DIESEL ENGINE MAINTENANCE

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The reaction of some to the title of this article will be that of " Boats," for it has been stated that no single item of ship's equipment has given the Engineer Officer more headaches than internal combustion engine power boats which, in the course of time, have often acquired a reputation for unreliability throughout the Fleet. The lack of proper maintenance has played a large part in the creation of this reputation.

In this article the emphasis is laid on the maintenance of motor boat engines but the principles and importance of Diesel maintenance apply equally to Diesel generators and propulsion units in ships.

The advent of jet engines and, more recently, the successful trials of the gas turbine in M.G.B. 2009 have given cause for the piston engine to be regarded, by many engineer officers, as obsolete. This is a fallacy. The trend of the future events was described in *Papers on Engineering Subjects No.* 22, in the article " Modern Engineering from the Naval Aspect." This predicts that, in the immediate years ahead, Diesel engines will be the most suitable propulsion machinery for surface vessels, of powers up to 2,000 to 3,000 h.p. per set, and in suitable cases grouped around gearing to give up to four times this power per shaft.

The gas turbine is not at present suitable for powers below 2,000 h.p. and may never be for powers below 500 h.p. In its present form it suffers from one main disadvantage in comparison with the piston engine in that its overall thermal efficiency is low and it cannot be brought up to that of the average piston engine unless large and elaborate heat exchangers are installed. These heat exchangers would raise the average weight and space requirements above those of the piston engine. This lack of thermal efficiency means an increase in the quantity of fuel that must be carried for an equivalent operational range and this is a disadvantage which cannot be accepted except in the case of short range high speed craft.

It is more within the capacity of industry, during the next few years, to expand rapidly with the production of Diesel engines than with gas turbines. In addition, much development work on the gas turbine lies ahead. For these reasons it is safe to assume that piston engines will retain their importance for some years to come and that any emergency would lead to a very great expansion of the numbers used in the Navy.

It is not fully appreciated that the efficiency with which motor boats run is the outwardly visible standard by which the efficiency of a naval engineer officer and his ship are largely judged. Internal combustion engines are used in all ships' boats and also provide a very large proportion of the electrical power in most classes of H.M. ships. The envy which follows in the wake of a good motor-boat has been felt by many. How is it that one particular ship's motor-boats become outstanding in their performance ? Is it luck or good management ?

Whilst serving in the British Pacific Fleet, H.M.S. *Bermuda* decided to find the answer to this question. A determined effort was made to improve the reliability of the engines of the power-boats (Perkins P6M and Dorman engines) which had previously been giving continuous trouble and required many hours of extra, and often hurried, work to be carried out on the engines.

Basic Principles of Good Maintenance

It is intended here to illustrate the basic principles of good maintenance rather than maintenance details which vary from engine type to engine type and which are already covered in either makers' handbooks or Fleet Orders, and will incorporate proposals forwarded by H.M.S. *Bermuda*, whose report concluded with these words: " The result of introducing this system of boat maintenance exceeded our wildest expectations and gave dividends from its inception. After the scheme had been in operation for a couple of months, it could be claimed that breakdowns were the exception rather than the rule. If nothing else, it has proved that there is nothing inherently wrong with the design of the boats or of the engines. Even more important, perhaps, is the fact that the maintenance load is considerably lightened and the work becomes steady instead of in fits and starts with occasional night work thrown in."

Briefly, the policy adopted by H.M.S. *Bermuda* was one of regular and planned maintenance—nothing more revolutionary than that. The result was a striking example of the way in which good maintenance can reduce work and, at the same time, increase reliability.

Maintenance is the process of maintaining an engine in the best possible operating condition over the whole period between major overhauls. Though this process involves a considerable amount of detail, it can be divided roughly into three main aspects which are discussed briefly below.

Breathing

For satisfactory running at high power every cylinder must be able to inhale its designed quantity of air and to rid itself of the products of combustion without restriction. Any serious falling off in breathing efficiency will lead to a breakdown, and this point is most frequently overlooked.

A free passage of air to the intake, clean intake filters or gauzes orrect valve timings and travels, clear exhaust passages and silencers are the main requirements for good breathing.

Heat Balance

The I.C. engine, like the human being, is sensitive to temperatures. Every engine has to reject rather more than 60% of the heat supplied to it by the fuel and it is designed to reject this heat through three main paths: the exhaust gas, the circulating water and the lubricating oil. Overloading the engine, or a single cylinder, is likely to lead to overloading of the paths of heat rejection and overheating of the engine. Failure of any one path to take away its quota of rejected heat will lead to local overheating. In either case trouble will ensue. The fact that overcooling also leads to trouble must not be overlooked.

