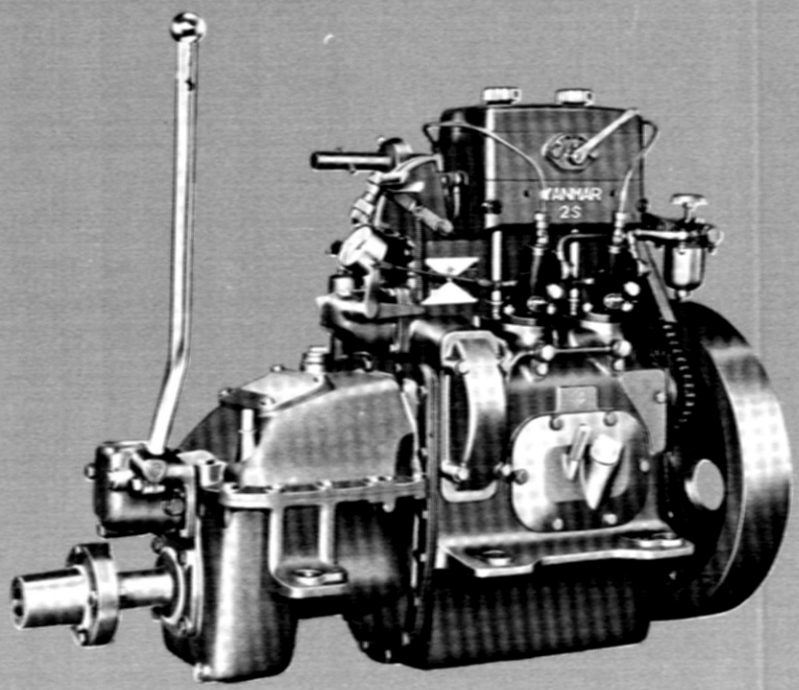
YANMAR DIESEL ENGINE

SERVICE MANUAL | MODEL 2S



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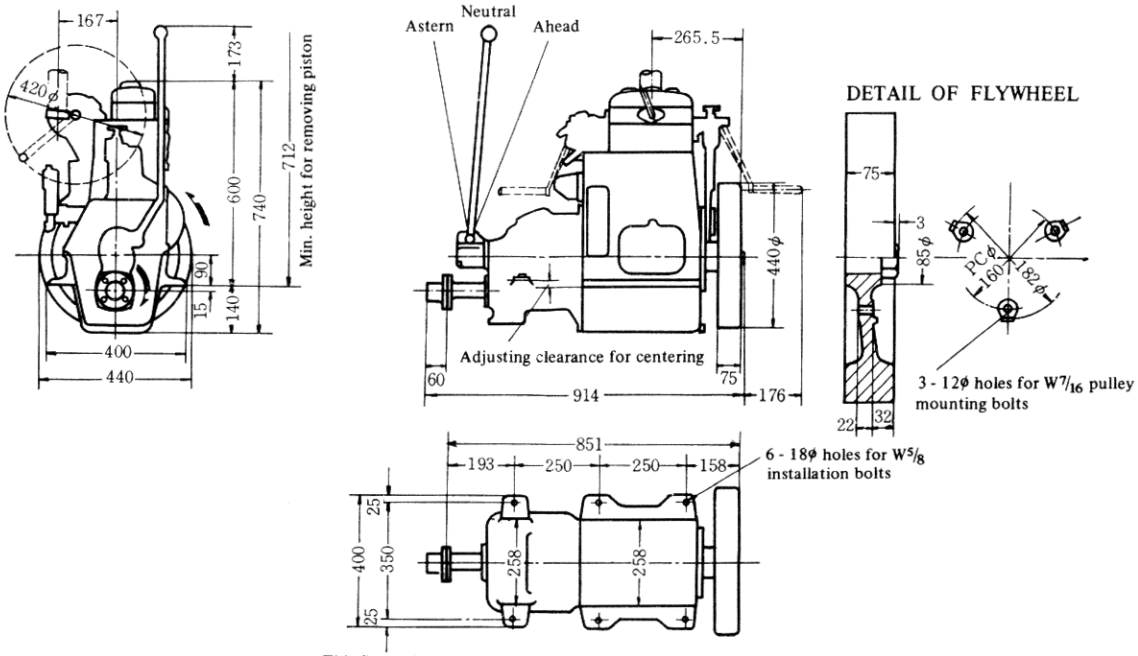
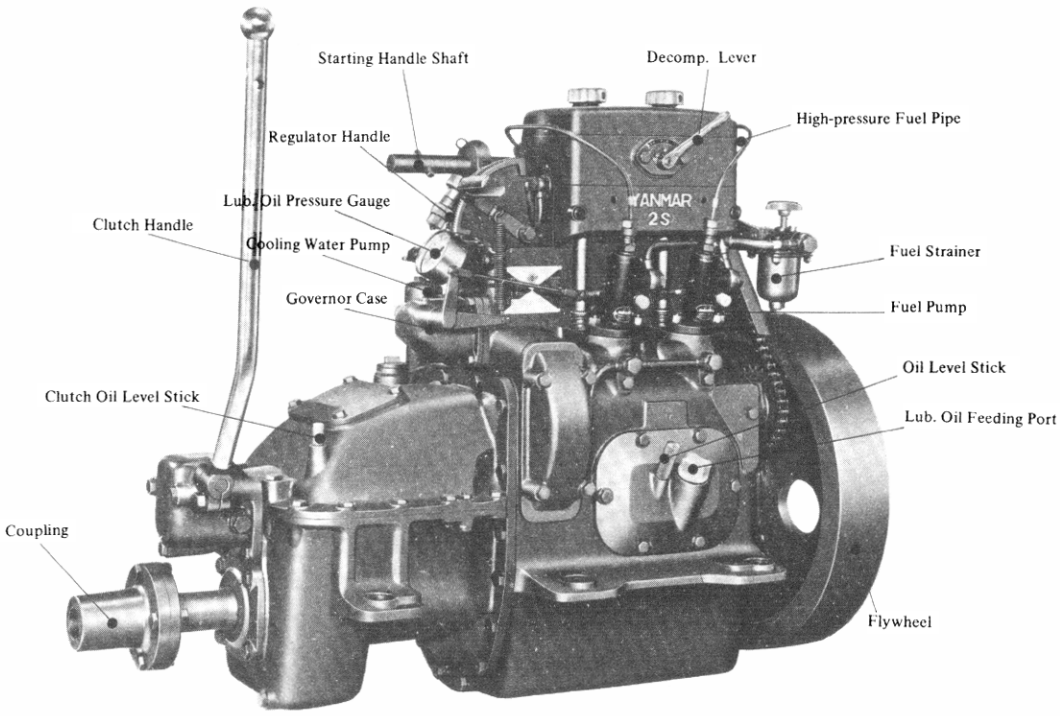


This figure shows installation details to be viewed from the engine bottom.



