YANMAR

SERVICE MANUAL

MARINE DIESEL ENGINE

MODELS

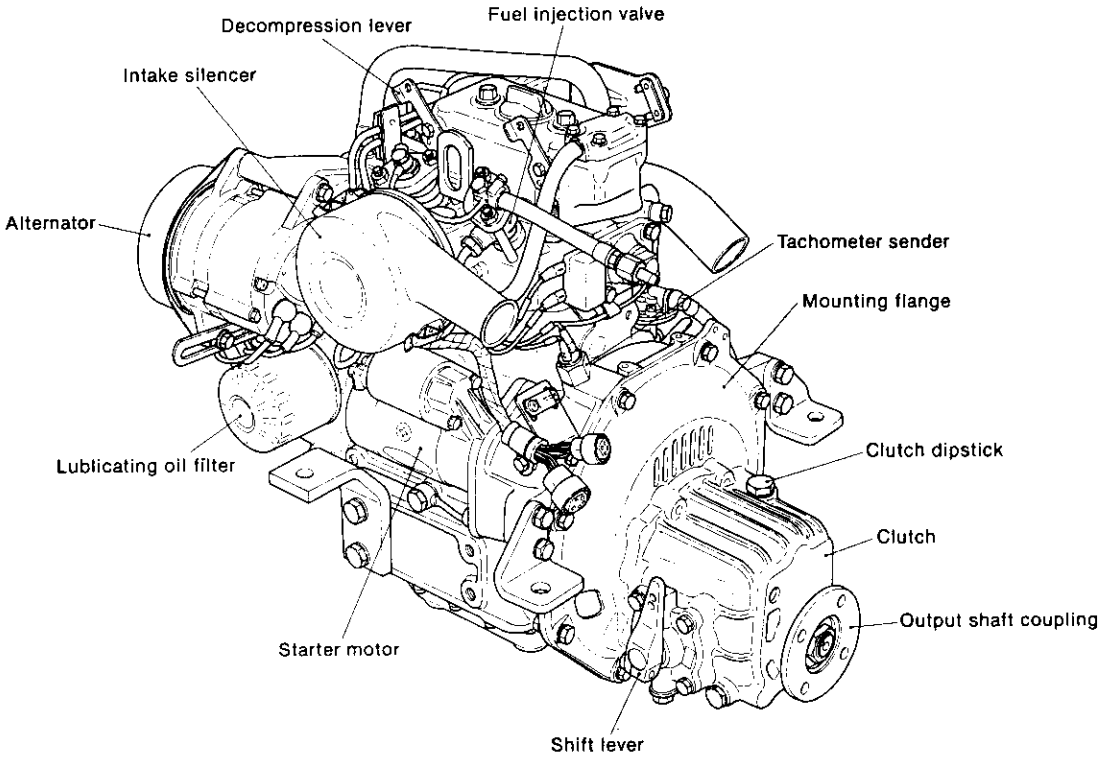
1GM (10L)
2GM (F)(L)
3GM (D)(F)(L)
3HM (F)(L)

CHAPTER 1

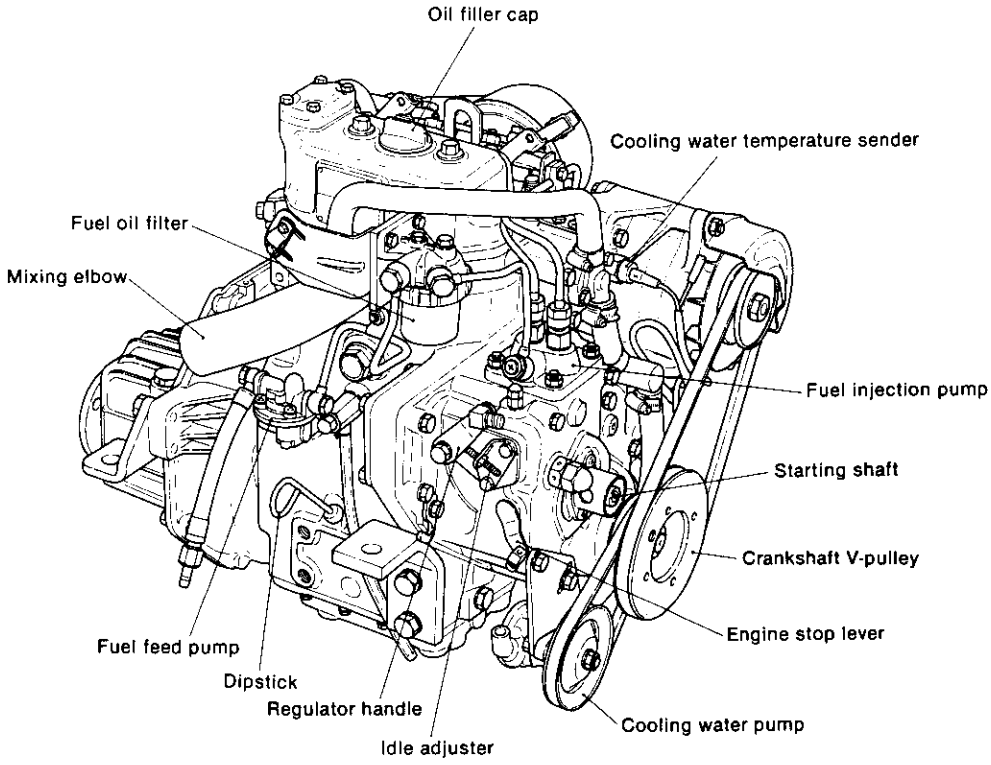
GENERAL

1-2 2GM

1-2.1 Intake side viewed from stem



1-2.2 Exhaust side viewed from bow



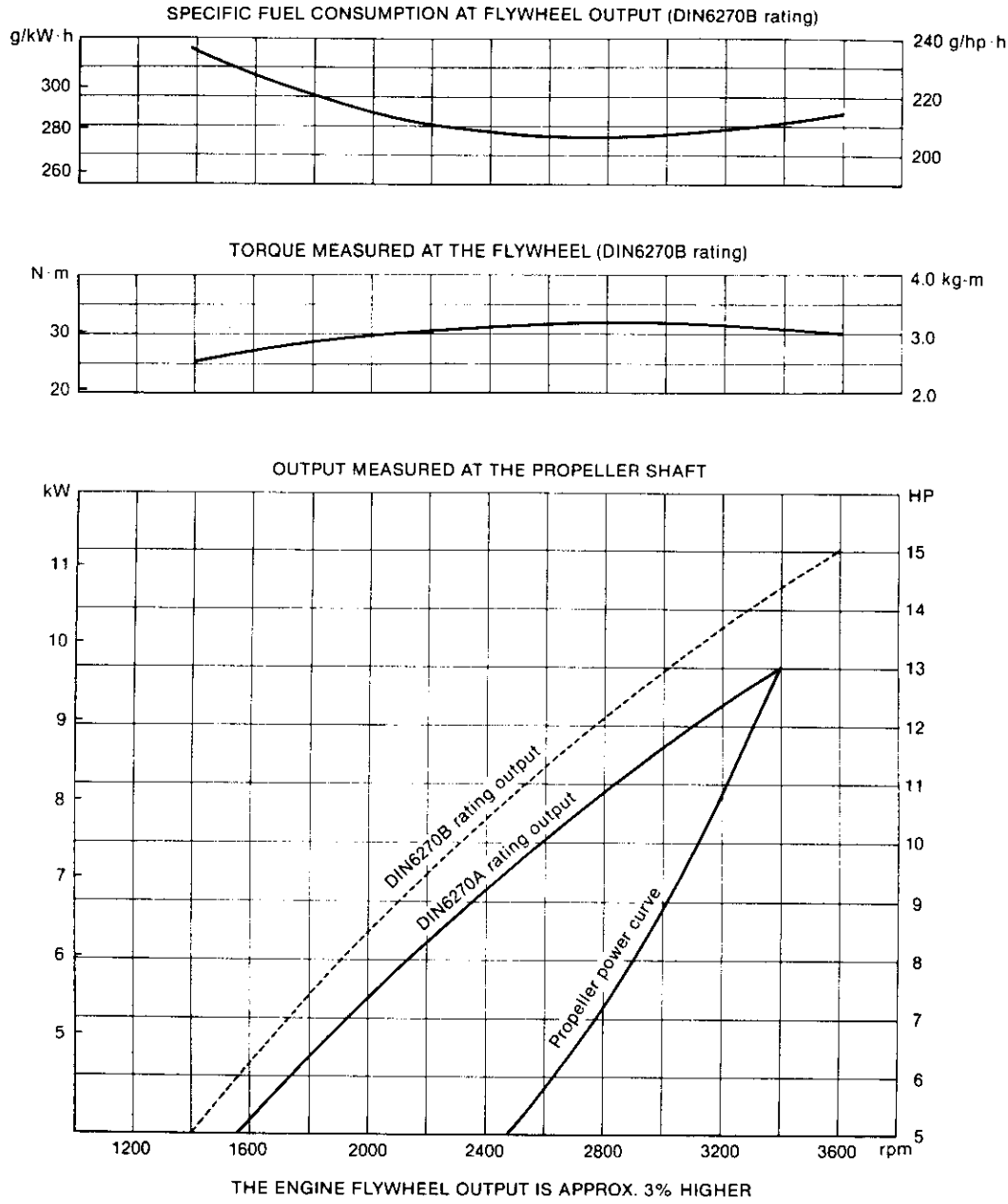
2. Specifications

Model			1GM	2GM	3GMD	3GM	3HM
Type			Vertical 4-cycle water cooled diesel engine				
Combustion chamber			Swirl pre-combustion chamber				
Number of cylinders			1	2	3		3
Bore × stroke		mm	72 × 72				75 × 85
Displacement		ℓ	0.293	0.586	0.879		1.126
Continuous rating output (DIN6270A)	Output/Crankshaft speed	HP/rpm	6.5/3400	13/3400	20/3400		27/3200
	Brake mean effective pressure	kg/cm²	5.87	5.87	6.02		6.74
	Piston speed	m/sec.	8.16				9.07
One hour rating output (DIN6270B)	Output/crankshaft speed	HP/rpm	7.5/3600	15/3600	22.5/3600		30/3400
	Brake mean effective pressure	kg/cm²	6.40				7.05
	Piston speed	m/sec.	8.64				9.63
Compression ratio			23.0				22.7
Fuel injection timing (FID)		degree	bTDC15±1	bTDC15±1	bTDC18±1	bTDC18±1	bTDC±21
Fuel injection pressure		kg/cm²	170				160
Main power take off			at Flywheel side				
Front power take off			at Crankshaft V-pulley side				
Direction of rotation	Crankshaft		Counter-clockwise viewed from stern				
	Propeller shaft (A head)		Clockwise viewed from stern				
Cooling system			Direct sea water cooling (rubber impeller water pump)				
Lubrication system			Complete enclosed forced lubrication				
Starting system			Electric and/or manual				Electric
Clutch	Model		KM2A		KM3A	KBW10D	KBW10E
	Type		Mechanical cone clutch with single stage for both ahead and astern			Wet multi-disc mechanical type	
	Reduction ratio (Ahead/Astern)		2.21/3.06	2.62/3.06	3.22/3.06	2.21/3.06	2.62/3.06	3.22/3.06	2.36/3.16	2.61/3.16	3.20/3.16	2.14/2.50	2.63/2.50	2.83/2.50	2.14/2.50	2.83/2.50
	Propeller speed DINA rating (Ahead/Astern)	rpm	1540/1113	1298/1113	1055/1113	1540/1113	1298/1113	1055/1113	1441/1076	1303/1076	1062/1076	1591/1360	1292/1360	1200/1360	1498/1280	1129/1280
	Lubricating oil capacity	ℓ	0.25			0.3			0.7							
	Clutch weight	kg	9.3			10.8			17			19				
Dimensions	Overall length	mm	527		623	740			755			791				
	Overall width	mm	410		410	410			410			451				
	Overall height	mm	485		495	495			502			612				
Lubricating oil capacity (rake angle 8°)	Total	ℓ	1.3		2.0	2.7			5.5							
	Effective	ℓ	0.6		1.3	1.8			3.0							
Engine weight with clutch (dry)		kg	70		100	130			130			158				

3. Principal Construction

Engine model		1GM	2GM	3GMD	3GM	3HM
Group	Part	Construction				
Engine block	Cylinder block	Integrally-cast water jacket and crankcase				
	Cylinder liner	Sleeveless	Dry sleeve type			
	Main bearing	Metal housing type				
	Oil sump	Oil pan				
Intake and exhaust systems and valve mechanism	Cylinder head	Integrated type cylinders				
	Intake and exhaust valves	Poppet type, seat angle 90°				
	Exhaust manifold	—		Separated water-cooled type		Integral water-cooled type
	Exhaust silencer	Water-cooled mixing elbow type				
	Valve mechanism	Overhead valve push rod, rocker arm system				
	Intake silencer	Round polyurethane sound absorbing type				
Main moving elements	Crankshaft	Stamped forging				
	Flywheel	Attached to crankshaft by flange, with ring gear				
	Piston	Oval type				
	Piston pin	Floating type				
	Piston rings	2 compression rings, 1 oil ring				
Lubrication system	Oil pump	Trochoid pump				
	Oil filter	Full-flow cartridge type, paper element				
	Oil level gauge	Dipstick				
Cooling system	Water pump	Rubber impeller type S	Rubber impeller type A			Rubber impeller type B
	Thermostat	Wax pellet type				
Fuel system	Fuel injection pump	YPFR-0707-1	YPFR-0707-2	YPFR-0707		
	Fuel injection valve	530 semi-throttle valve				
	Fuel strainer	Filter paper				
Governor	Governor	Centrifugal all-speed mechanical type				
Starting system	Electric	Pinion ring gear type starter motor				
	Manual	Camshaft starting				—
Electrical system	Charger	Alternator (with built-in IC regulator)				
Reduction reversing	Reduction gear	Helical gear constant-mesh system				
Clutch system	Clutch	Servo-cone type			Wet multi-disc mechanical type	

4-2 2GM (F)


SPECIFIC FUEL CONSUMPTION AT FLYWHEEL OUTPUT (DIN6270B rating)
g/kW·h
300
280
260
240 g/hp·h
220
200
TORQUE MEASURED AT THE FLYWHEEL (DIN6270B rating)
N·m
30
20
4.0 kg·m
3.0
2.0
OUTPUT MEASURED AT THE PROPELLER SHAFT
kW
11
10
9
8
7
6
5
HP
15
14
13
12
11
10
9
8
7
6
5
DIN6270B rating output
DIN6270A rating output
Propeller power curve
1200
1600
2000
2400
2800
3200
3600
rpm
THE ENGINE FLYWHEEL OUTPUT IS APPROX. 3% HIGHER

5. Features

5-1 Superior combustion performance

The unique Yanmar swirl precombustion chamber and new cooling system display superior combustion performance in all types of operation. Low-speed, low-load combustion performance, especially demanded for marine applications, is also superb, and stable performance is maintained over a wide range of speeds. Since starting characteristics are also excellent and warm-up is fast, full engine performance can be obtained within a short time.

5-2 Low operating costs

Excellent combustion and low friction reduce fuel costs, while the optimized piston shape and ring configuration and improved cooling system reduce oil consumption. Continuous operating time has been extended and operating costs reduced through improved durability.

5-3 Compact, lightweight

The cylinder head is the integrally-cast type, and the crankshaft is the housing type. Minimum weight has been pursued for each engine part, and a reduction reversing gear employing a special new mechanism has been incorporated to obtain revolutionary engine lightness.

5-4 Long term continuous operation

Improved durability has been achieved by adopting special construction and materials for main moving parts and the valve mechanism, which are the areas most subject to trouble in high-speed engines. Moreover, a bypass system with a thermostat maintains the cooling water at a stable high temperature, resulting in reduced cylinder liner and piston ring wear, reduced thermal load around the combustion chamber, and substantially improved durability. Long-term continuous operation is possible by correct operation and proper attention to fuel and lubricating oil.

5-5 Low vibration

Vibration has been reduced by minimizing the weights of the pistons, connecting rods, and other sources of vibration, stringent weight management at assembly, and balancing of the flywheel, V-pulley, etc. Vibration has also been suppressed through the adoption of a special cylinder block rib construction and improved rigidity. Rubber shock mounts are available when the engine is to be used under conditions which may lead to severe vibration.

5-6 Quiet operation

Intake and exhaust noises have been lowered by adopting an intake silencer, water-cooled exhaust manifold and water mixing elbow type exhaust system.
The precombustion chamber system and semi-throttle type injection valve suppress combustion noise substantially.
Moreover, gear noise has been reduced by the use of helical gears around the gear train and clutch gear, and by the buffering effect of a damper disc.
In addition, noise prevention measures have also been taken at the control valve mechanism and other parts.

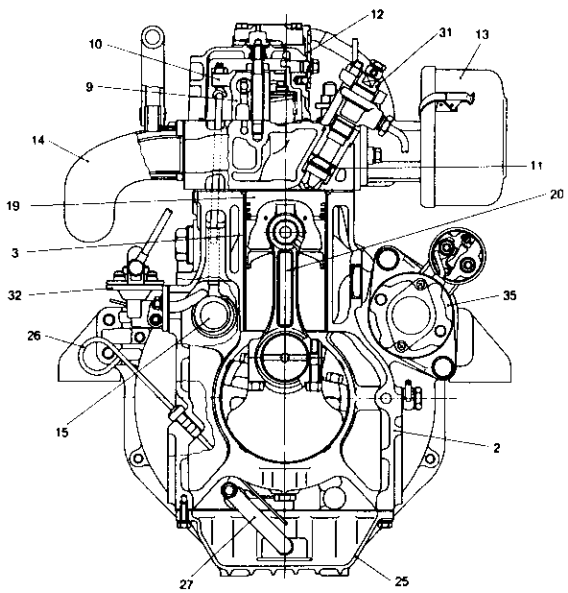
5-7 Superior matching to the hull

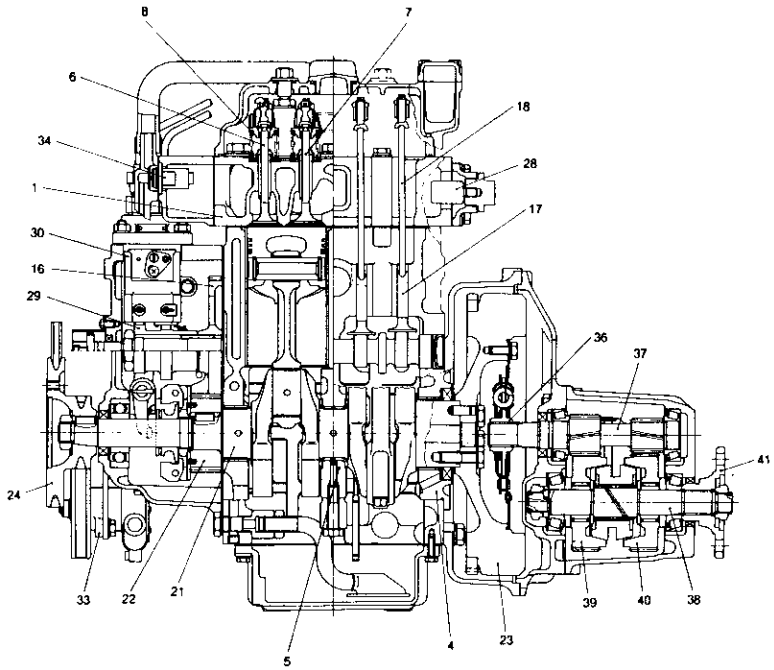
(1) Four-point support engine installation feet make installation easy.
(2) Mist intake system prevents contamination of the engine room.
(3) Since the fuel pump is mounted on the engine, the fuel tank can be installed anywhere.
(4) Water-cooled manifold prevents a rise in the engine room temperature.
(5) Independent type instrument panel can be installed wherever it is easiest to see.
(6) Speed, clutch forward and reverse, and engine stop can all be remotely controlled.
(7) The use of rubber and vinyl hoses for ship interior piping not only facilitates piping work, but also eliminates brazing faults caused by vibration.
(8) Electric type bilge pump is available as an option.

