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Operation and Maintenance of Diesel Engine

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Southeast Asian Fisheries Development Center

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FOREWORD

This textbook on the operation and maintenance of diesel engine is intended for use by the Royal Thai Customs Department training course and also for use by the Marine Engineering course trainees of the Training Department, SEAFDEC.

The Diesel engine has proven itself to be a dependable source of economical power wherever engine high in horsepower and reliability is required, especially in the marine field.

To meet the demand for understanding of diesel engines and their operation, maintenance and repair, and to help those who wish to become fully qualified operators, this text presents general information in a practical way.

For reasons of space this textbook does not include any information on trouble-shooting. For practical advice on this matter please refer to a separate volume entitled "Trouble-Shooting of Diesel Engine" which will appear in print shortly.

Bangkok
June 1980

SHINZO YAMAMOTO
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1. OPERATION AND MAINTENANCE OF DIESEL ENGINE

1.1 GENERAL

Successful operation and maintenance are closely tied together. The primary purpose of good maintenance is to obtain safe, reliable and economical operation. Competent operator must have good judgement of engine performance, in order to recognize what maintenance work should be done.

First of all, several items which generally require attention of the operator for handling the diesel engine.

In accordance with the well known proverb:

1.1.1 A LITTLE LEARNING IS A DANGEROUS THING

The operator should understand each system of the engine thoroughly and know the functions of each part.

Such technical knowledge can be obtained by studying the manufacturer's instruction book and parts list which accompanies the engine.

Read the instructions manual before handling the engine and make sure you understand every detail of the engine as thoroughly as you can. If the instructions manual is not supplied, ask your local agent to give you all the necessary information. It cannot be over-emphasized that the manufacturer's instruction book must be the owner's or operator's bible.

Especially, you should not disassemble the engine if you have insufficient technical knowledge. The consequences are at your own risk.

1.1.2 WELL BEGUN IS HALF DONE

In case of the engine handling this proverb is true because generally the engine trouble is generated at the first running.

When the new or overhauled engine is just installed, the moving parts such as cylinder liner, rings piston crank metal are not "accustomed" to each other, thus seizure of moving parts might easily occur.

This first running condition will effect the subsequent performance of the engine and its durability. During the first 50 hours of **break-in period it is recommended to use only.**

50 per cent load of maximum horsepower. At the end of that period lubricating oil and filter should be changed. It is also important to warm up the engine for 10 minutes before the start of daily operation.

1.1.3 AVOID BEING PENNY-WISE AND POUND-FOOLISH

Fuel and lubricating oil used should be of good quality. Change oil at regular intervals; many accidents occur as a result of failure to change lubricating oil.

To use low quality fuel and lubricating oil seems great deal of damage which can not be repaired easily.

The most important factors to affect the performance and durability of the engine are load (explained later), fuel and lubricating oil.

1.1.4 DILIGENCE OUTSTRIPS POVERTY

Checking and maintenance should be done punctually and diligently. Punctual check-up operations will help you to detect signs of the abnormal condition of the engine and will avoid the occurance of serious trouble. Generally, there are two categories of engine check: one is daily checking and other is the precaution of checking engine in operation, as follows:

(1) Daily check

(a) Lubricating oil level of crank case;

(b) Lubricating oil level of clutch case and reduction gear case;

(c) Fuel level and water drainage in the settling tank;

(d) Loosening of bolts.

(2) Operational check during operation

Close attention should be given to every part of the engine.

(a) Pressure of lubricating oil (leakage of L/O);

(b) Cooling water

(i) stopping of water by clogging of the pipes,

(ii) mixing of oil in the water;

(c) Abnormal noise of combustion or rotation;

(d) Exhaust gas colour and temperature and exhausting sounds.

Note: In order to detect the abnormal phenomena you should know what the normal condition is, otherwise you cannot notice the abnormal indications. Therefore, daily attention and experience are important factors.

1.1.5 EAT IN MEASURE AND DEFY THE DOCTOR

With stomach only 80 per cent full, one stays healthy. When overwork or overloading is imposed upon the engine every day, the result must be quite obviously catastrophic, causing cylinder head crack, exhaust valve trouble, seizure of piston, abnormal wear of moving parts etc., which increases maintenance costs.

1.1.6 SAFETY FIRST

There are possible dangers associated with boat handling, for instance from rotating parts, inflammable substances, heated parts, and electric circuit.

(1) Safety caution

(a) To avoid the repair work while operating engine

(b) Rotating parts should be equipped with protecting cover

(c) Fire caution

To seperate the exhaust pipe from fuel and lubricating oil, the exhaust pipe should be lagged by insulation cloth. Perfectly coated wire circuit is required to prevent the short circuit.

The most dominant factors to affect the performance of marine engine are load, fuel, and lubricating oil. Above all, load factor is most important.

1.2 LIMITATION OF ENGINE

The limitations of engine are shown in Fig. 1.

