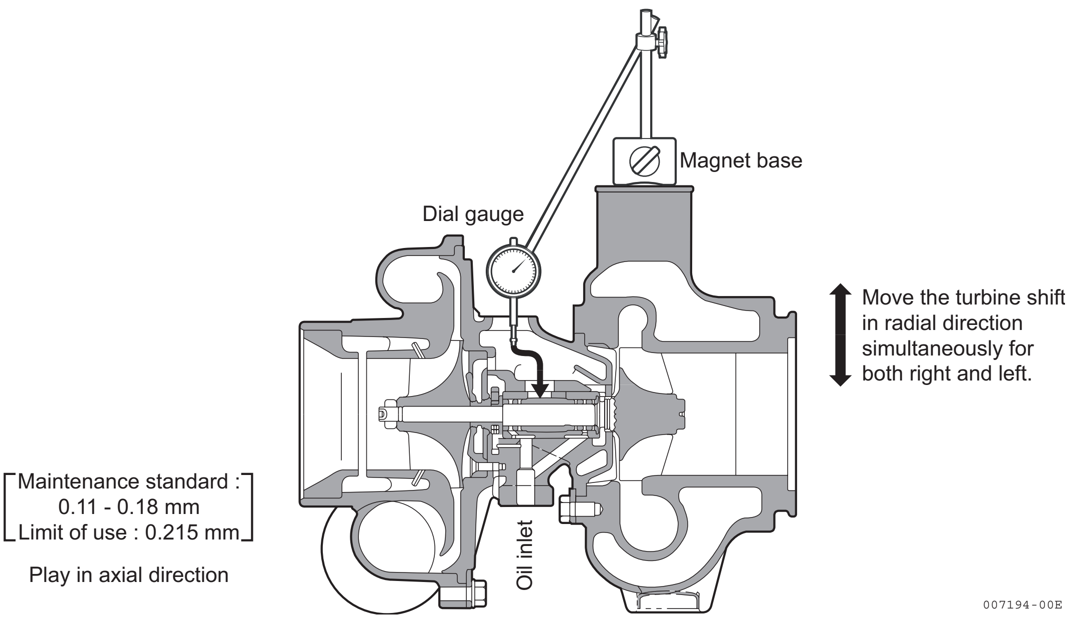
Dismount the turbocharger from the engine, and check the play of the rotor in axial and radial directions in the procedure below.
When the turbocharger is dismounted from the engine, cover the oil holes by gummed tape or the like.

1) Play of rotor in axial direction



Play in axial direction

2) Play of rotor in radial direction

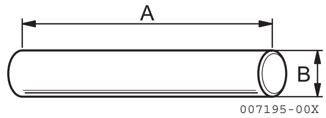


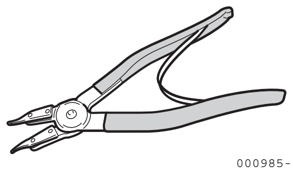
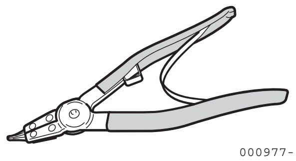
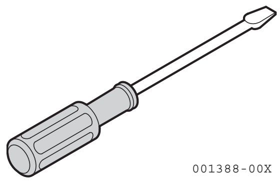
Play in axial direction

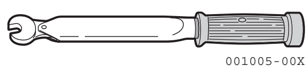
10.4 Disassembly procedure

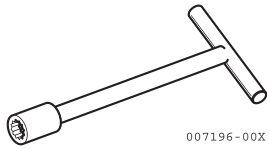
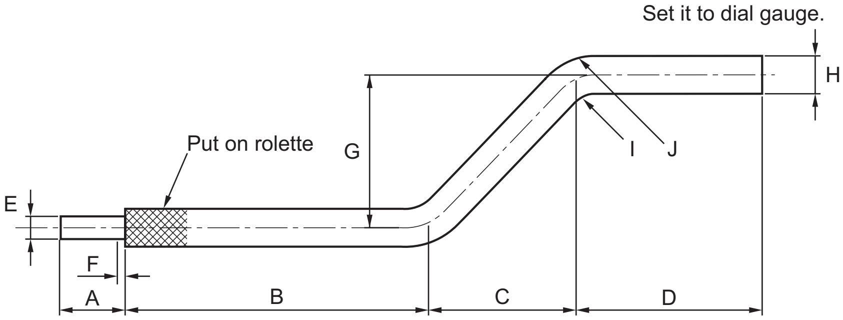
10.4.1 Preparations for disassembly

When assembling and disassembling the turbocharger, the special tools as shown below are necessary in addition.

<table>
<tr><th>Name of tool</th><th>Purpose of use</th><th>Remarks</th></tr>
<tr><td>Bar</td><td>Removal of thrust metal and thrust bush</td><td>

<table><tr><th>A</th><th>B</th></tr><tr><td>106</td><td>ø10</td></tr></table>
Material: Copper or brass</td></tr>
<tr><td>Pliers</td><td>Mounting and dismounting of retaining ring of floating metal</td><td>
</td></tr>
<tr><td>Pliers</td><td>Mounting and dismounting of seal ring</td><td>
</td></tr>
<tr><td>Torque screwdriver for
TORX bolt (Universal type)
5kg/cm-50kg/cm</td><td>Mounting of seal plate (38kgf•cm)
3.7±0.3 N•m for M4
Mounting of thrust metal
(13 kgf•cm) 1.27+1 N•m for M3</td><td>Available in the market


(Type: Equivalent to TORX TT20)</td></tr>
<tr><td>Torque wrench
(Single-purpose type)</td><td>Mounting of turbine housing
(285 kg-cm) 28+1 N•m for M8
Mounting of compressor housing
(230 kg-cm) 23+1 N•m for M8
Tightening of shaft end nut
(13mm, 80 kg-cm) for M8</td><td>Available in the market

</td></tr>
</table>

<table>
<tr><th>Name of tool</th><th>Purpose of use</th><th colspan="2">Remarks</th></tr>
<tr><td>Box wrench</td><td>Fixing of turbine shaft
(14 mm x 12 sq.)</td><td colspan="2">
007196-00X
Only box part of the wrench will do</td></tr>
<tr><td>Measuring probe</td><td colspan="3">Measurement of play in axial and radial directions

007197-00E</td></tr>
</table>

A	B	C	D	E	F	G	H	I	J
8	≧80	11	24	M26 P0.45	1	15	5ℓ	10ℓ	ø5

10.4.2 Check before disassembly

(1) Make sure that the turbine wheel and the blower wheel are out of contact with their cases, and check to see if the rotor rotates smoothly.

(2) Measure the play of rotor.
See the description in 3-2) for the measurement.

1) Play of rotor in axial direction

Limit of use: 0.110 mm

2) Play of rotor in radial direction

Limit of use: 0.215 mm

10.4.3 Disassembly

Since the assembling angles of the turbine wheel chamber, bearing wheel chamber and blower wheel chamber of the supercharger have been set according to the set-up posture to the engine, put match marks on them before disassembly.

(1) Disconnection of boost hose

1) Move the clip to the center of the boost hose
2) Disconnect the boost hose from the blower wheel chamber and the waste gate actuator.

(2) Dismounting of blower wheel chamber

1) Remove the M8 hexagon bolt and blower side pressure plate.
2) Dismount the blower wheel chamber.

Note-1: Liquid gasket has been applied to the mounting surface of the blower housing and bearing housing.

Note-2: Pay attention not to damage the blower wheel when disassembling the blower wheel chamber.

(3) Dismounting of blower wheel

1) Fit the box wrench (14 mm) to the turbine-side end of the turbine shaft (1) and remove the shaft end nut (7).

Note:
The shaft end nut has left-hand thread.
Pay attention to the turning direction.

2) Dismount the blower wheel (8).

(4) Removal of turbine housing

1) Remove the (M8) hexagon bolt 44 and turbine side pressure plate.
2) Remove the turbine housing.

(5) Removal of turbine shaft

1) Press down lightly with your hand on the radiation shield and pull out turbine shaft (1).

Note:
When there is difficulty removing the shaft tap lightly with a wooden hammer on the blower side shaft end.

2) Remove the radiation shield.

(6) Removal of seal plate

1) Loosen the M4 TORX T across-head machine screw used for attachment and removal of seal plate with the TORX screwdriver.
2) Remove the seal plate.

Note: Screw 2 pcs of M6 bolts into the screw holes used for removing the seal plate, and then use the bolts as handles to lift out the plate.

Note: Liquid gasket has been applied to the seal plate and the bearing housing.

3) Remove the oil thrower (3) from the seal plate.

(7) Removal of thrust bearing and thrust bush

1) Using the TORX screwdriver (TT20), loosen the TORX T across-head machine screw off the thrust bearing and thrust bush.
2) Remove the thrust bearing and the thrust bush (2) with use of the copper bar.

(8) Removal of floating metal

1) Remove the blower-side floating metal from the bearing wheel chamber.
2) Remove the turbine-side retaining ring from the bearing wheel chamber by means of the stop ring pliers.
3) Remove the turbine-side floating metal from the bearing wheel chamber.
4) Remove the turbine's far-side and the blower's far-side retaining rings from the bearing wheel chamber by means of the stop ring pliers.

(9) Removal of seal ring

1) Remove the turbine-side seal ring (6) from the turbine shaft (1).
2) Remove the blower-side seal ring (4), (5) from the oil thrower (3).

10.5 Cleaning and checking procedure

10.5.1 Cleaning

(1) Checking before cleaning

Before cleaning, visually check the disassembled parts for any seizure, wear, foreign matters or carbon deposits.
Closely check for the above-mentioned abnormalities in case of any trouble, and pinpoint the cause of trouble at this stage.

Major check items

Check item	Position to be checked
Carbon deposits	1) Turbine shaft (1) turbine-side seal ring, and turbine wheel backside. 2) Mounts for bearing wheel chamber and shroud, and bearing wheel chamber inside wall.
Lubrication (wear, seizure, discoloration, etc.)	1) Turbine shaft (1), journal and thrust bush (2), and oil thrower (3). 2) Floating metal and thrust bearing. 3) Bearing wheel chamber, and inner periphery of bearing snap ring.
Oil leak	1) Turbine wheel chamber inside wall. 2) Outer periphery of bearing wheel chamber, and shroud mount. 3) Turbine shaft (1), turbine-side seal ring, and turbine wheel backside. 4) Blower wheel chamber inside wall. 5) Blower wheel chamber (8) backside. 6) Sealing plate 11 surface and sealing ring insertion groove.

(2) Cleaning procedure

In cleaning the parts, keep the following points in mind.

Section	Tools and detergent	Cleaning procedure
1. Turbine shaft	1. Turbine shaft tools 1) Washing bucket (500 x 500) 2) Heat source: steam or gas burner 3) Brush 2. Detergent: carbon remover sold in the market may be used.	1) Immerse the turbine shaft in the washing bucket and heat the solution. Do not beat the wheel for removal of carbon deposit. 2) Immerse the parts until dirt deposits become soft by penetration of detergent. 3) When the deposits get soft, remove them with use of a plastic spatula or bristle brush. 4) Protect the bearing surface of the turbine shaft and the seal ring groove from damage during cleaning. 5) Incomplete cleaning will leave residual deposits which may cause an imbalance in shaft rotation. Do not use a wire brush for cleaning.
2. Turbine wheel chamber	1. Tools: Same as for cleaning the turbine shaft 2. Detergent: Same as for cleaning the turbine shaft	1) Apply cleaning fluid to heavily soiled parts of the turbine housing. 2) Use a plastic scraper or a stiff natural bristle brush to clean.
3. Blower wheel chamber	1. Tools 1) Washing bucket (500 x 500) 2) Brush 2. Detergent	1) Immerse the parts until dirt deposits become soft by penetration of detergent. 2) When the deposits get soft, remove them with use of a plastic spatula or bristle brush. Do not use a wire brush.
4. Others	1. Wash all the other parts with gas oil. 2. Clean the lube oil passages by blowing compressed air. 3. In the cleaning work, pay close attention not to damage the parts and get them rusted.	

10.5.2 Checking procedure

(1) Blower wheel chamber

Check the chamber surface for any scratch, nick, crack, etc. which may be caused by contact with the rotating wheel. If any of the defects is found, replace the chamber with new one.

(2) Turbine wheel chamber

Check the chamber surface for any scratch caused by contact with rotating wheel, removal of casting skin due to oxidization, thermal deformation, crack, etc. If any of the defects is found, replace the chamber with new one.

(3) Blower wheel (8)

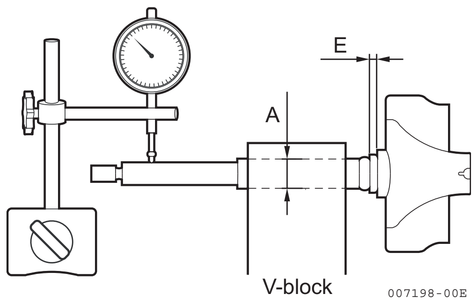
Check it for any scratch by contact, defect, corrosion, deformation, etc. If any, replace the wheel with new one.

(4) Turbine shaft (1)

1) Check the turbine wheel for any scratch by contact, defect, thermal discoloration, deformation, etc. Check also the shaft for any bend, journal's thermal discoloration or unusual wear, seal ring groove's scratch or wear, etc. If any of the defects is found, replace the shaft with new one.
2) Measure the outer diameter (A) of the turbine shaft journal and the seal ring groove width (E). If they are worn more than the limit of use, replace them with new ones.

Journal O.D. (A)
Limit of use: 12.28 mm

Seal ring groove width (E)
Limit of use: 1.63 mm



3) Check the turbine shaft for runout, and if it exceeds 0.011 mm, replace the shaft with new one.

(5) Shroud 42

Check the shroud for any scratch by contact, thermal deformation, corrosion, etc. If any of the defects is found, replace the shroud with new one.

(6) Thrust bush (2), oil thrower (3) and thrust bearing

Check these parts for scratch, discoloration, etc. Replace any defective part with new one even if it is still within the limit of use.