PREFACE

To operate the engine always under its best conditions, remember the following five points:

- ★ The engine always requires clean fuel oil of the best quality.
  Always keep the fuel tank, strainers, and fuel pipes clean.
- ★ The engine is always in need of clean lubricating oil of the best quality.
  Use an adequate grade lubricating oil and maintain the oil level above the minimum line on the oil level gauge at all times.
- ★ The engine must always have clean air.
  Check that there are no carbon deposits or other foreign particles precipitated at the air intake holes and exhaust system.
- ★ The engine must always be water cooled.
  Supply a sufficient amount of cooling water in the cooling system.
- ★ The engine functions more efficiently under normal load conditions.

1. OUTLINE OF MAJOR STRUCTURES

This outline briefly describes the structure of engine by the following 10 major groups.

No.	Major Group	Part	Description of Structure
1.	Engine main body section	Cyl. block	Monoblock cast of water jacket, crank case and oil sump
		Cyl. liner	Separate piece from cyl., wet type, chrome plated
		Main bearing	KJ triple round metal
		Oil sump	Monoblock cast with cyl. block
2.	Suc./exh. device & valve drive mechanism	Cyl. head	Monoblock cast of two cylinder, water-cooled
		Suc./exh. valve	Mushroom valve (120°)
		Exhaust silencer	No-resistance type
		Valve drive mechanism	Hardened, polished sliding contact portion of cam, tappet, valve arm
3.	Main working section	Crankshaft	Stamp forging, hardened, polished of pin journal
		Flywheel	Mounted with crankshaft and taper part
		Piston	Trunk piston
		Piston ring	3 compression rings & 2 oil scraper rings
		Piston pin	Wholly floating type
		Connecting rod	I-shaped main portion, stamp forging
		Crankpin metal	KJ triple thin metal
4.	Lub. oil system	Lub. oil pump	Spur gear type
		Lub. oil strainer	Pump suction side, hole bored steel plate; Delivery side, auto-clean type
		Oil level checking device	Oil level gauge
		Lub. oil cooler	Fin, full-capacity passing type
5.	Cooling system & bilge system	Cooling water pump	Reciprocating plunger type pump
		Bilge pump	Reciprocating plunger type pump (special order)
6.	Fuel system	Fuel injection pump	Bosch type, individual per cylinder
		Fuel injection valve	Sealed, automatic valve, pintle type
		Fuel oil strainer	Auto-clean type
7.	Governor system	Governor	Centrifugal, all-speed control type
8.	Starting system	Chain starting	Multiplying starting by chain (Electric starting as special order)
9.	Power transfer mechanism	Speed reduction gear	Spur gear type with built-in reversing clutch
		Reversing clutch	Single-plate disc. clutch mechanism
10.	Instruments	Tachometer	———
		Pressure gauge	Bourdon tube type

2. FUEL AND LUBRICATING OIL

As you already know that there are many classes and grades of fuel and lubricating oil marketed today for use in diesel engines. Naturally, a selection of wrong class and/or grade of fuel or lubricating oil might result in unexpected trouble of a diesel engine or otherwise sure to shorten the serviceable life of the engine. Use of quality fuel and lubricating oil of right class and grade will increase the life of the engine many times, offsetting the higher price of the quality oil because on long terms long serivce of the engine gives its owner much more savings than use of low-cost oil which tends to shorten the engine life.

2-1. Fuel

Except gas engine, nearly all types of internal combustion engine burn fuel derived from petroleum for power source. In the following paragraphes, we will explain you light oil and heavy oil used as fuel to run diesel engines.

2-1-1. Light Oil

1. Diesel Light Oil

   In general, light oil has the specific gravity of 0.83~0.89 and the boiling point of 200°C~370°C. Diesel light oil is widely used to run high-speed diesel engines of 1200 rpm or more employed in agricultural machinery, automobile, construction equipment, etc.

2. Requirements of Diesel Light Oil

   1) High cetane rating:

      Good ignitability and high combustion efficiency. Generally these requirements are met diesel light oil of the cetane number of over 45.

   2) Low sulphur content:

      High sulphur content of the oil speeds up corrosion and wear of engine parts particularly those parts which directly come in contact with fuel. Because of these reasons, such oil should not contain 1% or more of sulphur.

   3) Appropriate viscosity:

      Degree of viscosity must be appropriate with relation to ignition and combustion. If the viscosity is too high, atomized fuel particles are too large for dispersion; thus, the combustion time lags and color of the exhaust gas becomes poor. On the other hand, if the viscosity is too low, the atomized particles are too small for penetration of injection, resulted in scorching of the plunger and injection nozzle as they are not provided with lubricating action.

   4) No mixed dust and moisture:

      Impure oil usually contains dust and moisture which cause damage to the plunger and injection nozzle. We recommend use of pure fuel. Besides, be sure to filter the fuel prior to supply to the engine.

3. Cetane Rating

Cetane rating is the most conveniently used criterion for rating diesel fuel and is equivalent of octane rating for gasoline. Cetane rating is used as index of the ignitability and refractoriness. Low cetane number fuel has poor ignitability and tends to cause diesel knock. Causes of diesel knocking are in many cases opposite to those of knocking of gasoline engine, as you can see in the following table.

Causes of Engine Knocking

		Gasoline Engine	Diesel Engine
Engine	Compression Ratio	High	Low
	Temperature & Pressure of Suction Air	High	Low
	Temperature of Cylinder Wall	High	Low
	RPM	Low	High
	Ignition Point of Fuel	Low	High
	Cylinder Capacity	Large	Small
Fuel	Octane Number	Low	——
	Cetane Number	——	Low

2-1-2. Heavy Oil

1. Diesel Heavy Oil

Diesel heavy oil is generally used to run low-speed (average piston speed is below 5 m/sec), intermediate-speed (average piston speed is 5~6 m/sec) and high-speed (average piston speed is over 6 m/sec) diesel engines employed to power large marine vessels.

2. Requirements of Diesel Heavy Oil

1) Low viscosity:

In general, low viscosity is preferable because such fuel is easily injected and consequently combusted well.

B grade heavy oil is used for low-speed, large diesel engines; C grade oil is also used in the large marine vessel engine (of low speed) equipped with heater from the point of view of cost consideration.

2) Low ashes content:

For same reasons as described for sulphur content in connection with diesel light oil, ashes content should be trace amount.

In additions, other properties of diesel light oil also apply for diesel heavy oil generally.