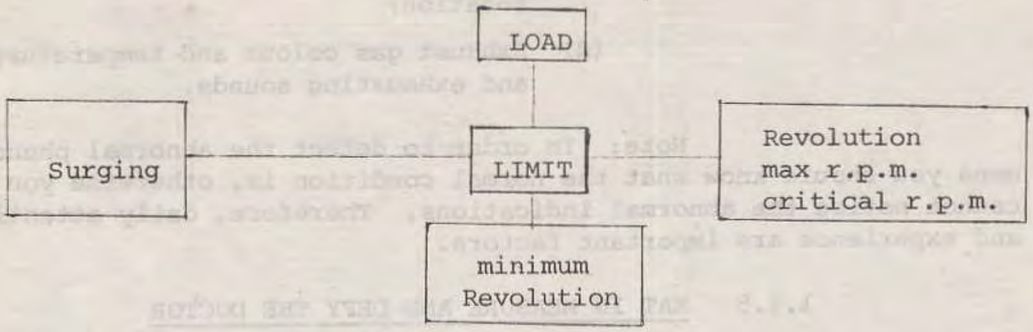


Fig. 1 Limitation of engine

The output horsepower or engine should be determined not only by revolution but also (to consider) the rack scale of fuel pump which is connected with the exhaust temperature. The adjustment of its performance should be conducted by the manufacturer. The engine operation should never exceed 100 per cent load (data on maximum load are supplied by the manufacturer). Optimum engine load is about 85 per cent of the maximum load. This is most economical in terms of operational cost and longevity of engine.

1.3 LOADING CHARACTERISTICS OF MARINE ENGINE

The loading horsepower required to propel the boat varies according to the boat's loading condition such as heavy or light, and the resistance of hull. Even if the rotation of engine is constant but the propeller is heavy or damaged by floating timber or touching obstacle, this will also impose more overload.

Moreover, the characteristics of propellers' law indicate that the required horsepower is proportional to the propeller's revolution to the power of three: n^3

Explanation	HP α V^3	
	HP α n^3	n - propeller's rpm
	Q α HP	Q - Fuel consumption
	Q α V^3	V - Boat speed

Note: Some actual results of small high speed engine show the proportion to be $n^4 \sim n^5$

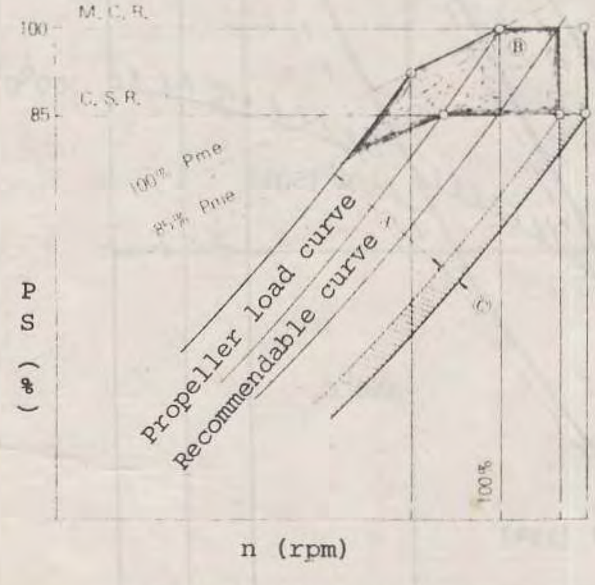
The above formulae indicate special featurs of marine engine.

The marine engine should not be used in the condition of torque rich.

Torque rich means as follows:

When the boat with fixed pitch propeller is cruising the n-PS curve is as shown in Fig. 2 below:

Fig. 2 Engine n(rpm) - SHP (PS) Curve



Zone A: Continuous cruising
B: Short time cruising
C: Test cruise

Torque rich zone indicates upper zone of propeller load curve and in this zone the exhaust temperature is higher than in torque poor zone at same rpm. (Refer also to Fig. 3 below)

As you know, the exhaust temperature of diesel engine must be strictly controlled because the excess of high temperature of gas is connected with all serious engine trouble.

Reducing the boat speed a little will bring fuel economy and reduce possibility of engine trouble.

