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HOW TO OPERATE A SMALL DIESEL ENGINE
FOR FISHING BOATS

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PREFACE

This manual on the operation of diesel engines for small-scale fishing boats is intended for use by officers of fisheries departments and fishing boat operators, to assist them in instructing local fishermen. It contains very little "theory" - instead, it offers practical advice on how to prolong the life of an engine and how to reduce its maintenance and running cost.

The manual was originally produced by Mitsubishi Heavy Industries Ltd. as a reference book for engineers of marine fishing boats in small-scale fisheries in Japan. I used the manual, of course in Japanese, when I was working as an instructor of diesel engine maintenance, teaching fishing boat engineers in Japanese fishing ports. I found it very useful, and I believe that if the manual is translated into the local languages, many small-scale fishermen in other countries of this region would find it helpful.

K. Tobo

MAINTENANCE OF FUEL FILTER

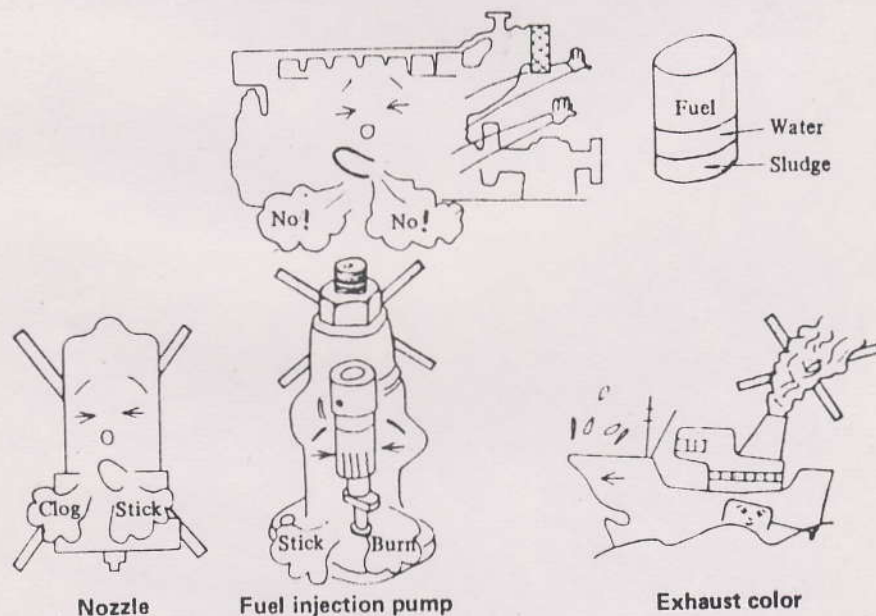
QUESTION 1: Why must we use a fine mesh fuel filter?

QUESTION 2: Does a wrong element cause premature clogging?

* It is important to remove impurities from fuel.

- 1 → The heavy oil "A" made by combining a light oil and the heavy oil "C" (Bunker oil) includes a lot of impurities, such as moisture, dust etc.

If such impurities enter into the fuel line of the engine, the durability of precision parts, such as the fuel injection pump and nozzle, deteriorates. Also, there is incomplete combustion and the unburned components accumulate on the piston and turbine nozzle, thus causing a remarkable drop in engine performance and durability.



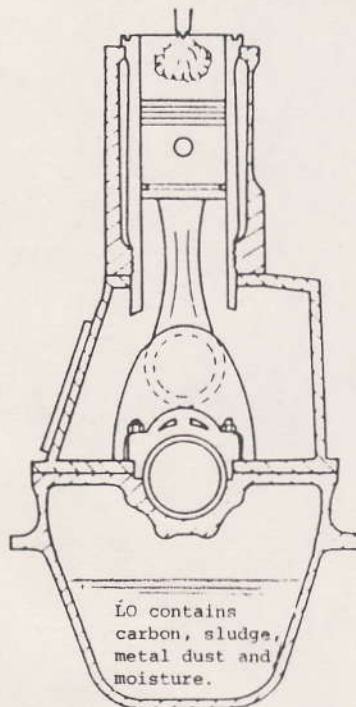
* Maintenance is important.

- 2 → A wrong element does not cause premature clogging. When a filter gets clogged up very fast, this shows two things; that the oil is full of impurities and that the filter is working well.

Nowadays, with rising oil prices, the proportion of rough heavy oil in fuel oils is increasing. Proper maintenance and a correct use of filters is becoming more important.

MAINTENANCE OF LUBRICATION OIL PURIFYING FILTER (BYPASS FILTER)

QUESTION: Why is the lubricating oil bypass filter required?



- * If lubricating oil is exposed to a high temperature for a long time, some of the lubricating oil will disintegrate and become carbon.
- * Sulphur in the fuel is harmful, it lowers the quality of lubricating oil.
- * Moisture in the lubricating oil promotes corrosion of engine parts, reduces lubricating properties and reduces its ability to disperse.
- * If the viscosity of lubricating oil falls, the oil film disappears and metal parts may come in direct contact with each other. However, if the viscosity is too high, the resistance increases and the movement of parts becomes heavy.

- * The lubricating oil filter plays an important part in removing metal dust, unburned particles and sludge.

A lubricating oil filter that is set in line is not sufficient. Usually an oil filter in line has rather a rough mesh to prevent clogging which causes severe damage to engine parts.

When operating the engine for a long time, the lubricating oil deteriorates and the fine particles which pass through the line filter may harm the engine as described above. Harmful particles can be removed by using a bypass filter - thus engine trouble can be avoided.

In addition to its antiwear and lubricating functions, lubricating oil has several other important roles: to clean and cool the engine parts, to make the pressure chamber airtight, to disperse stress and so on.

- * The cleaning function of the bypass filter is to remove the metal dust, unburned components and sludge so that the engine is not soiled.