5-8 Easy to operate

(1) Cooling water temperature switch and lubricating oil pressure switch are provided, and alarm lamps and buzzer are mounted on the instrument panel.
(2) Manual starting handle permits manual starting. (Except model 3HM.)
(3) Positive clutch engagement and disengagement; propeller shaft does not rotate when clutch is placed in neutral position.

6-2 2GM

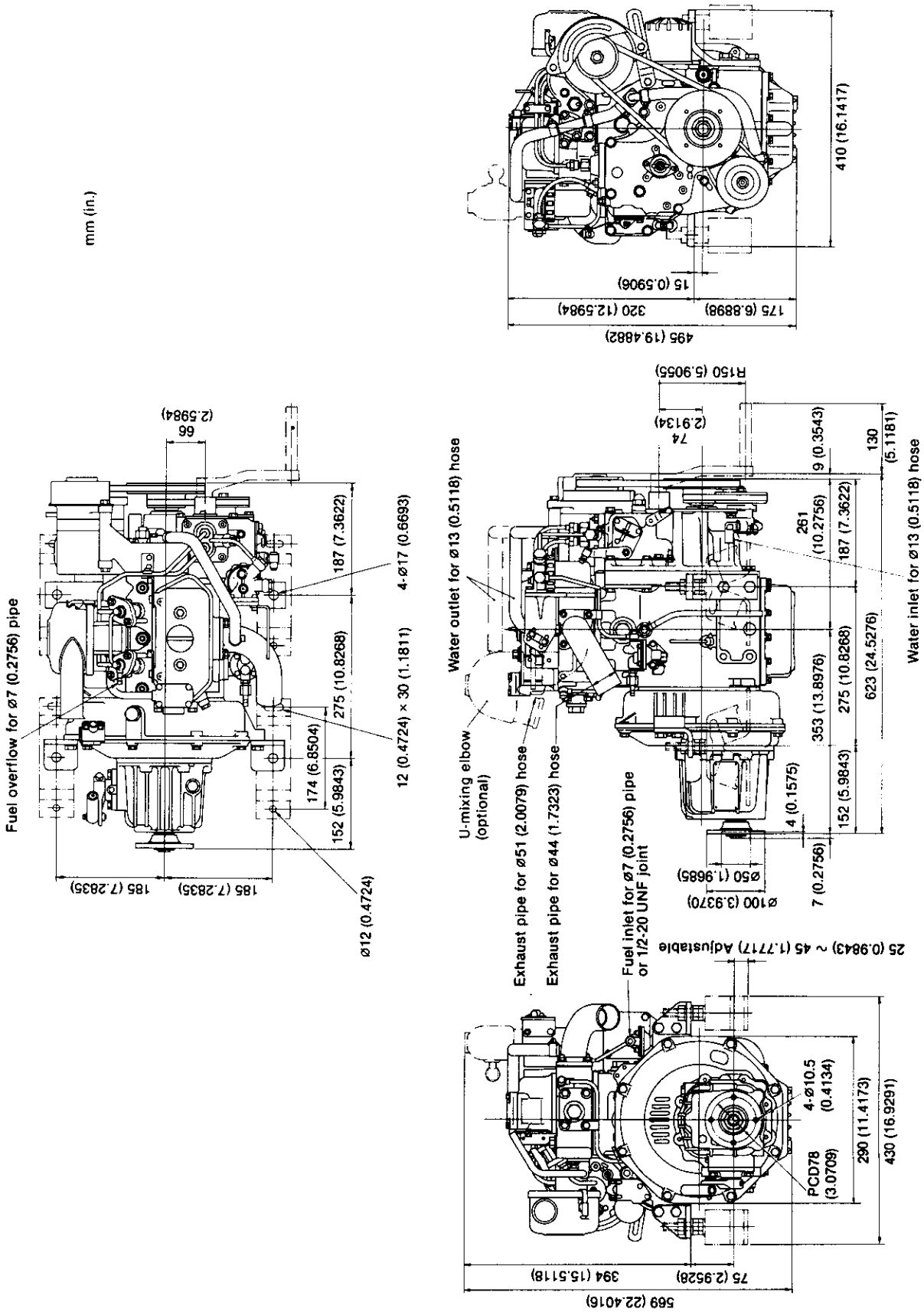




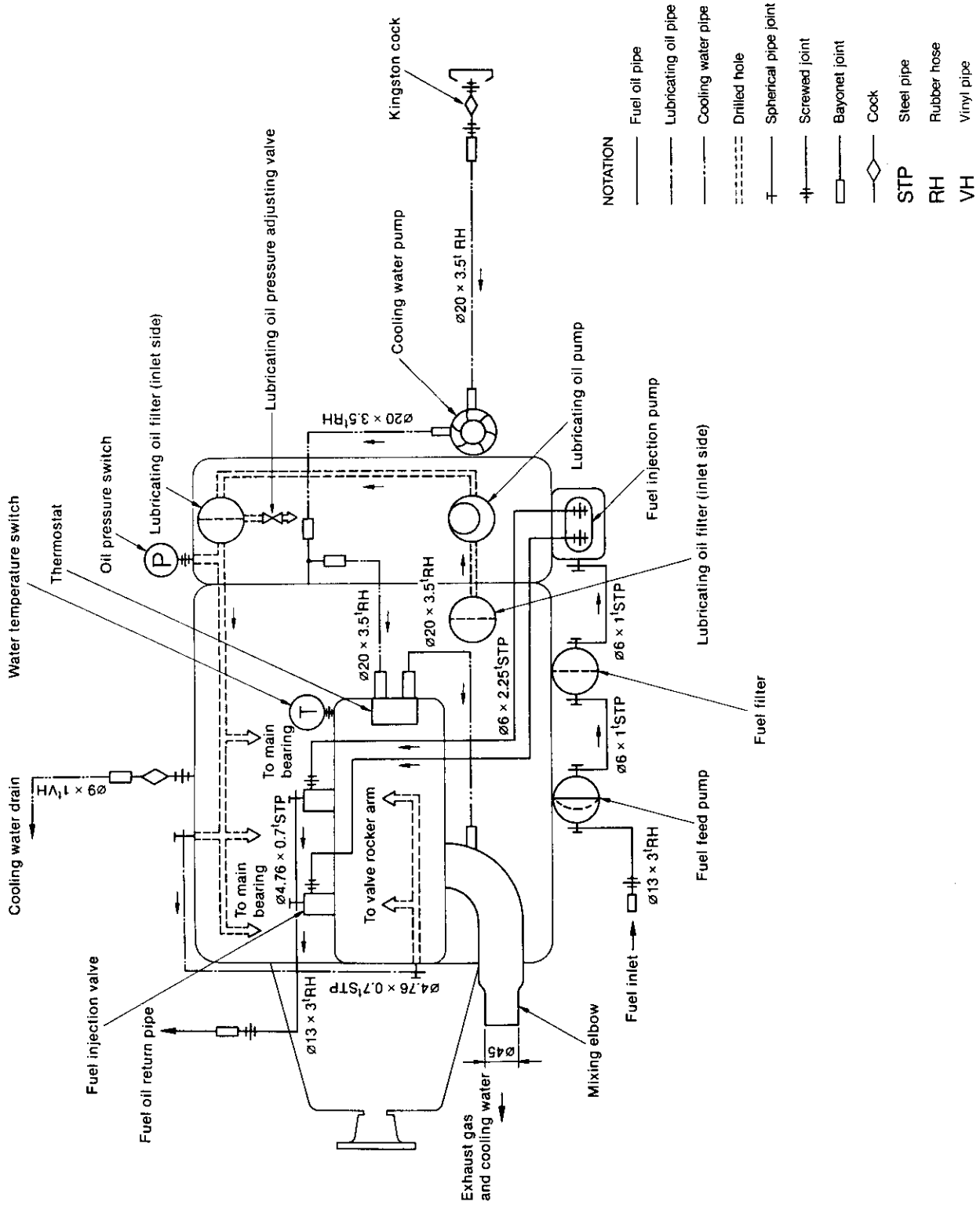
1. Cylinder head
2. Cylinder body
3. Cylinder liner
4. Main bearing housing
5. Intermediate main bearing housing
6. Exhaust valve
7. Intake valve
8. Valve spring
9. Valve rocker arm support
10. Valve rocker arm
11. Precombustion chamber
12. Decompression lever
13. Intake silencer
14. Exhaust manifold
15. Camshaft
16. Camshaft gear
17. Tappet
18. Push rod
19. Piston
20. Connecting rod
21. Crankshaft
22. Crankshaft gear
23. Flywheel
24. Crankshaft V-pulley
25. Oil pan
26. Dipstick
27. Lubricating oil inlet pipe
28. Anticorrosion zinc
29. Fuel injection pump cam
30. Fuel injection pump
31. Fuel injection nozzle
32. Fuel feed pump
33. Cooling water pump
34. Thermostat
35. Starter motor
36. Damper disc
37. Input shaft
38. Output shaft
39. Forward large gear
40. Reverse large gear
41. Output shaft coupling

7-2 2GM

mm (in.)


410 (16.1417)
15 (0.5906)
175 (6.8898)
320 (12.5984)
495 (19.4882)
R150 (5.9055)
74 (2.9134)
9 (0.3543)
130 (5.1181)
261 (10.2756)
187 (7.3622)
623 (24.5276)
275 (10.8268)
353 (13.8976)
152 (5.9843)
4 (0.1575)
7 (0.2756)
Ø50 (1.9685)
Ø100 (3.9370)
Water outlet for ø13 (0.5118) hose
Water inlet for ø13 (0.5118) hose
U-mixing elbow (optional)
Exhaust pipe for ø51 (2.0079) hose
Exhaust pipe for ø44 (1.7323) hose
Fuel inlet for ø7 (0.2756) pipe or 1/2-20 UNF joint
25 (0.9843) ~ 45 (1.7717) Adjustable
4-ø10.5 (0.4134)
PCD78 (3.0709)
290 (11.4173)
430 (16.9291)
75 (2.9528)
394 (15.5118)
569 (22.4016)
66 (2.5984)
Fuel overflow for ø7 (0.2756) pipe
187 (7.3622)
4-ø17 (0.6693)
275 (10.8268)
12 (0.4724) × 30 (1.1811)
174 (6.8504)
152 (5.9843)
185 (7.2835)
185 (7.2835)
ø12 (0.4724)

8-2 2GM


Kingston cock
Cooling water pump
ø20 × 3.5¹ RH
Lubricating oil pressure adjusting valve
Lubricating oil filter (inlet side)
Oil pressure switch
Thermostat
Water temperature switch
Lubricating oil pump
Fuel injection pump
Lubricating oil filter (inlet side)
Fuel filter
Fuel feed pump
Cooling water drain
To main bearing
To valve rocker arm
Fuel injection valve
Fuel oil return pipe
Fuel inlet
Mixing elbow
Exhaust gas and cooling water
NOTATION
Fuel oil pipe
Lubricating oil pipe
Cooling water pipe
Drilled hole
Spherical pipe joint
Screwed joint
Bayonet joint
Cock
STP Steel pipe
RH Rubber hose
VH Vinyl pipe

10. Standard Accessories

10-1 Parts packed with engine

The parts packed with the engine are listed below.

Part name	Remarks
Instrument panel with wiring harness, 3m	
Starting handle	except model 3HM
Tool box	
Operating manual	
Flexible mount.	

10-2 Parts mounted on engine

The parts mounted on the engine are listed below.

Part name	Remarks
Intake silencer	
Mixing elbow	
Cooling water pump	
Fuel feed pump	
Fuel oil filter	
Lubricating oil filter	
Oil pressure switch	
Cooling water temperature switch	
Thermostat	
Starter motor	
Alternator (with ICR)	
Electric wiring harness	
Speed remote control bracket	with cable clamp
Engine stop remote control bracket	
Engine stop device	
Clutch remote control bracket	with cable clamp
Clevis or spring joint	Fitted to clutch lever

11. Optional Accessories

11-1 Parts mounted on engine

The parts mounted on the engine are listed below.

Part name	Remarks
Tachometer sender	Hex plug M18 unnecessary

11-2 Parts packed with engine

The parts packed with the engine are listed below.

Part name	Remarks
Stop remote control cable ass'y	3m × 1
Morse one handle control	Model M12 top mounted type
Morse one handle control	Model MV side mounted type
Push-pull cable	33-C, 4m × 2
Battery switch	
Oil evacuation pump ass'y	
Kingston cock and cooling water pipe	Cooling water pipe; 2m × 1
Propeller shaft coupling	Taper type
Propeller shaft coupling	Slit type
Fuel oil tank and fuel oil pipe	Fuel oil tank; 30*l*, pipe; 2m
Spare parts kit	
Packing kit	
Special disassembly tools	
Instrument panel (large, with tachometer)	
Instrument panel (small)	
Extension wiring harness, 3m	To be selected according to order specifications. One harness is fitted as a standard accessory. However, longer parts are optionally available should the standard accessory prove too short.
U-type mixing elbow	except model 1GM

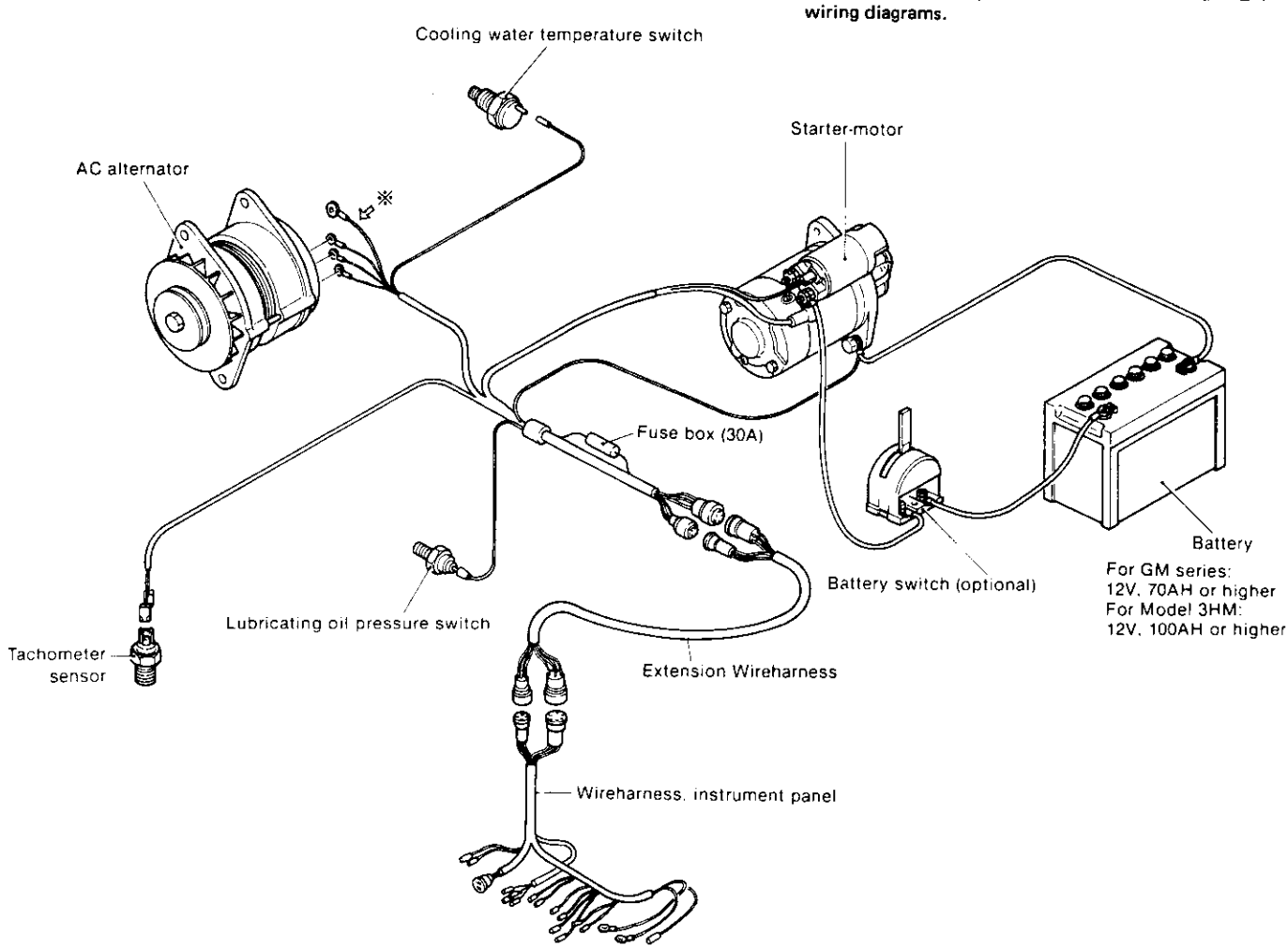
CHAPTER 10

ELECTRICAL SYSTEM

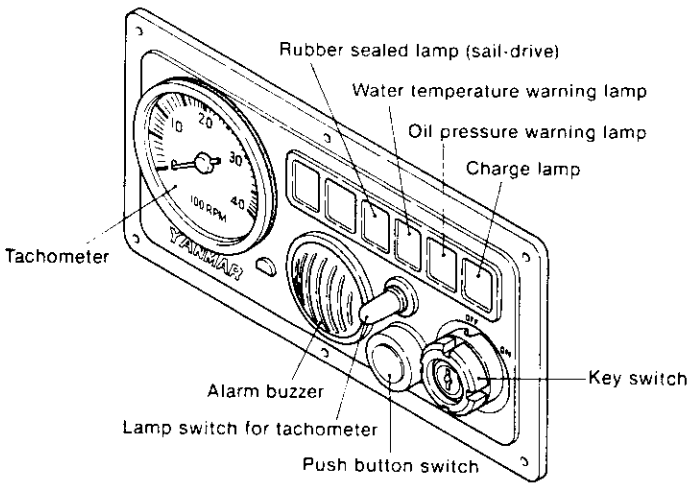
1. Electrical System

1-1 System diagram of electric parts

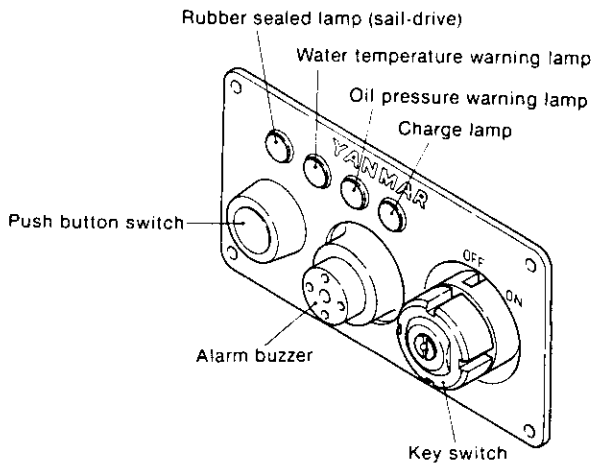
※ Additional terminal for new models.
For the applicable engine numbers, refer to the engines numbers specified under 1-2-2 and 1-2-4 wiring diagrams.