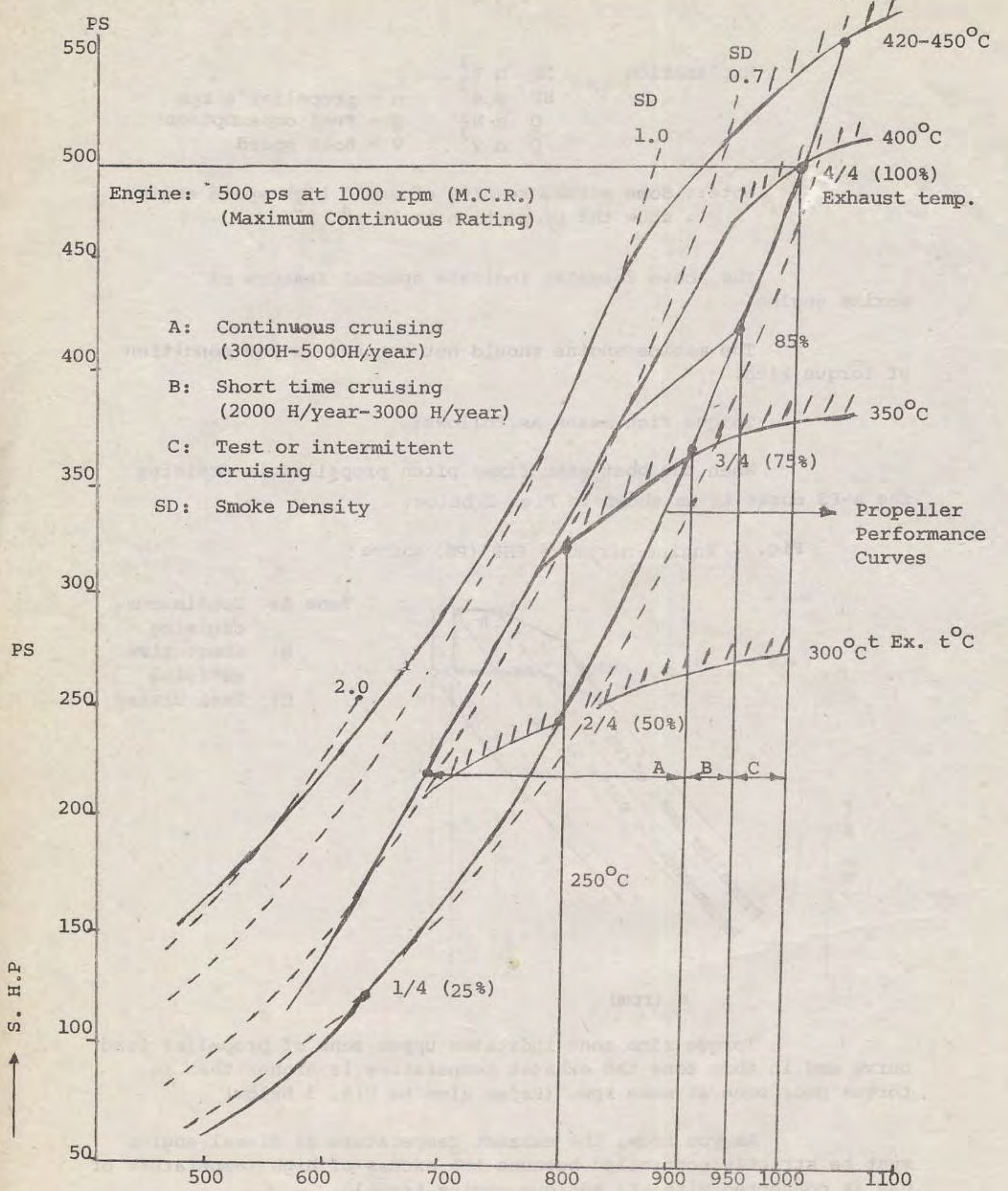


Fig. 3 Engine Revolution (rpm) - SHP (PS) curve

Note: 1. The recommended operating range of the main engine is A and B.

2. The continuous normal output horsepower should be restrained within each range according to the operating hour.

2. OPERATING A DIESEL ENGINE

GENERAL

Follow the Instruction manual and watch, listen, smell and touch to find abnormal condition.

2.1 BEFORE STARTING

There are several steps to be taken before starting a diesel engine, especially the first time, and it is good practice to work out a certain routine to be followed always:

(1) All moving parts of the engine must be examined for proper adjustment, alignment, and lubrication. This includes valves, cams, deflextion of crank shaft, valve timing, fuel pumps, the fuel-injection timing, the governor, lubricators, oil and water pumps, and the main driven machinery.

(2) The whole engine and machinery must be examined for loose nuts, broken bolts, loose connections, and leaky jackets, joints, or valves. It is good to remember that nothing that must be tight should be loose and nothing that must be free should be tight.

(3) All tools from the tool board should be checked to make sure that nothing is missing. They may be needed in a hurry when the engine is running or, if misplaced and left on the engine, may drop off from vibration and damage some moving parts.

(4) All pipes and valves for fuel, lubricating oil, water, and air, as well as ducts, must be checked for clogging up, lack of adjustment, dirt, etc.; for presence of foreign matter the piping systems must be checked carefully especially if the engine has been idle for some time or is just being put into service. In the latter case it is advisable to blow out the entire piping system with compressed air.