3) Low pour point:

In case the engine is not provided with heater, it is convenient to use a heavy oil having a low pour point.

4) Low residual carbon and sulphur contents:

These requirements are also met in regard to same reason given for low sulphur content of diesel light oil.

3. Classification of Heavy Oil

Grade of Heavy Oil	Specific Gravity	Viscosity (50°C) (Redwood)	Application
A	about 0.85~0.89	<85 sec.	diesel engine
B	about 0.90~0.935	about 85~200 sec.	diesel engine
C	about 0.93~0.96	about 200~600 sec.	heater type engine 6

For fuel to be used, the followings which best suitable for the engine are recommended. If, however, inferior fuel is used, poor exhaust color, damage of exhaust valve and its seat, fuel pump, fuel injection valve, and early abrasion of cylinder liner, piston and piston rings may be resulted. Use as good-quality fuel oil as possible.

Supplier	Brand Name
SHELL	Sheel Diesoline or local equivalent
CALTEX	Caltex diesel oil
MOBIL	Mobil diesel oil
ESSO	Esso diesel oil

2-1-3. Quality Fuel Oil

Most suitable oil as fuel for Yanmar Diesel Engines should possess the properties such as specific gravity, ignition point and viscosity similar to light oil.

It, along with diesel light oil, is widely used to power high-speed diesel engines.

1. Features

1) Good fuel injection performance and lubricating action on fuel injection pump:

Combustion of fuel in diesel engine begins with the injection nozzle. For the atomization, low viscosity requirement is prerequisite. However, to combust completely the atomized fuel, appropriate penetration of injection is requrired of fuel in mist form. In other words, to combust the fuel well, it is necessary to provide the atomized fuel to mix well with air uniformly throughout the combustion chamber instead of the fuel distributed only in neighborhood of the injection nozzle. Thus, to give fuel some degree of penetration of injection, in this respect, the viscosity of fuel must be maintained at sufficient level. Limited by these two factors, the range of appropriate viscosity is determined. Such viscosity appropriate for fuel of small-size, intermediate/high-speed engines is less than 89.5 seconds for RW (Redwood) No. 1, 50°C, as the experimental result.

Furthermore, inside the fuel injection pump, both the cylinder and plunger are to make reciprocating motion violently through the high precision processed narrow space. To provide sufficient lubrication on these parts, fuel itself must provide this additional function. Therefore, the viscosity of fuel must be such to prevent abnormal wear and scorching of the plunger. For this regard, experiment revealed that such viscosity value is more than 32 seconds with RW (Redwood) No. 1, 50°C. From these two findings, the sufficient viscosity required of diesel fuel is within 32~89.5 seconds with RW No.1, 50°C Yet for high-speed diesel engines, the range of appropriate viscosity is in neighborhood

of 32~38 seconds. Fuel oil should be produced with consideration given to above points; thus, it provides excellent atomization and good lubricating action on fuel injection pump.

2) Good ignitability and no diesel knock:

In diesel engine, it is ideal to have combustion occurring immediately upon ignition of the fuel injected into high-temperature compressed air. In detail, the injected fuel particles absorb heat from the surrounding air and begin to evaporate from their surfaces. Finally fuel vapors permeate through air until spontaneous ignition temperature is reached. At such time, ignition initially occurs. Time required for ignition from the moment fuel is injected is called "ignition waiting period" or "ignition delay." If ignition delay is significant, the fuel injected prior to ignition remains as it is and, when ignition initiates, begins to combust at once violently, raising the combustion pressure abruptly. Related to this combustion pressure rise, the pressure wave forms to knock the piston and cylinder wall as high metallic sound is heard. This is what is commonly known as "diesel knock" or "combustion knock" and links to poor run or out of order of engine. Thus, good ignitability of fuel is the most important factor for high-speed diesel engines. Ignitability is measured by crank angle, time required to ignite from the moment fuel is injected into the combustion chamber. However, commonly used measuring stick for ignitability of fuel itself is cetane rating. Higher the cetane number, better the ignitability of the fuel. Yet when considered from all angles, we cannot say that higher cetane number means better ignitability; there is appropriate value of cetane rating with relation to engine type and rpm. We may list below one view on this matter.

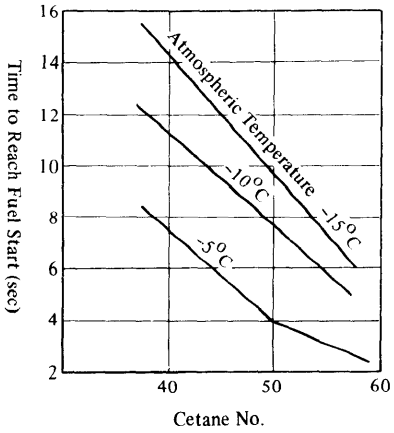
	Cetane Number
High-speed Diesel Engine	40 ~ 55
Intermediate-speed Diesel Engine	30 ~ 40
Low-speed Diesel Engine	20 ~ 30

Naturally, high cetane rating fuel is not required for intermediate- and low-speed engines. But in high-speed (greater than 1000 rpm) engine, inappropriate cetane rating fuel affects considerably engine performance. If fuel of lower than proper cetane rating is used, the following troubles may take place.

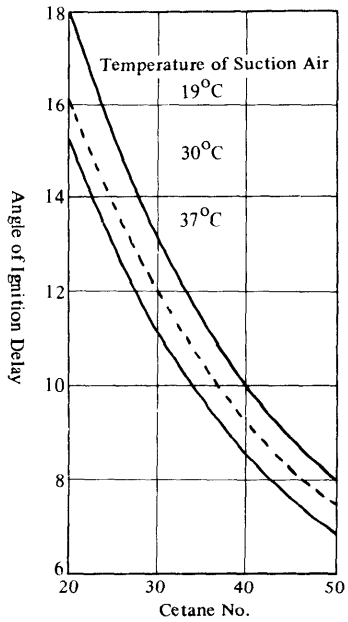
a. Difficult start.
b. Poor operation enven started.
c. High combustion pressure, causing diesel knock.
d. If diesel knocking occurred, output drop and seizure of engine due to overheat.
e. Damage of fuel injection nozzle and exhaust valve.
f. Intense smoking, increasing carbon accumulation inside engine and consequently soiling of oil.
g. Deterioration of oil, speeding up wear of piston rings, ring grooves, cylinder liner, etc.

It is advisable to use fuel oil with cetane rating of about 55;thus its ignitablity is superior, start of engine is easy with it, and no diesel knock is resulted.