1) Thrust bush (2)
   Measure the thrust bush groove-to-groove dimension (K). If it is found greater than the limit of use, replace the bush with new one.

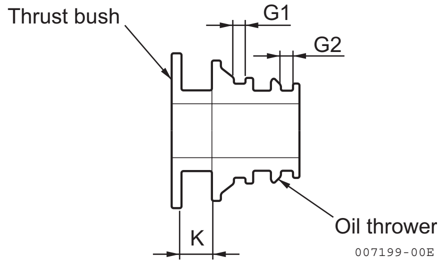
Limit of use: 4.68 mm

2) Oil thrower (3)
   Measure the widths (G1)(G2) of the seal ring groove.
   Replace if it exceeds the limit.

Limit of use: (G1) 1.75 mm (G2) 1.52 mm

3) Thrust bearing 22
   Measure the thrust bearing width (I), and if it is found greater than the limit of use, replace the bearing with new one.

Limit of use: 4.48 mm



(7) Floating metal 21

1) Check the floating metal for any abnormal wear, discoloration, scratch, etc. If any of the defects is found, replace the metal with new one.
2) Measure the metal I.D. (C) and O.D. (D), and if they are found greater than the limits of use, replace the metal with new one.

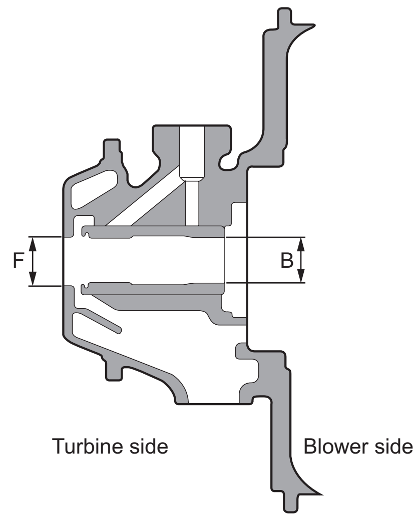
Limits of use: O.D. (D); 16.98 mm I.D. (C); 12.36 mm

(8) Bearing wheel chamber

1) Check the chamber for any removal of casting skin due to oxidation, nick, crack, etc. If any of the defects is found, replace the chamber with new one.
2) Check the retaining metal for any breakage, crack, etc. If any of the defects is found, replace the metal with new one.
3) Measure the dimensions (B) and (F) of the chamber as shown in the figure, and if they are found greater than the limits of use, replace the chamber with new one.

Bearing wheel chamber I.D. (B) Limit of use: 17.11 mm

Turbine-side seal ring insertion hole (F) Limit of use: 18.55 mm

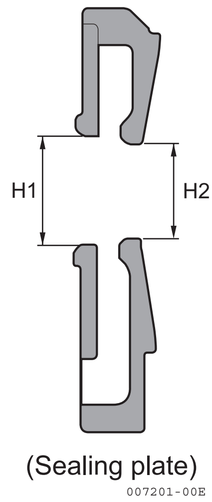


(Bearing wheel chamber)
007200-00E

(9) Sealing plate

1) Check the plate for any scratch by contact, nick, crack, etc. on its surface. If any of the defects is found, replace the sealing plate with new one.
2) Measure the seal ring insertion hole (H1)(H2), and if it is found greater than the limit of use, replace the sealing plate with new one.

Limit of use: 14.05 mm



(Sealing plate)

(10)Wastegate actuator

1) Check for damage (marks, scratches, bent shape) and replace together with the turbine housing as a unit.
2) Check the wastegate actuator by gradually introducing a stream of low-pressure air. If it fails to operate or if operation is not smooth, replace together with the turbine housing.

(11)Check seal rings (4), (5), (6)

Replace if damaged.

(12)Check bolts for damage and replace any faulty ones.

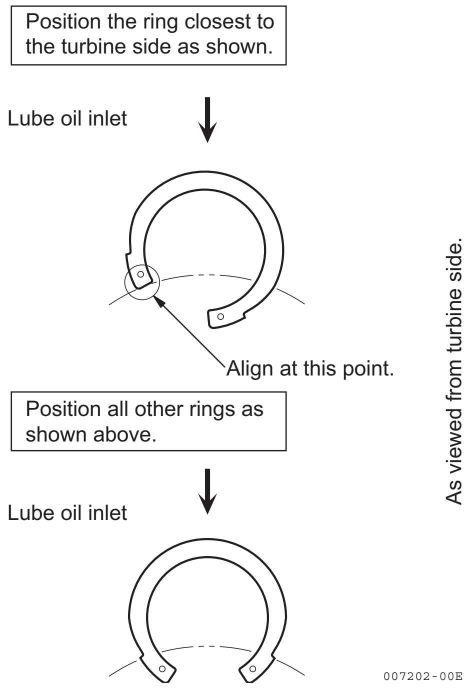
Replace M3TORX T across-head machine screw and M4TORX T across-head machine screw.

10.6 Reassembling procedure

10.6.1 Preparations for reassembly

(1) When reassembling the turbocharger, prepare the general and special tools, fluid sealant (Three Bond No.1215) and Locktite N0.242.

(2) Replace the following parts without fail before reassembling.
Blower-side seal ring (small) (4) x 1 pc
Blower-side seal ring (large) (5) x 1 pc
M3 pan-head screw 4 pcs
M4 pan-head screw 4 pcs



10.6.2 Reassembling procedure

(1) Reassembling of floating metal

1) Set the inner retaining ring to the bearing wheel chamber with use of the stop ring pliers.
2) Fit the turbine-side floating metal into the bearing wheel chamber.
3) Set the turbine-side outer retaining ring into the bearing wheel chamber with use of the stop ring pliers.
4) Fit the blower-side floating metal into the bearing wheel chamber.

Note 1: Set the retaining ring so that its round side faces the metal side.

Note 2: Apply engine oil to the floating metal before reassembling.

(2) Reassembling of turbine shaft

1) Fit the seal ring (6) to the turbine shaft (1).
2) Mount the shroud to the turbine side of the bearing wheel chamber.
3) Apply engine oil to the turbine shaft journal and insert the shaft into bearing wheel chamber from its turbine side.

Note:
Use due care not to damage the floating metal by the turbine shaft. When inserting the shaft, face the cut of the seal ring toward the oil inlet and align the ring with the turbine shaft.

(3) Mounting of thrust metal

1) Fit the thrust bush (2) to the turbine shaft (1).
2) Apply engine oil to the metal of the thrust bearing, and mount the bearing to the bearing wheel chamber.
3) M3 TORX T across-head machine screw.
   Fix the thrust metal with use of the TORX screwdriver.

Tightening torque: 13±1 kgf•cm

(4) Mounting of sealing plate

1) Fit the seal ring (4), (5) to the oil thrower (3).
2) Set the oil thrower (3) in the sealing plate.

Note:
Adjust the gap in the seal ring to match the diagram.

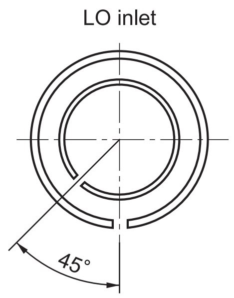
3) Apply fluid sealant (Three Bond N0.1207) to the turbine-side flange face of the sealing plate.

Note:
Apply the sealant to the spots as shown at right.

Thickness of sealant: 0.1 - 0.2 mm

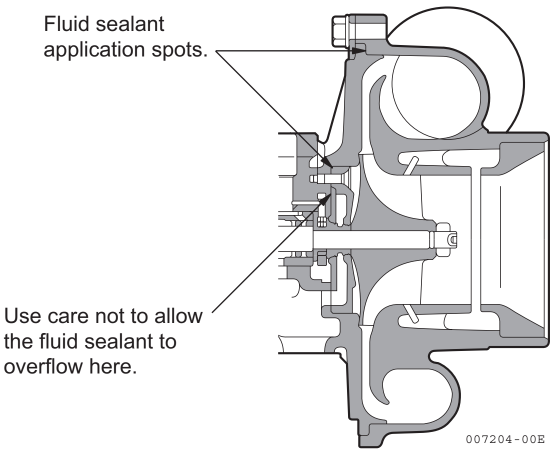
4) Mount the sealing plate to the bearing wheel chamber.
5) TORX T across-head machine screw.

Tightening torque: 38 ± 3 kgf•cm



Position the ring closest to the compressor side as shown.

007203-00E



007204-00E

(5) Mounting of blower wheel

1) Fit the blower wheel (8) to the turbine shaft (1).
2) Apply the box wrench (14 mm) to the turbine-side end of the turbine shaft (1), and tighten the shaft end nut (7).

Note:
Pay attention to the tightening direction of the nut, which has left-hand threads.

Tightening torque: 80 ± 5 kgf•cm

(6) Mounting of turbine housing

1) Assemble the turbine housing and the bearing housing aligning the guide marks made before disassembly.

Note:
When the parts have been replaced, make sure that the oil inlet and outlet and air outlet are in their specified positions.

2) Attach the turbine side pressure plate and tighten M8 Hexagon bolt with the torque wrench.

Tightening torque: 285 ± 10 kgf•cm

(7) Mounting of blower wheel chamber

1) Apply fluid sealant (Three Bound N0.1207) to the blower-side flange face of the bearing wheel chamber.

Thickness of sealant: 0.1 - 0.2 mm

2) Align the match markings and fit the blower wheel chamber to the bearing wheel chamber.

Note:
When the parts have been replaced, make sure that the oil inlet and outlet and the air outlet are in their specified positions.

3) Attach the blower side pressure plate and tighten M8 Hexagon bolt with the torque wrench.

Tightening torque: 230 ± 10 kgf•cm

(8) Connection of boost hose

1) Fit the clip to the center of the boost hose.
2) Insert the boost hose into the blower wheel chamber and the waste gate actuator.
3) Move the clip up to the nipples of the blower wheel chamber and the waste gate actuator in order to prevent the boost hose from slipping off.

(9) Measurement of play of rotor

For the procedure of measurement, see 10.3.2.
Play of the rotor beyond the maintenance standard is considered due to wrong reassembly or use of unspecified parts. It is therefore necessary to disassemble and reassemble the rotor.

1) Play of rotor in axial direction

Maintenance standard: 0.06 - 0.09 mm

2) Play of rotor in radial direction

Maintenance standard: 0.11 - 0.18 mm

10.7 Handling after reassembly

In mounting the supercharger to the engine or handling the mounted turbocharger, keep the following points in mind.
Use particular care to prevent any foreign matters from coming into the turbocharger.

10.7.1 Precautions for mounting the turbocharger to the engine

Lubrication system

(1) Before mounting to the engine, pour fresh engine oil from the oil filler port, and turn the turbine shaft by hand to lubricate the floating metal and thrust metal.

(2) Clean up the oil inlet pipe and outlet pipe running from the engine, and check them for any crush or dust and dirt remaining in the pipes.

(3) Connect the oil pipes securely to their connections part not to allow any oil leak from the connections.

Suction system

(1) Make sure that there is no rubbish or foreign matter in the suction system.

(2) Mount the supercharger securely not to allow any air leak at the suction air duct and air cleaner connecting parts.

Exhaust system

(1) Make sure that there is no rubbish or foreign matter in the exhaust system.

(2) The bolts and nuts made of heat-resisting steel are used for the exhaust system. Do not confuse them with ordinary bolts and nuts used for other systems. Apply anti-seizure agent to the lock bolts and nuts.
(Heat-resisting bolts are use for the turbine wheel chamber.)

(3) Connect the exhaust pipes securely not to allow any gas leak at the connections.

10.8 Troubleshooting

If the turbocharger gets in trouble, it can not perform as expected and a specified engine power can not be attained.
In this case, first check up each part of the engine for any trouble, and when it is confirmed that there is no problem with the engine, then check the turbocharger, referring to the tables below, and take proper measures.

10.8.1 Exhaust gas is dense

Insufficient amount of suction air

Possible cause	Correction
1) Air cleaner element is clogged. 2) Air take-in port is blocked up. 3) Air leaks at pipe connection.	• Replace or clean the element. • Remove obstruction. • Check and repair the pipe.

Supercharger does not operate

Possible cause	Correction
1) Impurities contained in oil precipitate at seal of turbine and hamper smooth rotation of turbine shaft.	• Change the engine oil and disassemble and clean the turbocharger.
2) Seizure of metal • Insufficient oil feed or clogging of pipe • Too high oil temperature • Imbalance in rotating part • Insufficient warm-up operation or abrupt stopping of operation under load (No-load operation)	• Disassemble and repair the turbocharger. • Check the engine oil system, and repair the trouble spot and at the same time change the oil. • Replace or clean the rotating part. • Observe the operating precautions described in operation manual.
3) Contact or breakage of turbine wheel or blower wheel • Over-rotation • Excessive rise of exhaust gas temperature • Entry of foreign matters • Wear of metal • Wrong reassembly	• Check each part of the engine and repair as required. • Disassemble the wheels and remove foreign matters completely and at the same time check the air cleaner and the engine and repair as required. • Disassemble and repair the turbocharger. • Reassemble the turbocharger.

Effect of exhaust gas resistance

Possible cause	Correction
1) Rotating speed does not pick up due to exhaust gas leak before the turbocharger. 2) Turbocharger fails to increase its speed due to deformed or blocked deformation or exhaust gas pipe.	• Check the pipe connection and repair as required. • Repair the pipe to normal state.

10.8.2 Whitish exhaust gas

Possible cause	Correction
1) Oil flows into blower side or turbine side due to clogged or deformed oil return pipe. 2) Seal ring is worn abnormally or broken due to excessive metal abrasion.	• Repair or replace the pipe. • Dissemble and repair the turbocharger.

10.8.3 Too early oil shortage

Possible cause	Correction
1) Seal ring is worn abnormally or broken due to excessive metal abrasion.	• Disassemble and repair the turbocharger.