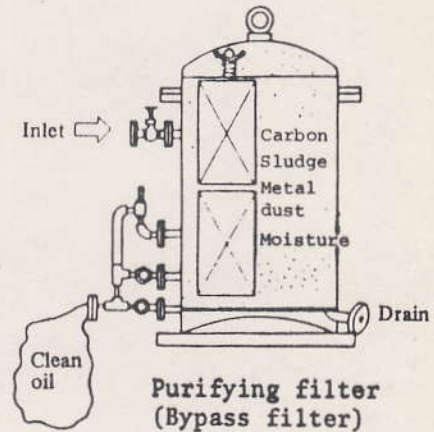
The presence of metal dust, unburned particles and sludge in the lubricating oil has the following effects on engine operation:

- | | | |
|--|---|---|
| (1) Increase of viscosity | → | Higher oil pressure and improper circulation of oil. |
| (2) Increase of undissolved components | } | Promotes wear of the liner, piston, ring, metal and other bearings. |
| (3) Increase of moisture | | |
| (4) Drop of alkalinity | | |

* Maintenance is important.

Harmful effects mentioned under (1), (2) and (3) above can be avoided by continuous use of a filter.

It is necessary to replace the element periodically in accordance with the running condition of the engine.

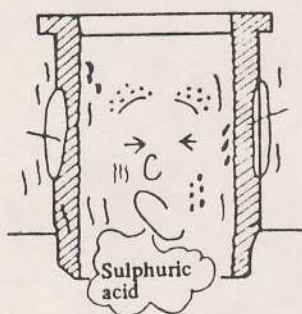


Falling alkalinity of a lubricating oil means higher acidity, which causes corrosion of cylinder liner, piston ring, bearing etc. Degree of alkalinity should be checked, either by a spot test on board vessel, or sometimes requesting the oil manufacturer to do the analysis.

TEMPERATURE OF COOLING WATER

QUESTION: Why should the cooling water temperature at the outlet be set to 40 - 50°C (sea water cooling)?

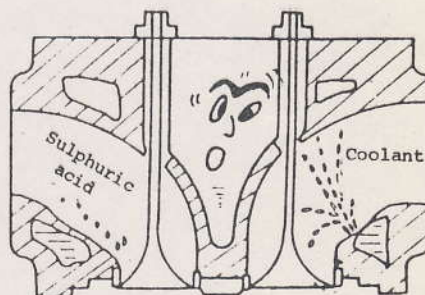
- * Excessive cooling causes corrosion (wear) due to the sulphuric acid.
- * Maintenance of automatic regulating valve for cooling water temperature is important.



Cylinder liner



Piston and ring

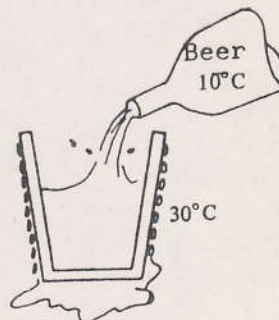


Cylinder head

A part of sulphur in the fuel becomes sulphuric anhydride during combustion. This comes in contact with water vapour in combustion gas and turns into sulphuric acid, on the inside surface of the cylinder.

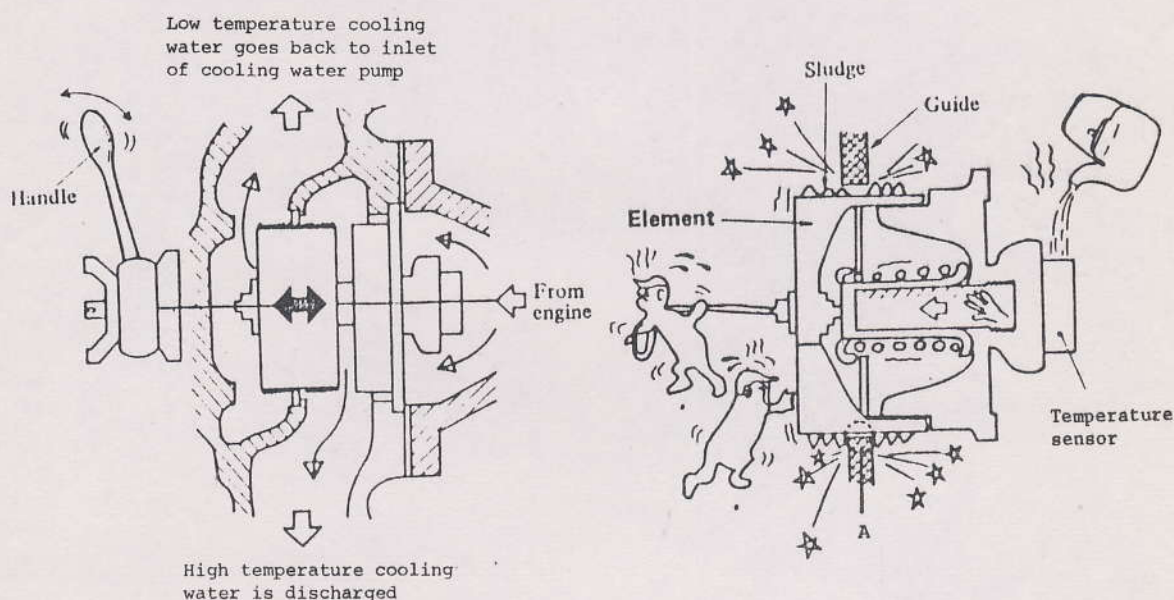
Sulphuric acid corrodes cylinder liner, piston, piston rings etc. The lower the temperature of cylinder liner i.e., the lower the water temperature, the more sulphuric acid is produced, and the more corrosive wear there is. Also, low grade fuels which contain more sulphur cause more corrosive wear.

Water drops form on the outside where the temperature is higher. The greater the temperature difference between the inside and the outside of the glass, the more moisture will stick to the outer surface.



Higher cooling water temperature means less sulphuric corrosion. However, in the case of sea water cooling, if temperature exceeds 55°C , the calcium and magnesium contained in sea water accumulate on the water jacket surface of the cylinder head. This scale causes cracks between the valve seats.

- * Maintenance of auto control valve for cooling water is important.



- * If the scale forms in the gap marked "A", the element does not work properly and the temperature cannot be regulated.

Occasionally turn the handle 2-3 turns to prevent the element from sticking.

