CHAPTER 13

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 is 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

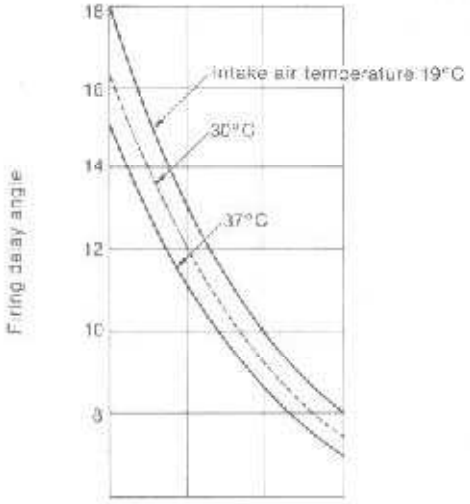
1-1.3 Fuel selection precautions

Pay careful attention to the following when selecting the fuel.

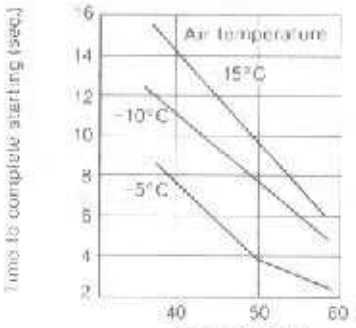
(1) Must have a suitable specific gravity
Fuel having a specific gravity of 0.88 ~ 0.94 at 15°C is suitable as diesel engine fuel. Specific gravity has no relation to spontaneous combustibility, but does give an idea of viscosity and combustibility or mixing of impurities.
Generally, the higher the specific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

Printed in Japan
FO23A9078

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	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	50 or more	50 or more	51.7 or more	55 or more	55 or more
Flow point	°C	−5 or less	−10 or less	−12 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	350 or below	350 or below	282.21 ~ 338	357 or below	357 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 the fuel contains resin or carbon black particles and impurities will appear when fuel and sulfuric acid are mixed in equal parts.
(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 reduce 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, the 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 heat 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.	−17.5°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
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
30	—	—	58 ~ 70	9.62 ~ 12.93	
40	—	—	70 ~ 85	12.93 ~ 16.77	35°C or greater
50	—	—	85 ~ 110	16.77 ~ 22.68	

Since only the 98.9°C viscosity is stipulated for S.A.E. No. 20 ~ 50 oil in the table, and only the −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 the 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 Fuel oil

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

Printed in Japan
F035A9078

1-2.6 Recommended lubricating oils

Supplier	Brand Name	SAE No.			
		Below 10°C	10~20°C	20~35°C	Over 35°C
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 interval should be change 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

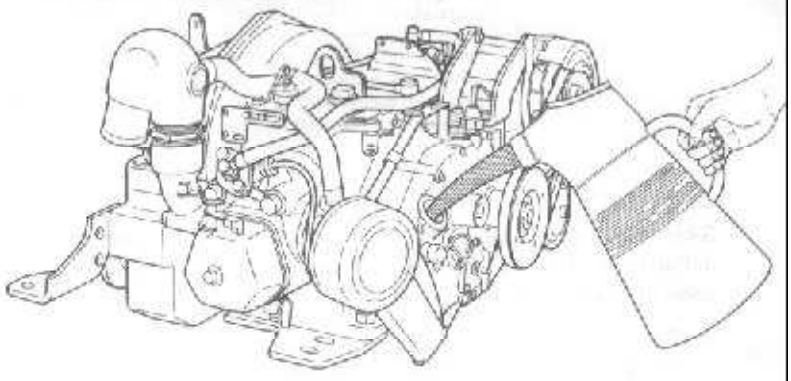
Drain the old oil completely and replace it with new oil while the engine is still warm.

CAUTION: Never mix different brands of lubricating oil.

1-2.8 Feeding the lubricating oil

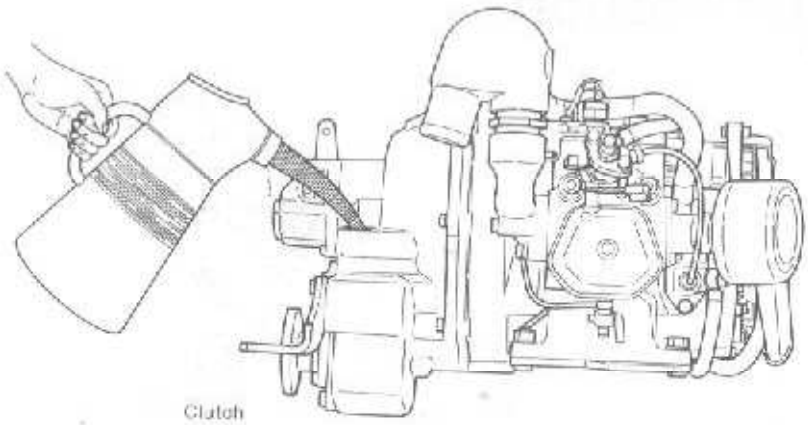
Although the crank chamber is not connected with the clutch case, the same lubricating oil is employed for both.