Relation between Cetane Rating and Starting Characteristics



Relation between Cetane Rating and Ignition Delay



3) Minor corrosion effect

Major agent affecting corrosion of engine parts is sulphur compound contained in diesel fuel. Unlike gasoline and kerosene, diesel fuel is not treated to remove sulphur; thus, the fuel contains considerable amount of sulphur compound. When diesel fuel is combusted, its content of sulphur compound forms sulfurous acid gas and a certain portion of this gas further reacts with air to form sulfuric anhydride. This in turn combines with water vapor produced as a part of the fuel combustion and becomes sulfuric acid. If cooled below the freezing points, it is condensed and corrode the metallic parts of engine it came in contact with. Formation of sulfuric acid is shown by chain reaction as follows:

$$S + O_2 \longrightarrow SO_2$$

$$2SO_2 + O_2 \longrightarrow 2SO_3$$

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

Cause of fast corrosion and wear-off of diesel engine parts is traced to the above chemical reactions in most cases. Particularly, when the engine is operated under a low atmospheric temperature and cooling water temperature of below 70°C, such undesirable effect takes place at a fast pace. Besides, during short-time running of the engine with light load or while the engine is at rest, this corrosion also tends to proceed. As the freezing point of the combusted gas is raised with the volume of sulphur content, corrosion of engine parts and soiling of oil become intense as the sulphur compound content increases.

Fuel oil should have been produced with sufficient consideration given to damaging effect of sulphur compound and contains extremely little of it, freeing engine parts from corrosion of this type.

4) No clogging of fuel injection nozzle

Fuel injection pump is very precise part of a diesel engine; thus, even a small foreign particle particularly small solid matter, might disable fuel injection mechanism. Among undesirable solid particles concerned here are (1) dust presented in air and (2) iron rust from oil drum or fuel tank entered into fuel. Naturally the latter one is in most cases filtered out by strainers before reaching the fuel injection system. However, for some resosns, if such particle penetrated to the injection system, it causes major troubles of abnormal wear-off of the fuel injection mechanism and of clogging of the nozzle. In addition, if moisture is mixed into fuel in noticeable degree, it affects the injection system adversely although indirectly, differing from directness of bad effect of the solid particle. In detail, the moisture hinders the filtering ability of fuel strainer and cause rust within the fuel system and on the nozzle during engine rest. Besides, it gives a bad effect on fuel injection and thus causes incomplete combustion consequently. Fuel oil should be given strict quality control throughout production and storage stages. Thus, foreign particle and moisture are near nil.

5) Economy

Output and fuel consumption rate of a diesel engine are largely influenced by the cetane number and specific weight of fuel used. Fuel of sufficient cetane number is completley combusted and is said to have a high efficiency of combustion. Thus, fuel consumption rate (gr/HP/hr) is low. On the other hand, if fuel of insufficient cetane number is used, incomplete combustion with smoking occurs, causing diesel knocks. Thus, such fuel has a low effective pressure, and naturally its consumption rate must be higher. Fuel consumption rate, however, is much more depended upon the specific weight (calorific value) than the cetane rating of the fuel. If the specific weight is low, the combustion rate (gr/HP) is raised abruptly.

6) Good for winter as well as summer

It is recommended to use such an oil having the pour point below -15°C; thus, even in severe winter season, it combusts well.

2-1-4. Properties of Fuel & Engine Performances

Property of Fuel	Starting Characteristic	Smoothness of Operation	Smoke Generation	Exhaust Fume	Output	Fuel Consumption	Accumulation within Combustion Chamber
Ignitability (Cetane Rating)	No direct relation but higher cetane rating, better starting characteristic.	No direct relation but higher rating, better smoothness of operation.	Closely related; not much difference if cetane rating is above the min. cetane number limit.	Direct relation; higher cetane rating, lower exhaust fume.	No relation.	No relation.	Relation exists; higher cetane rating, lower the accumulation.
Volatility (90% end point)	No clear relation.	Relation exists; poorer volatility, better the performance.	Direct relation; better volatility, higher smoke generation.	No clear relation.	No relation.	No relation.	Relation exists; smaller this property, larger this aspect.
Viscosity	No clear relation.	Relation in a certain degree, high viscosity is not good.	Relation exists; higher viscosity, dependant on relation with the higher volatility.	Not related specifically.	Not related.	Not related.	Direct relation exists; dependant on relation with volatility.
Specific Weight	Not related.	Not related.	Direct relation exists; dependant on relation with volatility.	Not related specifically.	Direct relation exists; dependant on relation with calorific value.	Direct relation exists; dependant on relation with calorific value.	Relation exists; dependant on engine characteristic.
90% Residual Oil & Carbon Content	Not related.	Not related.	Relation exists; slightly inverse relation.	Not related specifically.	Not related.	Not related.	Relation exists; slightly inverse relation.
ASTM Gum	Not related.	Not related.	Relation exists; slightly inverse relation.	Not related specifically.	Not related.	Not related.	Relation exists; slightly inverse relation.

Property of Fuel	Starting Characteristic	Smoothness of Operation	Smoke Generation	Exhaust Fume	Output	Fuel Consumption	Accumulation within Combustion Chamber
Sulphur Content				Not related specifically.			
Flash Point				Not related specifically.			

2-1-5. Cautions on Fuel

It is important to select the fuel which does not contain dust and water vapor particularly. Besides, prior to filling the fuel tank, filtering is required. To filter fuel, use a piece of clean, finely interwoven cotton or the like cloth. Fuel come in drum can contains some amount of impurities such as dust and water particles settled down on its bottom. Refrain from inverting the can prior to transferring fuel therefrom or avoid pumping up fuel from the very bottom of the can.

2-2. Lubricating Oil

Lubricating oils presently used for all types of internal engines are about all of them mineral oil refined from petroleum. Depending upon their application, viscosity and quality (superior, regular, with/without additive), there are numerous kinds marketed today. Among them are lubricants for diesel engine use. We shall describe the appropriate kinds, property requirements and handling method of this group of lubricants shortly.

2-2-1. Engine Oil

1. Purpose of Engine Oil Usage

   Engine oil mainly purports to check on friction and wear-off of clearance between the cylinder wall and piston rings and bearing section of the pin and journal portions of crankshaft. Besides, not only it seals off a gap between the cylinder wall and piston rings and thereby prevents blow-by of combustion gas and consequently rules out decrease of produced output, but also remove harmful impurity from various sections of the engine, playing a role of preventing corrosion and rusting as well as of carrying away and cooling the heat due to friction.

2. Types of Engine Oil

   Engine oil is roughly classified into two groups; namely, motor oil (gasoline engine oil) and diesel engine oil. Within respective group, they are further classified into several types, denpended upon quality, usage condition, and viscosity.

