

CHAPTER 13

OPERATING INSTRUCTIONS

1. Fuel Oil and Lubricating Oil	13-1
2. Engine Operating Instructions	13-8
3. Troubleshooting and Repair	13-13

1. Fuel Oil and Lubricating Oil

Selection of and proper attention to fuel and lubricating oils has a substantial effect on engine performance, and these 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

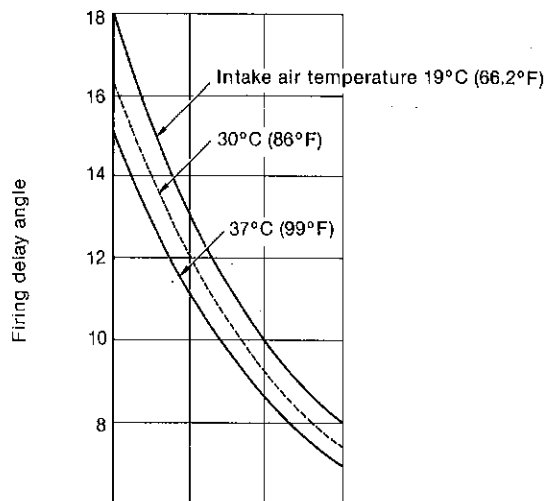
When the viscosity is too high, the fuel flow will be poor, operation of the pump and nozzle will be inferior, atomization will be faulty and fuel combustion will be incomplete.

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.

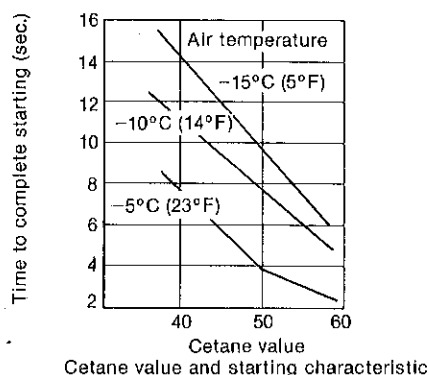
(3) Cetane value must be high.

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) Deterioration 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 (SO₂) and sulfuric anhydride (SO₃). 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		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 value		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 below (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 into 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 ensure 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 dispersant
- 5) Lubrication additive
- 6) Anticorrosion additive
- 7) Bubble elimination additive
- 8) Alkali neutralizer

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 10W 20W	Under 4,000 6,000 ~ 12,000 12,000 ~ 48,000	Under 869 1,303 ~ 2,606 2,606 ~ 10,423	— — —	— — —	20°C or less (68°F or less)
20 30	— —	— —	45 ~ 58 58 ~ 70	5.73 ~ 9.62 9.62 ~ 12.93	20°C ~ 35°C (68°F ~ 95°F)
40 50	— —	— —	70 ~ 85 85 ~ 110	12.93 ~ 16.77 16.77 ~ 22.68	35°C or greater (95°F or greater)

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 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, and 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

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. 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 extremely 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 Lubricating 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. Energol ICMB B.P. Energol DS-3	20W	20W	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.

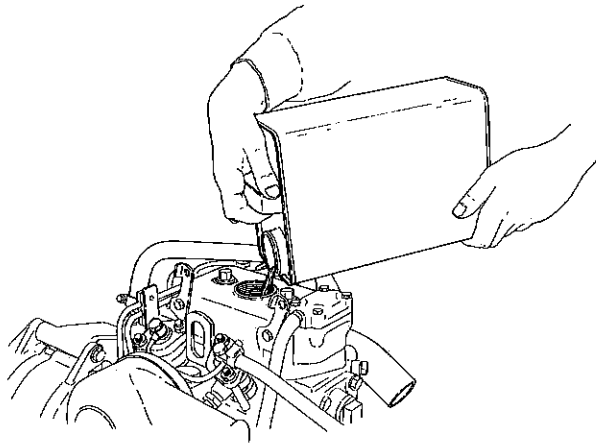
CAUTION: Never mix different brands of lubrication oil.