If the handle does not turn easily (if the temperature cannot be regulated to $40-50^{\circ}\text{C}$), disassemble the valve and wash it with a chemical cleanser.

- * For a newly built boat, it is recommended to adopt the fresh water cooling system (constant high temperature cooling).

The fresh water cooling system is not only effective for decreasing sulphuric corrosion (wear), but also has some other advantages, as follows:

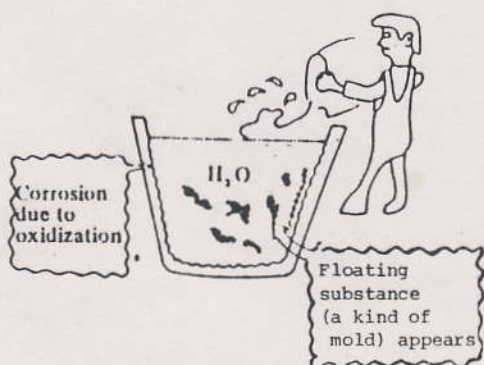
- protects the cooling system from the sea water corrosion;
- prevents accumulation of the sea water scale on the cooling system (scale obstructs cooling or causes partial heating);
- stabilizes engine performance even at the low load combustion;
- improves thermal efficiency and decreases fuel consumption by the constant high temperature cooling (60 - 70°C).

ANTICORROSIVE FOR FRESH-WATER COOLING SYSTEM

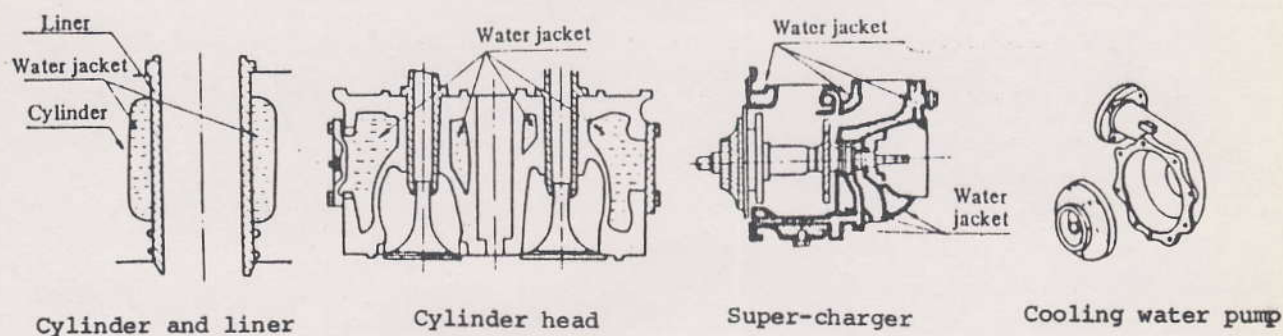
QUESTION: Why is it necessary to add anticorrosives even to the fresh-water cooling system?

- * It is necessary to use anticorrosives to prolong the engine life.

If we leave fresh water (distilled water or tap water) in the cooling system, at the temperature below 40°C, for more than 10 days, a gelatinous, moldy substance will appear. There will also be rust from oxidization of iron. These pollute the water and change it into electrolyte which corrodes the cylinder, cylinder head, liner, super-charger etc.



The cooling water system of a diesel engine consists of a cylinder block, cylinder head, turbine, intercooler, lubricating oil cooler, fresh-water cooler, cooling water pump and pipings made of cast iron (FC20 - 30), special cast iron or brass (BC3), and the packings made of organic materials. The parts made of cast iron and special cast iron must be protected against corrosion.



Corrosion is very troublesome as it occurs on the cooling water jacket parts which have complicated structures and cannot be checked visually from the outside. If there is a crack due to corrosion and the cooling water leaks to the inside of cylinder, it may cause a serious accident (water hammer).

In order to prevent corrosion it is necessary to use anticorrosives which will cover the metal parts with a protective film.

An adequate anticorrosive effect can be achieved only if we use anticorrosive additives of sufficiently high density. If this density is less than the standard value, the effect may be opposite, that is to say corrosion may be promoted.

The fatigue strength of the cylinder block, turbine, cylinder head etc., which bear high thermal and mechanical loads, depends on the additives in the cooling water. For example, if the fatigue strength in the open air is 100%, in water without the additive it drops to 62%.

It is necessary to adjust the PH value and the density of the anticorrosive:

PH value : 6 - 8.5

If the PH value is less than 6, add caustic soda. If it is more than 8.5, discharge 10 - 20% of cooling water and add fresh water.

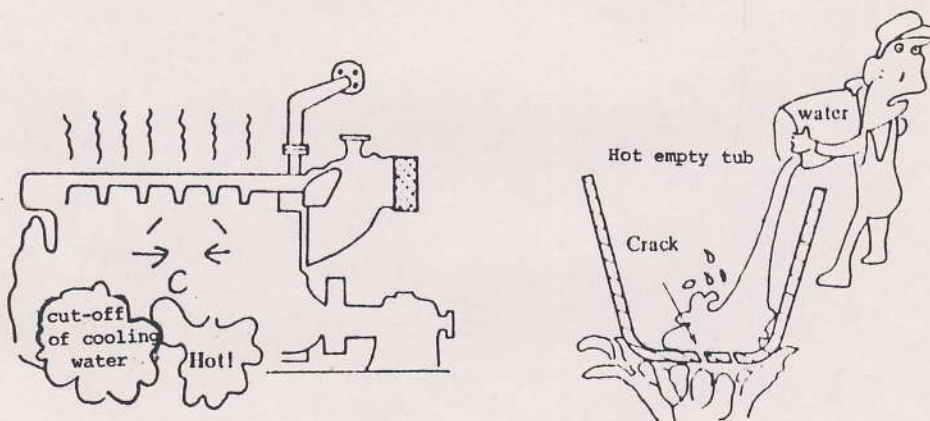
Density of anticorrosive:

As the density of anticorrosive differs a little according to the brand, follow the manufacturer's instruction.

* It is recommended to use anticorrosives of the subnitrate family.