Classification by Usage Condition

(API Service Classification)

Classification	Symbol	Quality & Application
Gasoline Engine Use	ML	Used under the most favorable operational condition of gasoline engine. No particular requirement is called for its lubricating action as the amount of worn-off particles is small.
	MM	Used under the average or heavy degree in severity of operational condition of gasoline engine. Consideration given to counteract corrosion of bearing and producing of worn-off particles when temperature of oil inside the crankcase is high.
	MS	Used under the severe operational condition of gasoline engine. Special lubricating action is called for taking a measure against producing of worn-off particles and corrosion of abrased bearings from standpoint of designed operational condition of the engine.
Diesel Engine Use	DG	Used under the light-load operational condition of diesel engine. Requirement is small in checking on producing of worn-off particles and abrasion due to designed roles of fuel, lubricating oil and engine itself.
	DM	Used under the severe operational condition of diesel engine when producing of worn-off particles, abrasion, etc. are evident due to sulphur content of fuel used or when residual carbon of lubricating oil affects greatly upon engine design.
	DS	Used under the heavy-load operational condition of disel engine when the fuel producing worn-off particles to a great extent, or when abrasion of the engine especially designed for high-output, high-load operation, etc. is serious.

NOTE: *Symbols operated in above table have the following meanings.*

	Symbol	Meaning
First Letter	M	Motor
	D	Diesel
Second Letter	L	Light
	M	Moderate
	S	Severe
	G	General

Engine oil has been refined and blended with addition of such necessary additives as oxidation inhibiter, corrosion inhibiter, rust preventive, dispersant, etc.

Classification by Viscosity

(SAE Viscosity Classification)

There are seven SAE numbers; namely, #5W, #10W, #20W, #20, #30, #40 and #50.
As list in the following table, engine oils are classified on base of viscosity alone. However, this classification is used for many decades and throughout the world; thus SAE number can well stand for convenient index on quality of engine oil.

List of SAE Viscosity Classification

	0°F (-17.8°C)		210°F (98.9°C)	
SAE No.	Saybolt Universal Viscosity (sec)	Kinematic Viscosity (CSt)	Saybolt Universal Viscosity (sec)	Kinematic Viscosity (CSt)
5W	4,000	869	———	———
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
30	———	———	58 ~ 70	9.62 ~ 12.93
40	———	———	70 ~ 80	12.93 ~ 16.77
50	———	———	85 ~ 110	16.77 ~ 22.68

NOTE: * *If kinematic viscosity is greater than 4.18 CSt (saybolt universal viscosity of 40 sec) at 98.9°C, it is permissible to have the viscosity of less than 6,000 seconds at -17.8°C.*

** *If kinematic viscosity is greater than 5.73 CSt (saybolt universal viscosity of 45 sec) at 98.9°C, it is permissible to have the viscosity of less than 2,606 CSt (saybolt universal viscosity of 12,000 sec).*

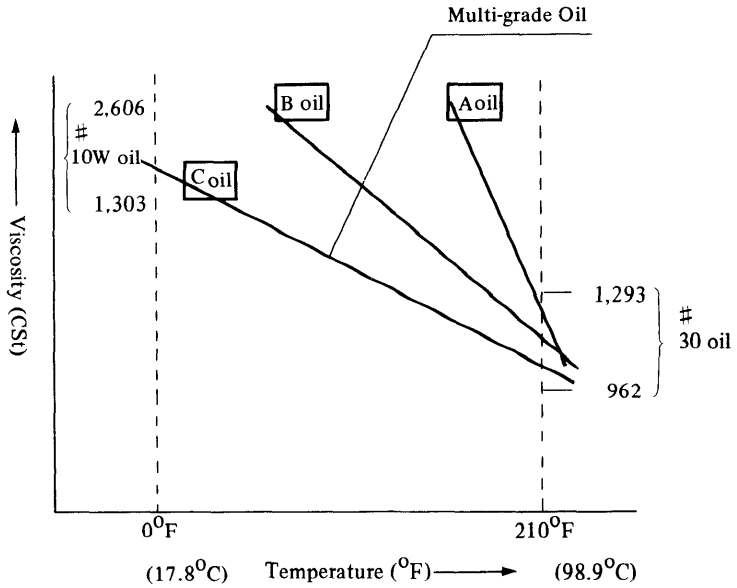
Reference: *SAE (Society of Automotive Engineers) Handbook (1959).*

2-2-2. W & Multi-purpose Grade Oils

The table of SAE viscosity classification listed above specifies only viscosities at 210°F for #20~#50 oils and at 0°F for #5W~#20W oils. Thus, there is no guarantee against some other temperatures. (Those oils designated with number suffixed by letter "W" are specified at a low temperature; therefore, they are generally used during very cold weather.) As can be seen in a graph below, even A oil and B oil are #30 oil, better oil has higher viscosity index and a smaller temperature change like in case of the B oil.

On the other hand, in case of the C oil in the graph below, it has the specified viscosity of #10W oil and in addition that of #30 oil at 210°F. Such oil as the C oil is called a multi-grade oil; C oil is #10W-30 multi-grade oil. Besides, #10W-30 oil, there are other multi-grade oils like #5W-20 and #20W-40 oils. Among them, #10W-30 is the most suitable for use in YANMAR air-cooled diesel engines as well as for the water-cooled diesel engines to be operated in cold region.

Viscosity of Multi-grade Oil



2-2-3. Property Requirements for Engine Oil

To operate an engine safely and economically, engine oil having the following properties is recommended.

1. Appropriate viscosity.
2. High viscosity index.
   Must have appropriate viscosity regardless of low or high temperature. (Make initial run easy and retention of oil film retainable.)
3. Low pour point. (Low solidifying point.)
4. Excellent oiliness, strong oil film, and good abrasion prevention. (Extends the lifetime of engine by preventing abrasion and seizure of metals.)
5. Large oxidation stability. (Extends the lifetime of engine as the oil does not deteriorate even subjected under worse operational condition.)
6. Corrosion inhibition. (Extends the lifetime of engine by preventing corrosion and rusting from forming on various parts of engine.)
7. Superior purity. (In case of diesel engine, although its interior is contaminated particularly by combustion produced matter and deteriorated oil and thus such major troubles as friction increase and seizure of important parts and poor lubrication, if the oil's purity is good, various parts of engine are to be maintained clean. Therefore, extends the lifetime of engine greatly.)
8. Good defoaming property. (Prevents a drop in performance of pump due to air bubbles.)