10.8.4 Output drop

Possible cause	Correction
1) Gas leaks at part (s) in exhaust gas system. 2) Air leaks at discharge side of blower. 3) Clogging of air cleaner element. 4) Turbocharger is contaminated or damaged.	• Disassemble and repair the turbocharger. • Clean or replace the element. • Disassemble and repair or replace the turbocharger.

10.8.5 Poor follow-up of supercharger

Possible cause	Correction
1) Carbon deposits stuck on turbine side (wheel seal) hampers smooth rotation of turbine shaft. 2) Incomplete oil combustion.	• Change the engine oil and at the same time disassemble and clean the turbocharger. • Check the engine combustion system and restore its combustion state.

10.8.6 Unusual sound or vibration

Unusual sound

Possible cause	Correction
1) If gas passage gets too narrow due to blockage of nozzle in turbine wheel chamber or gas flow speed is too fast, air discharged from blower is blocked and it flows reversely. (This phenomenon is generally called "surging".) 2) Rotating part is in contact.	• Disassemble and clean the turbocharger. • Disassemble and repair or replace the turbocharger.

Unusual vibration

Possible cause	Correction
1) Connection between turbocharge and suction or exhaust pipe or oil pipe is loosened. 2) Turbine wheel or blower wheel is broken due to trouble with metal, contact of rotating part with peripheral part(s) or entry of foreign matter. 3) Imbalance in rotating part(s).	• Check installation state of the turbocharger, and restore the loose part. • Disassemble and repair or replace the turbocharger. In the case of entry of foreign matter, remove it completely. • Repair or replace the rotating part(s).

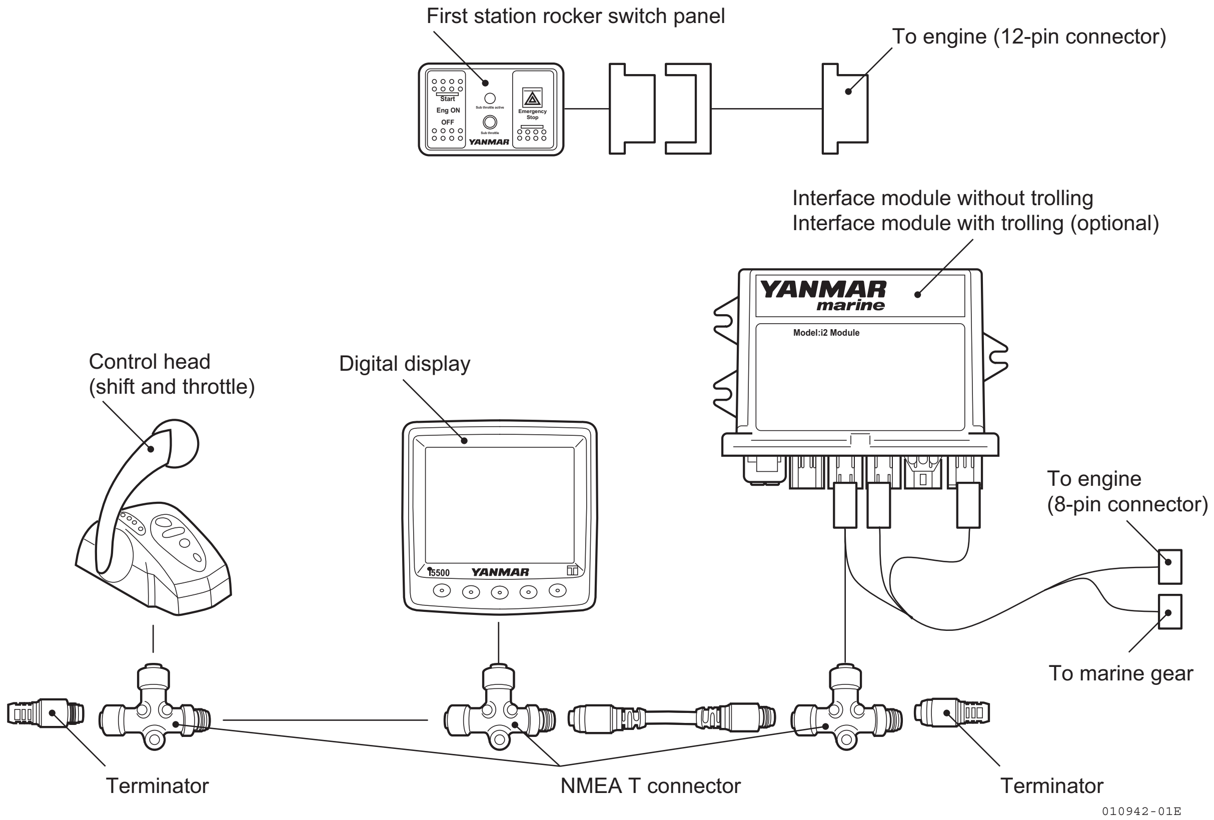
11. Reduction and reversing gear

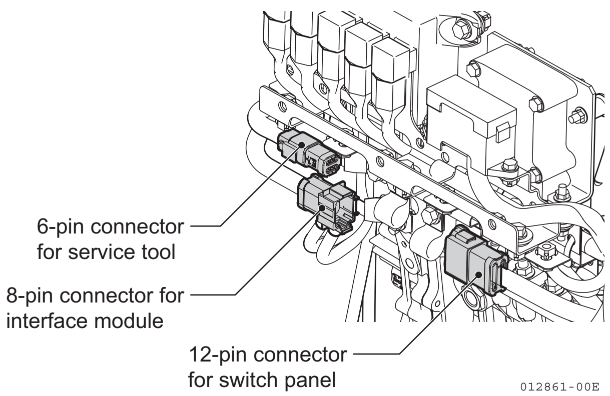
Refer to each marine gear service manual of the separate volume for inspection, disassembly and reassembly.

12. Remote control

12.1 Electronic control system (ECS)

The control equipment consists of the rocker switch panel, the digital display, the interface module and the control head, which are connected by the wire harness to the engine (electrical governor and marine gear) for remote control operation.



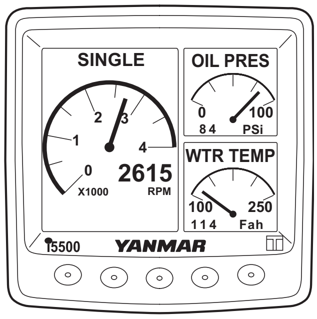


12.1.1 Digital display

The multi-function digital display has the following function.

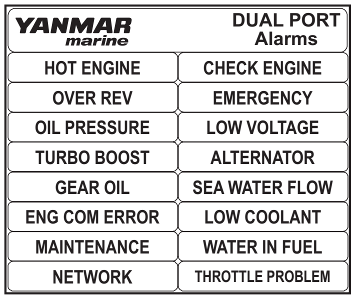
(1) Function of display

1) Runtime engine data with 3 screens.
   Tachometer, lube oil pressure, coolant temperature, lube oil temperature, fuel temperature, boost pressure, voltage, load factor, throttle value, fuel consumption rate and gear shift (F / N / R) can be shown.



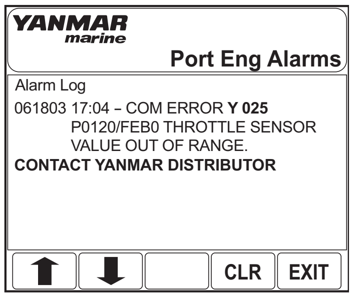
007159-00X

2) Alarm Indicators (Refer to right example.)
   Alarm window appears with audible alarm when some trouble happens.



007160-00X

3) Alarm Log screen. (Refer to right example.)



007161-00X

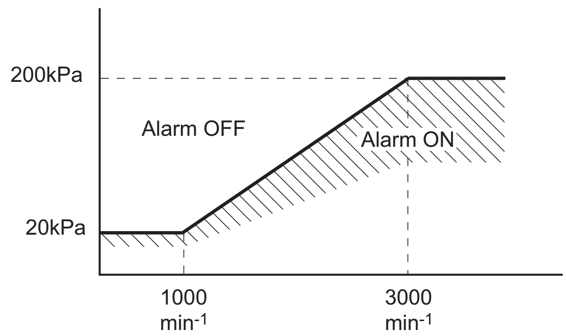
(2) Alarm indicator and logging

Alarm indicators and buzzer come on when sensors detect an abnormality during engine operation.
The alarm indicators are off during normal operation, but come on as follows when an abnormality arises.

Item		ON	OFF
Oil press (Logging *1)		(See below figure)	
Coolant temp	Alarm	100°C	95°C
	Engine protection *2 (Logging *1)	110°C	105°C
Oil temp	Alarm	110°C	105°C
	Logging *1	120°C	115°C
Fuel temp	Alarm	80°C	75°C
	Logging *1	90°C	85°C
Boost press *1, *2 (Engine protection, Logging)		250kPa	200kPa
Over speed (Engine stop, Logging *1)		3900min^{-1}	—

*1 "Logging" shows alarm and also it is memorized in ECU that there was an abnormality.

*2 "Engine Protection" shows alarm and also engine speed is limited at 1800 min^{-1} or less for engine protection.



Alarm diagram of lube oil pressure

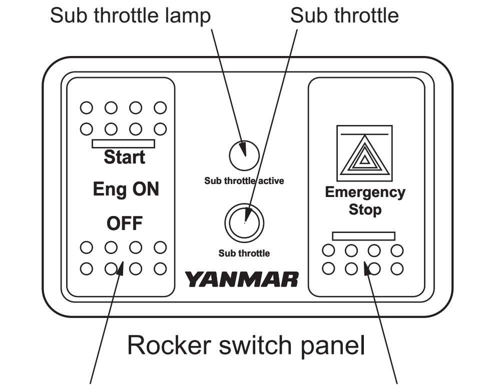
007162-00E

12.1.2 Rocker switch panel

The rocker switch panel has the following function.

(1) 1st station panel

1) OFF, ON, START switch.
2) Emergency stop
   An engine shuts down suddenly when the top of the emergency stop switch is pushed in an emergency. Push the bottom part of the switch after the engine has shut down, and return the switch to the former condition. (Restarting the engine after using the emergency stop may be slower or difficult.)
   Use this switch only in an emergency.
3) Sub throttle control
   In the unlikely event that the throttle control fails, the sub-throttle lamp will flash, and the engine speed is controlled by using sub throttle.
   Engine speed rises when sub-throttle knob is turned clockwise.
   - When sub-throttle lamp flashes, turn the sub-throttle knob counterclockwise to the end and turn the knob clockwise gradually until the sub-throttle lamp is turned on. (Steady light)
   - Each engine is controlled by it's own sub throttle controller.

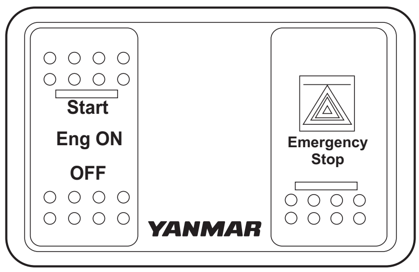


Rocker switch panel

007164-00E

(2) 2nd station panel (Optional)

1) OFF-ON-START switch is wired to 1st station panel.
2) Able to start & stop the engine from 2nd station panel.
3) Emergency stop switch is wired in series with 1st station panel.



2nd Station Panel

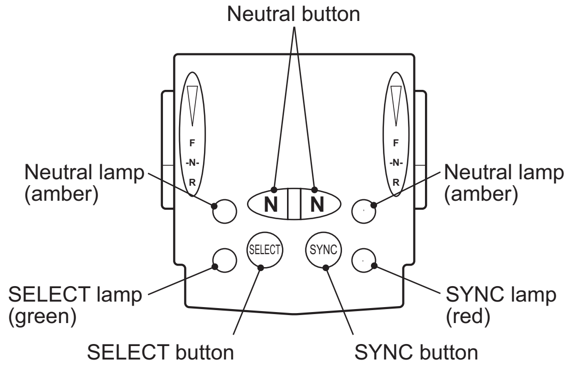
007164-00E

12.1.3 Control head (Shift &Throttle)

The control head in the helm station for ahead, astern and speed control is used.

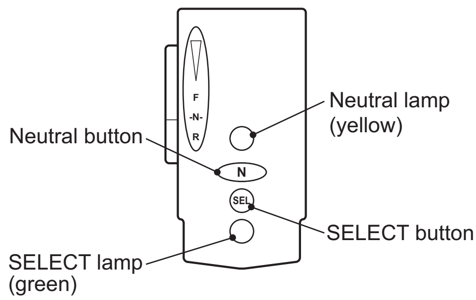
Control head button functions

- N button - Neutral button. If the associated control head lever is in the "Neutral Idle" position, pushing this button engages / disengages Neutral Throttle control, allowing throttle but no forward or reverse thrust. If the associated control head lever is in a "Gear Idle" position, pushing this button engages / disengages Split Range Throttle (SRT) (if installed).
- SELECT (or SEL) button - If the station is inactive, pushing this button activates the station (used in conjunction with two or more control stations.
- SYNC button - Pushing this button engages / disengages the Power Train Synchronization (PTS) option (if installed) when the port and starboard control head levers are set to nearly the same positions.