(1) Remove the oilers on the clutch case and the head cover. Be sure to add lubricating oil to the upper mark on the dipstick, the amount of oil should not be below the lower mark on the dipstick, nor should too much oil be added.



Engine

Printed in Japan
F023A9078



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 ship is afloat.

1-2.9 Oil capacity

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

liter

	YSM8	YSM12
Crankcase total/effective	1.9/0.8	3.0/1.0
Clutch case total/effective	0.7/0.2	0.7/0.2

- 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.
Fuel consumption for 10 hour/day operation is given below.

YSM8	7HP/3200 rpm	Approx. 18ℓ
YSM12	10HP/3000 rpm	Approx. 26ℓ

(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 are separated. Check both and add oil separately.

(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.

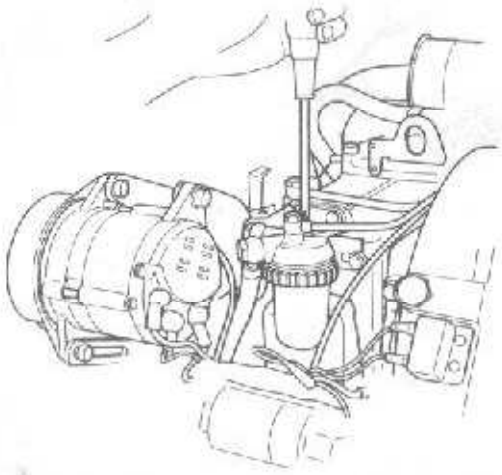
2-1.5 Bleeding the fuel system

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.

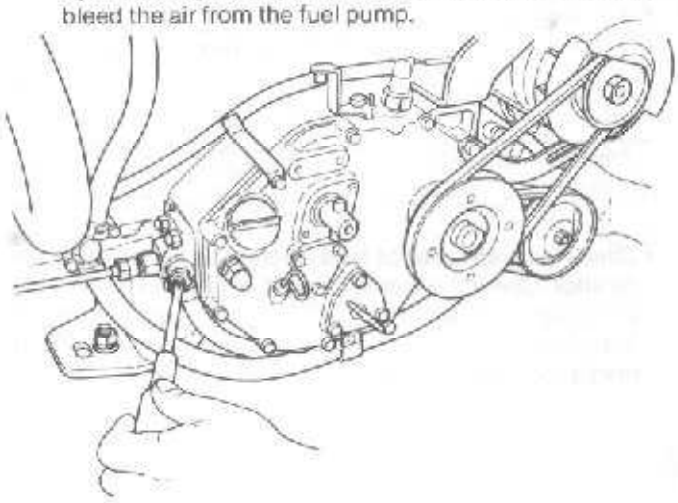
Bleeding the fuel system

(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) Bleeding the air from the fuel pump
By loosening the pipe joint bolt on the fuel pump side, bleed the air from the fuel pump.



(4) 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 priming lever.

(5) 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.

(6) 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 or starter motor.
(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) 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.)

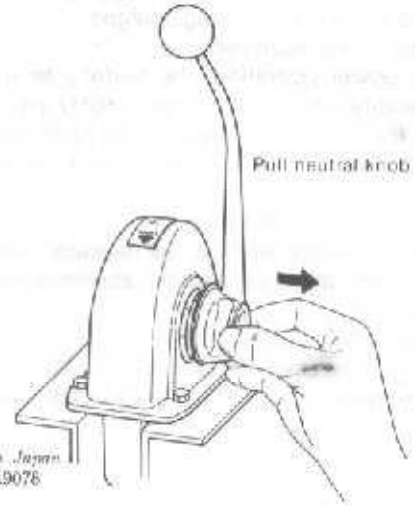
2-1.10 Checking appearance and exterior

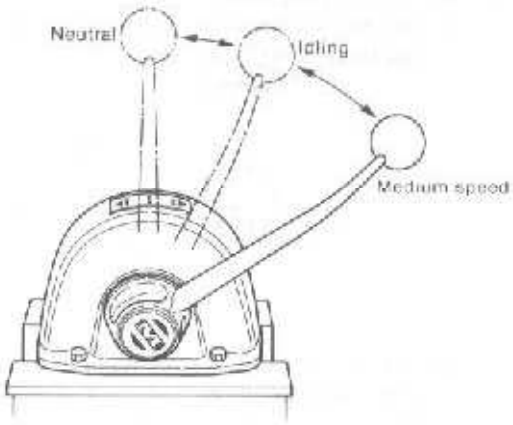
(1) Check for loose or missing bolts and nuts.
(2) Check for loose or disconnected piping and hoses.
(3) Check that there are no tools or other articles near rotating parts or on the engine.