2-2-4. Exchange of Engine Oil

1. Reasons for Exchange
   Engine oil is subjected to a high temperature during engine operation and, under such temperature, can be blended with air. Thus, the oil itself oxidizes and gradullay changes its property. Besides, water and impurities entered from external source, and fuel con-

taminate and dilute the oil, reducing the capability as a lubricating oil. As water and impurities are mixed into lubricating oil, there are emulsified compound and sludge which increase the viscosity of oil. In addition, if carbon particles deposited inside the cylinder enter the crankcase, oil therein becomes pitch black and can be seen to be worsened in quality at a look. If, however, deteriorated oil is continuously used, the reciprocating and/or rotating parts of engine interior are abrased or corroded, and finally possibility of seizure of bearings and cylinder beocmes great. For these reasons, used engine oil must be exchanged with new one at the time for which we describe below.

2. Exchange Time

Although the exchange time of engine oil differs from engine to engine, quality of lubricating oil, quality of fuel and engine operational condition, the first exchange time for DG grade oil should be following the total engine operation time of 20 hours from use of a brand new engine. The second time is at 30 hours following the first; the third and thereafter, 100 hours following the preceding exchange. The exchange should be conducted while the engine is still warm, discharging old oil completely and feeding new oil. For the exchange, however, observe the following cautions:

1) To exchange the oil inside the crankcase, remove old oil while the engine is warm, tilting the engine so that oil will rush out of the drain plug.
2) Prior to feeding new oil following the discharge of old oil, discharge soiled oil of the outlet side lub. oil strainer comptelely by turning the handle of the strainer several times, then by removing the screw at the lower part of the strainer, and finally by cranking the starting handle four or five times.
3) In course of overhaul of the engine, when the crankcase has been washed, wash oil is fully removed. Only then feed new engine oil. (Remember that for removing wash oil, do not use waste cloth because it might leave bits of down and dirt over the crankcase surface.

2-2-5. Cautions for Handling Engine Oils

At the time of exchanging, if different type of lubricating oil is to be used in place of old oil, pay your attention to the following cautions particularly: For an example, if DG gade heavy duty engine oil with purifier additive is to be fed to the engine using engine oil without additive, there will be no problem only if the engine is completely cleaned. However, if the sludge produced from the previously used oil is remaining inside the engine interior and through the pipe lines, this sludge is washed out due to purifying characteristic of the new oil. To prevent it is necessary to wash out engine interior as much as possible prior to feeding of the new oil. Adoption of the oil containing purifier additive for engine lubrication allows field oil to be soiled at much faster rate than at usual up to the second or third exchange time. It is thought not to be an evidence for poor oil but rather to clean the engine interior. If such is the case, therefore, it is actually a better sign for the engine.

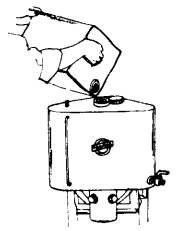
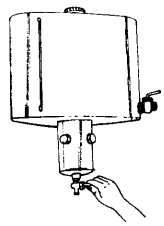
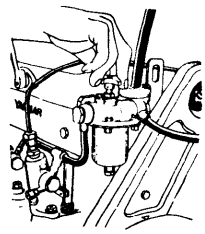
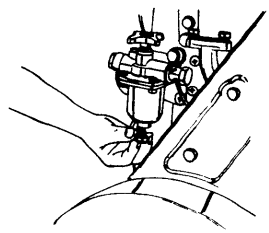
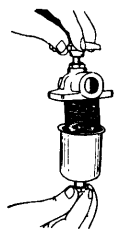
To make the engine easier to start and ensure efficient distribution of the oil and best fuel economy it is essential to select the appropriate viscosity grade, which depends upon the ambient temperature.
For your guidance herebelow is given a table by which the most suitable lub. oil can be chosen easily.

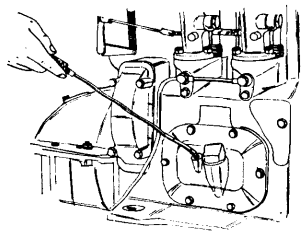
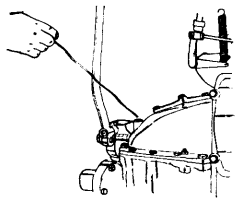
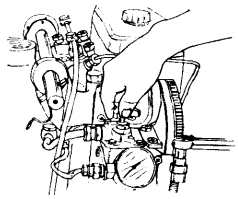
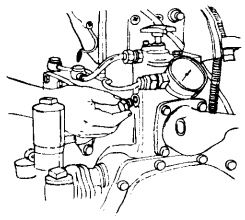
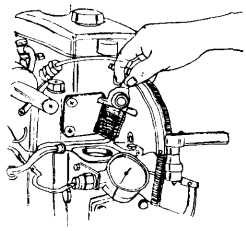
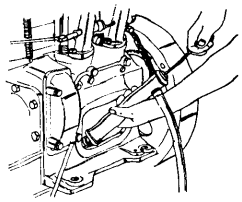
Supplier	Brand Name	SAE No.			
		below 10 °C	10-20 °C	20-35 °C	over 35 °C
SHELL	Shell Rotella Oil	10W 20/20W	20/20W	30 40	50
	Shell Talona Oil	10W	20	30 40	50
	Shell Rimula Oil	20/20W	20/20W	30 40	
CALTEX	RPM Delo Marine Oil	10W	20	30 40	50
	RPM Delo Multi-Service Oil	20/20W 10W	20	30 40	50
MOBIL	Delvac Special	10W	20	30 40	
	Delvac 20W-40	20-40	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

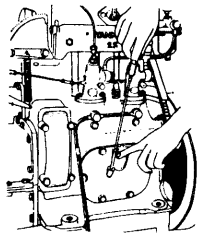
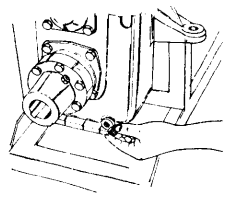
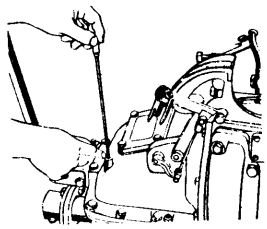
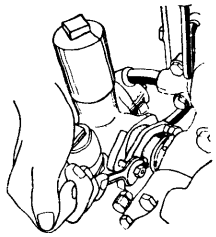
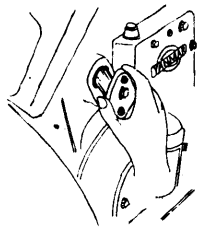
3. PERIODICAL CHECKING & SERVICING

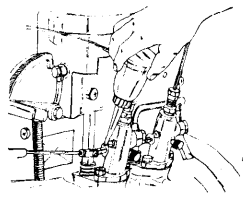
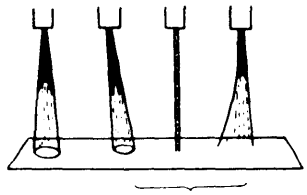
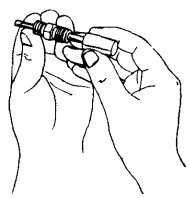
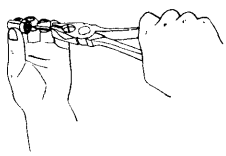
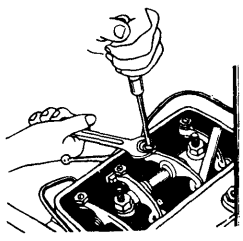
A periodical checking is necessary to keep the engine always in good condition. The frequency of the periodical checks may vary depending upon the purpose for which the engine is used, the conditions of use, the quality of oils used, and the method of handling of engine. It is, therefore, difficult to generalize on the frequency with which periodical checks and servicing should occur. However, here we will explain in general.