REFILLING OF COOLING WATER AFTER CUT-OFF

QUESTION: Why should the cooling water not be let in immediately after a cut-off in the water supply?



If for some reason the water supply is cut off in the cooling system, a great quantity of steam comes out, the cooling water pressure falls and the engine overheats.

When this happens, first stop the engine and check the cause of the water cut-off. Having found and removed the trouble, do not turn on the cooling water supply if the engine is still hot. A sudden contact between cool water and the hot metal would cause cracks, especially between the valve seats of cylinder head, or sticking of piston and liner. It is absolutely essential to allow the engine to cool before resuming normal operation.

VENTILATION OF ENGINE ROOM

QUESTION: Why is it necessary to have good ventilation in the engine room?

* Most of the latest engines are equipped with a supercharger.

Natural ventilation



Shortage of oxygen
(closed room)



Forced ventilation
(with ventilator)



In a fishing boat the engine room (and the whole hull) is small and closed, the air flow necessary for the combustion of supercharged engine cannot be satisfactorily supplied by natural ventilation. For this, a blower (suction) is required.

If the blower in the engine room is for exhaust ventilation only, the air does not enter and there is a shortage of oxygen. In such conditions the engine horsepower drops, and then the consumption of fuel and lubricating oil increases.

The following precautions must be taken:

1. Make sure to switch on the blower during engine operation;
2. The capacity of the ventilating blower should be higher than the air flow necessary for the combustion and exhaust ventilation.

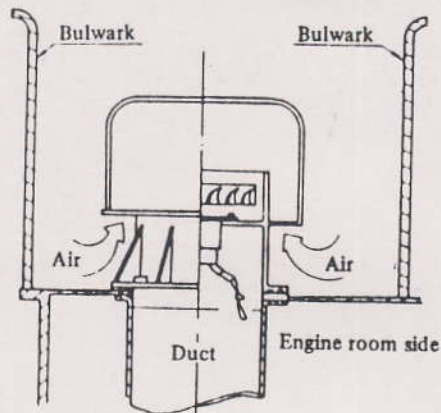
For example:

the air flow for exhaust ventilation : $50 \text{ m}^3/\text{min}$.

the air flow necessary for combustion: $100 \text{ m}^3/\text{min}$.

the total air flow required to the blower (suction),
 $50 + 100 = \text{over } 150 \text{ m}^3/\text{min}$;

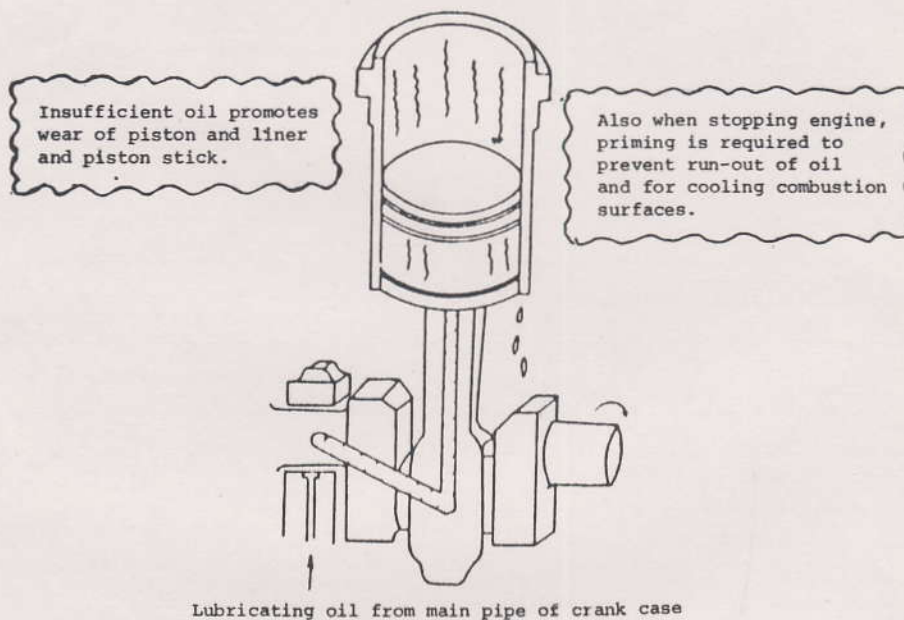
3. Install the blower at a place where the bulwarks are provided so as not to suck in the sea water even in stormy weather.



PRIMING OF LUBRICATING OIL BEFORE STARTING AND
WHEN STOPPING ENGINE

QUESTION 1 : Why is the priming of lubricating oil required before starting the engine?

QUESTION 2 : Why is the priming of lubricating oil required when stopping the engine?



* After the engine stops, lubricating oil runs down.

- 1 → When starting the engine, the oil film is too thin on all sliding parts, (especially the piston which is at a high position where oil reaches last; it is therefore necessary to let the lubricating oil circulate to all moving parts before starting the engine.

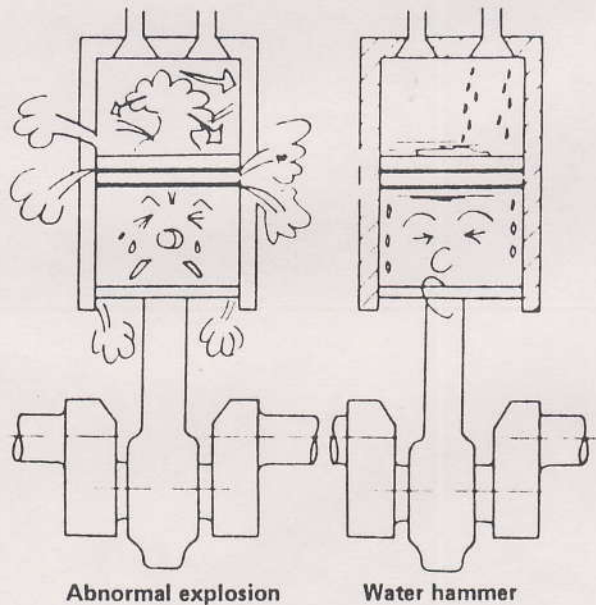
* It is necessary to cool the engine.