Two-lever head for twin installation

009437-00E



Single lever head for single installation

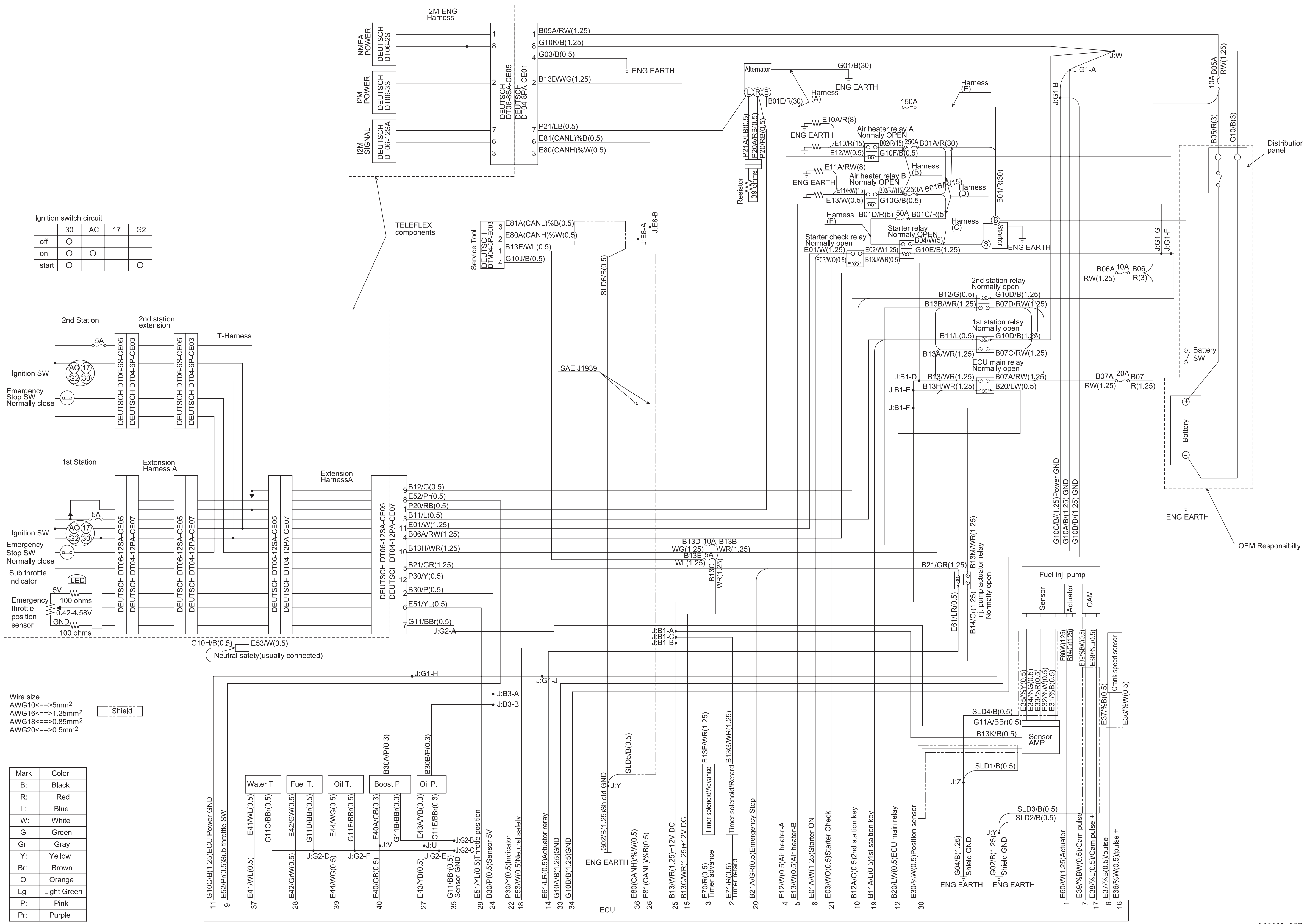
009438-00E

13. Electrical system

13.1 Electrical system

13.1.1 Wiring diagram

For TELEFLEX digital display



Ignition switch circuit

	30	AC	17	G2
off	O			
on	O	O		
start	O			O

Wire size
AWG10<==>5mm²
AWG16<==>1.25mm²
AWG18<==>0.85mm²
AWG20<==>0.5mm²

Shield

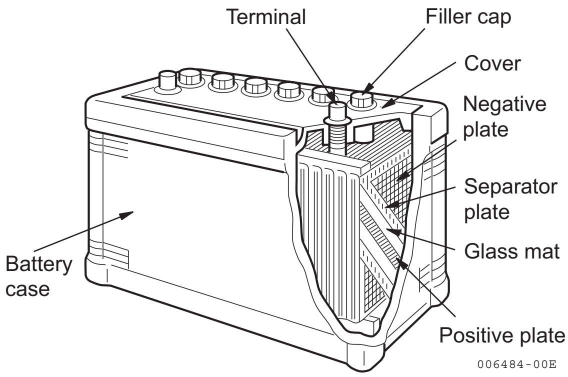
Mark	Color
B:	Black
R:	Red
L:	Blue
W:	White
G:	Green
Gr:	Gray
Y:	Yellow
Br:	Brown
O:	Orange
Lg:	Light Green
P:	Pink
Pr:	Purple

13.2 Battery

Refer to 2.2.5(9) for electrolyte level and battery charge.

13.2.1 Construction

The battery utilizes chemical action to convert chemical energy to electrical energy. This engine uses a lead acid battery which stores a fixed amount of power that can be used when required. After use, the battery can be recharged and used again.
As shown in the figure, a nonconductive container is filled with dilute sulfuric acid electrolyte. Lead dioxide positive plates and lead dioxide negative plates separated by glass mats are stacked alternately in the electrolyte. The positive and negative plates are connected to their respective terminals.
Power is removed from the battery by connecting the load across these two terminals.
When the battery is discharging, an electric current flows from the positive plates to the negative plates. When the battery is being charged, electric current is passed through the battery in the opposite direction by an external power source.



13.2.2 Battery capacity and battery cables

(1) Battery capacity

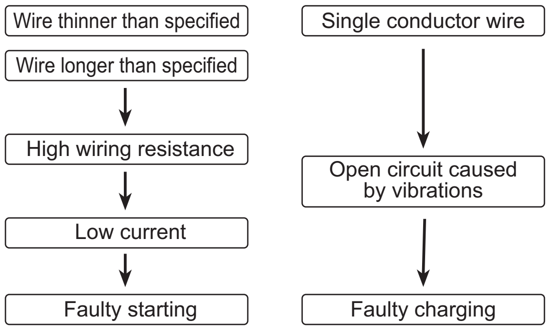
Battery capacity	standard	12V-150AH
	cold weather	12V-150AH
Full charged specific gravity		1.26

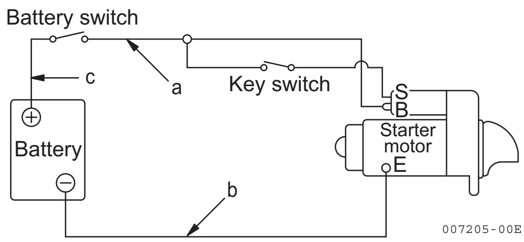
(2) Battery cable

Wiring must be performed with the specified electric wire. Thick, short wiring should be used to connect the battery to the starter, (soft automotive low-voltage wire [AV wire]). Using wire other than that specified may cause the following troubles:
The overall lengths of the wire between the battery (+) terminal and the starter (B) terminal, and between the battery (-) terminal and the starter (E) terminal, should be determined according to the following table.

Voltage system	Allowable wiring voltage drop	Conductor cross-section area	a + b + c allowable length
12V	0.2V or less/100A	20mm^2	UP to 3.5m
		40mm^2	UP to 7m

Note:
Excessive resistance in the key switch circuit (between the battery and start [S] terminals) can cause improper pinion engagement. To prevent this, follow the wiring diagram carefully.





13.2.3 Inspection

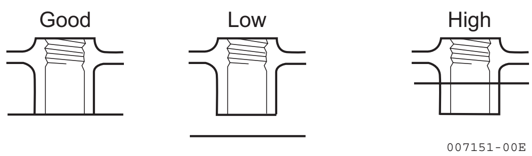
The quality of the battery governs the starting performance of the engine. Therefore the battery must be routinely inspected to ensure that it functions perfectly at all times.

(1) Visual inspection

1) Inspect the case for cracks, damage and electrolyte leakage.
2) Inspect the battery holder for tightness, corrosion, and damage.
3) Inspect the terminals for rusting and corrosion, and check the cables for damage.
4) Inspect the caps for cracking, electrolyte leakage and clogged vent holes.
   Correct any abnormal conditions found. Clean off rusted terminals with a wire brush before reconnecting the battery cable.

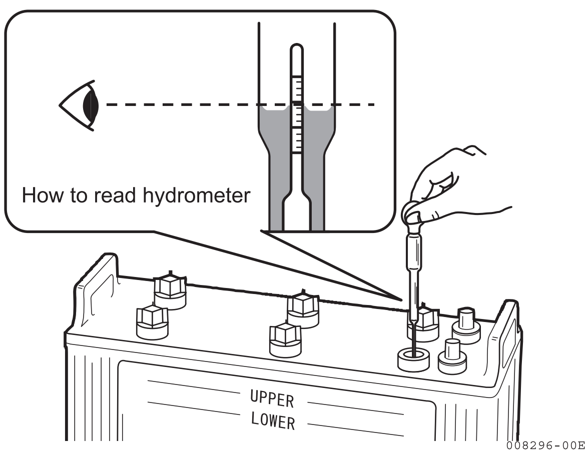
(2) Checking the electrolyte

1) Electrolyte level
   Check the electrolyte level every 7 to 10 days. The electrolyte must always be 10-20mm (0.3937-0.7874in.) over the top of the plates.



Note:
1. The "LEVEL" line on a transparent plastic battery case indicates the height of the electrolyte.
2. Always use distilled water to bring up the electrolyte level.
3. When the electrolyte has leaked out, add dilute sulfuric acid with the same specific gravity as the electrolyte.

2) Measuring the specific gravity of the electrolyte
   a) Draw some of the electrolyte up into a hydrometer.
   b) Take the specific gravity reading at the top of the scale of the hydrometer.
   c) The battery is fully charged if the specific gravity is 1.260 at an electrolyte temperature of 20°C. The battery is discharged if the specific gravity is 1.200 (50%). If the specific gravity is below 1.200, recharge the battery.
   d) If the difference in the specific gravity among the cells of the battery is ±0.01, the battery is OK.

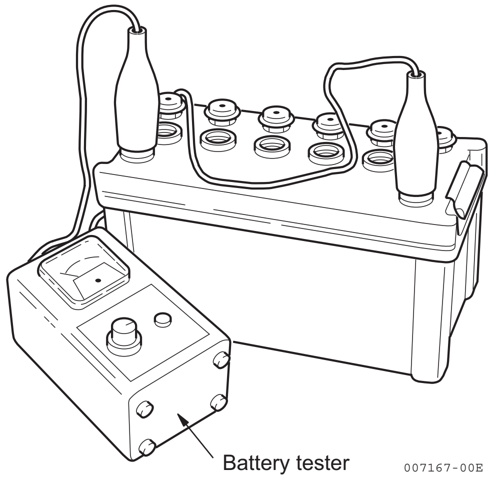


e) Measure the temperature of the electrolyte. Since the specific gravity changes with the temperature, 20°C is used as the reference temperature.
Reading the specific gravity at 20°C
S_{20} = St + 0.0007(t-20)
S_{20}: Specific gravity at the standard temperature of 20°C
St: Specific gravity at the electrolyte at t °C
0.0007: Specific gravity change per 1°C
t: Temperature of electrolyte

(3) Voltage test

Using a battery tester, the amount of discharge can be determined by measuring the voltage drop which occurs while the battery is being discharged with a large current.

1) Connect the tester to the battery.
12V battery tester.
Adjust the current (A).
2) Connect the (+) lead of the tester to the (+) battery terminal, and the (-) tester lead to the (-) battery terminal.
3) Push the TEST button, wait 5 seconds, and then read the meter.
• Repeat the test twice to make sure that the meter indication remains the same.



(4) Washing the battery.

1) Wash the outside of the battery with a brush while running cold or warm water over the battery. (Make sure that no water gets into the battery.)
2) When the terminals or other metal parts are corroded due to exposure to electrolyte leakage, wash off all the acid.
3) Check the vent holes of the caps and clean if clogged.
4) After washing the battery, dry it with compressed air, connect the battery cable, and coat the terminals with-grease. Since the grease acts as an insulator, do not coat the terminals before connecting the cables.

13.2.4 Charging

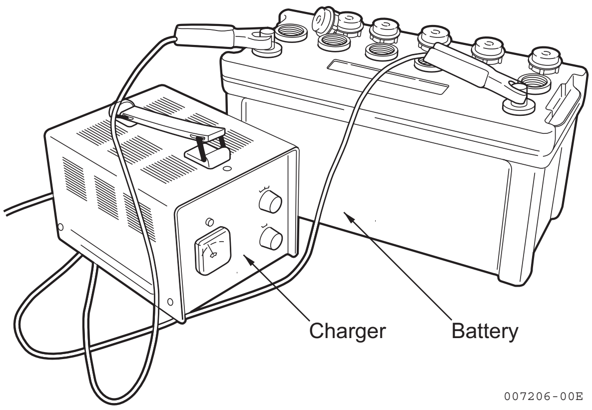
(1) Charging methods

There are two methods of charging a battery: normal and rapid.
Rapid charging should only be used in emergencies.

- Normal charging.... Should be conducted at a current of 1/10 or less of the indicated battery capacity (10A or less for a 100AH battery).
- Rapid charging...... Rapid charging is done over a short period of time at a current of 1/5-1/2 the indicated battery capacity (20A-50A for a I 100AH battery).
  However, since rapid charging causes the electrolyte temperature to rise too high, special care must be exercised.

(2) Charging procedure

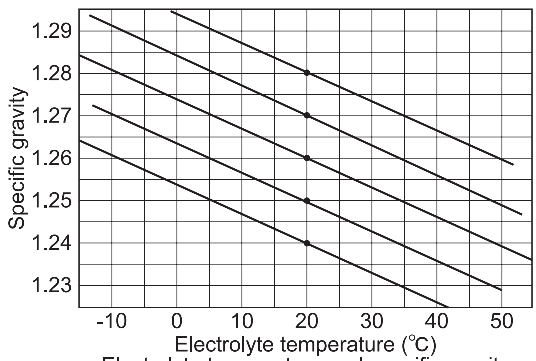
1) Check the specific gravity and adjust the electrolyte level.
2) Disconnect the battery cables.
3) Connect the red clip of the charger to the (+) battery terminal and connect the black clip to the (-) terminal.
4) Set the current to 1/10 -1/5 of the capacity indicated on the outside of the battery.
5) Periodically measure the specific gravity during charging to make sure that the specific gravity remains at a high fixed value. Also check whether gas is being generated.