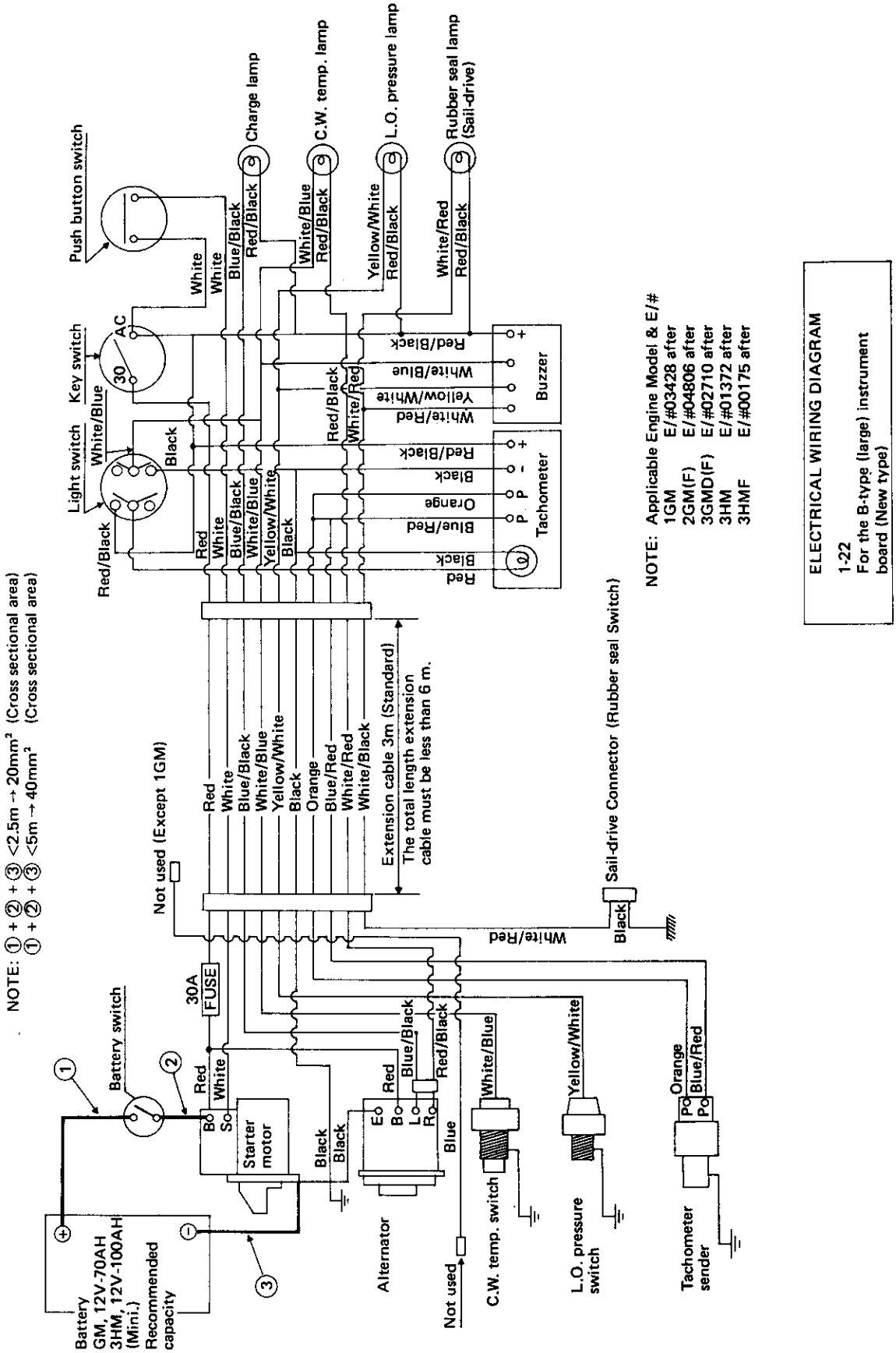
B-type instrument panel (large)



A-type instrument panel (small)

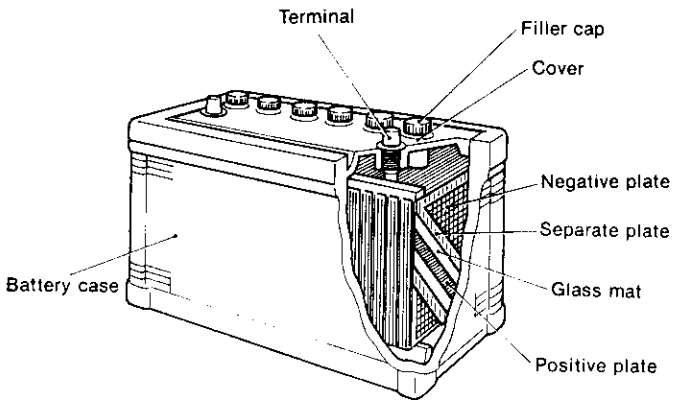


1-2.2 For the B-type (large) instrument board (New type)



2. Battery

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.

2-2 Battery capacity and battery cables

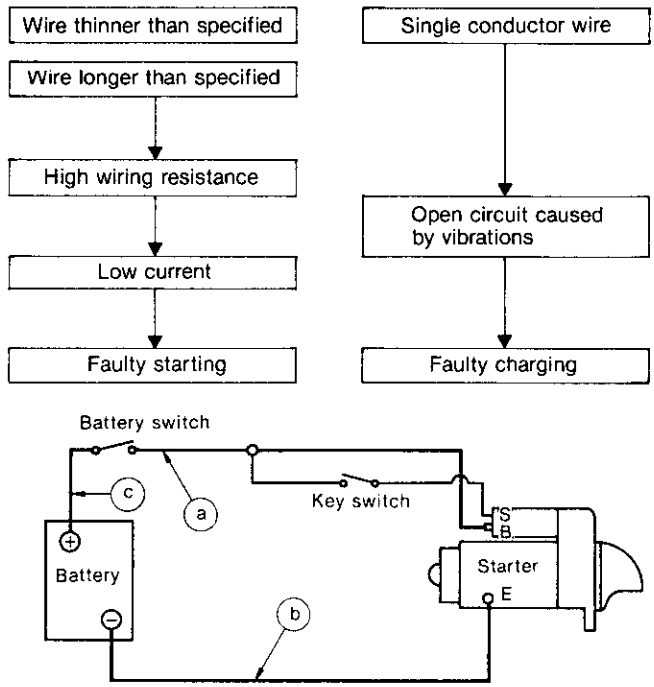
2-2.1 Battery capacity

Since the battery has a minimum capacity of 12V, 70AH, it can be used for 100 ~ 150AH.

	1GM, 2GM 3GM(D)	3HM
Minimum battery capacity	12V 70AH	12V 100AH
Fully charged specific gravity	1.26	1.26

2-2.2 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 wiring between the battery (+) terminal and the starter (B) terminal, and between the battery (−) terminal and the starter (E) terminal should be based on the following table.

Voltage system	Allowable wiring voltage drop	Conductor cross-section area	a + b + c allowable length
12V	0.2V or less/100A	20mm² (0.0311 in.²)	Up to 2.5m (98.43 in.)
		40mm² (0.062 in.²)	Up to 5m (196.87 in.)

NOTE: Excessive resistance in the key switch circuit (between battery and start (S) terminals) can cause improper pinion engagement. To prevent this, follow the wiring diagram exactly.

2-3 Inspection

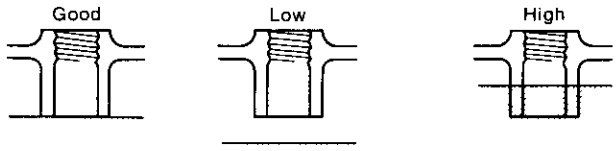
The quality of the battery governs the starting performance of the engine. Therefore the battery must be routinely inspected to assure that it functions perfectly at all times.

2-3.1 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.

2-3.2 Checking the electrolyte

(1) Electrolyte level

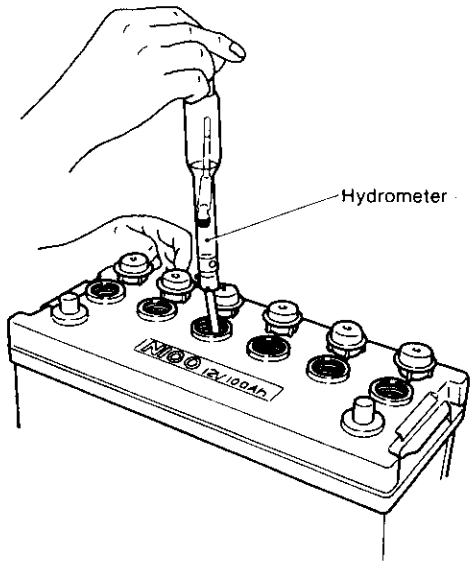


Check the electrolyte level every 7 to 10 days. The electrolyte must always be 10 ~ 20mm over the tops of the plates.

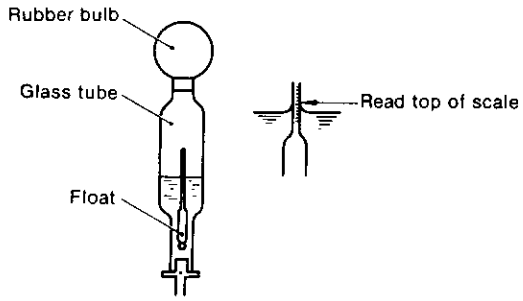
NOTES: 1) The "LEVEL" line on a transparent plastic battery case indicates the height of the electrolyte.
2) Always use distilled water to bring up the electrolyte level.
3) When the electrolyte has leaked out, add dilute sulfuric acid with the same specific gravity as the electrolyte.

(2) Measuring the specific gravity of the electrolyte

1) Draw some of the electrolyte up into a hydrometer.



2) Take the specific gravity reading at the top of the scale of the hydrometer.



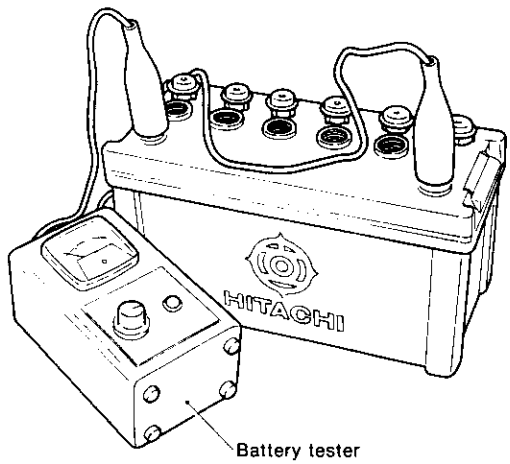
3) The battery is fully charged if the specific gravity is 1.260 at an electrolyte temperature of 20°C. The battery is discharged if the specific gravity is 1.200 (50%). If the specific gravity is below 1.200, recharge the battery.

4) If the difference in the specific gravity among the cells of the battery is ±0.01, the battery is OK.

5) 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 of the electrolyte at t°C
0.0007: Specific gravity change per 1°C
t: Temperature of electrolyte

2-3.3 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.

2-3.4 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.

2-4 Charging

2-4.1 Charging methods

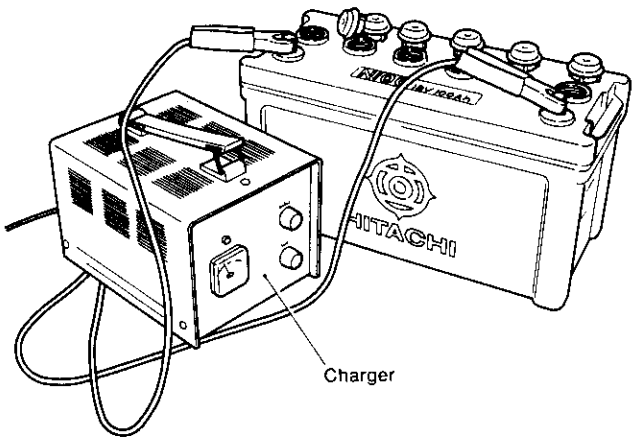
There are two methods of charging a battery: normal and rapid.

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 100AH battery). However, since rapid charging causes the electrolyte temperature to rise too high, special care must be exercised.

2-4.2 Charging procedure

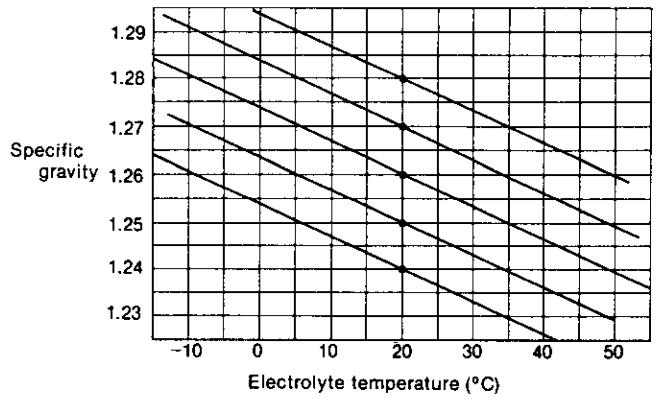
(1) Check the specific gravity and adjust the electrolyte level.
(2) Disconnect the battery cables.
(3) Connect the red clip of the charger to the (+) battery terminal and connect the black clip to the (−) terminal.



(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.

2-4.3 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].)

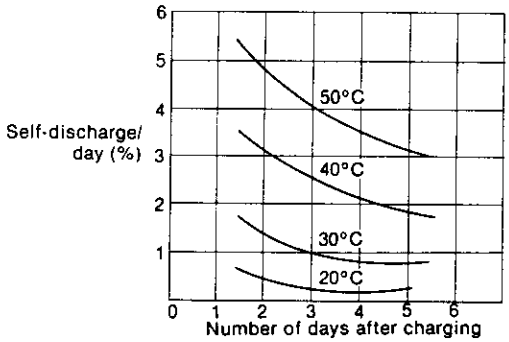


Electrolyte temperature and specific gravity

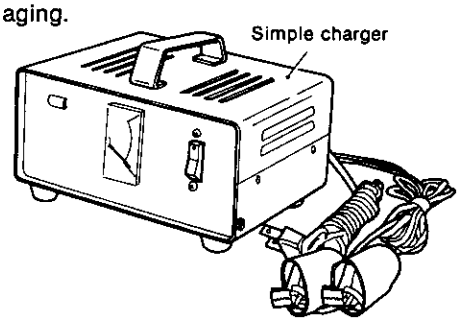
2-5 Battery storage precautions

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.

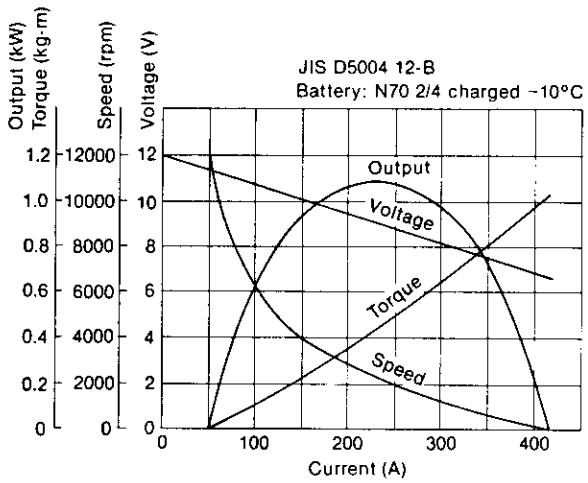


3. Starter Motor

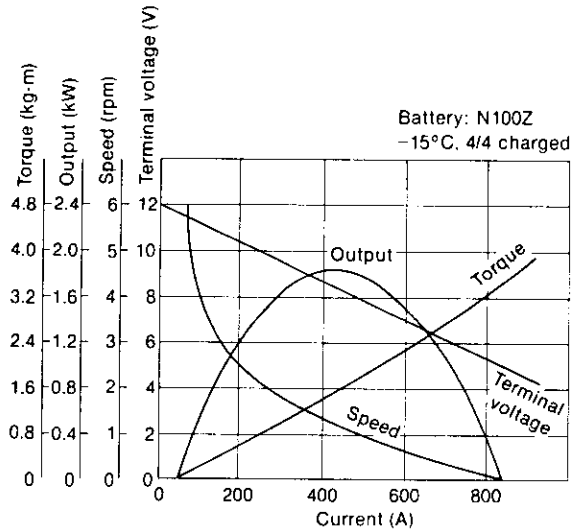
The starter motor is installed on the flywheel housing. When the starting button is pushed, the starter motor pinion flies out and engages the ring gear of the flywheel. Then the main contact is closed, current flows, and the engine is started.
After the engine starts, the pinion automatically returns to its initial position when the starting button is released. Once the engine starts, the starting button should be released immediately. Otherwise, the starter motor may be damaged or burned out.

3-1 Specifications and Performance.

Engine model		1GM, 2GM 3GM(D)	3HM
Model		S114-303	S12-79
Rating (sec)		30	30
Output (kW)		1.0	1.8
Direction of rotation (viewed from pinion side)		Clockwise	Clockwise
Weight kg (lb)		4.4 (9.7)	9.3 (20.5)
Clutch system		Overrunning	Overrunning
Engagement system		Magnetic shift	Magnetic shift
No. of pinion teeth		9	15
Pinion flyout voltage (V)		8 or less	8 or less
No-load	Terminal voltage (V)	12	12
	Current (A)	60 or less	90 or less
	Speed (rpm)	7000 or greater	4000 or greater
Loaded characteristics	Terminal voltage (V)	6.3	8.5
	Current (A)	460 or less	420
	Torque kg-m (ft-lb)	0.9 (6.51) or greater	1.35 (9.76) or greater



S114-303 Performance curves



S12-79 Performance curves

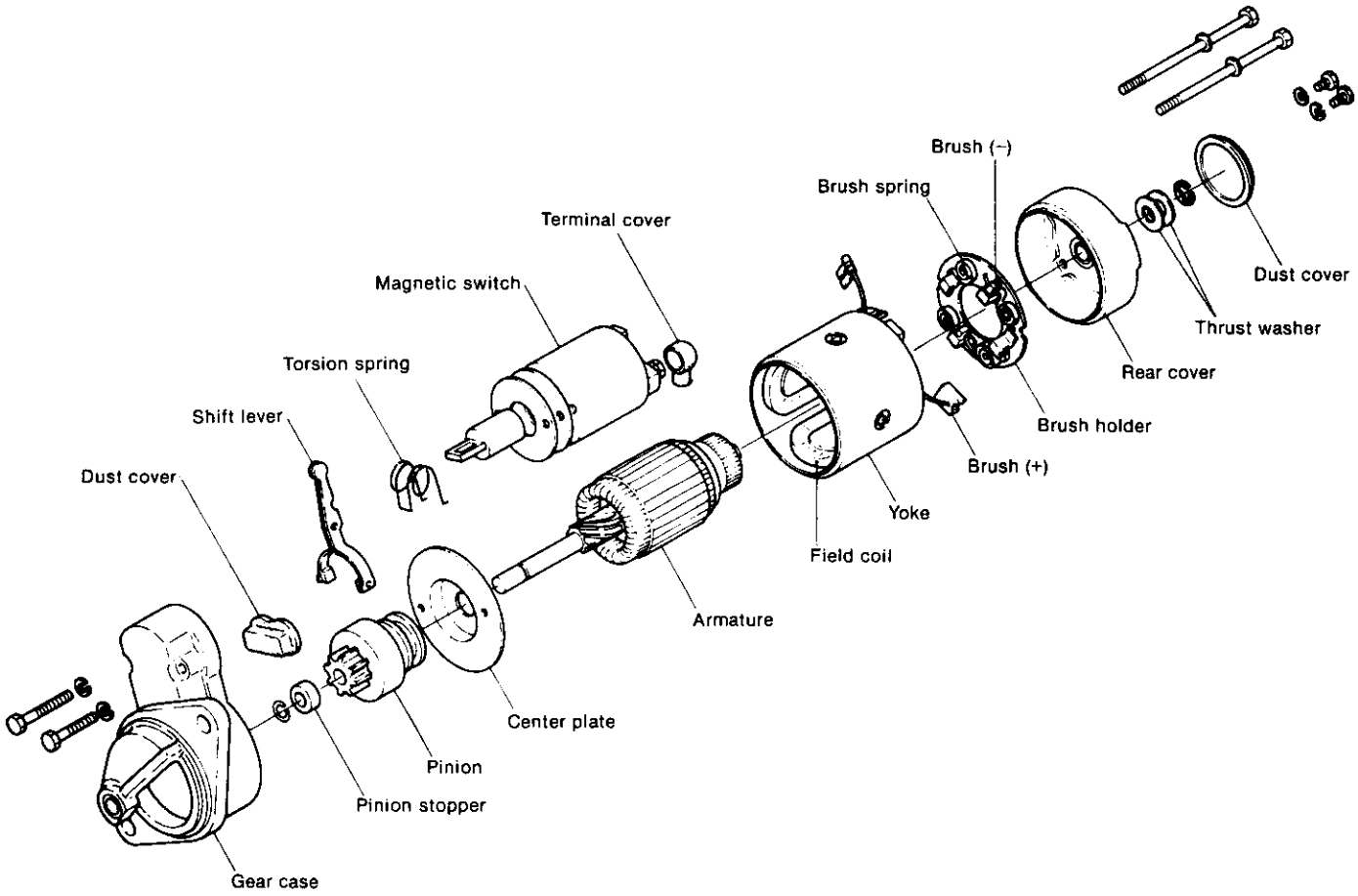
3-2 Construction

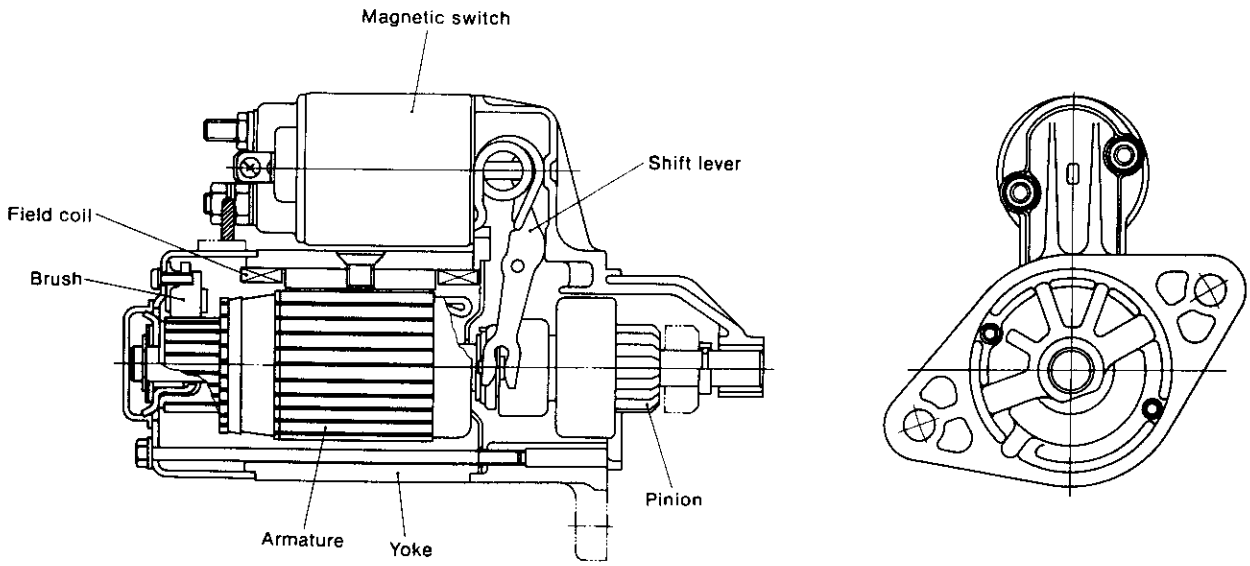
This starter motor described in this section is a conventional pre-engaged 4-brush 4-pole starter motor with a screw roller drive clutch.
The starter motor is composed of three major parts, as follows:

(1) Magnetic switch
Moves plunger to engage and disengage pinion, and through the engagement lever, opens and closes main contact (moving contact) to stop the starter motor.