- 2 → The parts facing the combustion chamber are exposed to a high temperature and high pressure during engine operation. If we turn off the engine abruptly the cooling function of oil is stopped and those parts expand and deform, due to overheating. Also, if this happens repeatedly fatigue of materials forming the combustion chamber is promoted, or the piston sticks.

Stop the engine after the cooling water temperature at the outlet of cylinder falls below 35 °C.

AIR RUNNING AT NO-LOAD BEFORE STARTING ENGINE

QUESTION: Why is air running required before starting the engine?



- * It is important to check the condition in the cylinder.

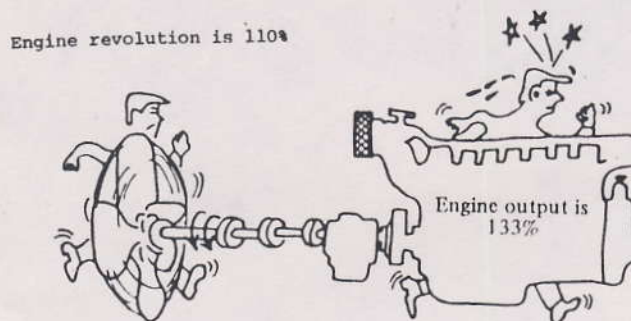
If there is water or fuel in the cylinder for some reason, the water hammer or abnormal explosion may occur and cause engine trouble. Since it is not possible to predict when such things happen, it is important to allow air running every time before starting the engine.

When the engine does not have an air starting system, the engine should be turned by hand at least two revolutions of crankshaft

PREVENTION OF OVERLOAD OPERATION

QUESTION: Why does the engine output increase sharply just after the engine revolution exceeds the rated revolution?

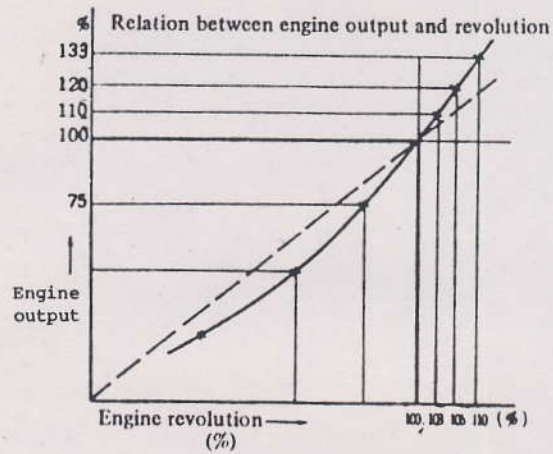
- * If the engine revolution increases by 10%, the engine output increases by 33% of the rated revolution.



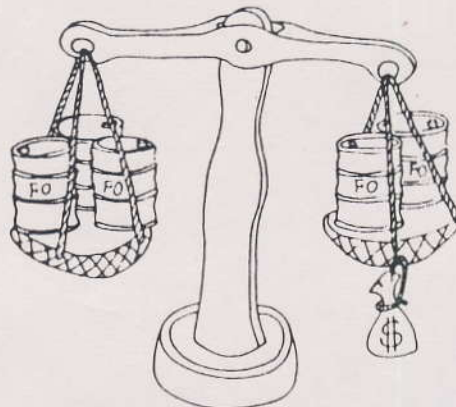
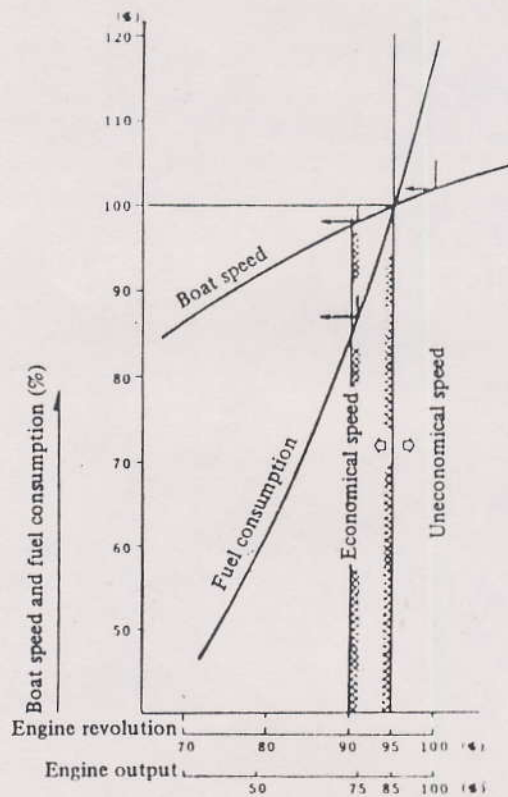
- * If overloading continues, the engine performance (durability) drops remarkably.

The engine output increases and decreases in proportion to the cube of engine revolution.

For example, consider an engine with rated output 800 hp, and revolution 900 rpm: If the revolution is raised to 929 rpm or 956 rpm, the output becomes 880 hp (10% increase) or 960 hp (20% increase) respectively.



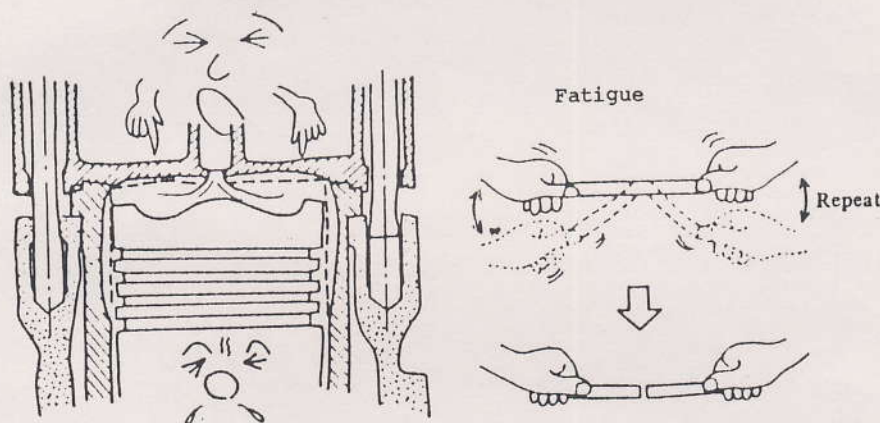
If operating the engine at the economical revolution, which is 90 - 95% of the rated revolution, it is not only possible to greatly decrease the fuel consumption without a significant drop of the boat speed, but also it means to run the engine in the best condition.