007206-00E

(3) Charging precautions

1) Remove the battery caps to vent the gas during charging.
2) While charging, ventilate the room and prohibit smoking, welding, etc.
3) The electrolyte temperature should not exceed 45°C during charging.
4) Since an alternator is used on this engine, when charging with a charger, always disconnect the battery (+) cable to prevent destruction of the diodes.
   (Before disconnecting the (+) battery cable, disconnect the (-) battery cable [ground side].)



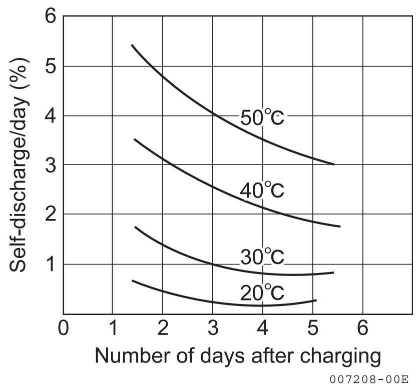
Electrolyte temperature and specific gravity

007207-00E

13.2.5 Battery storage precautions

The life of a battery depends considerably on how it is handled. Generally speaking, however, after about two years its performance will deteriorate, starting will become difficult, and the battery will not fully recover its original charge even after recharging. Then it must be replaced.

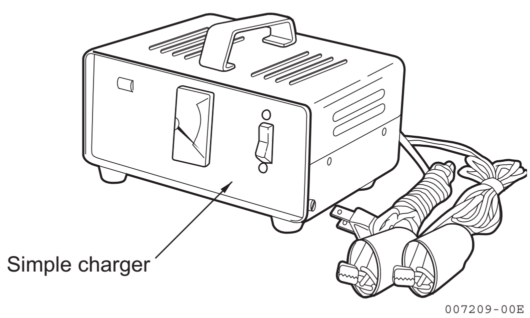
(1) Since the battery will self-discharge about 0.5% / day even when not in use, it must be charged 1 or 2 times a month when it is being stored.



(2) If charging by the engine alternator is insufficient because of frequent starts and stops, the battery will rapidly lose power.
Charge the battery as soon as possible after it is used under these conditions.

(3) An easy-to-use battery charger that permits home charging is available from Yanmar. Take proper care of the battery by using the charger as a set with a hydrometer.
When the specific gravity has dropped to about 1.16 and the engine will not start, charge the battery up to a specific gravity of 1.26 (24 hours).

(4) Before putting the battery in storage for long periods, charge it for about 8 hours to prevent rapid aging.



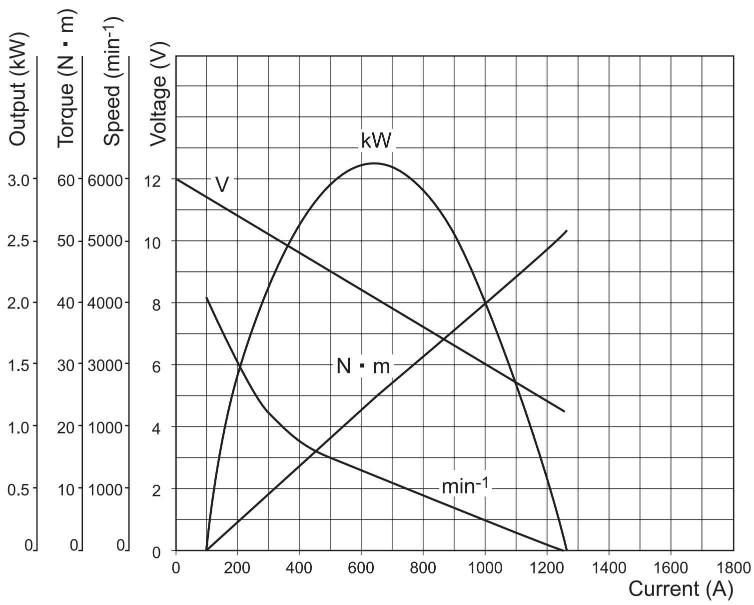
13.3 Starting Motor

A starting motor turns the ring gear installed on a engine flywheel by the pinion while overcoming resistance such as the compression pressure and the friction loss of the engine and makes the engine start.

13.3.1 Specifications

YANMAR Part No.		129940-77010
HITACHI Model No.		S14-102
Nominal power (kW)		3.0
Nominal voltage (V)		12
Rating (sec)		30
Direction of rotation (Looking from the pinion side)		Clockwise
Number of pinion teeth		9
Mass (kg)		6.5
No load	Terminal voltage (V)	12
	Electric current (A)	160 (MAX)
	Revolutions (min^{-1})	3600 (MIN)
Load	Terminal voltage (V)	10.85
	Electric current (A)	300
	Torque (N•m)	6.9 (MIN)
	Revolutions (min^{-1})	2000 (MIN)

13.3.2 Characteristics

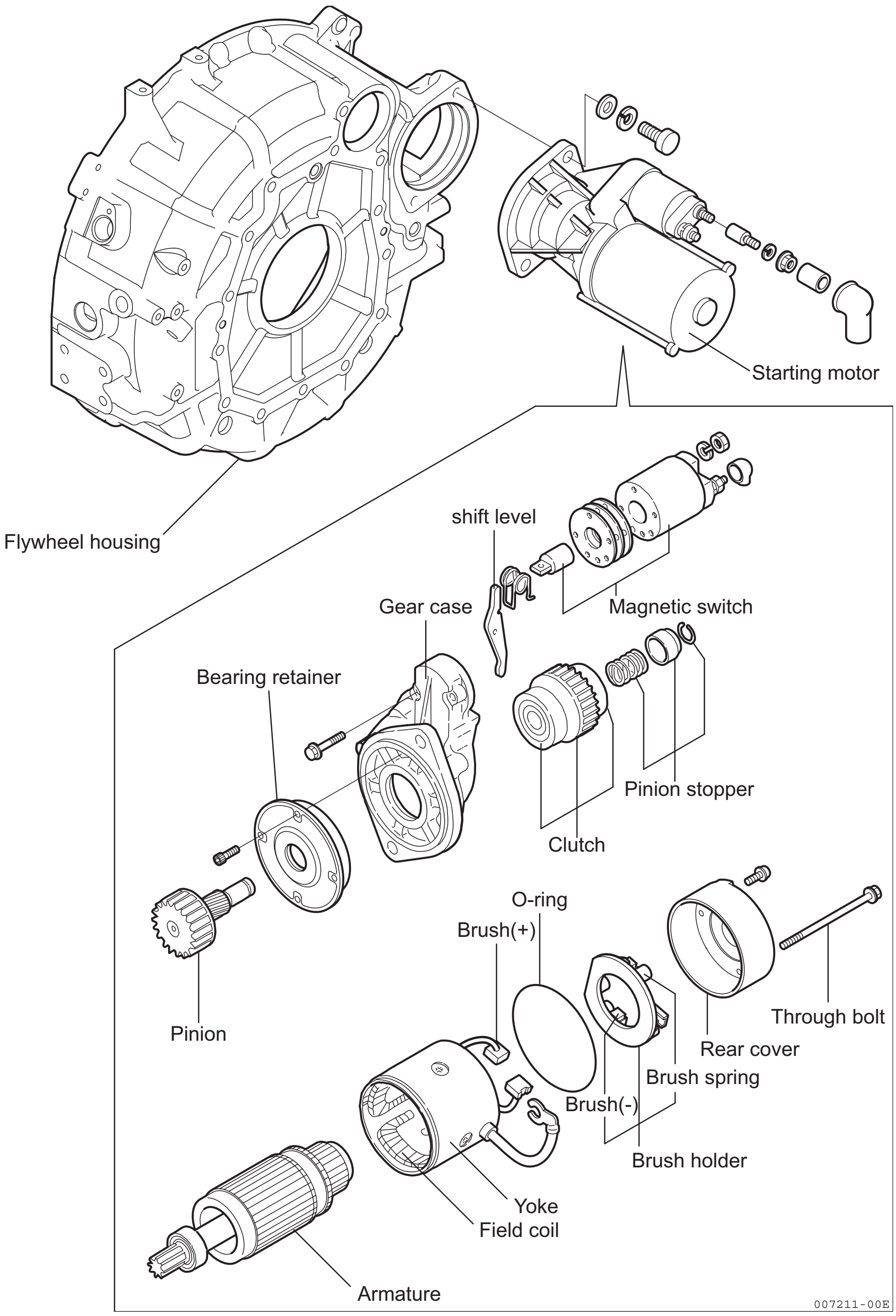


Standard characteristics

007210-00E

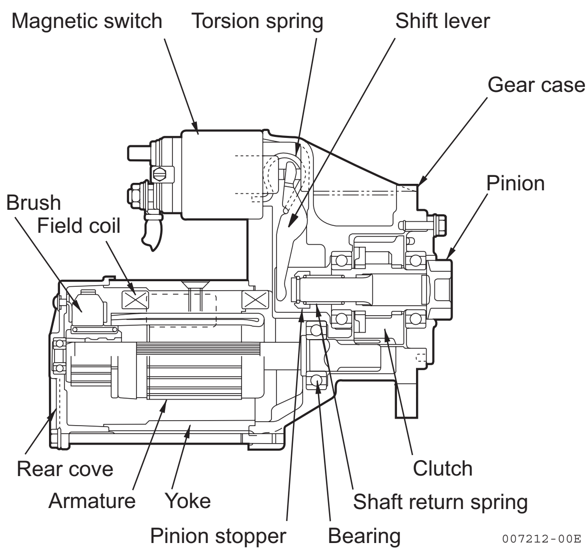
13.3.3 Structure

(1) Disassembly drawing



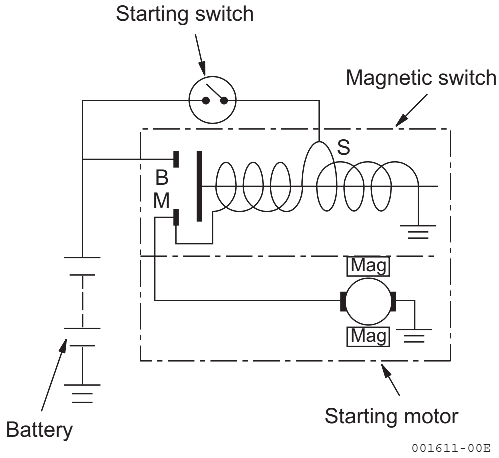
(2) Structure

When the starting switch is turned on, a magnet switch takes a voltage, and a pinion projects. The pinion engages with the ring gear of a engine, and the engine is started.



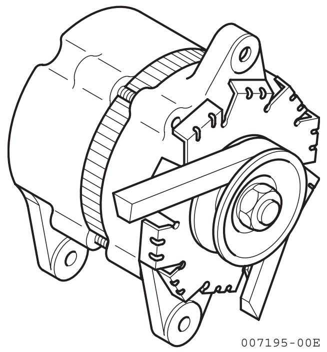
13.3.4 Wiring diameter of a starting motor

1) When a starting switch is turned on, a magnet switch is charged, and a moving core is absorbed, and a pinion clutch is moved forward through a lever, and the pinion engages with a ring gear.
2) When the pinion engages the ring gear, because a main contact point is closed and the main electric current flows and a pull coil is short-circuited by the main contact point and it stops being charged with electricity, the pinion is kept at the position by a holding coil during the start.
3) When the starting switch is turned off, the main contact point becomes open, and the pinion clutch is returned to the stop position by a return spring.



13.4 Alternator standard, 12V/80A

The alternator serves to keep the battery constantly charged. It is installed on the gear case, and is driven from the V-pulley at the end of the crankshaft by a V-belt.
The type of alternator used in this engine is ideal for high speed engines with a wide range of engine speed. It contains diodes that convert AC to DC, and an IC regulator that keeps the generated voltage constant even when the engine speed changes.