(5) A complete check-up must be given to the lubricating system to make sure that oil is present in every place required, that the lubricator and all bearings that are individually oiled have an ample supply of clean oil, that all grease cups are filled. The lubricator should be checked for proper functioning of the pumps and for the amount of oil delivery, and filled with oil to the proper level; the lubricator should be turned by hand and the points to which it delivers oil should be well lubricated. Make sure that the engine will receive proper lubrication the very moment it starts to turn.

(6) The cooling system must be checked, and if the pumps are driven by electric motors, they must be started; suction line must be opened to have water in the engine before starting. The correct amount of water circulation should be adjusted later, while the engine is being warmed up.

If the engine has oil-cooled pistons with oil delivered by a special pump, start the oil pump and adjust the pressures to the amount stated on the name plate or given in the engine builder's instruction book.

(7) The fuel-oil system must be checked in every respect, to make sure that pipes are clean, pumps are working, and that a supply of fuel is in the tanks. The fuel-injection pumps should then be primed, and air or water removed from the discharge line, valves, or nozzles. One or two strokes on the fuel-injection pump is usually sufficient. Care should be taken not to force too much fuel into the combustion chamber or cylinder in order not to obtain an excessively high pressure with the first firing - causing the safety valves to pop - and not to get the fuel oil into the crankcase pump. However, the fuel-pumps must be primed sufficiently so that each discharge line is filled clear to the nozzles. The fuel-control lever is set wide open so that injection will start at once. The fuel-pump control is put in the FUEL-ON position.

(8) The safety valves, usually installed on each cylinder head, should be checked. These valves are set to pop off depending upon the maximum pressure allowed in the engine. The valves are exposed to high-temperature gases and have a tendency to stick. The checking may be done either by compressing the spring with a crowbar or by unscrewing the cap and taking the valve out for inspection.

(9) The engine should be turned over one or two times if it has not been operated for some time. To do this it is necessary to open the indicator cocks or compressor-relief valves and to turn the engine over, either by hand with a bar inserted in the holes in the flywheel rim, or with a jack or air motor, as the case may be. Then the indicator cocks should be closed with the engine in proper position for starting-one cylinder having the starting-air valve open and the piston about 10 deg. past top center.

(10) The starting-air in the tanks must be checked to see that it is up to the required pressure. If not, it must be pumped up. The starting-air system from the tanks to the starting main control valve must be opened, after it has been checked that the main control valve is closed.

(11) The engine load should be off: the switch should be open if the engine drives a generator, or the clutch should be in neutral position if the driven is through a friction clutch. If the engine drives a pump or compressor, the by-pass should be open.

2.2 STARTING

If all eleven points of the preparatory program have been observed, starting with compressed air is very simple.

First, the main starting-air valve is opened and the starting lever manipulated according to the instructions given in the engine instruction book.

Second, the engine is watched; no unnecessary air should be used. At the first indication of combustion, air should be cut off and the ventilating valve opened. An engine in good condition usually begins to fire between the second and fourth revolution of the crankshaft.

Third, if the engine fails to start after four or five revolutions, there is something wrong. Useless turning of the engine should be stopped and the cause of trouble investigated.

Low Air Pressure. If the starting-air pressure is too low either from a slow loss of air through some leaky joints or from failure of the engine to start at the first attempt, and there is no air compressor to pump up air, several methods may be used for securing the necessary starting pressure but never should pure oxygen be used for starting purposes.

Warming Up. After the engine is started, before putting on the load, it should be allowed to idle for a few minutes (up to ten) and warm up. During this time the following observations must be made:

1. Listen to find out if combustion is regular and firing order correct, check all cylinders for combustion, and note the working of the fuel-injection pumps to see whether they all operate properly.

2. Observe the cooling water system throughout to see whether the pumps are working and there is sufficient water; watch to see if the water temperature is building up properly; and regulate the water flow accordingly.

3. Observe lubrication pressures and the working of the lubricator, and count the number of drops for correct operation. Feel whether any of the cylinders is warming up too fast - indicating an unlubricated piston - and listen for an unlubricated piston - pin or crankpin bearing. If any moving part receives an insufficient amount of lubricating oil, serious trouble may result.

4. Observe the exhaust, color and sound, to note proper conditions. These observations should be repeated after the load is put on. The color of the exhaust can tell many things, as will be shown later.

The making of these observations during the first five minutes after starting should be a regular habit with the engine operator. This procedure is the best and most reliable method of preventing improper operation. It is based upon the fact that a diesel engine requires neither much attention nor continuous attention, but it requires proper attention at the proper time. It is also based on the known fact that a diesel engine should be operating properly in five minutes or there is something wrong which should be detected in those five minutes.

However, it should be noted that certain observations should be carried on even after the 5-min. warming-up period. Thus, if there are any leaky water jackets, injection valves, air valves, etc., they may not show up until full expansion of the corresponding part has taken place after the engine has been in operation a longer time at normal load. No leaks of any kind should be allowed; if they cannot be stopped while the engine is running, the engine should be stopped and not restarted until the trouble is corrected.