(2) Motor
A continuous current series motor which generates rotational drive power.

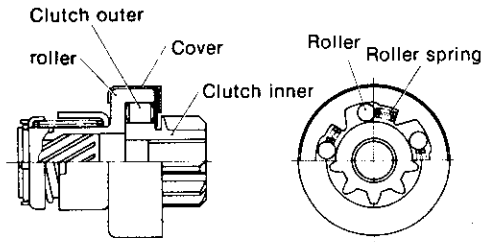
(3) Pinion
Transfers driving power from motor to ring gear. An overspeed clutch is employed to prevent damage if the engine should run too fast.


Brush (−)
Brush spring
Terminal cover
Magnetic switch
Dust cover
Thrust washer
Torsion spring
Rear cover
Shift lever
Brush holder
Brush (+)
Dust cover
Yoke
Field coil
Armature
Center plate
Pinion
Pinion stopper
Gear case

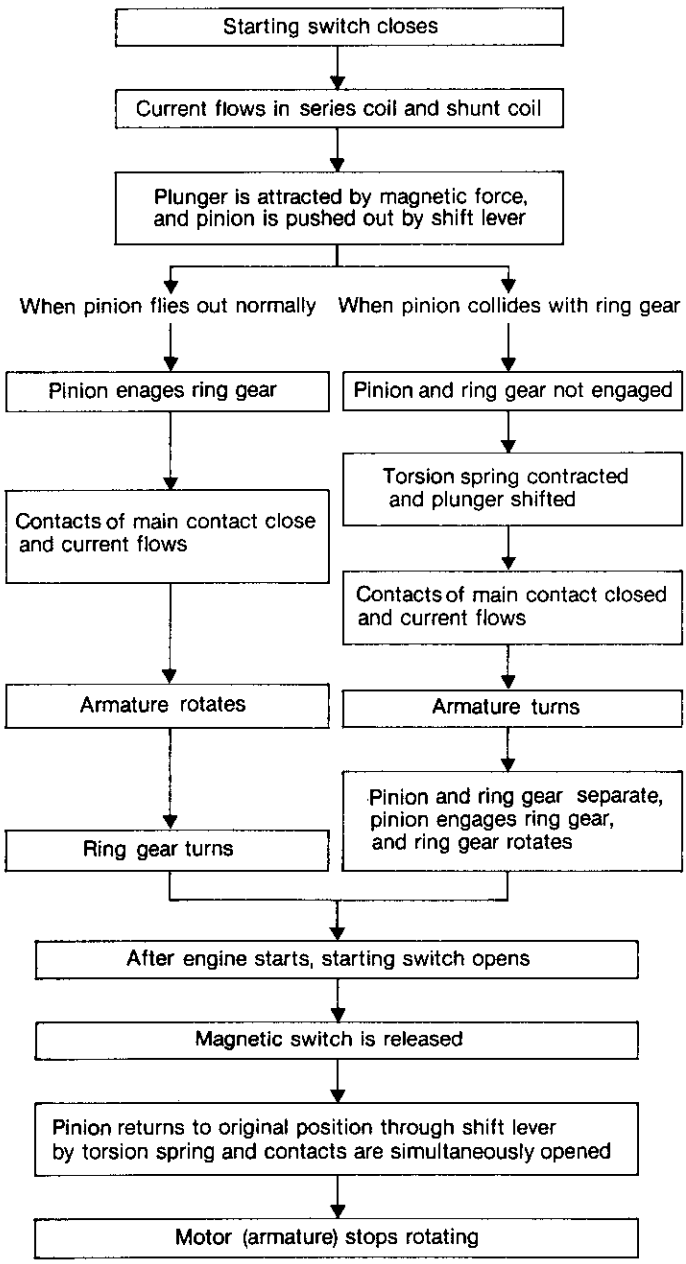

Magnetic switch
Shift lever
Field coil
Brush
Pinion
Armature
Yoke

To prevent the motor receiving a shock which will occur as the engine starts and over-runs, this starter motor is installed with an over-running clutch.

Over-running clutch



3-3 Operation



3-4 Adjustment and performance test

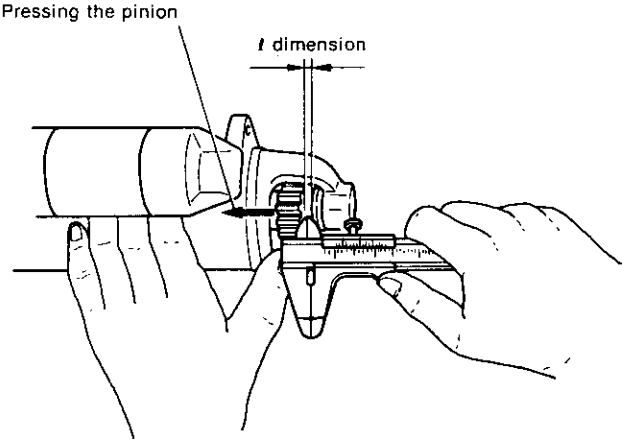
3-4.1 L-size measurement (gap between pinion and pinion stopper)

When the pinion is at the projected position, measure between pinion and pinion stopper. This check should be made with the pinion pressed back lightly to take up any play in the engagement linkage.

mm (in.)

	Starter motor	*l* dimension
1GM, 2GM, 3GM(D)	S114-303	0.3 ~ 2.5 (0.0118 ~ 0.0984)
3HM	S12-79	0.2 ~ 1.5 (0.0079 ~ 0.0591)

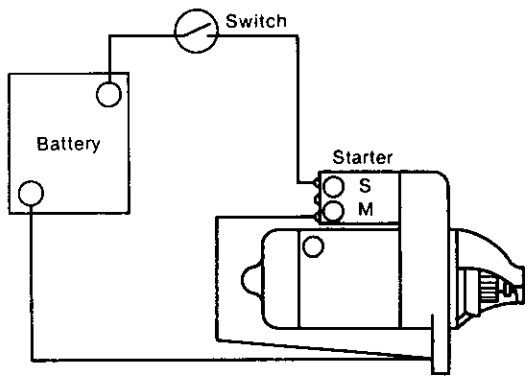
Pressing the pinion



Measuring of *l* dimension

3-4.2 Pinion movement

After complete assembly of the starter motor, connect up the motor as in Fig.



3-10 Various problems and their remedies

(1) Pinion fails to advance when the starting switch is closed

Problem	Cause	Corrective action
Wiring	Open or loose battery or switch terminal	Repair or retighten
Starting switch	Threaded part connected to pinion section of armature shaft is damaged, and the pinion does not move	Repair contacts, or replace switch
Starter motor	Threaded part connected to pinion section of armature shaft is damaged, and the pinion does not move	Replace
Magnetic switch	Plunger of magnetic switch malfunctioning or coil shorted	Repair or replace

(2) Pinion is engaged and motor rotates, but rotation is not transmitted to the engine

Problem	Cause	Corrective action
Starting motor	Overrunning clutch faulty	Replace

(3) Motor rotates at full power before pinion engages ring gear

Problem	Cause	Corrective action
Starter motor	Torsion spring permanently strained	Replace

(4) Pinion engages ring gear, but starter motor fails to rotate

Problem	Cause	Corrective action
Wiring	Wires connecting battery and magnetic switch open or wire connecting ground, magnetic switch and motor terminals loose	Repair, retighten, or replace wire
Starter motor	Pinion and ring gear engagement faulty Motor mounting faulty Brush worn or contacting brush spring faulty Commutator dirty Armature, field coil faulty Field coil and brush connection loose	Replace Remount Replace Repair Repair or replace Retighten
Magnetic switch	Contactor contact faulty Contactor contacts pitted	Replace Replace

(5) Motor fails to stop when starting switch is opened after engine starts

Problem	Cause	Corrective action
Starting switch	Switch faulty	Replace
Magnetic switch	Switch faulty	Replace

4. Alternator

The alternator serves to keep the battery constantly charged. It is installed on the cylinder block by a bracket, 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 having a wide range of engine speeds. It contains diodes that convert AC to DC, and an IC regulator that keep the generated voltage constant even when the engine speed changes.

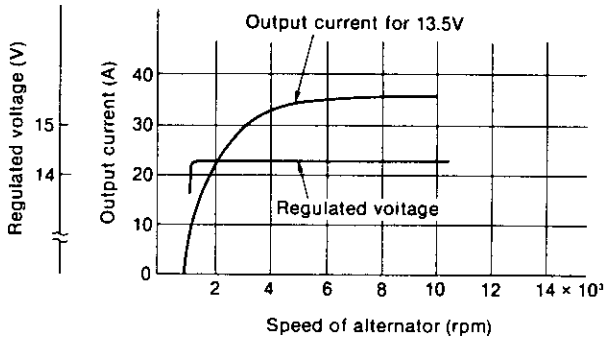
4-1 Features

The alternator contains a regulator using an IC, and has the following features.

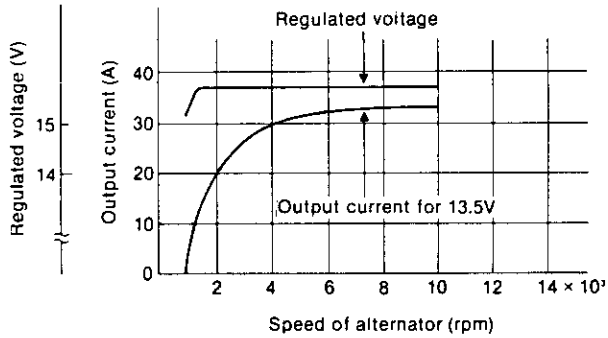
(1) The IC regulator, which is self-contained, has no moving part (mechanical contact point), therefore it has superior features such as, freedom from vibration, no fluctuation of voltage during use, and no need for readjustment.
Also, it is of the over-heating compensating type and can automatically adjust the voltage to the most suitable level depending on the operating temperature.
(2) The regulator is integrated within the alternator to simplify external wiring.
(3) It is an alternator designed for compactness, light weight, and high output.
(4) A newly developed U-shaped diode is used to provide increased reliability and easier checking and maintenance.
(5) As the alternator is to be installed on board, the following countermeasures are taken to provide salt-proofing.
1) The front and rear covers are salt-proofed.
2) Salt-proof paint is applied to the diode.
3) The terminal, where the harness inboard is connected to the alternator, is nickel plated.

4-3 Characteristicscs

(Old type)



(New type)

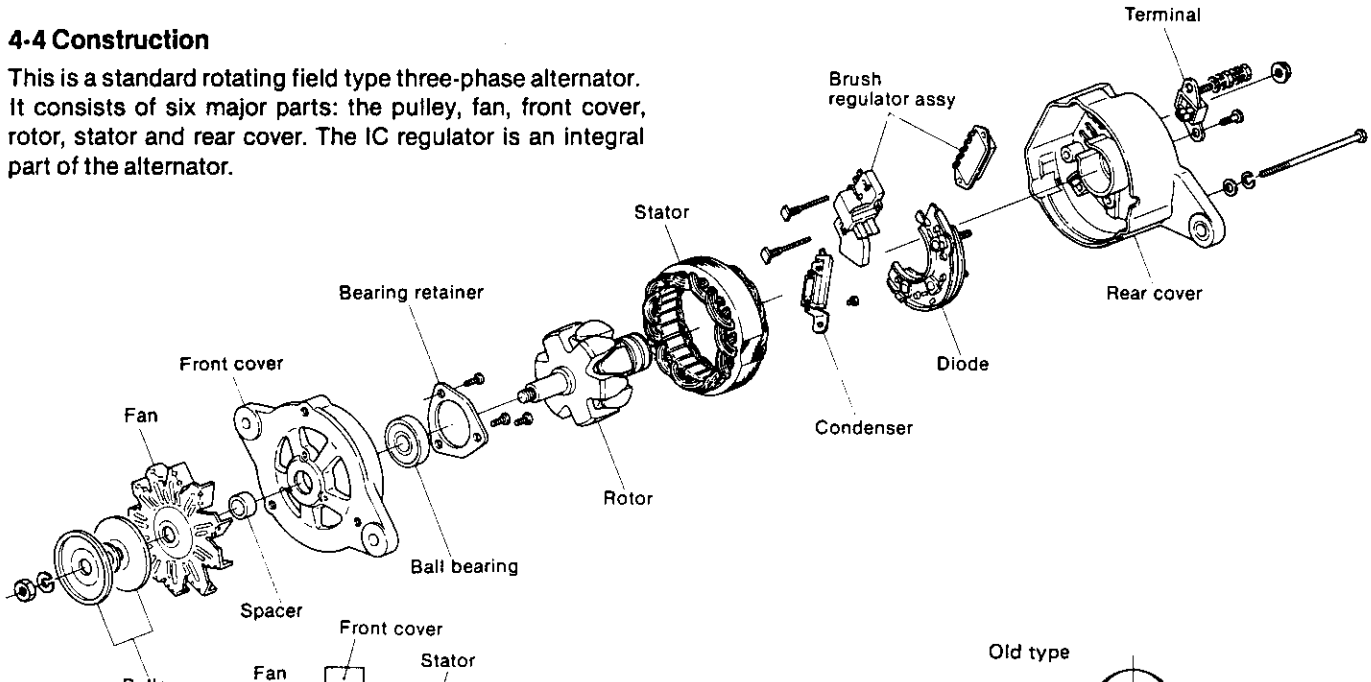


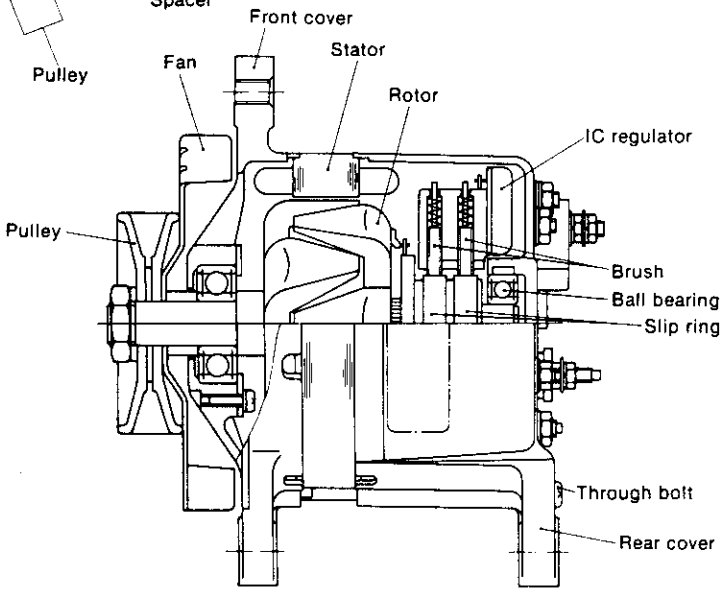
4-2 Specifications

	Old type	New type	Remarks
Model of alternator	LR135-74	LR135-105	Design changed for Feb. 1, 1982 Applicable Eng. Model/Number. 1GM and after; 2GM(F) #04806 "; 3GMD(F) #02710 "; 3HM # #01372 "; 3HMF #00175 "
Model of IC regulator	TR1Z-49	TR1Z-63	
Battery voltage	12V	12V	
Nominal output	12V 35A	12V, 35A	
Earth polarity	Negative earth	Negative earth	
Direction of rotation (viewed from pulley end)	Clockwise	Clockwise	
Weight	3.5kg (7.7 lb)	3.5 kg (7.7 lb)	
Rated speed	5000 rpm	5000 rpm	
Operating speed	1000 ~ 8000 rpm	900 ~ 8000 rpm	
Speed for 13.5V	1000 rpm or less	900 rpm or less	
Output current (when heated)	2500 rpm 27.5±2A (5000 rpm 35±2A)	5000 rpm 32±2A	
Regulated voltage	14.3±0.3V (at 20°C, Full battery)	14.5±0.3V (at 20°C, Full battery)	
Standard temperature/ voltage gradient	-0.0136V/°C	-0.01V/°C	

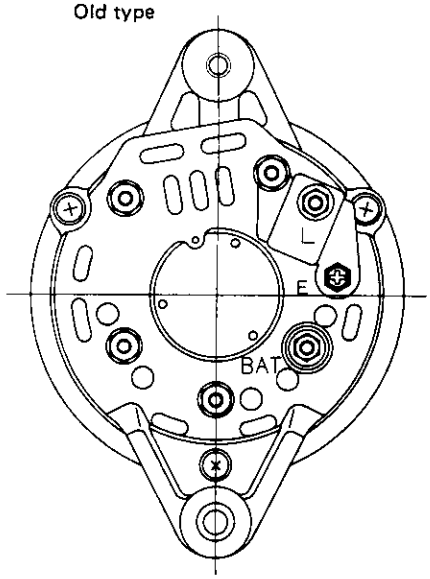
4-4 Construction

This is a standard rotating field type three-phase alternator. It consists of six major parts: the pulley, fan, front cover, rotor, stator and rear cover. The IC regulator is an integral part of the alternator.