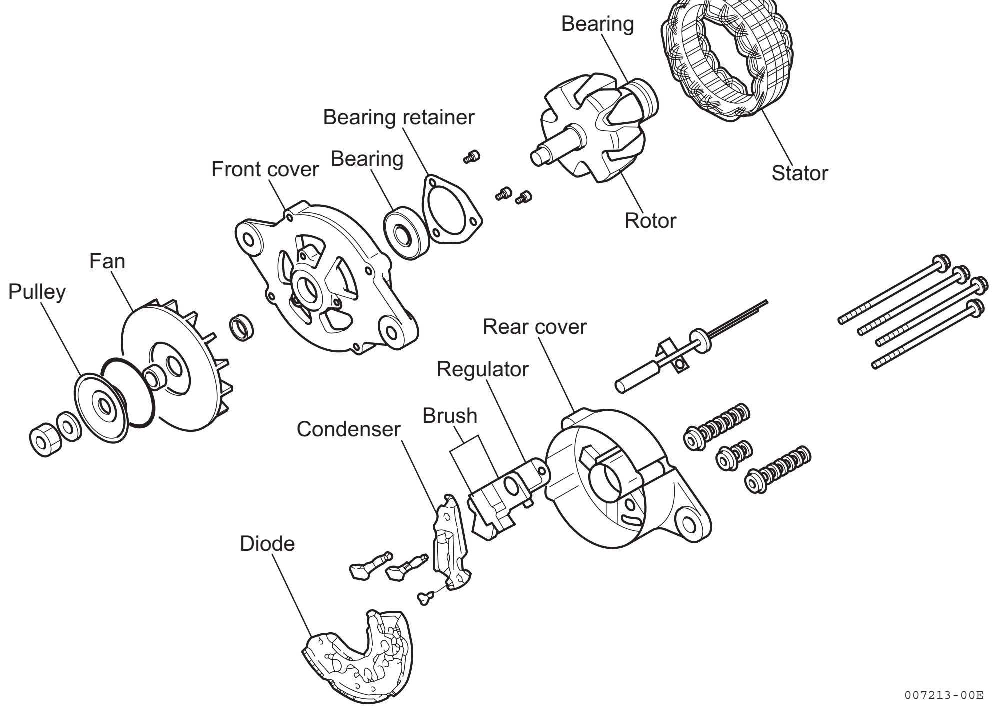


13.4.1 Specifications

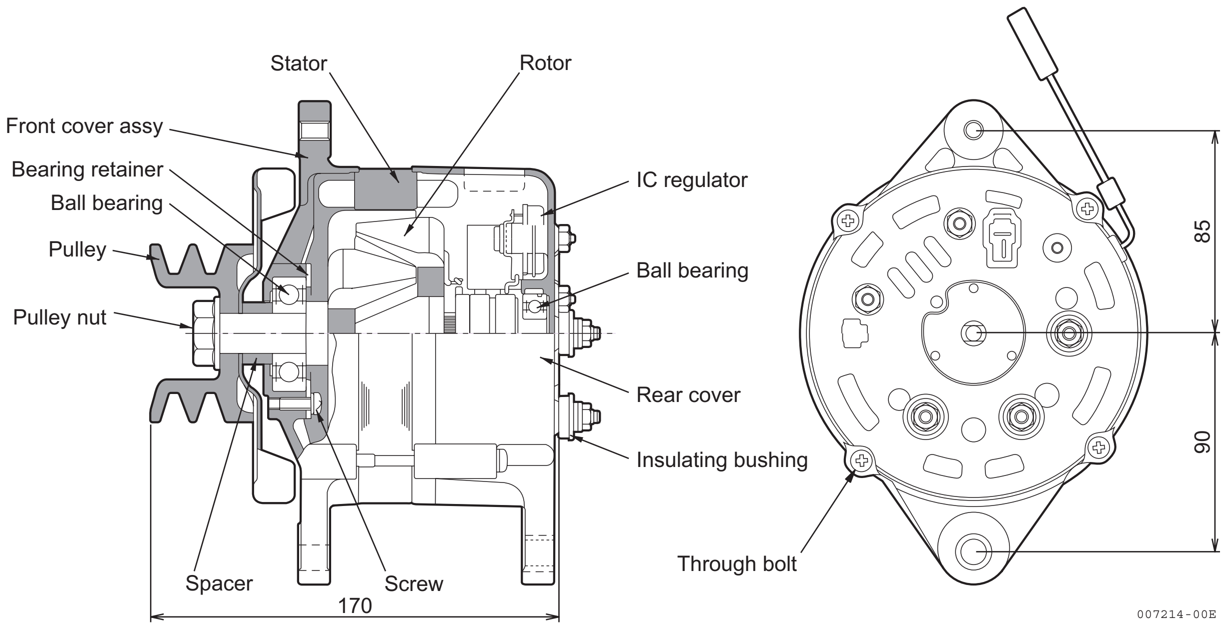
Yanmar code	119578-77210
Model of alternator	L-X4447 (HITACHI)
Battery voltage	12V
Nominal output	12V/80A
Earth polarity	Negative earth (-)
Direction of rotation (viewed from pulley end)	Clockwise
Mass	5.8 kg
Rated speed	5000 min^{-1}
Operating speed	1,200-9,000 min^{-1}
Speed for 13.5V at 20°C	1200 min^{-1} or less
Output current for 13.5V	75A or more at 5000 min^{-1}
Regulated voltage	14.5±0.3V (at 20°C, voltage gradient -0.01V/°C)

13.4.2 Structure

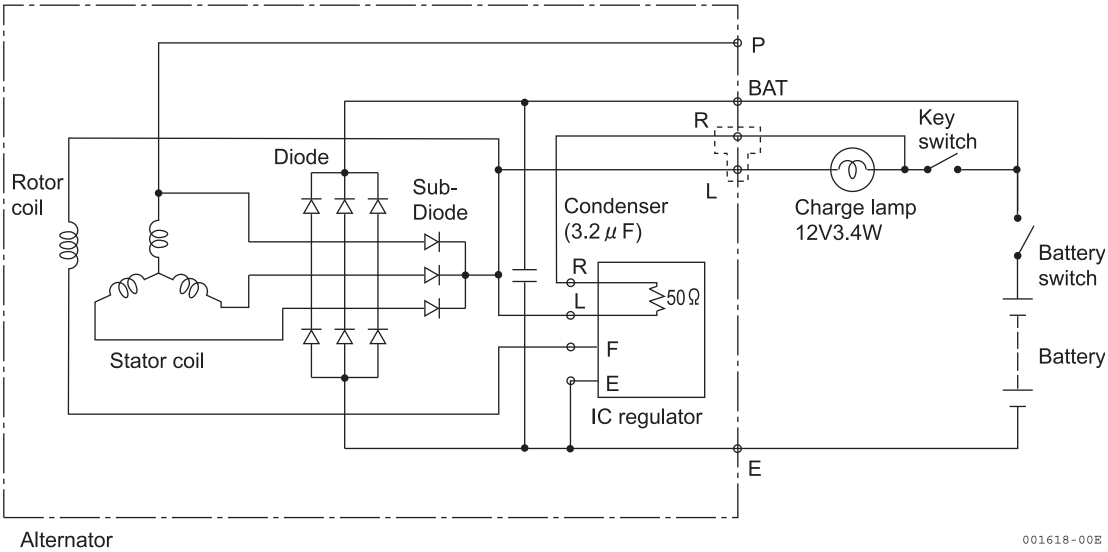
(1) Disassembly drawing



(2) Structure



13.4.3 Wiring diagram

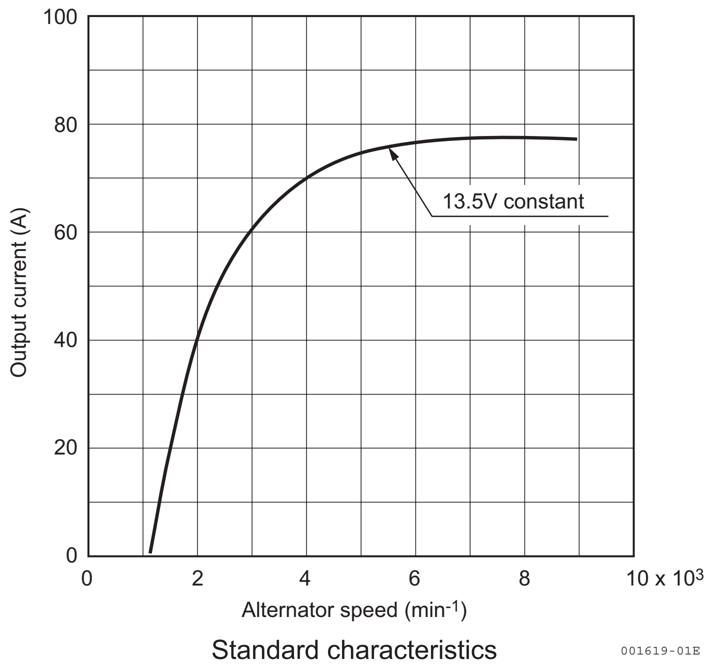


[NOTICE]

1) Don't do mis-connecting and short-circuit of each terminal.
2) Don't remove a battery terminal and a B terminal when rotating.
3) Shut out a battery switch during the alternator stop.

13.4.4 Standard output characteristics

The standard output characteristics of this alternator are shown as the below figure.

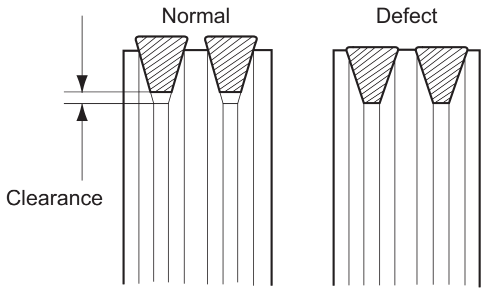


Standard characteristics

13.4.5 Inspection

(1) V-belt inspection

1) Inspect the matter whether there are not crack, stickiness and wear on the belt visually.
   Check that a belt doesn't touch the bottom part of the pulley groove. If necessary, replace the V-belt set.
2) V-belt tension:
   (Refer to 2.2.3(3) in Chapter 2.)



(Inspection of V pulley)

001616-01E

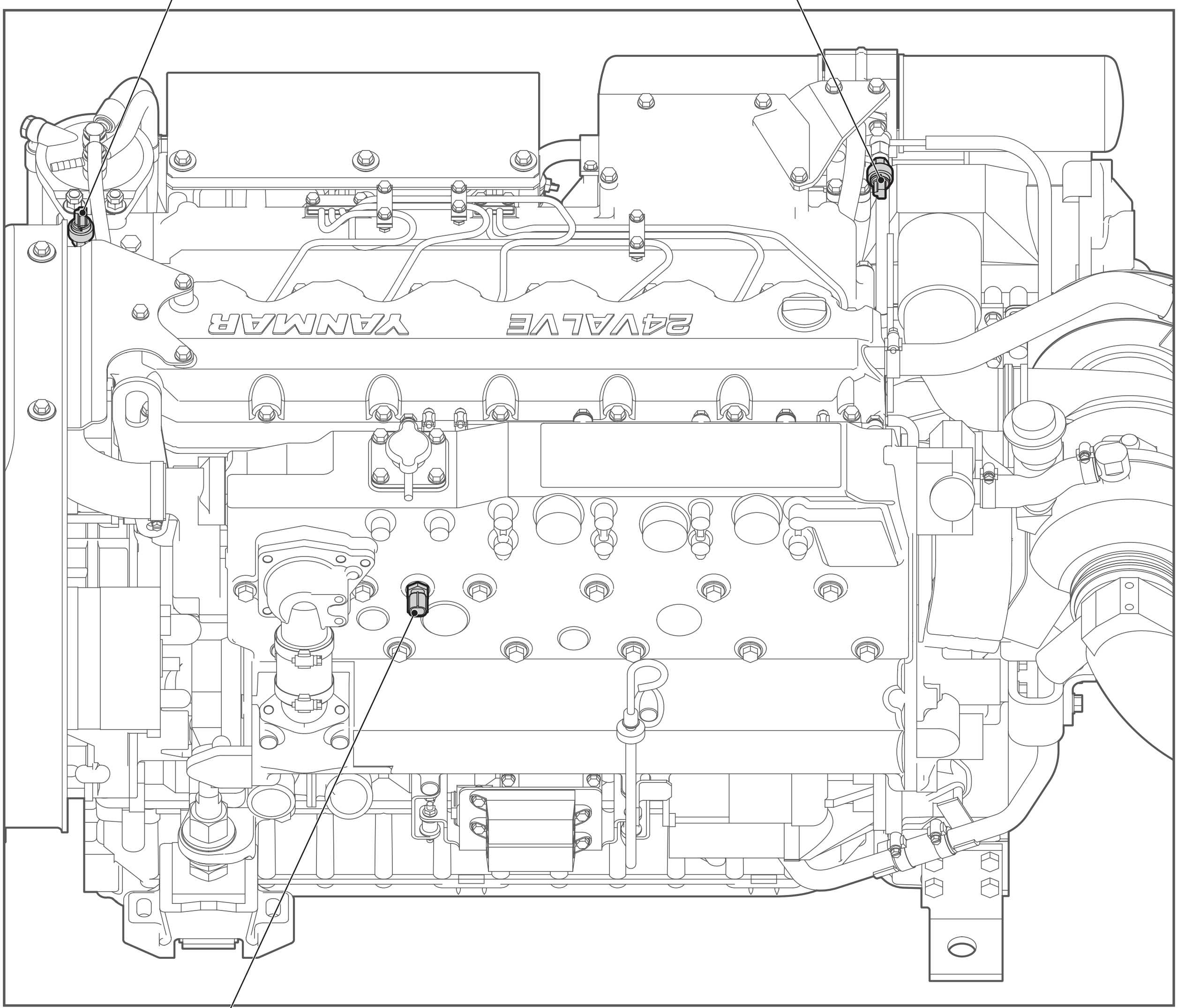
(2) Visual check of wiring and check of unusual sound

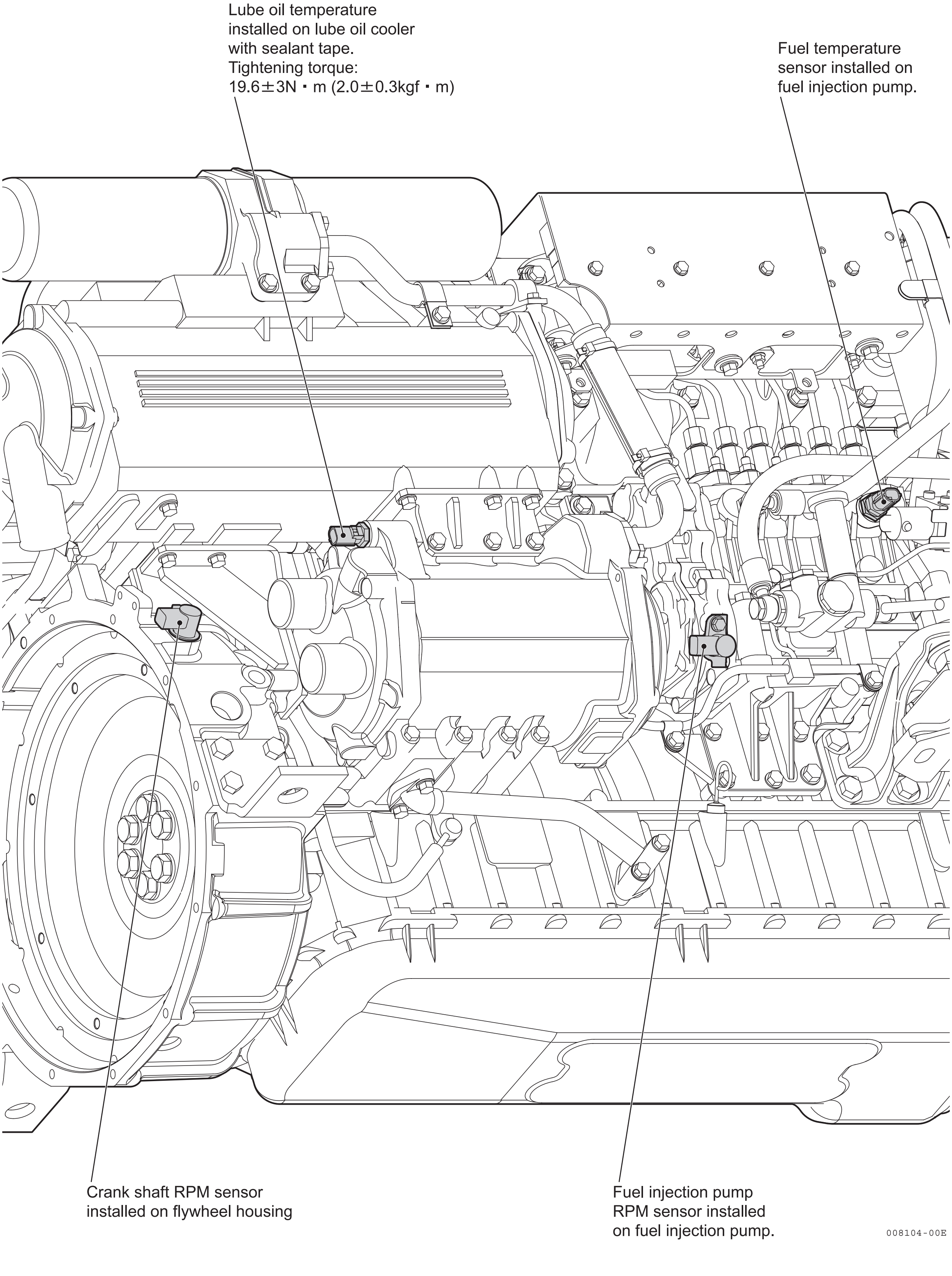
1) Confirm whether wiring is right or there is no looseness of the terminal part.
2) Confirm that there is no unusual sound from the alternator during the engine operation.