2.3 RUNNING

In general the attention which an operator must give to the engine in regular operation is along the same lines as during the warming-up period. The difference is that the corresponding observations should be made periodically every 15 or 20 min. and at least every half hour, even if the engine is equipped with a sufficient number of automatic danger-warning signals, and second, that all observations must be entered in the engine log.

The entries in a complete engine log are the following:

1. Time of entering the readings, or rather the first reading in each series.

2. Engine load or, in the case of electric load, volts and ampere readings.

3. Engine speed from the tachnometer, of if the engine has an adding revolution counter, the counter reading; in this case it is essential to have in the engine room a large electric clock with a hand indicating seconds, to enable the operator to read the revolution counter at exact intervals.

4. Fuel consumption, either the instantaneous reading of a Rotameter or the reading of a fuel meter in which case it is also important to make the readings at exact intervals.

5. Exhaust: (a) readings of the temperature of exhaust from each cylinder; (b) exhaust temperature in the exhaust line close to the exhaust manifold; (c) color of exhaust - either by simple description such as "clear, little haze, light gray, gray, dark gray, and very dark gray", or better by a number according to a standardized smoke scale, such as Bosh's scale.

6. Lubricating oil: (a) pressure as discharged from the oil-pressure pump; (b) temperature of the oil before the oil cooler; (c) temperature of the oil after the oil cooler.

7. Cooling water: (a) temperature of the water as delivered to the water-cooling manifold; (b) temperature as discharged from each cylinder, or in the water-outlet line; (c) flow, gallons per minute, either from a Rotameter or a water meter.

8a. Scavenge air: (1) temperature after blower; (2) pressure after blower, usually in inches of mercury.

8b. Supercharger conditions: (1) temperature of air after booster pump; and (2) pressure of air after boosting.

9. Barometric pressure

10. Temperature of the air at the air intake, before the air filter.

11. Remarks about what happened at a certain moment during operation of the engine, such as: put second engine on line or stopped it, found lubricating-oil filter clogged by dirt as indicated by excessive pressure drop, switched to the second filter, or by-passed filter and exchanged filter element, etc.

Between taking readings and entering them in the engine log, the operator should listen to find out if the engine is running uniformly, without unusual sounds, smell or vibration; he should feel whether the bearings are running warmer than usual, and particularly watch that the engine as a whole does not become overloaded or some of the cylinders become overloaded because the combustion in one or two cylinders does not proceed correctly, as indicated by a considerably lower or higher temperature of the exhaust from that particular cylinder or cylinders.

Naturally, the operator must also see that the day fuel tank is not depleted and, if the engine has hand-lubricated places, that they are oiled at regular intervals.

The camshaft valve levers, valves, fuel pump levers, etc., should be oiled every two hours. The exhaust valve stems should receive a few drops of kerosene instead of oil every three or four hours in order to keep them in good working condition. The circular groove around the valves and the whole top of the cylinder head must be wiped clean at all times. Oil must not be allowed to accumulate on the cylinder head and run down the sides of the engine, as it could easily work into the joints between the cylinder and heads and decompose the rubber gaskets which form the water joint.

If the flow of cooling water or oil should stop for any reason, the engine or any one cylinder will become overheated. The engine must be stopped at once and permitted to cool off gradually. It is extremely dangerous to admit water to a hot engine as a sudden change in temperature may cause the pistons to seize of one of the cylinder heads, liners, or the exhaust manifold to crack.

Exhaust Conditions. Normally, the exhaust from the engine should be perfectly clear. However, if the engine is operating under an overload, the exhaust may become visible, with a light-grayish smoke. If the engine exhaust is visible under other than overload conditions, the cause should be found and immediately remedied. An engine should under no condition be operated for any length of time with a visible, smoky exhaust.

If a pyrometer with thermocouples is installed on the engine, the cylinder that yields a smoky exhaust may be found by noting the exhaust temperatures of the various cylinders. If an abnormal condition exists in any one cylinder, this condition will usually be accompanied by an increase in the temperature of the exhaust from this cylinder. However, smoky exhaust may be caused by one or two cylinders with abnormally low exhaust temperatures, which indicates that these cylinders do not get their share of fuel, and as a result, the other cylinders are overloaded. If possible, the engine should be stopped and the cause found and remedied.

2.4 STOPPING THE ENGINE

To stop the engine, proceed as follows: Move the fuel-pump control to STOP position and shut the fuel supply valve.

The cooling water and piston-cooling oil should be left running after the engine is shut down until the outlet temperatures are not more than 5°C higher than the inlet temperature. This prevents local overheating which would cause scale deposits in the jackets. If hard water is used and the engine is supplied with direct-connected pumps, it will be necessary to start the auxiliary pumps to cool the engine down as indicated above.

If the engine is to be shut down for a considerable length of time, the water jackets must be completely drained so as to prevent rust. Naturally, all drop oilers must be stopped, all switches turnedoffand friction clutches put in neutral position.