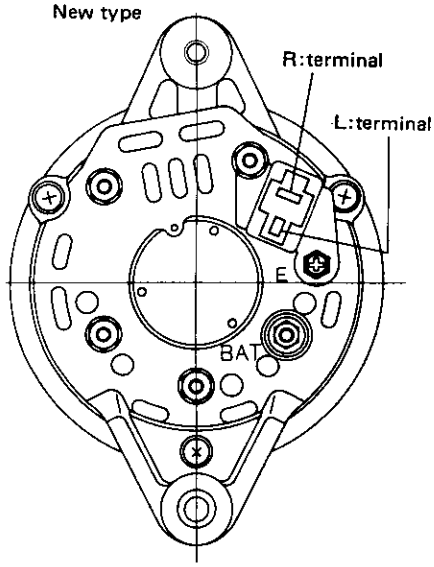




Old type

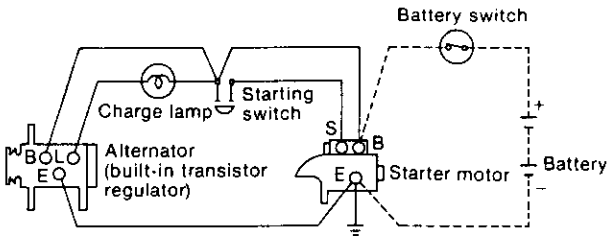


New type



4-5 Wiring

(1) Wiring diagram



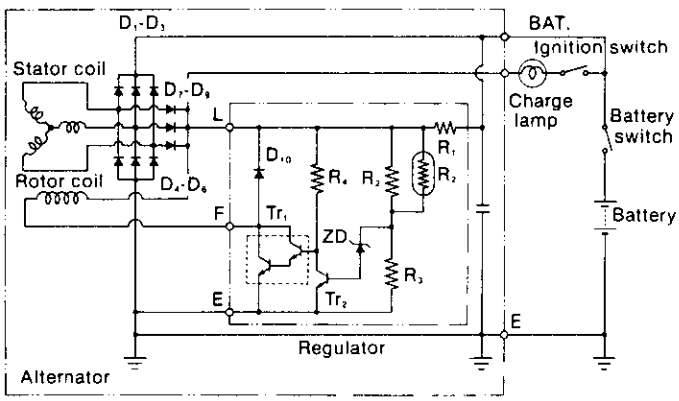
(2) Terminal connections

The alternator has the following terminals. Connect these terminals as indicated below.

Symbol	Terminal name	Connection to external wiring
B	Battery terminal	To battery (+) side
E	Ground terminal	To battery (−) side
L	Lamp (charge) terminal	To charge lamp terminal

4-6 Circuit diagram

4-6.1 Circuit diagram



BAT: Battery output terminal
L: Charge lamp terminal
E: Earth
$D_1 \sim D_6$: Diodes for rectifying the output current
$D_7 \sim D_9$: Diodes for switching the charge lamp
D_{10}: Diode for protecting the IC
ZD: Zener diode
Tr_1, Tr_2: Transistors
$R_1 \sim R_5$: Resistors
F: Rotor current
Rn: Thermistor (resistors with current/temperature gradient)

4-6.2 Principle of IC regulator function

The IC regulator controls the output voltage of the alternator by switching the rotor current (exciting current) on or off by means of the transistor Tr_1 which is connected in series with the rotor coil.

When the output voltage of the alternator is within the regulated values, transistor Tr_1 is "ON" but when the voltage is outside the regulated value, the Zener diode ZD comes "ON", and regulates the output voltage rise by turning transistor Tr_1 "OFF".

The output voltage is kept within the regulated values by repeating the "ON"—"OFF" operation.

4-7 Alternator handling precautions

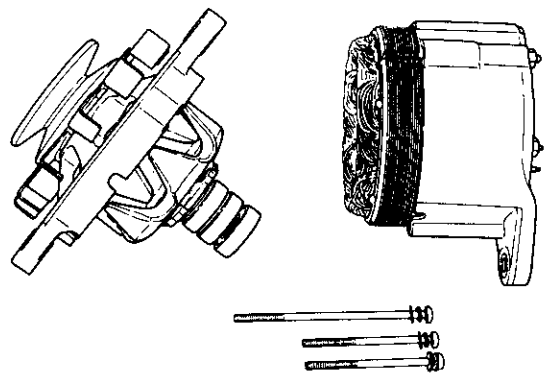
(1) Pay attention to the polarity of the battery; be careful not to connect it in reverse polarity. If the battery is connected in reverse polarity, the battery will be shorted by the diode of the alternator, an overcurrent will result, the diodes and transistor regulator will be destroyed, and the wiring harness will be burned.
(2) Connect the terminals correctly.
(3) When charging the battery from outside, such as during rapid charging, disconnect the alternator B terminal or the battery terminals.
(4) Do not short the terminals.
(5) Never test the alternator with a high voltage meter.

4-8 Alternator disassembly

Disassemble the alternator as follows.

The major points of disassembly are the removal of the cover, the separation of the front and rear sides, and detailed disassembly.

(1) Remove the cover attached to the rear cover, remove the through bolts, and disassemble into front and rear sides.



4-13 Alternator troubleshooting and repair

(1) Failure to charge

Problem	Cause	Corrective action
Wiring, current	Open, shorted, or disconnected	Repair or replace
Alternator	Open, grounded, or shorted coil Terminal insulator missing Diode faulty	Replace Repair Replace
Transistor regulator	Transistor regulator faulty	Replace regulator

(2) Battery charge insufficient and discharge occurs easily

Problem	Cause	Corrective action
Wiring	Wiring shorted or loose, wiring thickness or length unsuitable	Repair or replace Replace
Generator	Rotor coil layer short Stator coil layer short; One phase of stator coil open Slip ring dirty V-belt loose Brush contact faulty Diode faulty	Replace Replace Clean or polish Retighten Repair Replace

(3) Battery overcharged

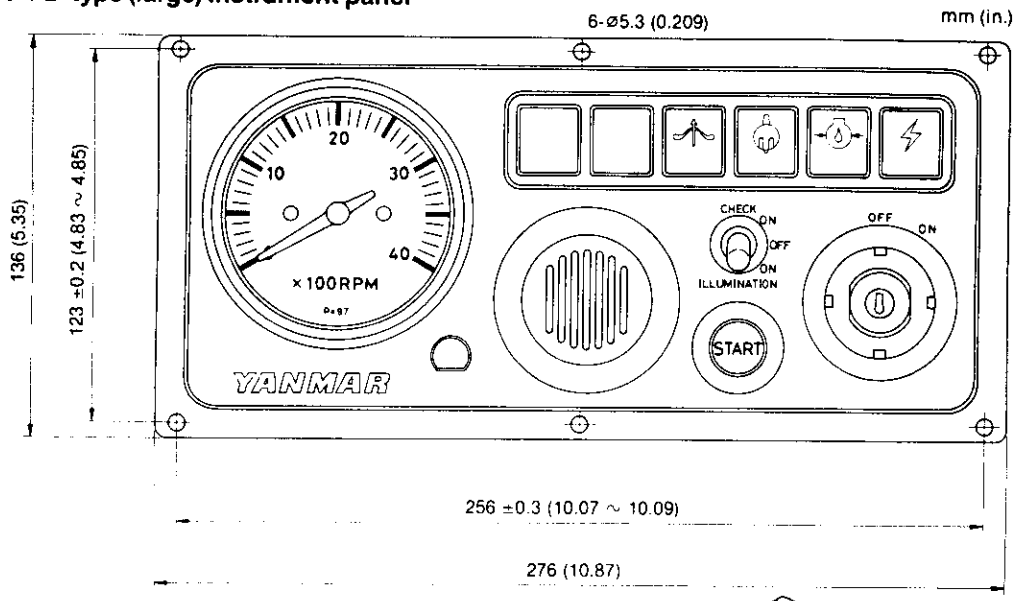
Problem	Cause	Corrective action
Battery	Electrolyte low or unsuitable	Add distilled water Adjust specific weight Replace
Transistor regulator	Regulator transistor shorted	Replace regulator

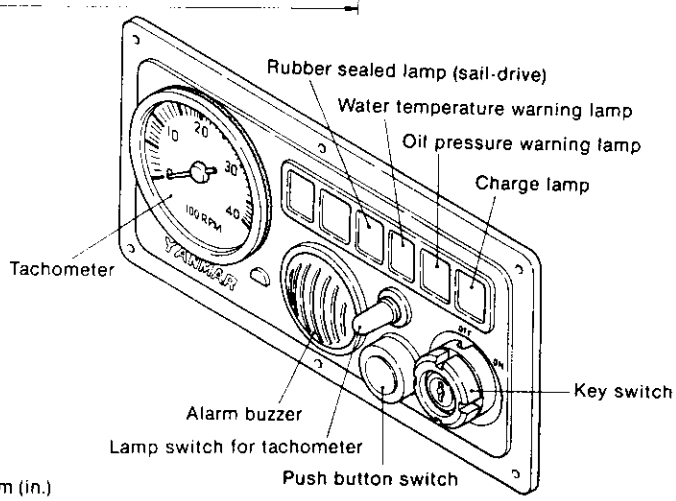
(4) Current charge unstable

Problem	Cause	Corrective action
Wiring	Wiring shorted at a break in the covering due to hull vibration or intermittent contact at break	Repair or replace
Alternator	Layer short Balance spring damaged Slip ring dirty Coil open	Replace Replace Replace Repair or replace

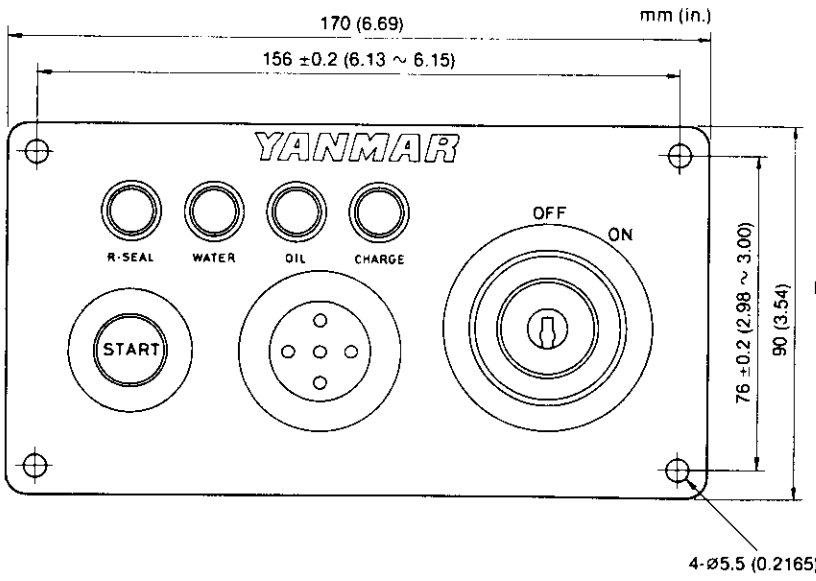
5. Instrument Panel

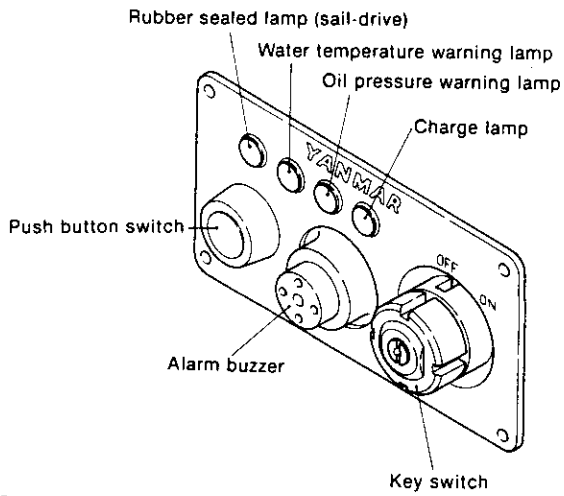
5-1 B-type (large) instrument panel





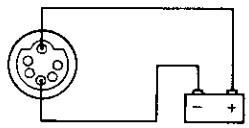
5-2 A-type (small) instrument panel





5-7

Fault	Diagnosis		Remedy
Warning lamp does not light.	Check if there is a loose or open-circuit connection at the coupling connector between the instrument panel and the relay harness.	Yes	Make good the connection.
	↓ No		
	Take out the lamp from P box case and check if it is unserviceable.	Yes	Replace the lamp. (G-1 amp 12V 3.4W)
	↓ No		
	It must be an open-circuit connection in the harness.		Replace the harness.
Buzzer does not sound.	Check if there is a loose or open-circuit connection at the coupling connector between the instrument panel and the relay harness.	Yes	Make good the connection.
	↓ No		
	Check if the buzzer is serviceable. (Fig.)		Replace the buzzer.
	↓ Yes		
	It must be an open-circuit connection in the harness.		Replace the harness.
Other switches and items do not operate.	Check if there is a loose or open-circuit connection at the coupling connector between the instrument panel and the relay harness.		Make good the connection.
	↓ No		
	Check the continuity of the individual switch when the switch is closed by the tester.		Replace the defective item.
	↓ OK		
	It must be an open-circuit connection in the harness.		Replace the harness.



CHAPTER 11

OPERATING INSTRUCTIONS

1. Fuel Oil and Lubricating Oil

Selection of and proper attention to fuel and lubricating oils have a substantial effect on engine performance, and are vital factors governing engine life.
The use of low quality fuel and lubricating oils will lead to various engine troubles. Yanmar diesel engines will display satisfactory performance and ample reliability if the fuel and lubricating oil recommended by Yanmar are used correctly. For the engine to have long-term high performance, sufficient knowledge of the properties of the fuel and lubricating oils and their selection, management and usage are necessary.

1-1 Fuel

1-1.1 Properties of fuel

Numerous kinds of fuels are used with diesel engines, and the properties and composition of each differ somewhat according to the manufacturer.
Moreover, the various national standards are introduced here for reference purposes.

1-1.2 Recommended fuels

Manufacturer	Brand name
Caltex	Caltex Diesel Oil
Shell	Shell Diesoline or local equivalent
Mobil	Mobil Diesel Oil
Esso	Esso Diesel Oil
British Petroleum	BP Diesel Oil

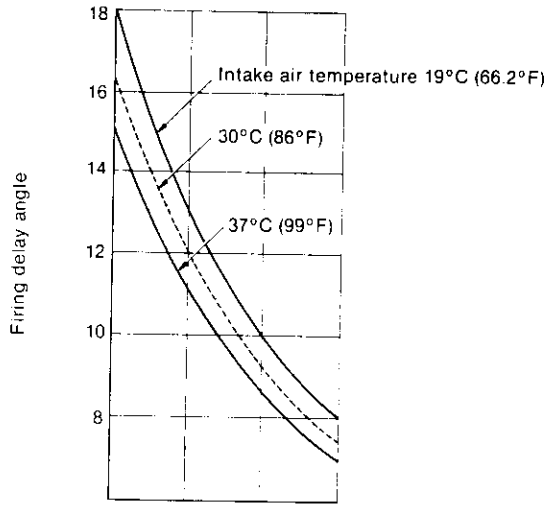
1-1.3 Fuel selection precautions

Pay careful attention to the following when selecting the fuel.

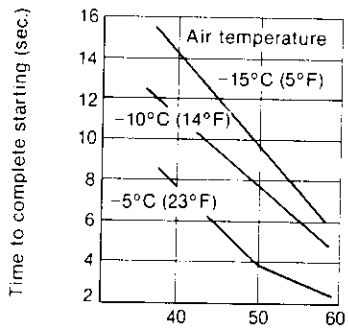
(1) Must have a suitable specific gravity
Fuel having a specific gravity of 0.88 ~ 0.94 at 15°C is suitable as diesel engine fuel. Specific gravity has no relation to spontaneous combustibility, but does give an idea of viscosity and combustibility or mixing of impurities.
Generally, the higher the specific gravity, the higher the viscosity and the poorer the combustibility.

(2) Must have a suitable viscosity
When the viscosity is too high, the fuel flow will be poor, operation of the pump and nozzle will be inferior, atomization will be faulty and fuel combustion will be incomplete.
If the viscosity is too low, the plunger, nozzle, etc. will wear rapidly because of insufficient lubrication. Generally, however, the higher the viscosity, the lower the quality of the fuel.

(3) Cetane value must be high.
The most important indicator of fuel's combustibility is its cetane value (also represented by cetane index or diesel index), The cetane value is particularly important for fuels used in high-speed engines. The relationship among the cetane value, startability and firing delay is shown in the figure below. Firing delay becomes smaller and starting characteristics better as the cetane value becomes higher.



Relationship between cetane value and firing delay



Cetane value and starting characteristic

The use of a fuel with an unsuitable cetane value will cause the following troubles:

1) Difficult starting.
2) Poor operation.
3) High combustion pressure and diesel knock.
4) Lower output and engine damage because of overheating caused by knocking.
5) Sticking of nozzles and exhaust valves.
6) Severe smoking, carbon build-up inside the engine, and oil contamination.
7) Deterioriation of the oil and excessive wear in the piston rings, ring grooves, and cylinder liner.

(4) The level of impurities must be low

1) Sulfur
With proper combustion sulfur in the fuel turns to nitrous acid gas (SO_2) and sulfuric anhydride (SO_3). When combustion is imperfect, it becomes sulfuric acid containing water that corrodes and wears the cylinder liners, pistons, exhaust valve and exhaust pipe.

Properties and compositions of fuel of various national standards

National standard / Properties and components		Japan JIS-K-2204-1965		U.S.A. ASTM-D975-74	U.K. BS-2689-70	
		Class No.1 light oil	Class No.2 light oil	No. 2D Diesel oil	Class A1	Class A2
Specific gravity	15/4°C	—	—	—	—	—
Kinetic viscosity	30°C cst (86°F cst)	2.7 or more	2.5 or more	(~ 5.2)	(~ 7.5)	(~ 7.5)
	37.8°C (100°F) cst	(2.3 or more)	(2.2 or more)	2.0~4.3	1.6 ~ 6.0	1.6 ~ 6.0
Reaction		Neutral	Neutral	—	—	—
Flash point	°C (°F)	50 or more (122 or more)	50 or more (122 or more)	51.7 or more (125 or more)	55 or more (131 or more)	55 or more (131 or more)
Flow point	°C (°F)	−5 or less (23 or less)	−10 or less (14 or less)	−12 or less (10.4 or less)	—	—
Residual carbon	Weight %	(10% residual oil) 0.15 or less	(10% residual oil) 0.15 or less	0.35 or less	0.2 or less	0.2 or less
Moisture	Volume %	—	—	—	0.05 or less	0.05 or less
Ash	Weight %	—	—	0.01 or less	0.01 or less	0.01 or less
Sulfur	Weight %	1.2 or less	1.2 or less	0.5 or less	0.5 or less	1.0 or less
Cetane valve		50 or more	45 or more	40 or more	50 or more	45 or more
Sludge or sedimentation	%	—	—	0.05 or less	0.01 or less	0.01 or less
Distillation properties, temperatures at 90% distillation	°C (°F)	350 or below (662 or below)	350 or belw (662 or below)	282.21 ~ 338 (540 ~ 640)	357 or below (675 or below)	357 or below (675 or below)

2) Water content
A high water content causes sludge, resulting in lower output, imperfect combustion and trouble in the fuel injection system.
3) Carbon content
If the carbon content is high, carbon will remain inside the combustion chamber, causing accelerated cylinder liner and piston wear and corrosion of the pistons and exhaust valves.
4) Residual carbon (coke content)
Coke becomes a carbide that sticks to the end of the nozzle, causing faulty injection. In addition, unburned carbon will build up on the pistons and liners, causing piston ring wear and sticking.

1-1.4 Simple methods of identifying fuel properties

(1) Fuel that is extremely odorous and smoky contains a large amount of volatile components and impurities.
(2) Fuel that emits little smoke when used in a lamp is of good quality.
(3) Fuel that emits a crackling sound when soaked in paper and ignited contains a high water content.
(4) If a transparent film of diesel oil is squeezed between two pieces of glass, the water content and impurities can be determined.
(5) If cracked by mixing with an equal amount of sulfuric acid in a glass tube, numerous black particles and impurities will appear. These are mainly carbon and resin.
(6) Discoloration of litmus test paper indicates the presence of acids.