13.5 Warning devices

The electronic sensors are applied to this engine. The engine data from electronic sensors is sent to electronic control unit (ECU) and used for engine control.

13.5.1 Sensor installation position

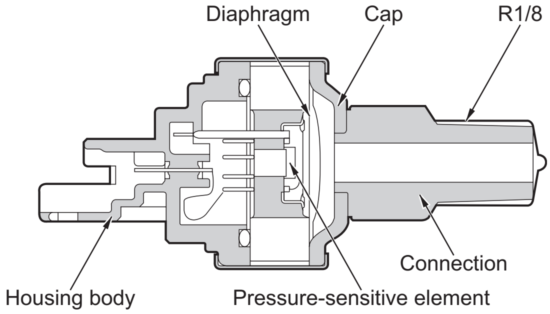


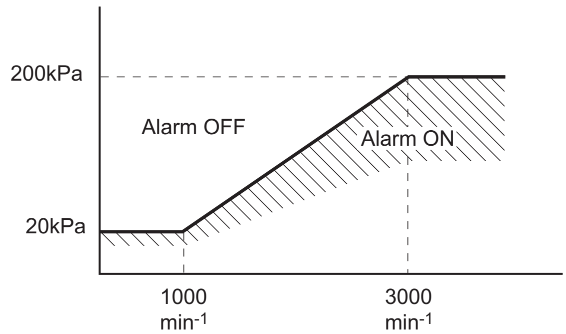

Lube oil temperature
installed on lube oil cooler
with sealant tape.
Tightening torque:
19.6±3N・m (2.0±0.3kgf・m)
Fuel temperature
sensor installed on
fuel injection pump.
Crank shaft RPM sensor
installed on flywheel housing
Fuel injection pump
RPM sensor installed
on fuel injection pump.
008104-00E

13.5.2 Lube oil pressure sensor and boost sensor

The lube oil pressure sensor is located on lube oil filter bracket and the boost sensor is located on intake manifold.
A lube oil pressure switch is not applied. The data of the lube oil pressure sensor is used by ECU for alarm indicator instead of a lube oil pressure switch.

Part code No.	119578-91300
Output	DC 0.5-3.5V
Operating pressure	0-1 MPa



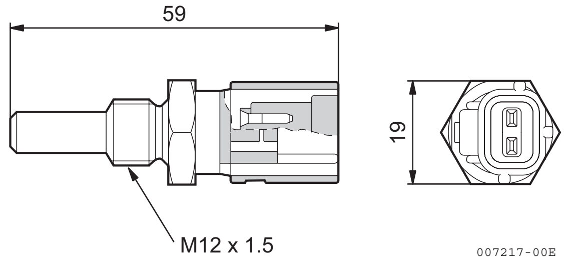


Alarm diagram of lube oil pressure

007162-00E

13.5.3 Temperature sensor for water, lube oil and fuel

The water temperature sensor is located on exhaust manifold near thermostat.
A water temperature switch is not applied. The data of the water temperature sensor is used by ECU for alarm indicator instead of a water temperature switch.
The lube oil temperature sensor is located on the top of lube oil cooler. The fuel temperature sensor is located on the side of fuel injection pump.
Refer to 14.1.

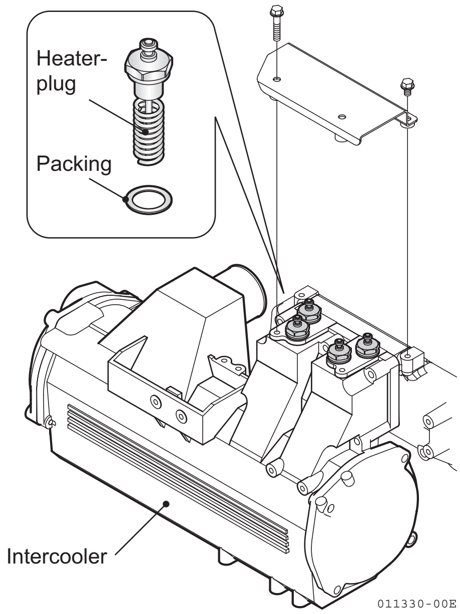


Part code No.	119254-44910
Rated voltage	DC 5V
Operating temperature	-30°C ~ +120°C
Tightening torque	19.6N•m (200kgf•cm) or less

13.6 Air heater

A heater-plug for starting aid is available for warming charging air when starting in cold areas in winter. The heater-plug is mounted on the upper part of the intercooler.
The heater-plug is automatically controlled by sensing the coolant temperature with ECU (engine control unit). When pressing a starter switch to "Eng ON" position, the heater-plug is automatically turned on (pre-heat) for maximum 30 seconds according to the coolant temperature (operating at 10 °C or less), and heats the charging air to facilitate the engine start.
After the engine starting, the heater-plug automatically continues to be turned on (after-heat) for maximum 10 minutes and improves low-load combustion in a cold season.
When the coolant temperature reaches 45°C, energizing the heater-plug is cut off.

Part No.	119575-77050
Rated current	58 A
Rated voltage	DC 11V
Tightening torque	25 N•m or less



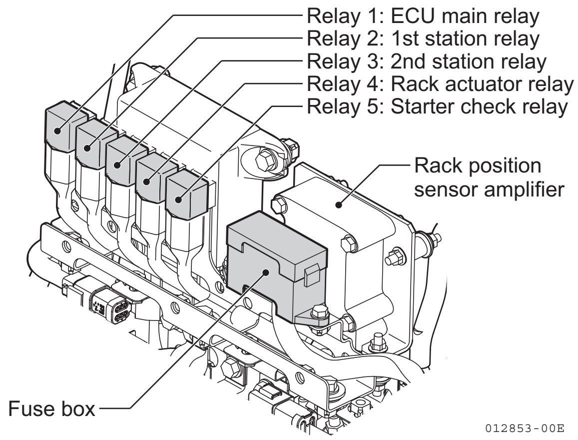
13.7 Fuse, relay and harness

When a harness short-circuits in some causes, the fuse burns out. (A fuse never burns out under the usual state of use.)
As another cause if the power supply of the peripheral device is taken from the engine harness without notice, the fuse may burn out.
Refer to 3.2.1 "Troubleshooting from malfunction" for the fuse troubleshooting.
All the fuses for 6LY3 engine are shown in the table below.

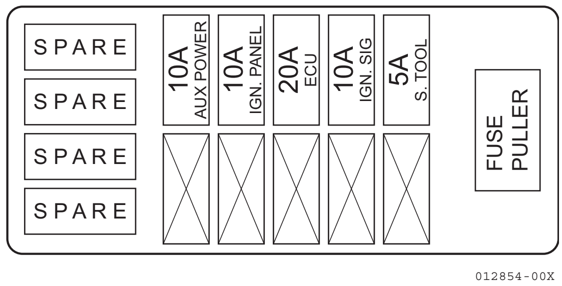
(1) Fuse

No.	Fuse size	Application	Fuse location	Parts No.
1	10A	AUX POWER	Fuse box	198535-52120
2	10A	IGN. PANEL (Switch panel)	Fuse box	198535-52120
3	20A	ECU	Fuse box	198535-52140
4	10A	IGN. SIG (Switch ON signal)	Fuse box	198535-52120
5	5A	S. TOOL (Service tool)	Fuse box	198535-52110
6	250A	Air Heater A	Below exhaust manifold	119578-77150
7	250A	Air Heater B	Below exhaust manifold	119578-77150
8	150A	ALTERNATOR	Below exhaust manifold	119578-77090
9	50A	STARTER RELAY	Below exhaust manifold	119578-77080
10	5A	IGN. SIG 1st Station (Switch ON signal)	Rocker switch panel (1st Station)	170203-91930
11	5A	IGN. SIG 2nd Station (Switch ON signal)	Rocker switch panel (2nd Station)	170203-91930