PREVENTION OF SUDDEN RISE OR FALL IN ENGINE REVOLUTION

QUESTION: Why is it undesirable to abruptly raise or lower the engine revolution?

* For most recent boats, it is possible to raise or lower the engine revolution by operating a remote control handle in the steering room. Therefore, boats are often seen sailing at full speed just after starting the engine when leaving the port.



When the engine revolution is raised suddenly to high load just after starting, the combustion side surface of cylinder is exposed to high pressure of 70-100 kg/cm² and high temperature of 1,000-1,200°C. But the inside of cylinder metal and outer side of cylinder are not warmed up yet. Thus there is a large difference of temperatures between the inner surface and the other part of cylinder. This causes a considerable internal stress. The cylinder liner, piston, and cylinder head are designed so as not to crack under normal operating conditions as the temperature becomes low in proportion from combustion side surface to back surface of these cylinder parts.

When the engine is stopped suddenly after running at full load, the coolant around the cylinder will stop circulating. This results in abnormally high temperature and irregular internal stress around the cylinder. If the engine is repeatedly operated under such conditions, the fatigue of these parts is quickened and cracks may occur.

The boat should leave the port only when the cooling water temperature at the outlet of engine rises over 40°C. For 30 minutes after leaving the port the engine should be operated at below 50-60% of the rated revolution.

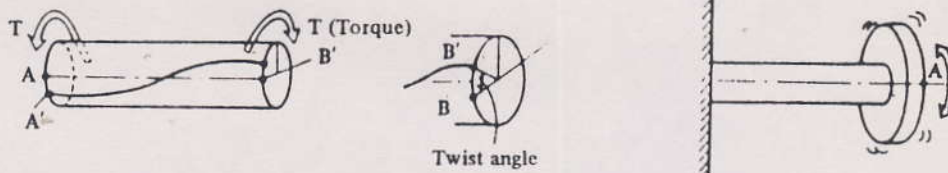
When the boat comes back to port, the engine should be stopped after no-load running of more than 15 minutes.

CRITICAL REVOLUTION

QUESTION: Why is it necessary to avoid operating the engine at the critical revolution for a long time?

* Torsional vibration of the rotating shaft is unavoidable.

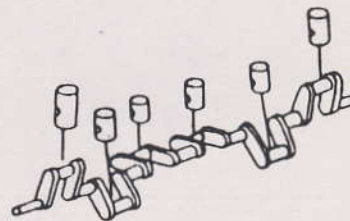
The figure shows an elastic bar with one end fixed and with a disc at the other end. If we turn the disc a little by hand and abruptly set it free, the disc passes its original position once and returns back to the original position. This is called the torsional vibration (natural frequency).



* It should be absolutely avoided to operate the engine at the critical revolution for a long time.

In normal conditions of power transfer, there is no problem as the shaft rotates while keeping the twist angle in proportion to the average torque. However, if the produced torque (forced vibration or acceleration of vibration due to combustion) synchronizes with the natural vibration, the amplitude becomes unexpectedly large due to sympathetic vibration.

When operating the engine in such a condition of sympathetic vibration (critical revolution), the piston, gears, clutch and crankshaft suffer a repeated stress. After some time the stress causes torsional break (fatigue break).

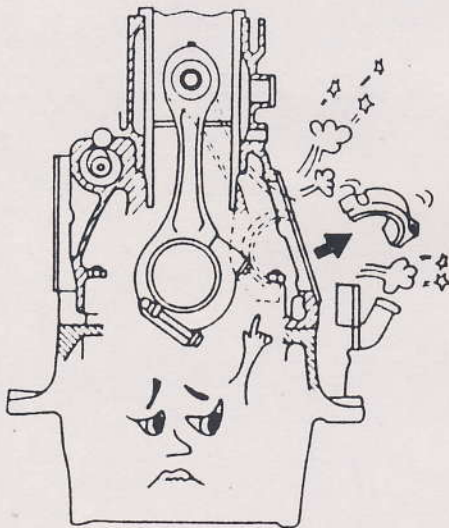


TIGHTENING TORQUE OF ROD BOLT

QUESTION: Why does the projecting trouble of the rod occur?

* The projecting trouble of the rod is mostly caused by improper tightening, that is to say, too little or too much tightening torque of the rod bolt.

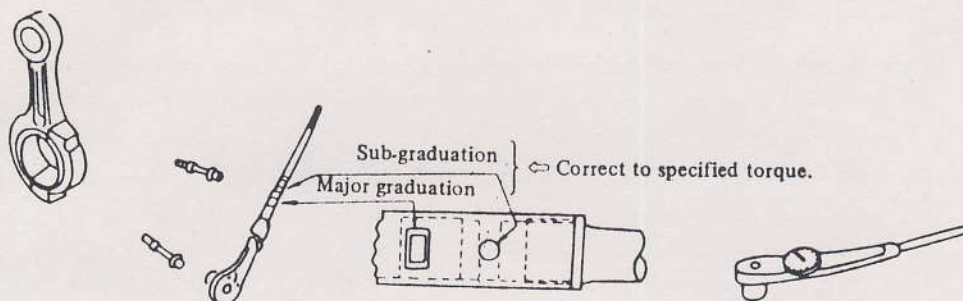
Causes of short or excessive tightening torque:



- Uneven torque due to the tightening method;
- The yielding of tightened parts, the contact condition of thread portion and seating surface of the bolt itself, and the torque-down due to yielding;
- The coefficient of friction of the antirust coating material on the thread and seating surface of the bolt. This coating should be cleaned off and the bolt should be coated with lubricating oil;
- The reliability of torque wrench (accuracy).