The heat balance side of maintenance necessitates a careful watch on temperatures and immediate investigation of any departures from normal. There is also a preventative side which is equally important and this consists of periodical inspection, cleaning, and adjustment of those items which can throw the heat rejection out of balance. Most parts of the engine can affect the heat balance to some degree but the following are the most important: timing of fuel pumps and the condition of injectors, compression pressure, scaling of heat transfer surfaces in water spaces, coolers, and heat exchangers, sludge deposit in oil coolers, wear in pumps, leaking bye-pass valves, worn or unbedded piston rings, bad breathing, and excessive bearing clearance spilling oil before it has completed its circuit. Intelligent attention to these points is well repaid in trouble-free running and reduction of repair work.

Control of Wear

Control of wear—a very important aspect of maintenance—consists almost entirely of inner and outer cleanliness.

Absolute cleanliness is of extreme importance. The rate of wear of such parts as precision bearings, lapped fuel injection equipment and closely fitted pistons, liners and rings, is a direct function of the amount of foreign material entering the engine via the air system, the lubricating and fuel oil.

Air-carried dirt is not usually a menace at sea, but may be harmful close to the shore. Due to weight and space considerations, air filters are not usually fitted to naval engines. It should, however, be remembered that dirt can come from within the ship—for instance, it is most undesirable to run a boiler room generator while brickwork repairs are in progress.

In order to give an idea of the degree of cleanliness required for the lubricating oil the most reliable information on the subject states that it is desirable, in order to reduce wear in an engine, to remove all particles larger than $2\frac{1}{2}$ microns (25 microns = ·001″).

Attention is invited to the article " Heavy Duty Oils " in the *Journal of Naval Engineering*, *Vol.* 1, *No.* 2, in which the reduction of wear and maintenance of internal cleanliness consequent upon the use of H.D. oils is discussed.

Fuel cleanliness is of vital importance. It is generally realised that abrasives play havoc with the precision fitted injection pumps and injectors, but the damage is not immediately apparent and therein lies the danger. What is not usually realised is that abrasive dust is invariably present in Diesel fuel when received on board and that the quantity increases continuously due to corrosion of the fuel tanks and systems and due to dirt drawn into the tank through the vent.

Pumps and injectors will gradually lose their efficiency, but not all to the same degree and this is how the trouble will be diagnosed. Engine performance becomes erratic, distribution of load between cylinders becomes unbalanced and so troubles accumulate.

Where filters, gauzes and strainers have been installed to reduce to a minimum the entrance of foreign material into the engine they must receive regular attention if breathing efficiency is to be maintained at a maximum and the full benefit gained from the lubricating oil and fuel filters.

Of almost equal importance to clean fuel and lubricating oil is the necessity for external cleanliness. Oil and water leaks, apart from the increase in oil consumption, collect dust, dirt, and camouflage the fuel oil leaks, cause untold damage to the electrics, and foul the bilges. The effect of a leaky injector pipe union which, on a dirty engine, may be just one more undetected leak, needs little magnification when one realises that in the Coventry KF4, only ·028 c.c. are injected per stroke at full power and that individual pump units are calibrated to within ·001 c.c. per stroke to give an even distribution of load between cylinders. The best filtration arrangement will not save an engine if external dirt falls inside whenever a crankcase door or valve rocker cover is removed.

Maintenance Schedules

With cleanliness as a basis, the next step is to lay down maintenance routines. To this end a series of maintenance schedules were produced and issued in A.F.O. Diagram 374/45. The aim of these schedules was that they should be a guide for the Engineer Officer and should assist him to plan his routines.

Particular attention should be paid to the following points :—

(i) Experience has shown that a considerable quantity of water condenses inside a fuel tank on a cold night and therefore to reduce this to a minimum, fuel tanks should be topped up at the end of a day's run and not left partially empty until the following morning.

(ii) In many cases the interval laid down for the servicing injectors is proving too long whereas careful operation would permit this period to be extended. Idling periods should be kept to a minimum, and prior to stopping the engine should be revved up to remove any carbon deposits from the nozzle.

When cleaning injectors shop cleanliness is of paramount importance.

To test injectors correctly, the handle of the test pump should be pressed down slowly and held at a pressure just below injection pressure. The nozzle should remain perfectly dry. This is a severe test but is absolutely essential if the injector is to operate satisfactorily. The usual test for spray quality should then be carried out.

(iii) The Admiralty Fleet Orders relating to major overhaul, of which eleven have been published, include much useful data to maintenance personnel such as lubricating oil and circulating water pump clearances, and valve spring free lengths and rates. The latter should be checked at each top overhaul, and provided the protective coating, bakelite slush or cadmium is undamaged, used again.

(iv) At top overhauls every endeavour should be made to clean thoroughly the circulating water spaces of scale and deposit.

The basis of future policy is that more stress should be laid on maintenance. The maintenance schedules, which at present are Admiralty Fleet Order Diagrams, are being revised and re-published as S and D Forms, in order that they may be readily available on demand. They should be used with intelligence for no two engines behave alike. It may be discovered with experience that additional routines will be required, that certain periods should be reduced or possibly increased, though the latter should only be done after careful consideration.