3. MAINTENANCE

GENERAL

An internal-combustion engine is a complicated machine, built with a high degree of precision throughout, and capable of long dependable service if kept in good operating condition.

Two general procedures are in common use for maintaining engines. They are referred to as:

(a) Periodic inspection maintenance, and
(b) A preventive maintenance program.

3.1(a) PERIODIC INSPECTION MAINTENANCE. (Regulation inspections)

This type of maintenance is based on inspection periods which are timed according to past performance of the vital assemblies as observed by the manufacturer or determined by the operator. These inspections require the partial or complete tear down, inspection, and cleaning of the engine parts with the replacement of universal parts.

Table 1 shows a suggested maintenance & inspection schedule. Overhauling or major inspection is listed for every 4800 - 5000 hrs. Such inspections insures good condition of parts and assemblies.

However, such procedure has its disadvantages, the chief one being needless disassembly of the engine while in good operating condition. No matter how carefully the work is done, trouble may be induced either due to simply disturbing parts which have found a good running fit and finish, or by dust getting into the engine during assembly in spite of careful cleaning procedures. (Some bearing manufacturers claim that 90 per cent of bearing failures are due to dust, frequently introduced during to inspection work.)

In order to insure good operation after major overhaul, the engine should have a careful break-in period, similar to that recommended for a new engine. This permits the surfaces to become adjusted to the new conditions.

3.1(b) PREVENTIVE MAINTENANCE (PM)

There is no substitute for the so-called PM program. This entails periodic inspection of specific items, and accurate record system which presents the result in such a manner that any change in operating conditions will be clearly indicated. Such a system is only as good as the records. They must be kept up to date and be accurate. Records must then be studied and correctly interpreted by competent personnel.

It is obvious that an engine should not be run to destruction before overhaul. It is well know that many engine parts will operate longer and better if they are not frequently disassembled. Many engine builders claim that 90 per cent of all failures are preceded by definite conditions signs or indications of approaching trouble. The ideal PM should serve as a guide (a (a) for determining when an engine should be overhauled and (b) to prevent serious premature engine failures.

A simple PM program having log and curve sheets is shown in Fig. 4 and Table 3. This log sheet should be used in conjunction with a simple daily log of operating data where any abnormal condition should be noted. The most valuable part of this system is the curve sheet which shows the condition of the engine at a glance. Curves should be plotted daily, weekly or monthly. Each curve shows a trend of specific characteristic value of the engine operating condition.

The characteristic values are: comprssion pressure, lubricating oil consumption in BHP. HRS per quantity, crank case pressure mm H_2O, fuel oil consumption PS-Hr per quantity, pressure drop across L.O. filter, cranking r.p.m. etc.

Table 1. REGULAR INSPECTION

Classification		Check points	Every day	Every (hrs) 50	250	500	1000	2000	5000
Fuel oil system	Tank	Oil level	O	(Before feeding)					
		Drainage	O						
	Injection pumps	Oiling to control rack	O						
		Priming	O						
		Injection timing			O				
	Injection on valves	Injection pattern			O				
		Cleaning of strainer			O				
	Filter	Turning of handle	O						
		Drainage		O					
		Disassembling & cleaning			O				
Lub. oil system	Lub. oil	Oil level (crankcase & reversing gear case)	O						
		Change		First	O				
	Lub. oil filter	Turning of handle	O						
		Drainage		O					
		Disassembling & cleaning			O				
	Cleaning of Lub. oil cooler					O			

Table 1. REGULAR INSPECTION (Cont'd)

Classification		Check points	Every day	Every (hrs) 50	250	500	1000	2000	5000
Cooling water system		Pump packing gland	O						
		Circulation	O						
		Anti-corrosive zinc				O			
Cylinder head and suc. & exh. valves	Cylinder head	Re-tightening of nuts			O				O
		Cleaning of combustion face				O			O
		Cleaning of pre-combustion chamber				O			O
	Suc. & EXH, valves	Valve clearance			O				
		Lapping on valve seat				O			
		Lever & guide				O			
Reciprocating parts	Piston & connecting rod	Rings					O		O
		Rod metal & bolts					O		O
		Piston pin bush					O		O
Clutch system	Oil	Oil level	O						
		Change					O		
	Filter						O		
Supercharger	Cleaning & checking BRG replace						O		O
	Intercooler						O		

Table 2. MAJOR INSPECTION (4800 H - 5000 H)

Check points
Crank shaft deflexion
Main bearing
Cylinder head
Piston
Crank shaft main journal
Piston ring
Cylinder liner
Cam gear
Injection pump
Crank pin journal
Thrust bearing
Supercharger
Inter-cooler
L.O. pump
Oil cooler
(Hydraulic) clutch