1-1.5 Troubles caused by bad fuel

(1) Clogging of exhaust valve
In addition to faulty compression, incomplete combustion, and high fuel consumption, a clogged exhaust valve will cause fuel to be mixed in the exhaust, leading to corrosion of the exhaust valve seat.
(2) Clogging of piston ring grooves
Clogged piston ring grooves will cause accelerated cylinder liner and piston wear due to sticking rings, fuel gas blowback, faulty lubrication, incomplete combustion, high fuel consumption, contaminated lubricating oil, and combustion gas blowback.
(3) Clogged or corroded injection valve hole
This will cause incomplete combustion and piston and liner wear, fuel injection mechanism wear, corrosion, and groove wear and corrosion.
(4) Sediment inside crankcase
Since sediment in the crankcase is often mistakenly judged as coming from the lubricating oil, care must be taken in determining its true origin.

1-1.6 Relationship between fuel properties and engine performance

Fuel property	Starting characteristic	Lubrication characteristic	Smoke generation	Exhaust odor	Output	Fuel consumption	Clogging of combustion chamber
Firing Cetane value	Directly related—Starting characteristic improves as cetane value increases	Directly related—Lubrication improves as cetane value rises	Closely related—Smoke increases as cetane value decreases	Directly related—Decreased by increasing cetane value	Irrelevant	Related	Related—Decreased by reducing cetane value
Volatility 90% end point	No clear relationship	Related—Becomes poor when volatility is poor	Directly related—Increases as volatility decreases	No direct relationship	Irrelevant	Irrelevant	Related—Increases as volatility decreases
Viscosity	No clear relationship	Some relationship—Becomes poor when viscosity increases	Related—Increases as viscosity increases	No independent relationship	Irrelevant	Irrelevant	Related—Increases with viscosity
Specific gravity	Irrelevant	Irrelevant	Related—Increases as specific gravity increases	No independent relationship	Directly related—Associated with calorific value	Related—Associated with calorific value	Related—Depends on properties of engine
10% residual carbon	Irrelevant	Irrelevant	Related—Improves as residual carbon decreases	No independent relationship	Irrelevant	Irrelevant	Related—Decreases as residual carbon decreases
Sulfur				No independent relationship			
Flash point				No independent relationship			

1-1.7 Fuel handling precautions

(1) Fill the fuel tank after work to prevent condensation of water in the tank.
(2) Always use a tank inlet strainer. Water mixed in the fuel can be removed by removing the strainer quickly.
(3) Remove the plug at the bottom of the fuel tank and drain out the water and sediment after every 100 hours of operation, and when servicing the pump and nozzle.
(4) Do not use fuel in the bottom of the fuel tank because it contains large amounts of dirt and water.

1-2 Lubricating oil

Selection of the lubricating oil is extremely important with a diesel engine. The use of unsuitable lubricating oil will cause sticking of the piston rings, accelerated wear and seizing of the piston and cylinder liner, rapid wear of the bearings and other moving parts, and reduced engine durability. Since this engine is a high-speed engine, always follow the lubricating oil replacement interval.

1-2.1 Action of the lubricating oil

(1) Lubricating action: Builds a film of oil on each moving part reduces wear and its accompanying damage.
(2) Cooling action: Removes heat generated at moving parts by carrying it away with the lubricating oil flow.
(3) Sealing action: Maintains the air tightness of the pistons and cylinders by the oil film on the piston rings.
(4) Cleaning action: Carries away carbon produced at the cylinders as well as dust that has entered from the outside.
(5) Rustproofing action: Prevents corrosion by coating metal surfaces with a thin film of oil.

Various additives are added to the lubricating oil to assure that adequate performance is assured under the high-speed, high-load and other severe operating conditions met by modern diesel engines. While these additives differ with each manufacturer, commonly used additives include:

1) Flow point reduction additive
2) Viscosity index improvement additive
3) Oxidation prevention additive
4) Cleaning dispersent
5) Lubrication additive
6) Anticorrosion additive
7) Bubble elimination additive
8) Alkali neutralizer

1-2.2 Required lubricating oil conditions

(1) Must be of suitable viscosity
If the viscosity is too low, the oil film will be too thin and the lubricating action insufficient. If the viscosity is too high, the friction resistance will be increased and starting will become especially difficult.
(2) Viscosity change with temperature must be small.
While the lube oil temperature goes from low at starting to high during operation, the viscosity change by temperature should be small. That is, the viscosity index should be high at all temperatures.
(3) Must have good lubricating capability
That is, it must coat metal surfaces as a thin film. In other words, the lubricating oil must coat the metal surfaces so that metal-to-metal contact caused by breaking of the oil film at the top dead center and bottom dead center piston position does not occur, or that the oil film is not broken by collision, even at the bearings.
(4) Mixability with water must be low
Since water can mix with the oil because of the presence of cooling water in the engine, emulsification of water and oil, which causes the oil to lose its lubricating properties, must be prevented.
(5) Must be neutral and difficult to oxidize
Since acids and alkalis corrode metal, the lubricating oil must be neutral. Moreover, since even a neutral oil will be oxidized easily by contact with the combustion gas, the oil must be stable with few oxidizing elements.
(6) Must withstand high temperature and must evaporate or combust with difficulty
Oil must have a high flash point. If it is evaporated by heat or is not burned completely, carbon will be produced. This carbon is toxic.
(7) Must not contain any water or dirt and must have a low sulfur and coke content

1-2.3 Classification by viscosity

SAE No.	−17.8°C (6°F)		98.9°C (210°F)		Applicable temperature range (outside temperature)
	Saybolt universal viscosity (sec)	Dynamic viscosity (cst)	Saybolt universal viscosity (sec)	Dynamic viscosity (cst)	
5W	Under 4,000	Under 869	—	—	20°C or less (68°F or less)
10W	6,000 ~ 12,000	1,303 ~ 2,606	—	—	
20W	12,000 ~ 48,000	2,606 ~ 10,423	—	—	
20	—	—	45 ~ 58	5.73 ~ 9.62	20°C ~ 35°C (68°F ~ 95°F)
30	—	—	58 ~ 70	9.62 ~12.93	
40	—	—	70 ~ 85	12.93 ~ 16.77	35°C or greater (95°F or greater)
50	—	—	85 ~ 110	16.77 ~ 22.68	

Since only 98.9°C viscosity is stipulated for S.A.E. No. 20 ~ 50 oil in the table, and only −17.8°C viscosity is stipulated for S.A.E. No. 5W ~ 20W oil, they are not guaranteed at other temperatures. On the other hand, S.A.E. No.10W viscosity is stipulated and oil having viscosity equal to that of S.A.E. No.30 even at 98.9°C is called S.A.E. No.10W—30, or multigrade oil. Multigrade oil comprises S.A.E. No. 5W—20, 10W—30, and 20W—40. In arctic regions, oil from S.A.E. No. 20W to 10W—30 can be used.

1·2.4 SAE service classification and API service classification

SAE new classification (1970)	API service classification (1960)
CA	DG
CB•CC	DM
CD	DS

(1) DG grade: Used when deposits and engine wear must be controlled when the engine is normally operated at a light load using low sulfur fuel.
(2) DM grade: Used when the generation of deposits and wear caused by sulfur in the fuel is possible under severe conditions.
(3) DS grade: Used under extemely severe operating conditions or when excessive wear or deposits are caused by the fuel.

Classification	Engine service (API)
CA	Light duty diesel engine service: Mild, moderate operation diesel engine service with high-performance fuel, and mild gasoline engine service. The oil designed for this service was mainly used in the 1940s and 50s. This oil is for high performance fuel use and has bearing corrosion and high temperature deposit prevention characteristics.
CB	Moderate duty diesel engine service: Mild, moderate operation diesel engine service using low performance fuel requiring bearing corrosion and high temperature deposit prevention characteristics. Includes mild gasoline engine service. Oil designed for this service was introduced in 1949. The oil is used with high sulfur fuels and has bearing corrosion and high temperature deposit prevention characteristics.
CC	Moderate duty diesel engine service and gasoline engine service: Applicable to low supercharged diesel engines for moderate to severe duty. The oil designed for this service was introduced in 1961 and is widely used in trucks and agricultural equipment, construction machinery, farm tractors, etc. The oil features high deposit prevention characteristics in low supercharged diesel engines, and rust, corrosion and low temperature sludge prevention characteristics in gasoline engines.
CD	Severe duty diesel engine service: Applicable to high-speed, high-output high supercharged diesel engines which are subjected to considerable wear and deposits. This oil was introduced in 1955, and is used as a wide property-range fuel in high supercharged engines. It also has bearing corrosion and high temperature deposit prevention characteristics.

1·2.5 Lubricationg oil

SAE new classification CB grade or CC grade fuel having suitable viscosity for the atmospheric temperature must be used in this engine.

1-2.6 Recommended lubricating oils

Supplier	Brand Name	SAE No.			
		Below 10°C (Below 50°F)	10~20°C (50~68°F)	20~35°C (68~95°F)	Over 35°C (Over 95°F)
SHELL	Shell Rotella Oil	10W, 20/20W	20/20W	30 40	50
	Shell Talona Oil	10W	20	30 40	50
	Shell Rimula Oil	20/20W	20/20W	30 40	—
CALTEX	RPM Delo Marine Oil	10W	20	30 40	50
	RPM Delo Multi-Service Oil	20/20W, 10W	20	30	50
MOBIL	Delvac Special	10W	20	30	—
	Delvac 20W—40	20W—40	20W—40	—	—
	Delvac 1100 Series	10W, 20/20W	20/20W	30 40	50
	Delvac 1200 Series	10W, 20/20W	20/20W	30 40	50
ESSO	Estor HD	10W	20	30 40	—
	Esso Lube HD	—	20	30 40	50
	Standard Diesel Oil	10W	20	30 40	50
B.P. (British Petroleum)	B.P. Varellus C3	10W, 20W	20W	30, 40	50

1-2.7 Engine oil replacement and handling

(1) Necessity of replacement

Since the engine oil is exposed to high temperatures during use and is mixed with air at high temperatures, it will oxidize and its properties will gradually change. In addition, its lubricating capabilities will be lost through contamination and dilution by water, impurities, and the fuel. Emulsification and sludge are produced by heat and mixing when the lubricating oil contains water and impurities, causing its viscosity to increase. Moreover, if the carbon in the cylinders enters the crankcase, the oil will turn pure black and the change in its properties can be seen at a glance. The continued use of deteriorated oil will not only cause wear and corrosion of moving parts, but will ultimately cause the bearings and cylinders to seize. Therefore, deteriorated oil must be replaced.

(2) Replacement period

Although the engine oil change interval differs with the engine operating conditions and the quality of the lubricating oil and fuel used, the oil change interval should be as follows when CB grade oil is used in a new engine:

1st time . . . . . After approximately 20 hours of use
2nd time . . . . . After approximately 30 hours of use
From 3rd time . . . After every 100 hours of use

Drain the old oil completely and replace it with new oil while the engine is still warm.

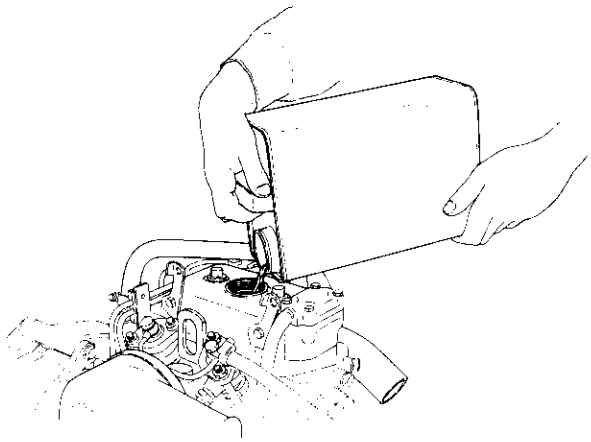
CAUTION: Never mix different brands of lubrication oil.

1-2.8 Adding oil

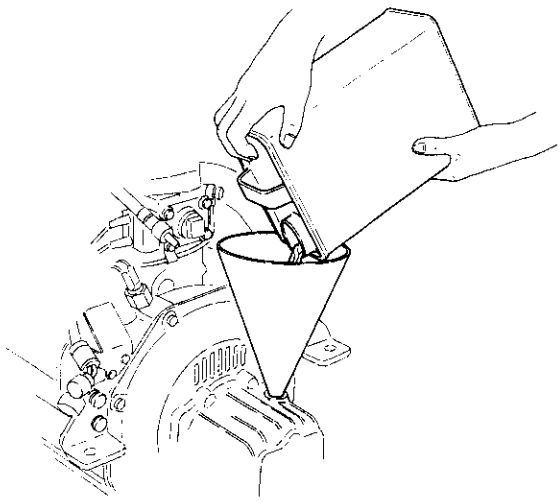
The crankcase and clutch case are not connected. For the crankcase, add one of the lubricating oils described in chapter 1.2.6. For the clutch case, add the lubrication oil described below. Be sure not to mix up the oils.

Supplier	1GM	2GM	3GMD	3GM , 3HM
SHELL	Same lube oil as for crankcase			SHELL DEXRON
CALTEX				TEXAMATIC FLUID (DEXRON)
MOBIL				MOBIL ATF 220
ESSO				ESSO ATF
B.P.				B.P. AUTRAN DX

(1) Remove the clutch case clutch and head cover filler plug (engine), and fill with specified lubricating oil up to the top marks on the respective dipsticks. (Oil levels must not drop below the lower marks on the dipsticks.)



Engine



Clutch

(2) Since it takes sometime for the oil to flow completely into the clutch case and oil pan, wait for 2 ~ 3 minutes after filling before checking the oil levels. Moreover, check the oil while the boat is afloat.

1-2.9 Oil capacity

Lubricating oil capacity at an engine mounting angle (rake) of 8° is given below.

	Crankcase	Clutch case
1GM	1.3ℓ	0.25ℓ
2GM	2.0ℓ	
3GMD	2.7ℓ	0.3ℓ
3GM		0.7ℓ
3HM	5.5ℓ	

- Check the crankcase oil level by completely inserting the dipstick. Check the clutch case oil level without screwing in the cap.
  The oil levels must be between the upper and lower limit marks on both dipsticks.

2. Engine Operating Instructions

2-1 Preparations before starting

2-1.1 Fueling up

(1) Check the fuel level in the fuel tank and add fuel if necessary.
(2) Remove water and dirt collected in the bottom of the tank using the fuel tank drain cock.
(3) Add clean fuel to the tank.
Since dirt and water sink to the bottom of the fuel drum, do not turn the drum upside down and do not pump the fuel from the bottom of the drum.

2-1.2 Adding lubricating oil

(1) Check the oil level with the dipstick, and add oil, if necessary, to bring the level up to the to mark of the dipstick.
The level must neither be too low nor too high.
(2) The crankcase and clutch case require different oil. Check both and add oil separately, being careful not to mix the oils.
(3) Since the crankcase oil flows into the crankcase through the camshaft and valve chambers, wait 2 ~ 3 minutes before checking its level.

2-1.3 Lubricating each part

(1) Lubricate each pin of the remote control lever.

2-1.4 Checking fuel priming and injection

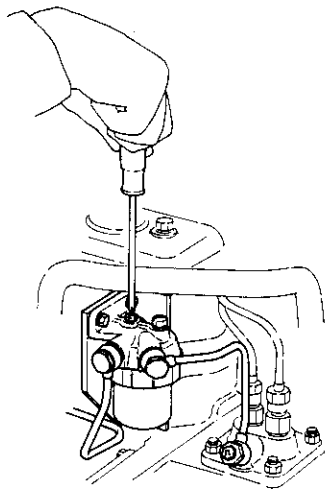
(1) Operate the priming lever of the fuel pump.
(2) Set the regulator handle to the full speed position and check for injection sound by turning the engine over several times.
(3) If there is no fuel injection sound, bleed the air from the fuel system.

2-1.5 Bleeding the fuel system

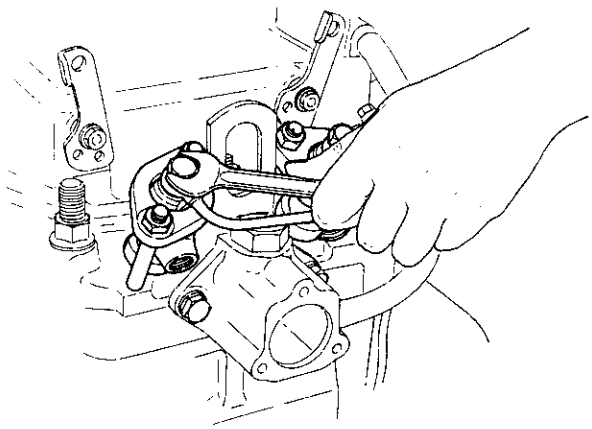
Since the presence of air in the fuel system anywhere between the fuel tank and the injection valve will cause faulty fuel injection, always bleed the air from the system when the fuel system is disassembled and reassembled.

Bleeding the fuel system

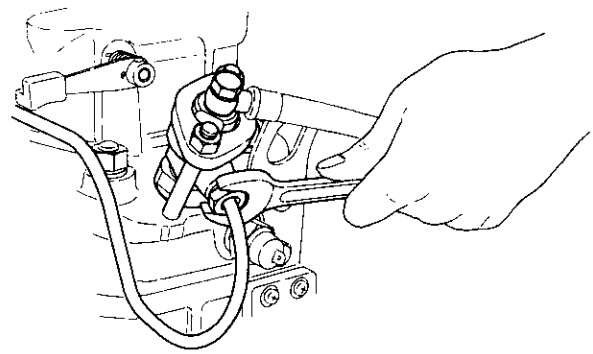
(1) Open the fuel tank cock.
(2) Bleed the air from the fuel filter.
Loosen the air bleeding plug at the top of the fuel filter body and operate the manual handle of the fuel pump until no more bubbles appear in the fuel flowing from the filter.
Then install and tighten the air bleeding plug.



(3) Bleed the air from the fuel return pipe.
Loosen the connnector bolt of the fuel return pipe installed on the fuel injection valve, and bleed the air by operating the manual handle of the fuel pump.
Bleed the air in the No.1 cylinder (timing gear case side) and No.2 cylinder (clutch side), in that order.



(4) Bleed the air from the fuel injection pipe.



Loosen the nipple on the fuel injection valve side, set the regulator handle to the operating position and the decompression lever to the decompression position, and crank the engine. When no more bubbles appear in the fuel flowing from the end of the injection pipe, retighten the nipple.

(5) Check injection.
After bleeding the air, set the regulator handle to the operating position, set the decompression lever to the decompression position, and crank the engine. When fuel is being injected from the injection valve, an injection sound will be heard and you can feel resistance if you place your hand on the fuel injection pipe. This check must not be performed more than two or three times since overchecking will flood the combustion chamber with fuel, and faulty combustion will occur at starting.

2-1.6 Checking for abnormal sounds by cranking

(1) Set the regulator handle to the STOP position, release the compression of the engine by setting the decompression lever, and crank the engine about 10 times to check for abnormal sounds.
(2) Crank the engine with the starting handle
(Always turn the engine in the proper direction of rotation.)

2-1.7 Checking the cooling system

(1) Open the Kingston cock.
(2) Check for bending and cross-sectional deformation of the cooling water inlet pipe.
(3) Set all water drain cocks to the CLOSED position.

2-1.8 Checking the remote control system

(1) Check that the remote control handle operates correctly.
(2) Check that the engine stop remote control operates smoothly.

2-1.9 Checking the electrical system

(1) Check the battery electrolyte level and add distilled water if low.
(2) Check that the wiring is connected correctly.
(Especially for polarity.)
(3) Turn the battery switch on, set the main switch to the ON position, and check if the oil pressure lamp and charge lamp are illuminated and if the alarm buzzer sounds when the engine is stopped.
(The charge lamp should be on while the engine is stopped and should be off while the engine is running.)