1-2.8 Adding oil

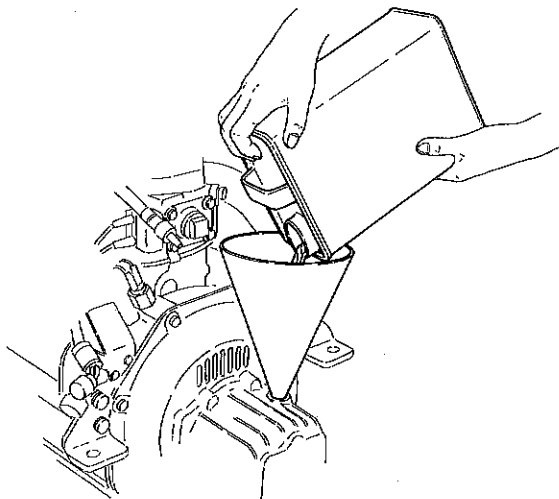
The crankcase and clutch case are not connected. For the crankcase, add one of the lubricating oils described in chapter 1.2.6. For the clutch case, add the lubrication oil described below. Be sure not to mix up the oils.

Supplier	1GM10	2GM20 (F)	3GM30 (F)	3HM35(F)
SHELL	Same lube oil as for crankcase			SHELL DEXRON
CALTEX				TEXAMATIC FLUID(DEXRON)
MOBIL				MOBILE 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

1-2.9 Oil capacity

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

	Crankcase	Clutch case (except sail-drive)
1GM10(C)	1.3ℓ	0.25ℓ
2GM20(F)(C)	2.0ℓ	
3GM30(F)(C)	2.6ℓ	0.3ℓ
3HM35(F)(C)	5.4ℓ	0.7ℓ

- 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) 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.

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 full mark of the dipstick.
The level must be neither 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

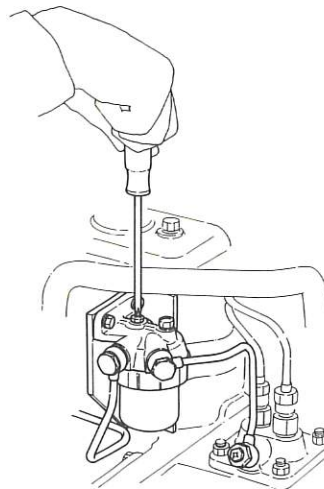
- (1) Operate the priming lever of the fuel pump.
- (2) Set the regulator handle to the full speed position and check for injection sound by turning the engine over several times.
- (3) If there is no fuel injection sound, bleed the air from the fuel system.

2-1.5 Bleeding the fuel system

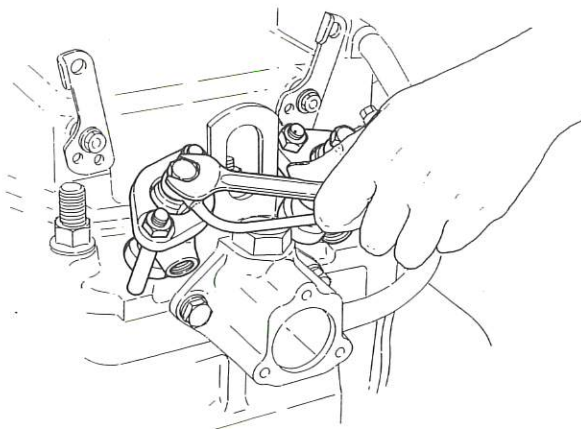
Since the presence of air in the fuel system anywhere between the fuel tank and the injection valve will cause faulty fuel injection, always bleed the air from the system when the fuel system is disassembled and reassembled.

Bleeding the fuel system

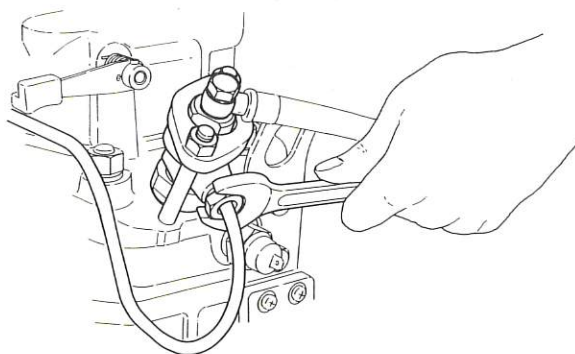
- (1) Open the fuel tank cock.
- (2) Bleed the air from the fuel filter.
Loosen the air bleeding plug at the top of the fuel filter body and operate the manual handle of the fuel pump until no more bubbles appear in the fuel flowing from the filter.
Then install and tighten the air bleeding plug.



- (3) Bleed the air from the fuel return pipe.
Loosen the connector 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.