At the assembly, the alignment marks are put on the rod bolt and nut when they are tightened with a specified torque. However, if the rod bolt and nut are tightened with the specified torque after a long time of operation, the alignment marks get out of alignment a little due to the elongation of bolt and the yielding of seating surfaces of bolt and nut.

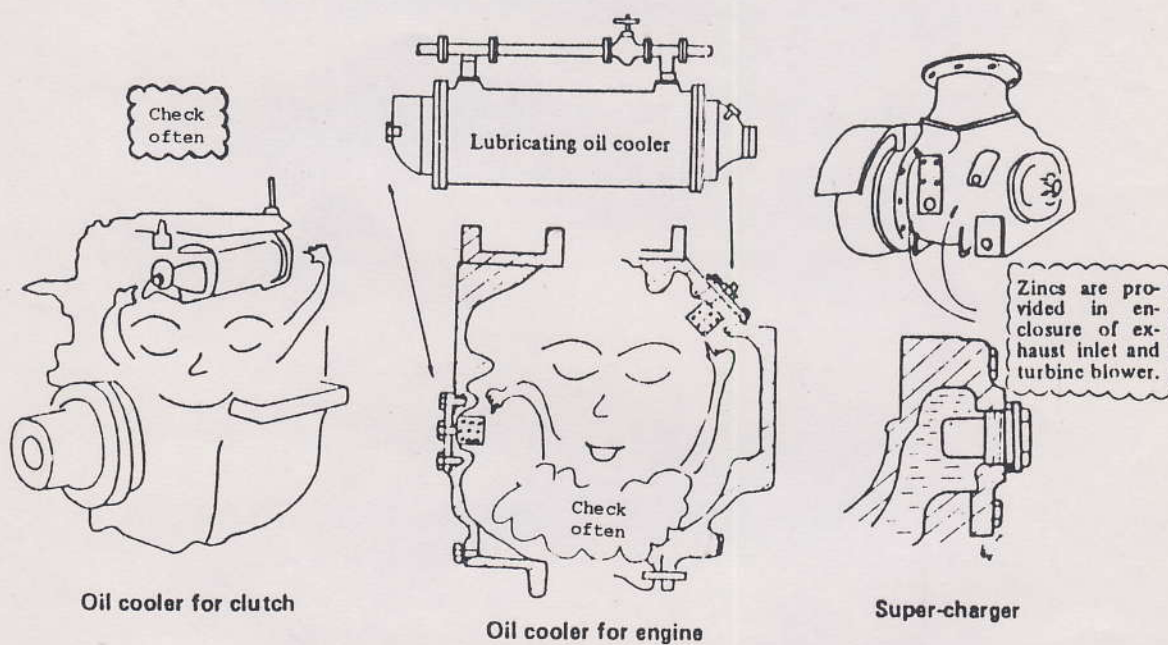
It is important to tighten the bolt and nut with the specified torque using the corrected torque wrench.



It is necessary to tighten the bolt and the nut by hand until the seating surface of bolt and nut touch the rod. Make sure that there is no projection or dust on the thread, to prevent the tightening torque from variation.

PERIODIC REPLACEMENT OF ANTICORROSIVE ZINC

QUESTION: Does corrosion of anticorrosive zincs for the clutch oil cooler, turbine etc., occur sooner than in other parts?

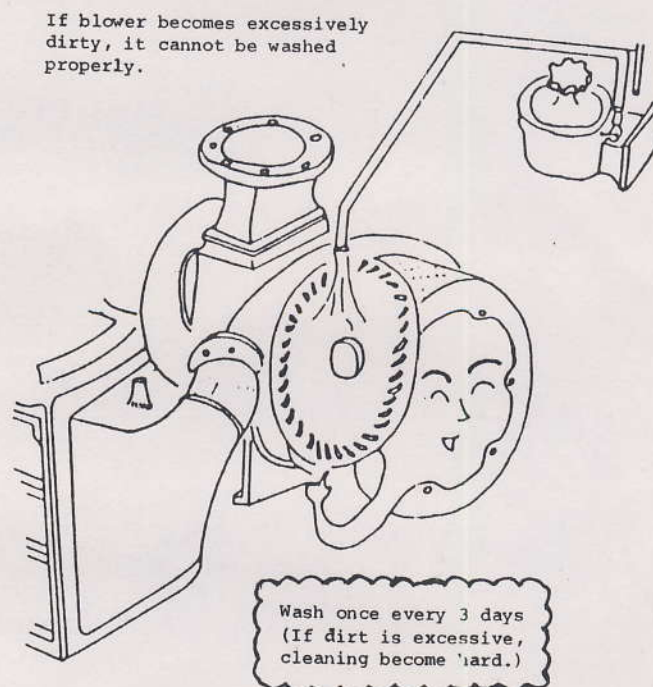


* It is necessary to check and replace the anticorrosive zincs frequently.

A large piece of anticorrosive zinc in a limited space obstructs the flow of cooling water and becomes small. Therefore, it is necessary to check the anticorrosive zincs often and replace those corroded to below 1/3 of their original sizes.

WASHING OF TURBINE BLOWER

QUESTION: Why is it necessary to pour water on the turbine blower and clean it periodically?



Use turbine washing liquid first and then rinse with clean water.

Clean the turbine blower during operation with the load more than 75% of the rated load.

Open the drain cocks for the intercooler and suction pipe.

Rinse the blower washer at 4-10 sec. intervals.

When there is no reset of the suction pressure, try once more after 10 minutes. If there is no result, this blower should be disassembled and washed once again.

After washing, operate the engine for at least one hour to dry it.

* If the blower becomes dirty, the exhaust temperature rises and there may be troubles due to the heat.