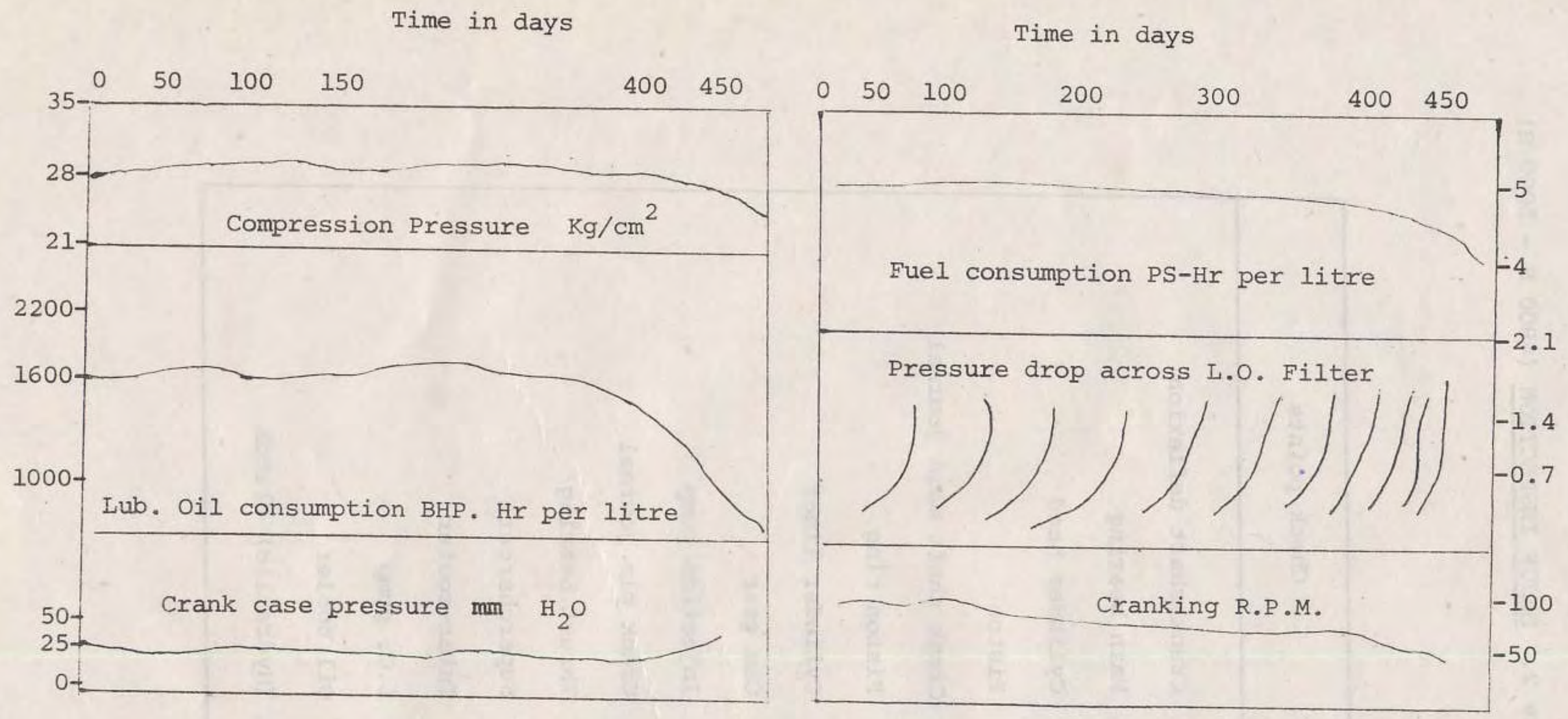


Fig. 4 Curve Sheets

Ref. Diesel Engineering Handbook, Cooper Bessemer Corp.

Table 3. ENGINE MAINTENANCE LOG

Engine Maintenance Log
Remarks on Daily Readings
If any changes are noted in following readings include the remarks below:
1. Exhaust temp. 2. Pre-turbo temp. & Boosting pressure 3. Water temp. to/from engine 4. Lub. oil temp. to/from cooler 5. Lub. oil press. 6. Vapor from crank case breather 7. Color of exhaust 8. Sound of engines 9. Others

3.2 ENGINE OVERHAULING

GENERAL

(The purpose of engine overhauling is to return it to its normal operating condition before serious troubles develop)

When a diesel engine is being overhauled, it is completely taken apart: every piece is inspected and whatever piece shows appreciable deterioration is reconditioned to original shape and dimensions, or replaced by a new one.

After this, the engine is reassembled, but on a test stand, started, tuned-up, carefully tested. In respect to these engines the word overhauling is sometimes used to designate major maintenance work such as the simultaneous pulling of all pistons, the cleaning of scale from cylinder jackets and heads, and the checking of the crankshaft alignment. Marine diesel engines have to be overhauled because they have to operate continuously for many days and weeks at practically full load without stopping and without a chance for much maintenance work while at sea. Therefore, depending upon the type of work, general overhauling of engines is done at regular intervals, every 12 months (300H - 6000H) or 24 months (12000H) necessary for the kind of service.