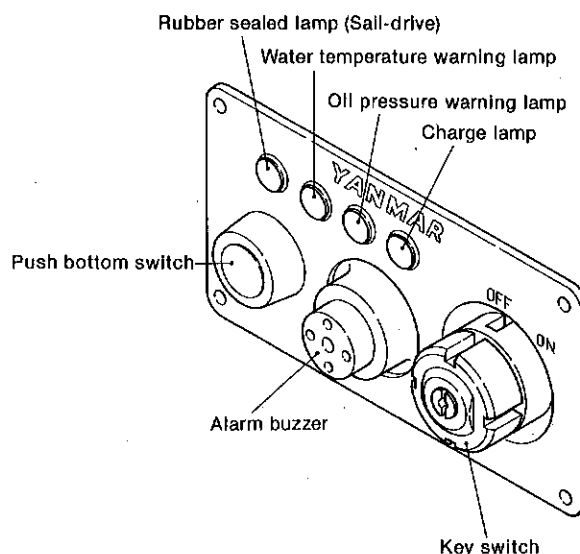
2-2 Starting and warm-up

2-2.1 Starting

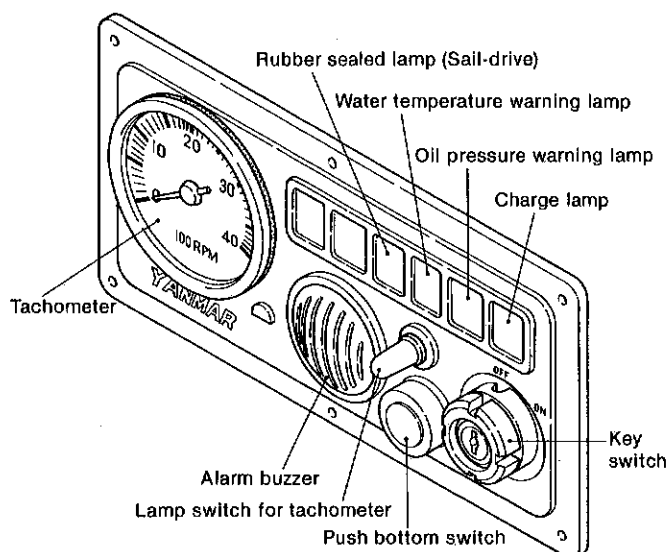
(1) Starting procedure

- 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



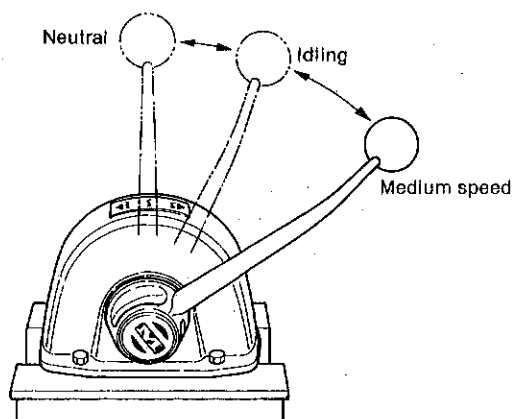
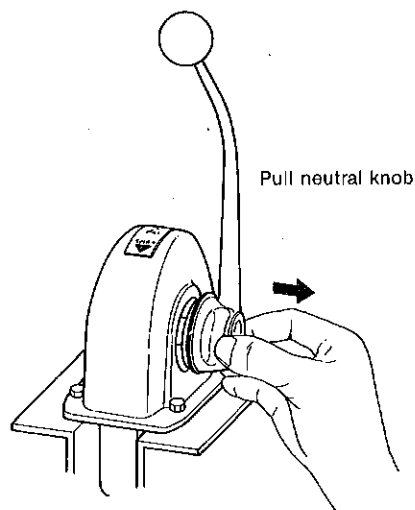
(2) Starting precautions

- 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

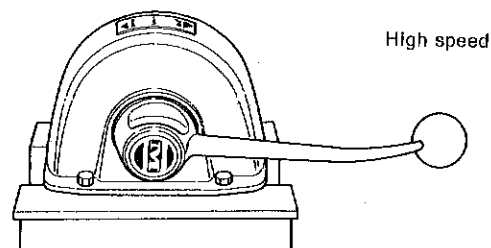
- 1) Pull the neutral knob and set the control lever to the "MEDIUM SPEED" position.



- 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 ex-

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