2-1.10 Checking appearance and exterior

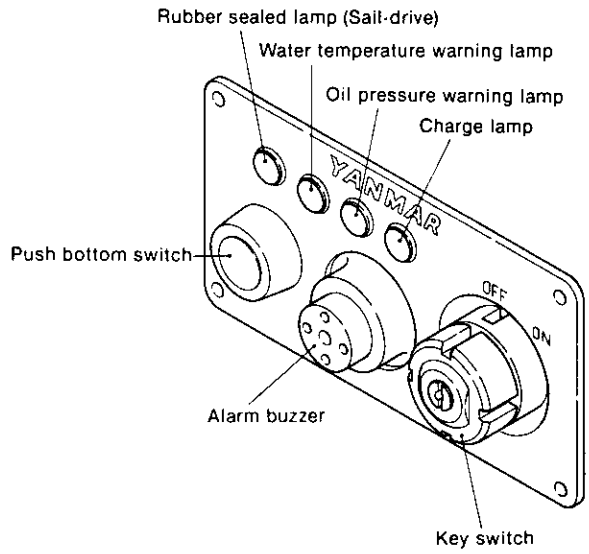
(1) Check for loose or missing bolts and nuts.
(2) Check for loose or disconnected piping and hoses.
(3) Check that there are no tools or other articles near rotating parts or on the engine.

2-2 Starting and warm-up

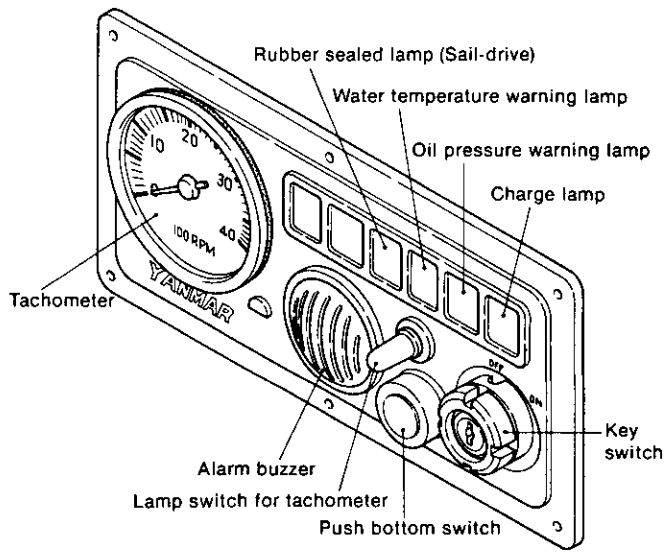
2-2.1 Starting

(1) Starting procedure
1) Set the clutch handle to the "NEUTRAL" position.
2) Set the governor lever to the "MEDIUM SPEED".
3) Keep the decompression lever in the "OPERATION" position.
4) Set the main switch to the ON position.
The alarm buzzer will sound.
5) Push the starting button to start the engine.
Release the start button after the engine has started.
6) When the engine has started, the alarm lamps and buzzer will go off.
If the lamps or buzzer stay on, immediately stop the engine and check for trouble.

A type



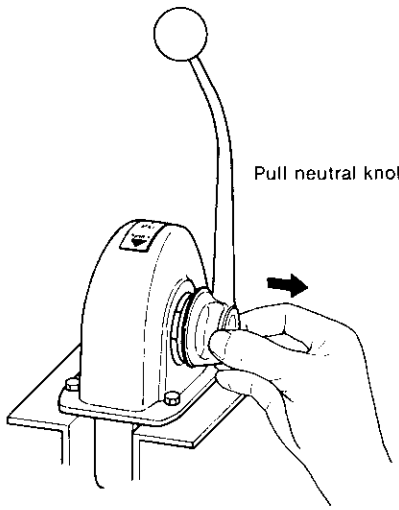
B type

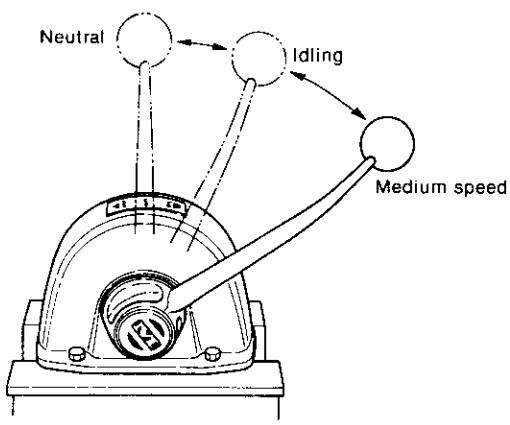


(2) Starting precautions
1) Don't continue to push the starting button over 15 seconds.
If the engine doesn't start, wait 30 seconds or more.
2) When restarting the engine, always confirm the flywheel is stopped.
If you re-start the engine while the flywheel is rotating, the pinion gear of the starter motor and the ring gear of the flywheel will be damaged.
3) When starting is difficult in cold weather lift the decompression lever to decompress the engine, and turn the starting motor. Once the engine has reached a certain speed, return the decompression lever to the "OPERATION" position. In this way, starting is made easier while current consumption is reduced.

2-2.2 Starting with one-handle remote control (option)

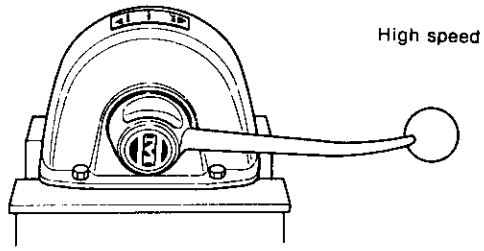
(1) Starting procedure
1) Pull the neutral knob and set the control lever to the "MEDIUM SPEED" position.





2) Set the main switch to the "ON" position, and push the starting button to start the engine.

(2) Starting in cold weather
1) Pull the neutral knob, and set the control lever to the HIGH SPEED position.



2) Set the decompression handle to the DECOMPRESSION position.
3) Set the main switch to the ON position and start the engine by pushing the starting button, at the same time putting the decompression lever to the COMPRESSION position. After the engine has started, return the control lever to the MEDIUM SPEED position.

*When the control lever is set in the HIGH SPEED position, injection timing is automatically delayed to facilitate starting.

CAUTION: When the engine is started with the control lever in the HIGH SPEED position, the starting button must be released immediately and the control lever must be returned to the idling position after the engine has started.
If the starting button is not released, the starter motor will overrun, causing it to be damaged or burnt out.

2-2.3 After starting

(1) Warm-up operation
The engine must not be suddenly operated at full load immediately after starting. Warm up the engine for about 5 minutes after starting by running the engine at about half speed, and begin full load operation only after the temperature of each part has risen to a uniform value. Neglecting to warm up the engine will result in:
1) Seizing of the piston and liner due to sudden heat expansion of the piston.
2) Burning of piston rings and seizing of bearings/bushings because of insufficient lubrication.
3) Faulty intake and exhaust valve seat contact and shortening of the life of each part due to sudden heating.

Warm-up time (no-load operation)
1,000 ~ 1,200 rpm 3 minutes
1,600 ~ 1,800 rpm 2 minutes

CAUTION: Do not run the engine at full speed for 50 hours after installation to assure proper break-in.

(2) Checking after starting
Check the following with the clutch in the NEUTRAL position:
1) Meters and lamps on the instrument panel
• Check that all alarm lamps are off (1,000 rpm or higher).
• Alarm buzzer must be off.
2) Cooling water discharge
(Check that the cooling water temperature reaches 45 ~ 55°C before beginning operation.)
3) Check for abnormal sounds and heating.
4) Check for oil and water leakage from piping.
5) Check the state of lubrication of the valve arms.

2-3 Operation

If warm-up operation is normal, engage the clutch and begin normal operation. Check the following during operation and stop the engine and take suitable corrective action if there are any abnormalities.

2-3.1 Checks during operation

(1) Oil pressure
Check that the lubricating oil pressure and operating oil pressure lamps are off.
Lubrication oil pressure during operation: 2.5 ~ 3.5 kg/cm²

(2) Cooling water
Periodically check whether water is being discharged from the cooling water outlet pipe.
If the cooling water is being discharged intermittently or if only a small amount of water is being discharged during high speed operation, immediately stop the engine and check if air is being sucked into the cooling system, the impeller of the water pump is abnormal, or the water pipes and Kingston cock are clogged.
Cooling water temperature during operation: 45 ~ 55°C.
Check that the water temperature alarm lamp is off.

(3) Fuel
Check the fuel level in the fuel tank and add fuel before the tank becomes too low. If the fuel level is low, air will enter the fuel injection system and the engine will stop.

(4) Charging
Check that the charge lamp is off.
If the charge lamp is still on even when the engine is run at 1,000 rpm or above, the charging system is faulty and the battery is not being charged.

(5) Temperature of each part
At full power operation, the surface temperature of each engine part is about 50 ~ 60°C and hot to the touch. If engine temperature is too high, the oil will be used up, the propeller shaft will not be centered, or other troubles may occur.

(6) Leakage and abnormalities
Check for water leakage, oil leakage, gas leakage, loose bolts, abnormal sounds, abnormal heating, and vibration.

(7) Exhaust color
Black exhaust smoke indicates that the engine is being overloaded and that the lives of the intake and exhaust valves, piston rings, cylinder liners, and injection nozzle will be shortened. Do not run the engine for long periods when exhaust is this colour.

(8) Abnormal sounds, abnormal heating
When abnormal sounds or abnormal heating occur during operation, immediately stop the engine and check for trouble.

2-3.2 Operating precautions

(1) Always set the battery switch and main switch to the ON position during operation.
Since the diodes of the alternator will be damaged, don't set the switches OFF position.

(2) Do not touch the starting button during operation. Operation of the starter motor pinion will damage the gears.

(3) Since the boat will resonate and vibrate at a certain speed, depending on the structure of the hull, do not operate it at that speed.

(4) Always set the clutch in the neutral position and wait for the propeller to stop rotating before raising the propeller shaft (if hoisting type stern gears are installed).

(5) Do not suddenly apply a full load to the engine or operate it at full load for long periods.

2-4 Stopping

2-4.1 Stopping procedure

(1) Before stopping, put the clutch in NEUTRAL and run the engine at approximately 1,000 rpm for about 5 minutes.

(2) Before stopping, temporarily raise the speed to the rated speed to blow out residue in the cylinders. Then stop the engine by pulling the engine stop lever to cut the fuel.

2-4.2 Stopping precautions

(1) Do not stop the engine with the decompression lever.
If the engine is stopped with the decompression lever, fuel will remain in the combustion chamber and abnormal combustion will occur when the engine is started again, perhaps damaging the engine.

(2) If the engine is stopped immediately after full-load operation, the temperature of each part will rise suddenly, leading to trouble.

2-4.3 Inspection and procedures after stopping

(1) Always close the Kingston cock after the engine is stopped.
Water may enter because of a faulty water pump, etc.

(2) In cold weather, the cooling water should always be drained after engine use to prevent freezing. There are water drain cocks on the cylinders and the exhaust manifold. (Drain the water after the engine has cooled.)

(3) Check for oil leakage and water leakage, and repair as required.

(4) Check for loose bolts and nuts, and repair as required.

2-5 Storage when moored for an extended period

(1) Securely close engine room windows and doors so that rain and snow cannot enter.
Also plug the exhaust outlet since water that enters the cylinder from the exhaust pipe will be compressed when the engine is started, causing serious trouble.
(2) The boat may also sink because of water leakage at the stern tube stuffing box packing. This can be prevented by tightening the packing.
(3) Change the lubricating oil before cranking the engine.
(4) Wipe off each part and coat with oil to prevent rusting of the engine exterior.
(5) Coat the regulator handle stand and each link with a thin film of lube oil or grease.
(6) Run the engine once a week to lubricate each part.This will prevent rusting of the bearings, pistons, and cylinder liners.

2-6 Emergency stop

(1) Loosen the fuel valve high-pressure pipe to release the fuel.
(2) Pull the decompression lever (decompression mechanism) so that compression is not applied to the combustion chamber.
(3) Block the air intake port so that air does not enter the combustion chamber.

3. Troubleshooting and Repair

If trouble occurs in the engine, the engine must be immediately stopped or run at low speed until the cause of the trouble is located.
If even extremely small troubles are not detected and corrected early, they can lead to serious trouble and even disaster. Detecting and correcting troubles quickly is extremely important.

3-1 Troubles and corrective action at starting

Trouble	Cause	Corrective action
Flywheel fails to rotate correctly	(1) Battery not charged (2) Starter motor faulty (3) Moving parts seized (4) Lubricating oil viscosity too high	1) Recharge battery 2) Disassemble and repair starter motor 3) Inspect and repair 4) Replace with lubricating oil of suitable viscosity
Starter motor rotates, but engine fails to start	(1) Fuel not injected, or injection faulty	1) Prime and bleed air from fuel lines 2) Inject fuel through injection valve and replace needle if required 3) Clean fuel filter 4) Check operation of fuel pump, plunger, plunger spring, and delivery valve, and replace if required 5) The remote control system or governor is faulty, so check if fuel is cut off, and adjust if required
	(2) Fuel injection timing incorrect	1) Correct the fuel injection timing 2) Check if alignment mark of timing gear is aligned
	(3) Compression pressure low	1) Lap valves when air tightness of intake and exhaust valve is poor 2) Replace cylinder head packing if gas is leaking 3) Clean or replace piston rings when sticking occurs 4) Readjust timing when intake and exhaust valve closing is considerably slow.
	(4) Drop in compression ratio	1) Replace piston pin bearing and crank pin bearing if worn 2) Replace piston rings if worn

3-2 Troubles and corrective action during operation

Trouble	Cause	Corrective action
Engine stops suddenly	(1) Fuel injection cut off due to trouble in the governor or governor system	1) Inspect, and repair or replace
	(2) Air in fuel tank	2) Add fuel
	(3) Air in fuel system	3) Bleed air
	(4) Piston, bearing, or other moving parts seized	4) Inspect and repair or replace the parts
Speed decreases unexpectedly	(1) Governor maladjusted	1) Adjust
	(2) Overload	2) Lighten the load (check propeller system and power take-off system)
	(3) Piston seized	3) Stop the engine, and repair or replace
	(4) Bearing seized	4) Stop the engine, and repair or replace
	(5) Fuel filter clogged	5) Clean the fuel filter
	(6) Fuel injection pump or injection valve sticking Dirt in fuel pump delivery valve	6) Stop the engine, and repair or replace
	(7) Air in fuel system	7) Prime and bleed air
	(8) Water in fuel	8) Drain the fuel tank and fuel filter Add fuel if insufficient
Exhaust color is bad	(1) Load unsuitable	1) Adjust the load (check propeller system and power take-off system)
	(2) Fuel injection timing off	2) Adjust injection timing
	(3) Fuel unsuitable.	3) Change the fuel type
	(4) Injection valve faulty	4) Test injection and replace valve if required
	(5) Intake and exhaust valve adjustment faulty	5) Adjust valve head clearance
	(6) Intake and exhaust valves leaking.	6) Lap or grind valves
	(7) Output of cylinders uneven	7) Check the fuel injection pump and injection valve and replace if necessary
	(8) Injection pressure too low	8) Set injection pressure with shims
	(9) Precombustion chamber melted	9) Replace the precombustion chamber...Perform item (1) above
Full load operation impossible	(1) Fuel filter clogged	1) Check and replace filter element
	(2) Fuel pump plunger worn	2) Replace plunger and barrel as a set
Output of cylinders uneven	(1) Air in fuel pump or fuel line	1) Prime and bleed air from the fuel pump and fuel lines
	(2) Water in fuel	2) Drain the fuel tank and fuel filter and add fuel
	(3) Fuel injection volume uneven	3) Check and adjust injection volume
	(4) Fuel injection timing uneven	4) Check and adjust injection timing
	(5) Intake and exhaust valves sticking	5) Disassemble and clean
	(6) Injection valve faulty	6) If nozzle is clogged, clean; replace nozzle if necessary If the needle is sticking, inspect and replace

Trouble	Cause	Corrective action
Engine knocks	(1) Bearing clearance too large (2) Connecting rod bolt loose (3) Flywheel bolt, coupling bolt loose (4) Injection timing faulty (5) Too much fuel injected because of faulty fuel pump or injection nozzle	1) Inspect, and repair or replace parts 2) Check and retighten 3) Check and retighten or replace bolt as required 4) Check and adjust 5) Check fuel injection pump and injection nozzle and replace if required
Engine oil pressure low	(1) Lubricating oil leakage (2) Bearing, crankpin bearing clearance too large (3) Oil filter clogged (4) Oil regulator valve loose. (5) Oil temperature high; cooling water flow insufficient (6) Lubricating oil viscosity low (7) Excessive gas leaking into crankcase	1) Check engine interior and exterior piping, replenish oil 2) Check clearance, and replace bearing if necessary 3) Check and replace filter element 4) Check and readjust oil pressure 5) Check oil pump, and replace if necessary 6) Replace with oil having a high viscosity index 7) Check pistons, piston ring, and cylinder liners and replace if necessary
Lubricating oil temperature too high	(1) Cooling water flow insufficient (2) Excessive gas leaking in to crankcase (3) Overload	1) Check water pump 2) Check piston rings and cylinder liners 3) Lighten the load
Cooling water temperature high	(1) Air sucked in with cooling water (2) Cooling water flow insufficient (3) Cooling system dirty (4) Thermostat faulty	1) Check water pump inlet side pipe connections 2) Check water pump 3) Flush cooling system with cleaner 4) Replace thermostat
Propeller shaft rotates even when clutch is in neutral position	(1) Neutral position adjustment faulty (2) Friction plate seized (3) Steel plate warped	1) Reset neutral position adjusting bolt 2) Check and repair 3) Repair or replace
Ahead, neutral, astern switching faulty	(1) Clutch face seized (2) Moving parts, lever system malfunctioning (3) Remote control system malfunctioning	1) Replace 2) Readjust 3) Repair or replace
Abnormal heating	(1) Clutch slipping because of overload operation (2) Bearing damaged (3) Excessive oil (4) Oil deteriorated	1) Reduce load 2) Replace 3) Check oil level and adjust to prescribed level 4) Replace oil
Abnormal sound	(1) Gear noise caused by torsional vibration (2) Gear backlash excessive	1) Avoid high speeds 2) Replace

CHAPTER 13

INSPECTION AND SERVICING

1. Periodic Inspection and Servicing

Periodic inspection and servicing is necessary to keep the engine in top condition at all times.
The routine inspection period depends on engine application and usage conditions, fuel and lubricating oil quality, engine handling, etc., and cannot be definitely stated. However, a general guideline will be given here. The relationship between inspection and maintenance activities and operating time is given below.
Refer to pertinent inspection sections of this manual for details.

(1) Perform inspection at the operating times given below, and quickly correct any defects found.
(2) Before reusing disassembled parts, check that they are in good condition.

1-1 Routine inspection

○ Checking and adjustment
● Replacement

❶ Daily check
❷ Initial check after one month or 50 hrs.
❸ Every 100 hrs.
❹ Every 250 hrs.
❺ Every 500 hrs.
❻ Every 1000 hrs.