There are several points which should be rigorously observed when major inspection and overhaul work is being done. One of the most important rules is to make sure that all parts are well marked and identified as engine is dismantled. It is particularly important to mark camshaft gear and valves if manufacturer's mark cannot be found. Center-punch marking are the most convenient to use. The second point is to clean thoroughly every dismantled part, carefully examining it for cracks or pitting. After that, accurate measurement must be taken of all dimensions subject to wear and also of adjustment points of the various parts as the dismantling progresses. A complete record should be kept of each and every measurement, properly entered on consecutively numbered sheets to prevent them from being overlooked or lost.

The maintenance work is easier and much time is saved if this rule is followed. In order to make these records, the maintenance crew should be well equipped with micrometers both inside and outside,cylinder gauge, dial gauges, scales etc. It is impossible to obtain accurate readings with inadequate equipment. In taking measurements one must be as careful and accurate as it is humanly possible. No guesswork is permitted. Inaccurate measurements are worse than none.

3.2.1 DETERMINING TIME TO OVERHAUL

Generally a time to overhaul the engine is determined on the basis of reduced output, reduced compression pressure, increased blow-by gas, increased fuel and lubricating oil consumptions, reduced lubricating oil pressure, hard starting etc.

A reduced output, however, might be the result of a defective injection nozzle or maladjusted injection pump. Hard starting might be the result of trouble in the electrical system, including the battery generator, starter, etc.

(a) Compression Pressure

In determining a time to overhaul the engine, therefore,it is advisable to pay attention to a reduced compression due to wear of piston cylinder liner and other main moving parts (compare the figures of repair limit table). For the increase in fuel consumption and oil consumption daily record can be referred to. It is also important to know the change in compression pressure by measuring it periodically. If the drop of compression pressure exceeds the repair limit, the engine requires an overhaul.

For example

Description	Assemble Standard	Repair limit
compression pressure (kg)/cm^2 at engine speed n/rpm	A	A x 0.8

(b) Specific Oil Consumption

Specific engine oil consumption (Fuel/L.O, L.O/H) varies with engine operating conditions and the quality of engine oil. Let this specific oil consumption in a new engine be 100%. If it has decreased to about 30% (it means the oil consumption increase) the engine requires overhaul.

(c) Engine Oil Pressure

When the engine pressure is below the repair limit the lubricating system should be overhauled.

For example

		Assemble Standard	Repair limit
Oil pressure	At idling speed	$1.5^{kg}/cm^2$	$0.5^{kg}/cm^2$
at 60°C	At Max. speed	$3 - 5^{kg}/cm^2$	$2^{kg}/cm^2$

3.2.2 AFTER OVERHAUL

Inspection of parts and clearance should be conducted as indicated in manufacturers' maintenance manuals and service booklet.

Table 4 shows an example of repair limit of parts and clearance.

Table 4. REPAIR LIMIT OF PARTS AND CLEARANCE

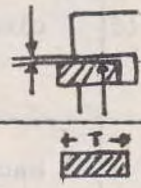
Name of Parts	Description Item	Repair Limit	Reference
Cylinder	wear limit W mm	$D < 250; W \leq \frac{1}{100} \times D$ $D > 250; w < 1.5 + \frac{5}{1000}D$ until cr-plated peeling	Average $\leq$ 0.02/1000H W mm Average W cr-plated < 0.01/1000H
Piston	pin journal clearance	<½ pin-metal repairing limit	Check once a year
	Ring groove wear	<0.3 mm	
	clearance of ring & groove	<0.3 or $0.2 + \frac{D}{5000}$	
Ring	wear of thickness	0.15 x T	
Crank (shaft)	main journal diameter (d) out of roundness	<500 rpm 0.15 + 0.0005d >500 rpm 0.10 + 0.0005d	
	pin journal	same	
	bending	0.05	
	Arm deflexion	$\frac{2}{10000}$ x Stroke (mm)	

Table 4. REPAIR LIMIT OF PARTS AND CLEARANCE (Cont'd)

Name of Parts	Description Item	Repair Limit	Reference
Main metal of crank	clearance	$150 \geqq d;\ \frac{20}{1000} \times d$ $150 \leqq d; 0.15 + 0.001d$	Replace bearing if overlay stripped 30% of total loading surface
Crank pin metal	clearance	same	
Crank pin tightening bolt	using time. limit	$t > 20000$ Hours permanent deformation elongation (mm) $\geqq 1$	Replace Replace
Piston pin(d) metal	clearance	$<0.2 + 0.001d$	
Gears	backlash	over 0.1 Module	Change gear or adjust the centre distance.

Source: Repair Limit of Marine diesel engine
(Marine Engine Society: Text-Japan)

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