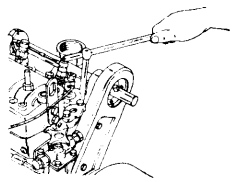
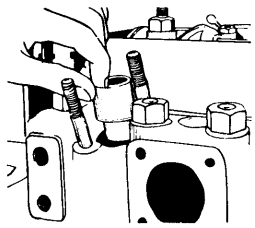
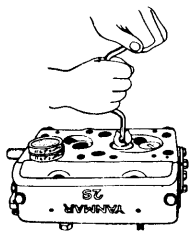
3-1. Periodical List of Items to be Checked and Frequency of Checks

Checking & Servicing Item		Service period					Illustration
		Daily	Every 50 hrs.	Every 250 hrs.	Every 500 hrs.	Every 1000 hrs.	
Fuel oil	(Prior to starting) Check fuel volume & replenish, if necessary	•					
	Discharge fuel tank drain to eliminate water condensation	•					
	Trun handle of fuel strainer	•					
	Discharge fuel strainer drain to eliminate particle build up		•				
	Clean fuel tank strainer			•			

Checking & Servicing Item		Service period					Illustration
		Daily	Every 50 hrs.	Every 250 hrs.	Every 500 hrs.	Every 1000 hrs.	
Lub. oil	Check lub. oil volume & replenish crankcase and reverse gear case, if necessary	•					 
	Turn handle of lub. oil strainers	•					
	Discharge lub. oil strainer drains		•				
	Clean lub. oil strainers			•			
	Change lub. oil of crankcase			•			

Checking & Servicing Item		Service period					Illustration
		Daily	Every 50 hrs.	Every 250 hrs.	Every 500 hrs.	Every 1000 hrs.	
Lub. oil	Change lub. oil of crankcase			●			
	Change lub. oil of reversing gear case					●	 
Cooling water	Check tightness of packing glands	●					
	Check cooling water circulation	●					
	Check anti-corrosive zinc				●		

Checking & Servicing Item		Service period					Illustration
		Daily	Every 50 hrs.	Every 250 hrs.	Every 500 hrs.	Every 1000 hrs.	
Fuel injection pump	Check oil feed to adjusting rod	•					
	Check atomization of fuel by priming	•					 Good Bad
	Confirm fuel injection timing			•			
Fuel injection valve	Clean fuel injection valve strainer			•			
	Clean needle valve				•		
Cylinder head	Adjust valve clearance (suc. & exh. valves)			•			

Checking & Servicing Item		Service period					Illustration
		Daily	Every 50 hrs.	Every 250 hrs.	Every 500 hrs.	Every 1000 hrs.	
Cylinder head	Retighten cylinder head			•			
	Clean combustion chamber wall				•		
	Clean precombustion chamber				•		
	Lap the suc. & exh. valves				•		
	Check valve levers & valve guides				•		
Piston	Disassemble piston & check piston rings					•	

3-2. Checking Locations

In addition to all the periodical checks and servicing items, after 2500 hours of total engine operation, disassemble the engine completely, measure and inspect each part carefully and repair or replace all the excessively worn parts with new ones as required, with reference to "List of Wear Limit."

It is recommended that parts which will wear out before the next overhaul, should also be replaced even if they are within tolerance limits at this time. It is required, therefore, that a workshop equipped with facilities for measurement, inspection, and testing be available.

3-3. Checking Locations by Systems

1. Fuel System
   1) Clean fuel tank interior.
   2) Clean inside the fuel pipes with compressed air, and check for any crack in fuel pipes.
   3) Clean fuel strainer filter plates and interior.
   4) Check fuel injection condition and pressure of fuel injection system.
2. Lubricating Oil System
   1) Clean and inspect cylinder block interior and clutch housing.
   2) Clean and inspect lub. oil passages and lines inside the cylinder block, cylinder head and lub. oil cooler.
   3) Clean lub. oil strainer filter plates and interior.
   4) Check condition of lub. oil pressure regulating valve for strain and its spring tension.
3. Cooling System
   1) Check degree of deterioration of anti-corrosive zinc.
   2) Check extent of abrasion of cooling water pump valve and its seat. Also check the extent of abrasion and strain of cooling water pump valve spring.
   3) Check degree of abrasion of plunger reciprocating section.
4. Engine Body
   1) Check presence or absence of cracked cylinder head and looseness of insert.
   2) Inspect extent of abrasion of pre-combustion chamber.
   3) Check clearance between valve guide and valve shaft.
   4) Check the contact condition of the valve spring holder with valve lever and inspect the abrasion condition of contacting section of valve with lock pieces.
   5) Check strain and tension of valve spring.
   6) Check extent of abrasion of valve lever and valve lever bush.
   7) Check degree of contact of valve seat.
   8) Check abrasion of push rod and tappets.
   9) Check for scoring, excessive abrasion and bending of cam shaft.
   10) Check for scoring and excessive abrasion of and dimension measurement of each part of the cylinder, cylinder liner, crank journal metal, crankpin metal and crankshaft.
   11) Inspect for cracks in cylinder body.
   (Piston and Its Accessories)
   12) Check for cracks and abnormal contact of piston head and measurement of piston outer diameter.
   13) Check friction of piston top ring, trigger weld and cracking of piston ring land.

14) Check sliding and fitting conditions of piston's outer lateral surface.
15) Measure contacting state of outer circumference of piston and oil scraping rings, clearance between piston ring groove and piston ring as well as size of piston ring notch.
16) Measure clearance between piston pin and piston pin metal.

5. Crankshaft
   1) Measure clearance between a crankpin and crankpin metal.
   2) Measure clearance between crank journal and crank journal metal.

6. Miscellaneous
   1) Check for scoring and degree of contact of governor end bearing with governor 2nd lever.
   2) Check for scoring and degree of contact of governor weight with governor spindle.
   3) Check the contact surface condition of gear teeth and check for backlash.