Classification	Work item	Adjustment standard	❶	❷	❸	❹	❺	❻
Fuel system	Checking the fuel level		○					
	Draining the fuel tank			○		○		
	Cleaning or replacement of fuel filter			○		●		
	Checking and adjusting the nozzle	1GM, 2GM, 3GM/3GMD: 165 ~ 175 kg/cm² (2347 ~ 2489 lb/in.²); 3HM: 155 ~ 165 kg/cm² (2205 ~ 2347 lb/in.²)					○	
	Adjusting the fuel injection timing	1GM, 2GM: 15° bTDC; 3GM/3GMD: 18° bTDC; 3HM: 21° bTDC					○	
Lubricating system	Checking the engine lubricating oil level and condition	1GM: 1.3ℓ; 2GM: 2.0ℓ; 3GM/3GMD: 2.7ℓ; 3HM: 5.5ℓ	○	●	●			
	Replacing the engine oil filter					● Every 300 hrs.		
	Checking the clutch lubricating oil level and condition	1GM, 2GM: 0.25ℓ; 3GM/3GMD: 0.7ℓ/0.3ℓ; 3HM: 0.7ℓ		●		●		
	Checking the oil pressure lamp action		○					
Cooling system	Checking the cooling water discharge		○					
	Checking the pump and impeller						○	●
	Checking the thermostat						○	
	Checking the anticorrosion zinc						○	
	Adjusting the pump drive V-belt			○		○		
Intake and exhaust system	Cleaning of intake silencer element					○		
	Checking the exhaust mixing elbow					○		
	Condition of exhaust smoke		○					
Electrical system	Checking the charge lamp action		○					
	Adjusting the alternator V-belt			○		○		
	Checking the battery electrolyte level	On electrode plate 10 ~ 15mm (0.3937 ~ 0.5906in.)	○	Every month				
	Checking each connector			○				
Engine block	Checking for oil, water, or fuel leaks		○	○				
	Additional tightening of cylinder head bolts and nuts	M10: 7.5 kg-m (54.2 ft-lb); M12: 10 kg-m (72.3 ft-lb)		○				○
	Additional tightening of each bolt			○		○		
	Checking and adjusting the valve clearance	Both for intake and exhaust valves 0.2mm (0.0016in.)		○			○	
Others	Checking and adjusting the remote control system			○			○	
	Checking V-belt or hose damage	Rubber hose must be replaced every 4 years						○●
	Adjusting the propeller shaft center line	Plane or center line off-set must be within 0.2mm (0.0016in.)		○		○		

2-1.2 2GM and 3GM(D)

(mm)

Classification	Part	Inspection point		Nominal dimension	Limiting dimension	Instructions for repair	Remarks *Refer to (page)*
Engine body	Cylinder block and liner	Inside diameter of cylinder block liner hole		ø76		Remove rust with emery paper.	
		Wear on the inside diameter of the cylinder liner		ø72	ø72.10	Replace liner. Correct stepped wear on the upper part or replace liner.	*(2-8)*
		Projection of the cylinder liner		0.005 ~ 0.075	—	Liner should have a projection.	*(2-8)*
		Roundness of the liner		0.02	0.04	Check for a hole in the cylinder block liner.	Make measurement when inserting cylinder liner in the cylinder block.
		Cylindricity of the liner				Check the rubber packing of the liner.	
	Cylinder head	Intake or exhaust valve sinkage		0.95	1.25	Replace valve and cylinder head.	Valve seat angle is 45° *(2-16)*
		Valve seat width	Intake valve	1.77		Correct width by using valve seat cutter or grinder.	Fit contact surface after correction. *(2-15)*
			Exhaust valve				
		Distortion of cylinder head (fitting surface)		0	0.07	Correct distortion by using surface grinder.	*(2-14)*
		Torque for tightening the cylinder head bolts and nuts	Nut for stud bolt	10 kg-m	—	Apply oil to bolts and tighten in the specified sequence.	*(2-18)*
			Aux. bolt	2.5 kg-m			
		Top clearance		0.7	—	Rotate slowly.	Fuse strip is 1.2mm in diam. Length of squeezed fuse strip is less than 10mm. *(2-23)*
Main moving parts	Piston	Piston-to-cylinder clearance		0.057 ~ 0.117			Measure it at room temperature and at the lower end of piston skirt.
		Maximum diameter of piston		$ø72^{-0.057}_{-0.087}$	ø71.85	Replace.	Measure it at room temperature and at the lower end of piston skirt. *(2-31)*
		Interference between piston and piston pin		−0.005 ~ +0.017	—	Replace piston when noise is produced.	Heat piston to about 80°C so that piston pin can be forced into it. *(2-32)*
		Wear of outside diameter of piston pin		$ø20^{0}_{-0.009}$	ø19.98	Replace.	*(2-32)*
	Piston ring	Gap between piston ring ends (within cylinder)	1st	0.20 ~ 0.40	1.5	Replace. When disassembling and servicing engine, replace piston ring.	Measure at a point about 100mm below the cylinder liner top which is free from wear. *(2-34)*
			2nd	0.20 ~ 0.40	1.5		
			Oil	0.20 ~ 0.40	1.5		
		Gap between piston ring and groove	1st	0.06 ~ 0.10	0.20	Replace piston ring or piston.	Mount piston ring with its marking surface directed toward piston top. *(2-31)*
			2nd	0.035 ~ 0.070	0.20		
			Oil	0.020 ~ 0.055	0.15		
		Size of piston ring	1st 2nd Thickness	3.2 ±0.10	—	Replace.	*(2-34)*
			1st 2nd Width	$2^{-0.01}_{-0.03}$	1.90		
			Oil Thickness	2.8 ±0.20	—		
			Oil Width	$4^{-0.01}_{-0.03}$	3.90		

(mm)

Classification	Part	Inspection point		Nominal dimension	Limiting dimension	Instructions for repair	Remarks *Refer to (page)*
Main moving parts	Connecting rod	Inside diameter of crankpin bearing		ø40.0	ø40.10	Replace crankpin bearing.	Tighten connecting rod bolts to the prescribed torque. *(2-37)*
		Crankpin-to-crankpin-bearing oil clearance		0.028 ~ 0.086	0.13		
		Contact of crankpin bearing		—	—	If contact is not correct, replace crankpin bearing.	Check the dimensional tolerance of crankpin.
		Inside diameter of piston pin bearing		ø20.0	ø20.1	Replace piston pin bearing.	*(2-39)*
		Oil clearance between piston pin and bearing		0.025 ~ 0.047	0.11	Replace either piston pin or bearing.	
		If the big end hole and small end hole are parallel (per 100mm)		0.03 or less	0.08	Replace.	*(2-36)*
		Torque for tightening the connecting rod bolt		2.5 kg-m	—	Apply oil to the bolt before tightening.	*(2-37)*
	Crankshaft	Wear on the crankshaft journal	Gear case side	ø44 $^{-0.036}_{-0.050}$	ø43.90	Replace or correct.	Carefully arrange so that the corner angle of both crankpin and crankshaft journal is 4 $^{+0.3}_{0}$. *(2-42)*
			Intermediate bearing	ø44 $^{-0.036}_{-0.050}$	ø43.90		
			Flywheel side	ø60 $^{-0.036}_{-0.050}$	ø59.90		
		Crankpin wear		ø40 $^{-0.036}_{-0.050}$	ø39.90		
		Uneven wear on the crankpin and crankshaft journal		—	0.01		
		Oil clearance between crankshaft journal and journal bearing	Gear side	0.036 ~ 0.092	0.15	Replace bearing or crankshaft.	*(2-42)*
			Intermediate gear side	0.036 ~ 0.092	0.15		
			Intermediate wheel side	0.036 ~ 0.092	0.15		
			Wheel side	0.036 ~ 0.095	0.15		
		Oil clearance between crankpin and bearing		0.028 ~ 0.086	0.13		
		Side gap of crankshaft		0.09 ~ 0.19	0.30	Replace crankshaft bearing.	Replace standard bearing. *(2-45)*
		Torque for tightening set bolts to the intermediate main bearing journal		3.0 ~ 3.5 kg-m	—	Apply oil to the threads before tightening.	Be sure that there is no score on the fitting surfaces of the bearing and bearing gap, and no dust, etc. between the fitting surfaces. *(2-46)*
		Torque for tightening the main bearing journal		2.5 kg-m	—		*(2-47)*
		Bend in the crankshaft		Less than 0.015	0.15	Replace.	*(2-44)*
		Oil seal wear	Timing gear side	25408	—	Replace oil seal.	Be careful that the oil seal doesn't collapse. *(2-50)*
			Main bearing journal side	60829	—		
	Camshaft	Outside diam. of journal	Flywheel side	ø30		Replace bearing or camshaft.	*(2-57)*
			Intermediate	ø41.5 [3GM(D) only]			
		Inside diam. of bearing	Flywheel side	ø30			
			Intermediate	ø41.5 [3GM(D) only]			
		Oil clearance between camshaft and bearing	Flywheel side	0.050 ~ 0.100	0.15		*(2-57)*
			Intermediate	0.050 ~ 0.100 [3GM(D) only]	0.15 [3GM(D) only]		
		Side clearance of camshaft				Replace gear side bearing.	
		Height of cam	Intake-exhaust valve	35	34.70	Replace camshaft.	Correct slightly stepped wear on the cam.
			Fuel pump	33	—		

(mm)

Classification	Part	Inspection point	Nominal dimension	Limiting dimension	Instructions for repair	Remarks *Refer to (page)*
Valve gear	Timing gear	Timing gear backlash (Crankshaft gear and camshaft gear)	0.05 ~ 0.13	0.3	Replace gear.	*(2-66)*
		Backlash				*(2-66)*
		Lubricating oil pump gear and crankshaft gear	0.05 ~ 0.13	0.3		*(2-66)*
	Intake-exhaust valve	Wear on the intake-exhaust valve stem	ø7	ø6.9	Replace intake-exhaust valve.	When replacing a valve due to valve seat wear, also replace the valve guide. *(2-20)*
		Inside diameter of the valve guide	ø7	ø7.08		
		Gap between valve guide and valve stem — Intake	0.040 ~ 0.065	0.15		Intake and exhaust valve guides are different. *(2-20)*
		Gap between valve guide and valve stem — Exhaust	0.045 ~ 0.070	0.15		
		Clearance between the valve guide and cylinder head	0.018 ~ 0.047		Lubricate the valve guide before press-fitting.	
		Valve thickness	0.75 ~ 1.15		Replace valve.	*(2-19)*
		Width of the intake-exhaust valve seat	3.15		Correct or replace valve seat.	Be sure to properly fit after correcting the seat. *(2-19)*
		Intake-exhaust valve sinkage	0.95	1.25		Valve recess. *(2-19)*
		Valve stem seal damage	—	—	Replace valve stem seal.	Be careful not to damage the seal lip.
		Valve spring — Spring load (load at fitting time/compressed dimension)	16.16kg	13.7kg	Replace valve spring.	*(2-22)*
		Valve spring — Free length	38.5	37		
		Valve spring — Collapse				
		Intake-exhaust valve head clearance	0.2	—	Adjust.	*(2-26)*
		Contact surface between valve stem and rocker arm	—	—	If there is excessive wear on the rocker arm tip or valve, correct or replace the rocker arm or valve stem.	*(2-26)*
		Outside diameter of the rocker arm shaft	ø14	ø13.9	Replace rocker arm shaft or bearing.	*(2-25)*
		Inside diameter of the rocker arm shaft bearing	ø14	ø14.1		
		Oil clearance between rocker arm shaft and bearing	0.016 ~ 0.052	0.15		
		Push rod bend	0.03 or less	0.3	Correct or replace.	*(2-61)*
		Push rod length	136	—	Correct or replace.	*(2-61)*
		Decompressor lift				After adjustment, check valve and piston contact.
	Tappet	Outside diameter of the tappet	ø10.0	ø9.95		
		Inside diameter of the cylinder hole for the tappet	ø10.0		Replace tappet.	*(2-60)*
		Gap between tappet and cylinder block	0.010 ~ 0.040	0.10		*(2-60)*
		Contact surface between tappet and cam	—	—	If contact surface is worn excessively or deformed, replace tappet.	*(2-60)*

(mm)

Classification	Part	Inspection point	Nominal dimension	Limiting dimension	Instructions for repair	Remarks *Refer to (page)*
Lubricating system	Oil pressure	Lubricating oil pressure kg/cm²	3.5 ±0.5	—	Correct any oil leakage and clear any clogged parts.	*(6-6)*
	Lubricating oil pump	Gap between outer rotor and body	0.050 ~ 0.105	0.15		
		Gap between inner rotor and outer rotor	0.050 ~ 0.105	0.15		
		Body-to-rotor side clearance	0.03 ~ 0.07	0.13		*(6-8)*
	Oil filter	Clogged or malfunctioning of filter element	—	—	Replace filter element every 300 hours.	
Cooling system	Water pump	Clearance between rubber impeller and pump cover	0.2	0.4	If impeller is damaged, replace pump.	*(7-10)*
		Water leakage from the sealing section	—	—	Replace pump.	
		Driving V-belt	M19in.	—	Replace.	*(7-9)*
Fuel injection device	Piping, etc.	Clogging, cracks, loose connection, and defective packing of fuel pipe, priming pump, fuel injection pump, and injector	—	—	Correct or replace.	
	Fuel filter	Clogging or failure of fuel filter element	—	—	Clean or replace.	
		Time interval for replacing element	Every 250 hours	—		First time 50 hours. *(3-29)*
	Delivery valve	Oil tightness of the delivery valve (Time required for pressure drop of 10 kg/cm² from initial pressure of 100 kg/cm²)	20 sec. or more	5 sec. or less	Replace delivery valve assembly.	The inside diameter of the pressure gauge pipe is 1.6mm and 100mm in length. *(3-23)*
		Wear on the piston section of the delivery valve	—	—	If wear is excessive, replace delivery valve assembly.	*(3-23)*
		Torque for tightening delivery valve holder	4.0 ~ 4.5 kg-m	—		*(3-22 or 3-23)*
	Plunger	Pressure generated by plunger			Replace plunger and barrel assembly.	The inside diameter of the pressure gauge pipe is 1.6mm and 100mm in length. *(3-22 or 2-23)*
		Plunger wear	—	—	If the lead section, etc. are excessively worn, replace plunger assembly.	*(3-22 or 3-23)*
		Top clearance of the plunger	1.0 ±0.05	—	Adjust by using adjusting shim.	*(3-22)*
		Injection spacing angle (crankshaft angle)	(*1)	—	Adjust tappet, or replace tappet and camshaft.	Crankshaft angle. *(3-23)*
		Injection amount pump speed	1800 rpm	—		*(3-24)*
		Plunger diameter × stroke	ø6 × 7	—		*(3-24)*
		Injection nozzle type	YDN-OSDYD1	—		*(3-24)*
		Pressure for fuel injection	170 kg/cm²	—		*(3-24)*
		Amount of injection at matching mark position	20 ±0.5cc	—		*(3-24)*
		Allowable error between cylinders	Less than 1 cc	—		*(3-24)*
		Stroke	1000	—		*(3-24)*

(*1) 2GM = $\overset{180°\ 540°}{1 \sim 2 \sim 1}$ 3GM(D) = $\overset{240°\ 240°\ 240°}{1 \sim 3 \sim 2 \sim 1}$

(mm)

Classification	Part	Inspection point	Nominal dimension	Limiting dimension	Instructions for repair	Remarks *Refer to (page)*
Fuel injection device	Fuel injection valve	Fuel injection timing (FID)	bTDC 15° 2GM, bTDC 18° 3GM(D)	—		*(3-21)*
		Nozzle valve type	YDN-OSDYD1	—		Semi-throttle. *(3-24)*
		Oil tightness of nozzle valve seat section (150 kg/cm²)	No oil leakage from nozzle with injection pressure being lowered by 20 kg/cm² from the specified injection pressure.	—	If oil leaks from valve seat section, correct or replace valve seat.	*(3-28)*
		Spray and injection (Adjust nozzle valve opening pressure to 170 kg/cm²)	1) There should be no scattering of comparatively large drops observable by the naked eye. 2) There should be no discrete drops flying sideways. 3) After injection the oil should not adhere to the nozzle body.	—	Replace malfunctioning nozzle valve.	*(3-28)*
		Injection pressure	170±5 kg/cm²	—	Adjust.	*(3-28)*
Electrical equipment	Wiring	Loose connections, disconnections, or bare wire	—	—	Repair or replace.	
	Battery	Battery terminal	—	—	Repair, if rusted or corroded.	
		Plate, separator, cell, etc.	—	—	Repair, if any damage is detected.	
		Specific gravity of electrolyte	1.260/20°: 100% charge 1.200/20°: 50% charge	—	Adjust specific gravity and charge the battery.	Coefficient of temperature conversion by taking 20°C as standard: −0.007 per +1°C +0.007 per −1°C *(10-5)*
		Capacity	70AH or more	—		*(10-4)*
		Terminal voltage	12V	—		*(10-4)*
	Starter motor	Brush — Spring force	1.6 ±0.2kg	—	Replace. Brush should be able to move smoothly in the brush holder.	*(10-14)*
		Brush — Brush height	16	12		*(10-13)*
		Magnetic switch resistance — Series coil	0.324Ω	—	Replace.	at 20°C *(3-14)*
		Magnetic switch resistance — Shunt coil	0.694Ω	—		
		Commutator — Outside diameter	ø33	ø32	Replace.	*(3-12)*
		Commutator — Difference between max. and min. diam.	0.4	Repair accuracy 0.05		
		Commutator — Depth of mica between segments	0.2	0.5 ~ 0.8	Correct.	*(3-12)*
		Commutator — Commutator runout			Correct.	*(3-12)*

(mm)

Classification	Part	Inspection point			Nominal dimension	Limiting dimension	Instructions for repair	Remarks *Refer to (page)*
Electrical equipment	Starter motor	ℓ dimension			0.3 ~ 2.5	—	Correct.	The clearance between the end of the pinion & its stopper. *(10-9)*
		Bearing and shaft S/B = Shaft/Bearing inside	Brush side bearing	S/B	12.450~12.468/ 12.500~12.527			
			Intermediate bearing	S/B	—			
			Pinion slide way	S/B	12.450~12.468/ 12.530~12.550			
			Pinion side bearing	S/B	12.450~12.468/ 12.500~12.527			
		Type			S114-303	—		*(10-16)*
		No-load	Terminal voltage		12V	—		
			Current		60A or less	—		
			Speed of rotation		7000 rpm or greater	—		*(10-17)*
	Alternator	Stator coil resistance			0.149Ω	—	Replace.	at 20°C, for 2 phase *(10-23)*
		Rotor	Rotor coil resistance		3.29Ω	—		at 20°C *(10-23)*
			Slip ring outside diam.		ø31.6	ø30.6		
			Slip ring runout		Limit of correction 0.3	Accuracy of correction 0.05	Correct or replace.	*(10-22)*
		Brush	Brush length		16.0	9.0	Repair or replace brush when there is not full contact with the slip ring; when brush spring force is not uniform or incorrect; when brush is worn; when part of the brush is gone; or when the brush holder is improperly holding the brush.	*(10-23)*
			Brush spring strength		300 ±45g	—		When the brush protrudes 2mm from the brush holder. *(10-24)*
		Stain on slip ring surface			—	—	Repair, if stained or damaged.	
		Adjusting voltage			14.3 ±0.3V	—		at 20°C Full batt. *(10-24)*
		Rated output current			27.5 ±2A/ 2500 rpm 35 ±2A/ 5000 rpm	—		*(10-18)*
Alarm	Water temperature unit	Operating temperature		ON	60 ±2°C	—		
				OFF	53°C or more	—		*(10-30)*
		Current capacity			DC 12V, 1A	—		*(10-30)*
		Pilot lamp			12V, 3.4W	—		
	Oil pressure unit	Rated voltage			12V			
		Operating pressure			0.2 ±0.1 kg/cm²			
		Lamp capacity			12V, 5W			*(10-29)*
	Buzzer	Current consumption			100mA or below			
		Range of operating voltage			10 ~ 15V			
		Sound output			75dB (A) (at 1m, 12V)			
		Frequency			3 ±0.5kHz (at 12V)			*(10-30)*

2-2 Summary of main adjustments

Classification	Inspection point			1GM	2GM	3GM(D)	3HM	*Refer to (page)*
Engine	Top clearance		mm (in.)	0.7 (0.0275)			0.8 (0.0314)	*(2-23)*
	Decomp lift		mm (in.)					
	Valve clearance (intake & exhaust)		mm (in.)	0.2 (0.0078) (When cold)				*(2-26)*
	Valve timing	Intake valve open	b.T.D.C.	20°				*(2-59)*
		Intake valve close	a.B.D.C.	50°				
		Exhaust valve open	b.B.D.C.	50°				
		Exhaust valve close	a.T.D.C.	20°				
	Lube oil pressure		kg/cm² (lb/in²)	3.5 ±0.5 (42.67 ~ 56.89)				*(10-18)*
	Fuel oil injection pressure		kg/cm² (lb/in²)	170 ±5 (2347 ~ 2489)			160 ±5 (2205 ~ 2347)	*(3-28)*
	Fuel oil injection timming		b.T.D.C.	bTDC 15°		bTDC 18°	bTDC 21°	*(3-21)*
Installation	Alignment (thrust & propeller shaft)		mm (in.)	0.005 (0.0019) or less				
	Deviation face (both coupling for thrust & propeller shaft)		mm (in.)	0.2 (0.0078) or less				
	Maximum rake angle			15°				