If the blower becomes dirty;

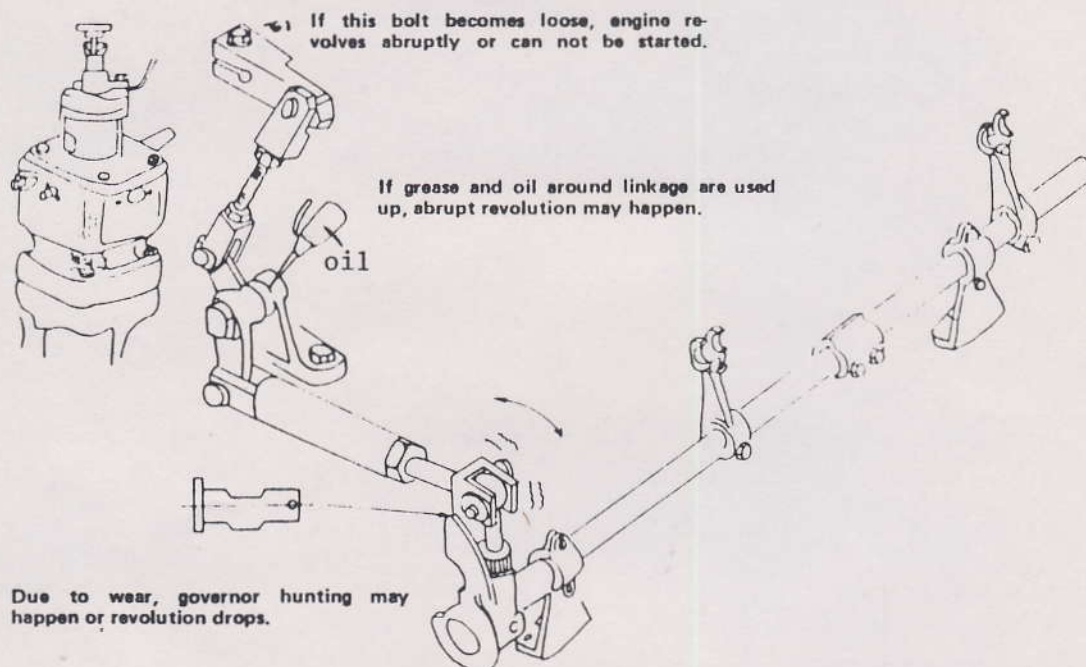
1. The air flow becomes short and then the engine output drops;
2. The exhaust temperature rises and then troubles due to the heat may occur.

If the blower becomes excessively dirty, it becomes impossible to wash it from the outside and then it is necessary to disassemble and wash the blower. It is better to wash the blower periodically so that it does not become dirty.



LINK MECHANISM OF GOVERNOR

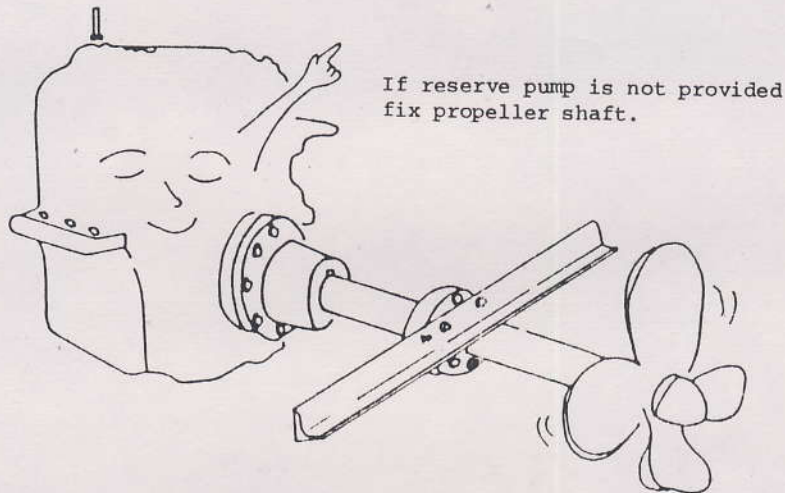
QUESTION: The engine which shows an irregular revolution (hunting), does not restore in spite of checking and adjusting the governor parts. Are there any other checking points?



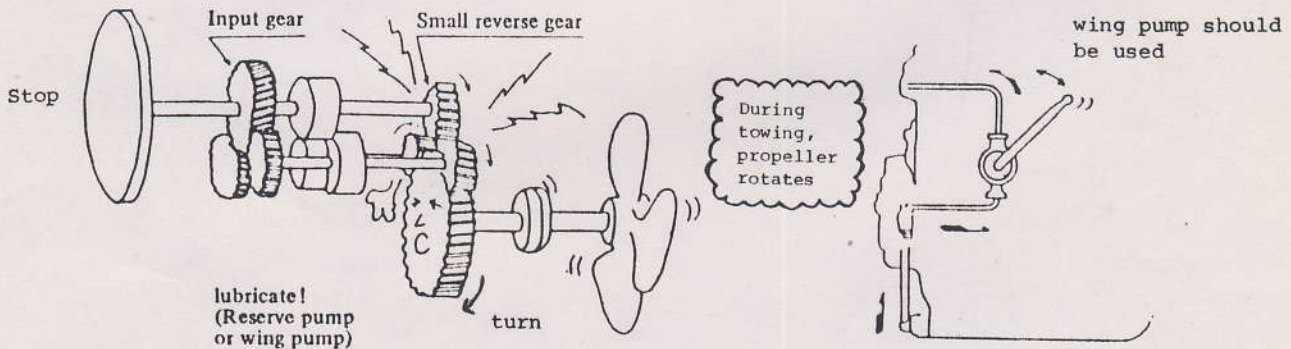
Even when the main parts of the engine are well maintained, trouble will occur if the linking mechanism if the governor is not in good condition. Especially check for partial wear around the connecting pin. If necessary, that is if the hole of the linkage part is enlarged by wear, use a larger diameter pin.

TREATMENT OF REDUCTION AND REVERSE GEAR IN EMERGENCY

QUESTION: When the boat is being towed, why is it necessary to drive the lubricating oil clutch and reserve pump (functional oil) or to fix the propeller shaft?



Flexible coupling



When the boat is towed, as the propeller is rotated by the water resistance, the output shaft of reverse gear rotates too. If this gear system has a clutch system, and the clutch is open, as the input shaft of the reverse gear does not rotate, the oil pump does not work and the shaft bearing and gear teeth are not lubricated. Therefore, if the output shaft rotates without lubrication, the clutch may be damaged.