4. MAINTENANCE STANDARDS OF MAIN PARTS

When an engine is used for a period of time, its parts will become worn, not only reducing the engines' performance, but also resulting in engine troubles unless these worn down parts are replaced. The lists of wear limits of main parts will be given at the end of this section. These wear limits are estimated values which will ensure superior performance of the engine and thus they are not absolute values by which the safety of worn down parts can be guaranteed. As indicated in the section concerning the periodical checks and servicing, it is recommended that the parts which will wear out before the next periodical check also be replaced, even if they are at the time of the check, not quite reaching their wear limits.

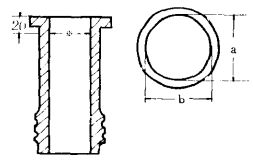
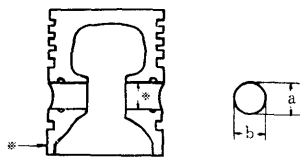
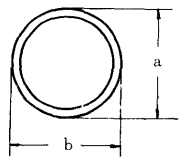
4-1. Maintenance Standards

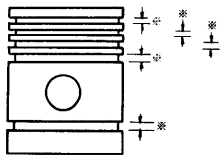
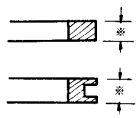
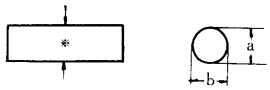
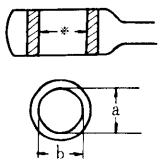
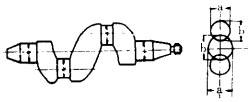
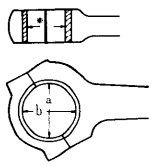
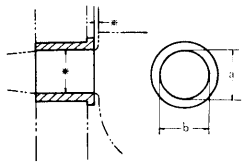
(Unit in mm)

Part Name				Standard Dimension	Variation of Tolerance	Max. Allowable Clearance	Wear Limit	Correction Measure
Cylinder liner			Inner dia.	85ϕ	$^{+0.030}_{0}$		When chrome plate is worn	Replacement of liner
			Lobe of rubber packing					Replacement when liner is extracted
Clearance of piston & cyl. liner	Inner dia. of piston		Top	85ϕ	$^{-0.415}_{-0.445}$			
			Skirt		$^{-0.125}_{-0.155}$		-0.30	Replacement of piston
	Inner dia. of cyl. liner				$^{+0.030}_{0}$			
Commpression clearance				1.85	±0.2			
	Cut opening (VS. st'd dia.)	Inside of liner	Comp. ring				1.5	Replacement
			Oil scraper ring				1.5	Replacement
Piston ring	Clearance betw. piston ring and ring groove	Comp. ring	Ring breadth No. 1	3.5	$^{-0.01}_{-0.03}$	0.2	-0.10	Replacement of piston ring or piston
			Ring breadth No. 2, 3	2.5				
			Groove width No. 1	3.5	$^{+0.025}_{+0.010}$		+0.15	
			Groove width No. 2, 3	2.5				
		Oil scraper ring	Ring breadth	4.0	$^{-0.01}_{-0.03}$	0.2	-0.10	Replacement of piston ring or piston
			Groove width		$^{+0.025}_{+0.010}$		+0.15	
Piston pin			Boss inner dia. of piston	32ϕ	$^{-0.004}_{-0.017}$	0.15	0.07	Replacement
			Outer dia. of piston pin		h_1 $^{0}_{-0.013}$			
			Bush inner dia. of piston pin		$^{+0.060}_{+0.030}$			
Crank pin			Outer dia. of crank pin	64ϕ	$^{-0.035}_{-0.050}$	0.15	0.7	Re-polishing when the pin worn >0.06 and use of the underisize metal of either -0.25 or -0.5
			Bearing back metal inner dia.					
Crank shaft	Journal	Dia.	Outer dia. of journal	70ϕ	$^{-0.040}_{-0.055}$	0.15	0.7	
			Bearing dia.		$^{+0.051}_{+0.010}$			
		Breadth	Journal	219	$^{+0}_{+0.05}$	0.3	0.5	
			Standard bearing					

Part Name				Standard Dimension	Variation of Tolerance	Max. Allowable Clearance	Wear Limit	Correction Measure
Cam-shaft	Dia.	Journal section outer dia.		46ϕ	f_7 $^{-0.025}_{-0.050}$	0.15	-0.12	Replacement
		Bearing inner			H_2 $^{+0.030}_{0}$			
	Breadth	Standard journal		35				
		Standard bearing		34				
Suc-tion/ exh-aust valve	Height of cam			37.5	±0.01		-0.5	Replacement
	Clearance betw. valve push rod & valve guide	Suction valve	Valve push rod outer dia.	9ϕ	$^{-0.040}_{-0.055}$	0.25	-0.15	Replacement of valve or valve guide
			Valve guide inner dia.		H_2 $^{+0.017}_{0}$			
		Exhaust valve	Valve push rod outer dia.	9ϕ	$^{-0.040}_{-0.055}$	0.20	-0.15	
			Valve guide inner dia.		H_2 $^{+0.017}_{0}$			
	Valve seat	Angle		120°	$^{+30}_{0}$			
		Sink depth		-0.7			1.6	Replacement of valve seat on exhaust side
	Clearance of head	Suction valve					0.10 ~ 0.20	
		Exhaust valve					0.10 ~ 0.20	

4-2. List of Measuring Positions

No.	Measuring Item	Measuring Position	Remarks	Measuring Instrument
1	Cylinder liner, inner diameter		"*" position in "a" & "b" directions	Cylinder gauge
2	Piston skirt, outer diameter		"*" position in "a" & "b" directions	Micrometer
3	Piston pin hole, inner diameter		"*" position in "a" & "b" directions	Cylinder gauge

No.	Measuring Item	Measuring Position	Remarks	Measuring Instrument
4	Breadth of piston ring grooves		"*" positions	Block gauge
5	Thickness of piston rings		"*" positions	Micrometer
6	Piston pin, outer diameter		"*" position in "a" & "b" directions	Micrometer
7	Piston pin metal, inner diameter		"*" position in "a" & "b" directions	Cylinder gauge
8	Crank journal, outer diameter and crank pin, outer diameter		"*" position in "a" & "b" directions	Micrometer
9	Crankpin metal, inner diameter		"*" position in "a" & "b" directions	Cylinder gauge
10	Crank journal metal, inner diameter		"*" position in "a" & "b" directions	Cylinder gauge
11	Clearance between crank journal and crank metal		"*" positions	Thickness gauge