Engine Maintenance Log Books

Comparable to the importance of carrying out routine inspections is the logging of action taken. The next requirement is that these routines should be carried out at regular intervals.

To meet this requirement an I.C. engine maintenance log is being produced. The log has been elaborated to include a section for the recording of defects. It is intended that it be kept by the stoker mechanic in charge of the engine and be inspected at regular intervals by the Engineer Officer. Correctly used this innovation should prove to be of great assistance in planning maintenance.

On the personnel side a recent Fleet Order has promulgated the news that a proportion of engine room ratings borne will have been through the I.C.E. course at M.T.E. Chatham, and H.M.S. *Alaunia*, Devonport. These ratings receive a thorough grounding of the basic principles of I.C. engines and their maintenance, and with encouragement, guidance, and experience will prove an invaluable asset.

Planned Maintenance

The following innovations were introduced and used in H.M.S. *Bermuda* with considerable success.

" The daily inspection form, shown below, was printed on board. This form was filled in daily by the driver of the boat and taken to the motor-boat Engineer Officer. The daily inspection should take place early, before the routine and other trips commence." H.M.S. *Bermuda* commenting on its value, remarked—" The use of the form had three beneficial effects:—

(i) It instructs the driver as to what he should do when checking his boat over in the morning instead of leaving it to chance.

(ii) It gives the Engineer Officer information concerning the condition of the boats and a warning of any defects that may be developing.
(iii) Probably even more important than (i) and (ii), it gives the driver an interest in his boat and this is half the battle."

DAILY CHECK OF POWER BOATS

This form is to be completed daily by 0830 by the Stoker Mechanic of each boat and given to the Boats Engineer Officer.

Boat..

Date..

1.	Is the fuel tank full ?		....
2.	Have you tested to see if there is water in the fuel ?		....
3.	Is the lub. oil up to the working level on the dipstick ?		....
4.	Does the oil look dirty or emulsified ?		....
5.	Have you checked the lub. oil level in the fuel pump ?		....
6.	Is the level of water in the battery above the plates ?		....
7.	Are the circulating water weed traps clear ?		....
8.	Are the engine trays clean and dry ?		....
Run up the engines and check :—		*Port*	*Starboard*
9.	Lub. oil pressure (to be recorded).	....	....
10.	Circulating water.	....	....
11.	Dynamos charging. Charge to be recorded.	....	....
12.	Even firing of engine.	....	....
13.	Clutch operation.	....	....
14.	Check weed trap and see if clear.	....	....

Any faults which may have arisen in your 24 hours' duty and any action to remedy them are to be recorded below.

....
Signature of Driver.

To work a system of planned maintenance satisfactorily, there are certain cardinal rules which must be adhered to.

(i) The power boats must come inboard promptly at their time for inspection. There must be no stretching of the period except in emergency, and then only with the permission of the Engineer Officer.
(ii) Close co-operation between the engine room and executive departments is essential, so that each has an idea of the other's requirements and can plan accordingly. As an example, the running hours must be adjusted

so that if two boats are in the water they do not both reach the time for their inspection simultaneously.

(iii) It must never be planned, except for very short periods in harbour, to run all the power boats. 75% serviceability should be planned for, not 100% which inevitably results in a series of breakdowns.

To enable anyone to size up the power boat situation at a glance, two boards were prepared by H.M.S. *Bermuda*, one for use in the Engineer's Office and a simpler one for the quarter deck.

READINGS FOR QUARTER DECK BOARD

Boat	S or U/S	Hours to next Inspection	Reason U/S	Expect to Complete
1st M.B.				
2nd M.B. ...				
Captain's M.B. ...				
Motor Cutter ...				

READINGS FOR ENGINEER'S OFFICE BOARD

Type		1st M.B.	2nd M.B.	Captain's M.B.	Motor Cutter
Boat No.					
Ship Designation ...					
Engines Fitted	P				
Type & No.	S				
S or U/S					
Last Inspection At ...					
Total Hours since Last Inspection					
Next Inspection due at					
Total Engine Hours	P				
	S				
Reason U/S					
Expect to Complete ...					

It will probably be generally preferred to arrange the Engineer's Office Board the same way as the Quarter Deck Board, i.e., all notations for any boat to be read horizontally: we have shown the readings of the Engineer's Board vertically only to simplify printing.—EDITOR.

Thus, with a combination of various factors which include the elimination of unreliable engine types, an increase of I.C.E.-trained personnel, a planned maintenance, and a higher standard of workmanship which will develop at the I.C.E. overhaul establishments, there is a very justifiable reason to believe that in the future the outwardly visible standard of efficiency will be a high standard, and it should soon become an accepted fact.