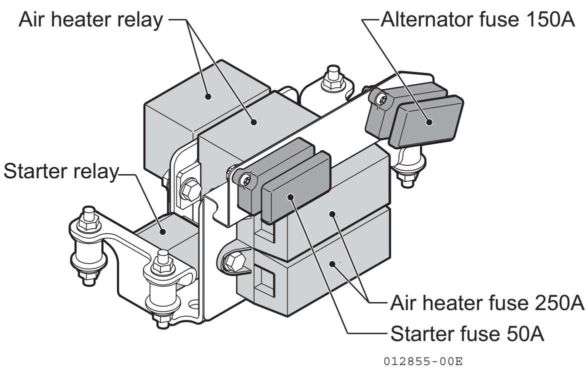
(2) Fuse and relay location



Fuse location label for fuse box

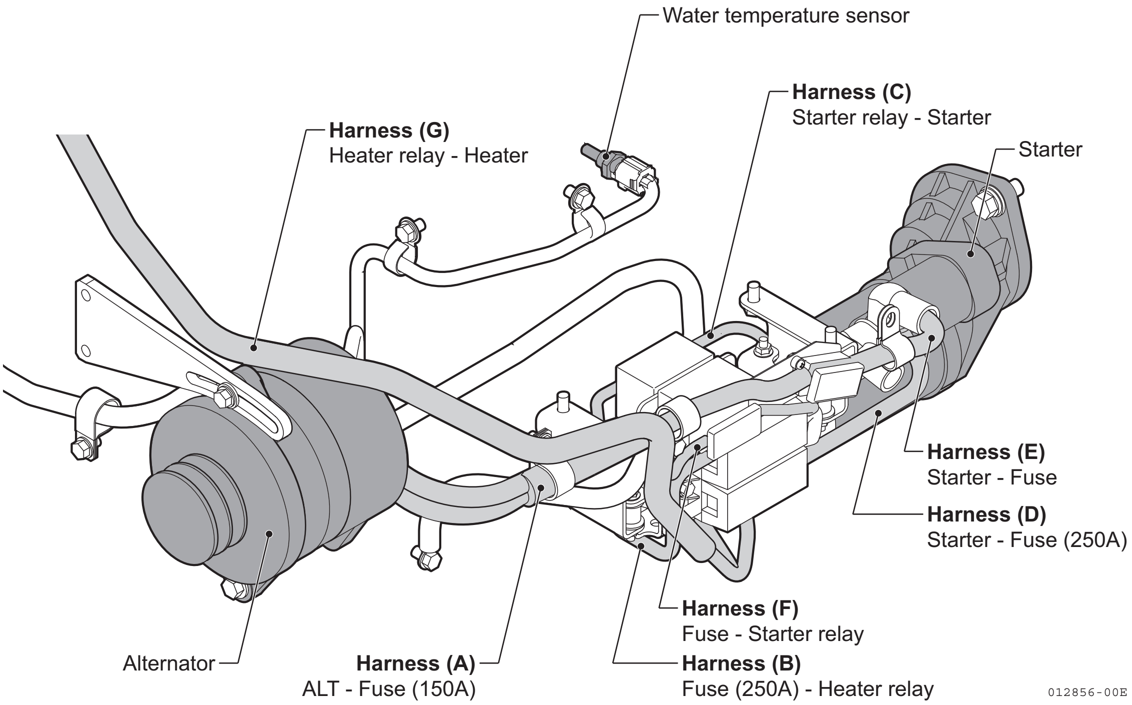


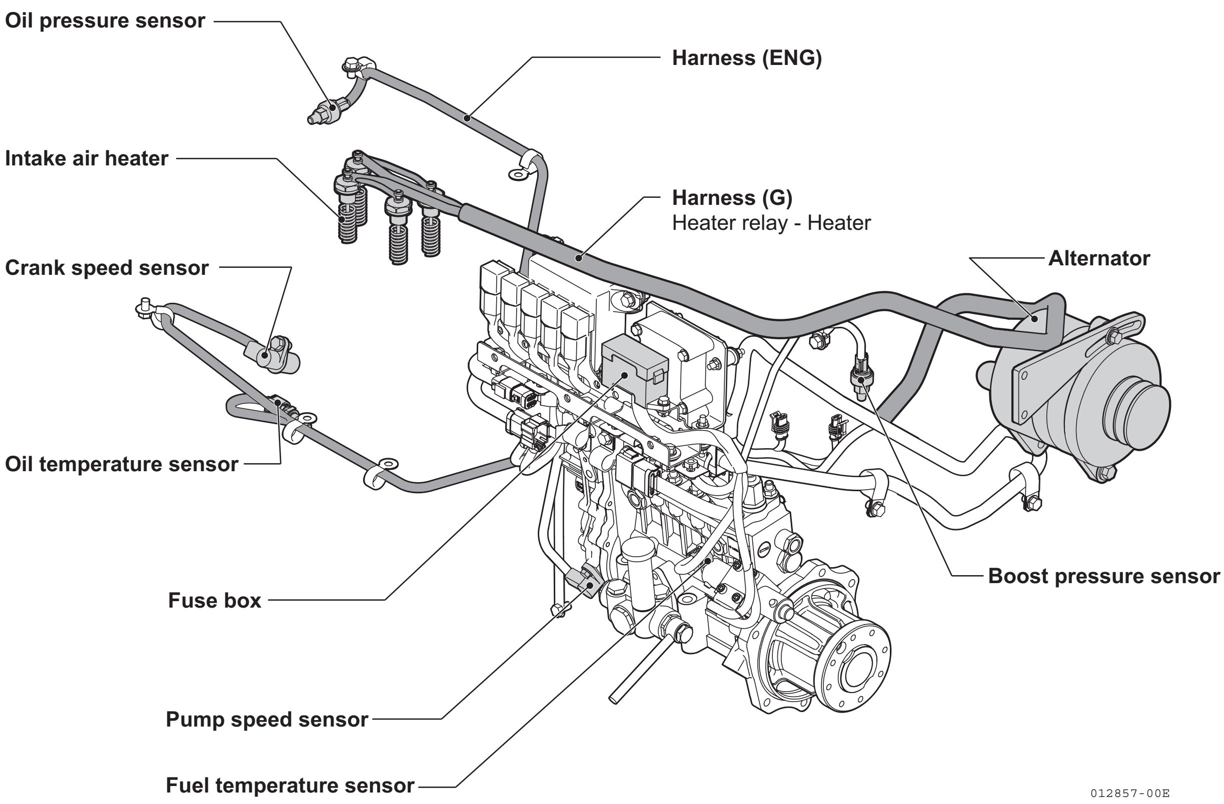
Relay assembly under exhaust manifold



(3) Wire harness location

Harness (ENG): Harness assembly for engine electric devices.
Harness (A) : for alternator (Connection between alternator B terminal and alternator fuse).
Harness (B) : for air heater A / B (Connection between heater relays A / B and heater fuses A / B).
Harness (C) : for starter (Connection between starter relay and starter S terminal).
Harness (D) : for starter / air heater (Connection between starter relay, starter S terminal and heater fuses A / B).
Harness (E) : for starter / alternator (Connection between starter B terminal and alternator fuse).
Harness (F) : for starter (Connection between starter relay and starter S terminal fuse).
Harness (G) : for air heater (Connection between heater relays A / B and heater A / B).




Oil pressure sensor
Harness (ENG)
Intake air heater
Harness (G)
Heater relay - Heater
Alternator
Crank speed sensor
Oil temperature sensor
Boost pressure sensor
Fuse box
Pump speed sensor
Fuel temperature sensor
012857-00E

14. Service standards

14.1 Engine tuning

No.	Inspection item			Standard	Limit	Reference page
1	Valve clearance	Intake	mm	0.15-0.25	-	2.2.4(2)
		exhaust		0.45-0.55	-	
2	V-belt tension at 98N (10kgf) force	Used part	mm	8-10	-	2.2.3(3)
		New part		6-8	-	
3	Fuel opening pressure	No.1 press.	MPa (kgf/cm^2)	24.00-24.98 (245-255)	-	2.2.4(1)
		No.2 press.		36.96-38.34 (377-391)	-	
4	Cooling water capacity	Engine	Liter	28	-	2.2.1(5)
		Coolant recovery tank		1.5	-	
5	Lube oil capacity (full) at rake angle 0 degree	Engine	Liter	18.8	-	2.2.1(3)
6	Lube oil pressure		MPa (kgf/cm^2)	0.40-0.50 (4.1-5.1)	-	8.2.4
7	Oil pressure alarm (ON)	1000 min^{-1}	kPa	20 or less	-	13.5.2
		3000 min^{-1}		200 or less	-	
8	Thermostat	Valve opening temperature	deg.C	69-73	-	2.4
		Full opening lift	mm	8 or above (90 deg.C)	-	
9	Coolant temperature alarm	ON	deg.C	100	-	13.5.3
		OFF		95	-	
10	Oil temperature alarm	ON	deg.C	110	-	
		OFF		105	-	
11	Fuel temperature alarm	ON	deg.C	80	-	
		OFF		75	-	
12	Top clearance		mm	0.78-0.98	-	5.2.7

14.2 Engine body

14.2.1 Cylinder head

(1) Cylinder head

Inspection item			Standard	Limit	Reference page
Combustion surface distortion		mm	0.05 or less	0.20	5.2.1(1)
Valve sink	Intake	mm	0.7-0.9	1.2	5.2.3(3)
	Exhaust		1.2-1.4	1.7	
Valve seat angle	Intake	deg.	90	-	5.2.1(3)
	Exhaust		90	-	

(2) Intake / exhaust valve and guide

Inspection item			Standard	Limit	Reference page
Intake	Guide inside diameter	mm	8.010-8.025	8.1	5.2.3
	Valve stem outside diameter		7.960-7.975	7.90	
	Clearance		0.035-0.065	0.18	
Exhaust	Guide inside diameter		8.015-8.030	8.1	
	Valve stem outside diameter		7.955-7.970	7.90	
	Clearance		0.045-0.075	0.18	
Valve guide projection	Intake	mm	9.0-9.5	-	5.2.3(4)
	Exhaust		7.0-7.5	-	
Valve guide driving-in method			Cold-fitted	-	

(3) Valve spring

Inspection item		Standard	Limit	Reference page
Free length (intake / exhaust)	mm	53.0	51.5	5.2.4(1)
Inclination (intake / exhaust)	mm	-	1.2	

(4) Rocker arm and shaft

Inspection item		Standard	Limit	Reference page
Arm shaft hole diameter	mm	20.000-20.020	20.090	5.2.8
Shaft outside diameter		19.970-19.990	19.955	
Clearance		0.010-0.050	0.140	

14.2.2 Camshaft and gear train

(1) Camshaft

Inspection item			Standard	Limit	Reference page
Side clearance		mm	0.05-0.20	0.29	5.6.1(1)
Bending (1/2 the dial gage reading)			-	0.02	5.6.1(4)
Cam height	Intake		49.435-49.565	49.185	5.6.1(2)
	Exhaust		48.135-48.265	48.110	
Camshaft and bearing	Bushing inside diameter	mm	56.980-57.050	57.130	5.6.1(3)
	Camshaft outside diameter		56.910-59.940	56.880	
	Clearance		0.040-0.130	0.240	

(2) Idle gear shaft and bushing

Inspection item		Standard	Limit	Reference page
Idle shaft dia.	mm	53.950-53.975	53.88	5.7.1(3)
Idle gear bushing inside dia.		54.000-54.025	54.08	
Oil clearance		0.025-0.075	0.15	

(3) Backlash of gear train

Inspection item		Standard	Limit	Reference page
Backlash of gear train	mm	0.08-0.16	0.25	5.7.1

14.2.3 Cylinder block

(1) Cylinder block

Inspection item			Standard	Limit	Reference page
Cylinder inside diameter		mm	105.900-105.930	105.950	5.1.5
Cylinder bore	Roundness	mm	0.03 or less	-	
	Cylindricity		0.02 or less	-	

(2) Crankshaft

Inspection item			Standard	Limit	Reference page
Bending (1/2 the dial gauge reading)			-	0.03	5.5.1(2)
Crank pin	Metal inside diameter	mm	65.000-65.045	65.100	5.4.2(2) 5.5.1(3) 5.5.2(2)
	Pin outside diameter		64.952-64.964	64.902	
	Metal thickness		1.987-2.000	-	
	Clearance		0.036-0.093	0.160	
Crank journal	Metal inside diameter		75.000-75.045	-	
	Journal outside diameter		74.952-74.964	74.90	
	Metal thickness		2.487-2.500	-	
	Clearance		0.036-0.093	0.15	

(3) Crankshaft thrust bearing

Inspection item		Standard	Limit	Reference page
Crankshaft side clearance	mm	0.132-0.223	0.29	5.5.1(4)

(4) Piston and ring

1) Piston

Inspection item			Standard	Limit	Reference page
Piston outside diameter (Measure in the direction vertical to the piston pin.)	L	mm	105.799-105.809	105.780	5.3.1(2)
	ML		105.794-105.799		
	MS		105.789-105.794		
	S		105.779-105.789		
Clearance between piston and cylinder			0.111-0.131	-	
Piston diameter measure position (Upward from the bottom end of the piston)			22	-	
Piston pin hole inside diameter			37.025-37.040	37.100	5.3.2
Piston pin outside diameter			36.994-37.000	36.964	
Clearance between piston pin and hole			0.025-0.046	0.110	

2) Piston ring

Inspection item			Standard	limit	Reference page
Top ring	Ring groove width	mm	2. 626-2.646	2.746	5.3.3(1) 5.3.3(2)
	Ring width		2.470-2.490	2.450	
	Side clearance		0.136-0.176	0.250	
	Gap		0.30-0.50	1.5	
Second ring	Ring groove width		2.570-2.585	2.140	
	Ring width		2.470-2.490	1.950	
	Side clearance		0.080-0.115	0.200	
	Gap		0.50-0.70	1.5	
Oil ring	Ring groove width		4.010-4.025	4.130	
	Ring width		3.970-3.990	3.950	
	Side clearance		0.020-0.055	0.150	
	Gap		0.25-0.45	1.5	

(5) Connecting rod

1) Rod big end

Inspection item		Standard	Limit	Reference page
Side clearance	mm	0.20-0.40	0.45	5.4.1(2)

2) Rod small end

Item		Standard	Limit	Reference page
Piston pin bushing inside diameter	mm	37.025-37.040	37.100	5.3.2 5.4.3(1)
Piston pin outside diameter		36.994-37.000	36.964	
Clearance		0.025-0.046	0.110	

(6) Tappet

Inspection item		Standard	Limit	Reference page
Tappet guide hole inside diameter	mm	14.249-14.270	14.30	5.6.2(2)
Tappet stem outside diameter		14.218-14.233	14.17	
Clearance		0.016-0.052	0.10	

15. Tightening torque for bolts and nuts

15.1 Main bolt and nut

No	Name		Thread diameter x pitch	Lubricating oil application (thread portion, and seat surface)	Torque N•m (kgf•m)
1	Head bolt	New bolt	M14 x 1. 5	Coat with lube oil	1st: 118 (12.0) 2nd: 177 (18.0) 3rd: 216-236(22.0-24.1)
		Used bolt			1st: 108 (11.0) 2nd: 167 (17.0) 3rd: 196-216(20.0-22.0)
2	Rod bolt		M12 x 1.25	Coat with lube oil	132.1-141.9(13.5-14.5)
3	Flywheel retainer bolt		M16 x 1. 5	Coat with lube oil	284-304 (29.0-31.0)
4	Metal cap bolt	New bolt	M15 x 1.5	Coat with lube oil	245-265 (25.0-27.0)
		Used bolt			225-245 (23.0-25.0)
5	Crankshaft pulley bolt (FC300 pulley)		M16 x 1.5	Coat with lube oil	216-236 (22.3-24.1)
6	Timer housing bolt		M8 x 1.25	No lube oil	33.3-37.3 (3.4-3.8)
7	Timer gear bolt		M8 x 1.25	Coat with lube oil	34.8-38.8 (3.5-4.0)
8	Idle gear shaft bolt		M10 x 1.5	Coat with lube oil	62-66 (6.3-6.7)
9	Lube oil pump bolt		M12 x 1.75	Coat with lube oil	98-118 (10.0-12.0)
10	Turbocharger V band bolt		1/4-28UNF	Coat with Moly Coat on thread portion	5.4-7.4 (0.55-0.75)
11	Seawater pump gear bolt		M14 x 1.5	Coat with lube oil	73-83 (7.4-8.5)
12	Fuel nozzle sleeve		M13 x 1.5	No lube oil	52.9-62.7(5.4-6.4)
13	Nozzle fastening bolt		M8 x 1.25	Coat with lube oil	29.4-33.4(3.0-3.4)
14	Fuel injection pipe joint nut		M12 x 1.5	No lube oil	22.5-26.5(2.3-2.7)
15	Fuel return pipe joint bolt		M6 x 1.0	No lube oil	7.0-9.0(0.7-0.9)
16	Lube oil filter (full flow)		1-12UNF	Coat with lube oil on rubber packing	After touching rubber packing, turn additional 3/4 of a turn.
17	Lube oil filter (bypass)		M25 x 1.5	Coat with lube oil on rubber packing	After touching rubber packing, turn additional one turn.
18	Silencer installation hose band			-	2.5-3.5 (0.25-0.36)

15.2 Standard bolts and nuts (without lube oil)

N•m (kgf•m)

Name	Screw dia. x pitch	Tightening torque	Remarks
Hexagon bolt t (7T) and nut	M6 x 1	9.8-11.8(1.0-1.2)	Use 80% of the value at left when the tightening part is aluminum. Use 60% of the value at left for 4T bolts and lock nuts.
	M8 x 1.25	22.5-28.5(2.3-2.9)	
	M10 x 1.5	44-54(4.5-5.5)	
	M12 x 1.75	78.2-98.2(8.0-10.0)	
PT plug	1/8	9.8 (1.0)	
	1/4	19.6 (2.0)	
	3/8	29.4 (3.0)	
	1/2	58.8 (6.0)	
Pipe joint bolt	M8	12.7-16.7(1.3-1.7)	
	M10	19.5-25.5(2.0-2.6)	
	M12	24.4-34.4(2.5-3.5)	
	M14	39.1-49.1(4.0-5.0)	
	M16	48.9-58.9(5.0-6.0)	