2-2 Starting and warm-up

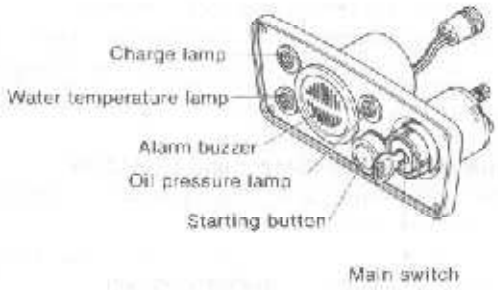
2-2.1 Electric Starting

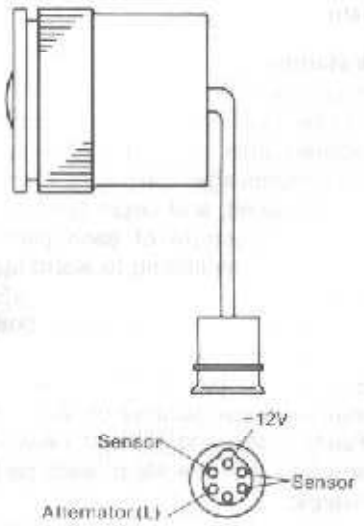
(1) Starting procedure
Pull the neutral knob and set the control lever to the MEDIUM SPEED position.





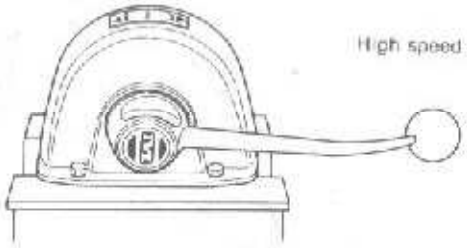
(2) Set the main switch to the ON position.
The alarm buzzer will sound.
(3) Push the starting button to start the engine.
Release the start button after the engine has started.
(4) When the engine has started, the alarm lamps and buzzer will go off.
If the lamps or buzzer stay on, immediately stop the engine and check for trouble.





(5) 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. After the engine has started, return the control lever to the MEDIUM SPEED position.

*When the control lever is set to 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.

2-2.2 Manual starting (for YSM 8-Y and YSM 12-Y)

To start the engine manually, turn the starting handle by hand so that the crankshaft rotates about 10 turns. When the crankshaft has gathered momentum, set the decompression handle to the operation position.
Although the starting handle momentarily offers some resistance, keep going. The engine will ignite and you will hear it rotate.

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 neat 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 state
   (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.

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.
Lubricating 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 it is overlouded.

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

Printed in Japan
F023A9078

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
Engine fails to start	(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 6) Adjust fuel limitter
	(2) Fuel injection timing incorrect	1) 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) Replace cylinder liner if worn 5) Readjust the valve timing
	(4) Drop in compression ratio	1) Replace piston pin bearing and crank pin bearing if worn 2) Replace piston rings if worn

Printed in Japan
F023A9078

3-2 Troubles and corrective action during operation

Trouble	Cause	Corrective action
Engine stops suddenly	(1) Overload	1) Lighten the load
	(2) Fuel tank empty	2) Add fuel
	(3) No fuel injection due to air in fuel system	3) Bleed air Inspect fuel system
	(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 is unsuitable	1) Adjust the load (Check propeller system and power take-off system)
	(2) Fuel injection timing is off	2) Adjust injection timing
	(3) Fuel is 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) Injection limitter maladjusted	7) Adjust
	(8) Injection pressure too low	8) Set injection pressure to 160 kg/cm² 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
Engine knocks	(1) Bearing clearance too large	1) Inspect, and repair or replace parts
	(2) Connecting rod bolt loose	2) Check and retighten
	(3) Flywheel bolt, coupling bolt loose	3) Check and retighten or replace bolt as required
	(4) Injection timing faulty	4) Check and adjust
	(5) Too much fuel injected because of faulty fuel pump or injection valve	5) Check fuel injection pump and injection valve and replace if required

Printed in Japan
F023A9078

3-2 Troubles and corrective action during operation

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

Note: As for electrical equipment refer to chapter 11 "Electrical System".