TUNING SUBMARINE MAIN ENGINES
(ADMIRALTY TYPE)

by

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The loading of submarine engines is more complex than that of surface ships where overloading conditions only occur when the ship's bottom is foul, in heavy seas, towing, or when steaming with a reduced number of boilers or units. In the latter case the Engineer Officer can tell at a glance by the number of sprayers, oil fuel pressure and the engine receiver steam pressure, when the maximum output or power condition is reached. The revolutions will naturally vary with the conditions, but these minor variations in no way compare with those obtaining in submarines.

In a submarine, the power required from the engines when propelling at any speed, can be, and is, increased by trimming down the boat, by using the main motors which are integral with the main line of shafting for generating the electric load of the ship, or for charging the main batteries which supply the power for submerged propulsion. All, or any, of these means may be used. At sea, one engine may be used for propelling and the other as a generator, or one or both engines propelling or generating.

These various methods of running, coupled with a dirty bottom and head sea, make it imperative for the Engineer Officer or watchkeeper to have a simple method of knowing the state of loading of the engines at any speed or condition of running, to ensure that he is not overloading his engines.

The engines to which the following instructions apply are of the single acting four-stroke type, fitted with jerk injection fuel pumps, and are designed to run at any speed below the designed maximum revolutions, with a limit set by obtaining a maximum brake mean effective pressure (B.M.E.P.). Overloading conditions obtain if this B.M.E.P. is exceeded at any revolutions.

During bench trials of "first of class," characteristic trials are carried out from which engine loading curves are produced. During the characteristic trials the engine is run at various revolutions on different loads, and records of fuel consumptions, exhaust temperatures, maximum pressures, fuel lever and timing settings are taken. These results are plotted on graphs and are issued in slide rule form to the Engineer Officers. Typical data from an " S " class slide rule is facing page 38. The lines on the cursor are marked in green. Assuming the engine revolutions are 320 and the fuel consumption is 165 lb./hr., then the other details can readily be read off as indicated on the slide rule by the crosses (+). To avoid overloading at the same revolutions, it is evident that the fuel consumption should not exceed 250 lb./hr. as indicated at point A. To get the correct settings at this power the curser must be moved vertically until the cross above the fuel consumption curve is on the red line which is the maximum allowable fuel line (marked in this case " A "). The other crosses will have moved accordingly and will indicate the other settings, temperatures and pressures, etc.

Although the engine will not be overloaded under the maximum allowable fuel conditions, it may well be that certain individual cylinders will be, as some cylinders may be taking more fuel than the others. It is to ensure equal power per cylinder that tuning is of the utmost importance. To do this, measurement or observation of revolutions, fuel consumption of the engine, and exhaust temperature and maximum pressure of each cylinder, tell the engineer all he wants to know of his engine; coupled of course with a smokeless exhaust. If these agree with the engine loading curve he knows that the engine is running as designed and with the greatest efficiency.

The object of tuning the engine is to obtain this condition in each cylinder. To ensure these factors each cylinder has its remote reading exhaust gas thermometer and indicator connection. Also, all the fuel passing to the engine is measured by a Kent flowmeter and in addition a one or two gallon *snap* reading tank can also be used for quick checks of fuel consumption. No torsionmeters are fitted.

Each cylinder has individual fuel pump quantity control and pump timing control. These usually can be adjusted while running. Other adjustments such as valve settings are done in the early stages, about which more details are given in the remarks on tuning.

Tuning can be divided into three phases :—

(i) Preliminary adjustments,
(ii) Static settings, and
(iii) Running settings.

Assuming an engine is new or has just been refitted the sequence of operations is as follows :—

Preliminary Adjustments

(*a*) Check and adjust piston bumping clearances. Compression plates are fitted under the feet of the connecting rods for this purpose.

(*b*) Phase the camshaft. This phasing is not based on valve openings and shuttings, but to the correct lifts of the valves at T.D.C. at the top of the exhaust stroke. This has an important bearing on breathing efficiency. The designed lifts are based on hot roller clearances which are estimated at 25/1000″ for induction and exhaust valves.

The method of checking the opening and closing of the valves by feel of the roller on the cam, or with a clock micrometer on the valves, is not at all satisfactory, and in any case a few degrees out on the designed openings and closing of the valves will make no difference to the running of the engine. The important point is that the lift of the induction valve must be more than the exhaust valve at T.D.C. For example, in a certain engine a difference of 1½ degrees on the camshaft phasing made the following difference on the valve lifts at top dead centre :—

	Exhaust Valve Lift	Induction Valve Lift
Final setting	·283″	·352″
1½ degree error	·344″	·299″

Under the latter condition the engine was less economical and exhaust temperatures were about 50° higher for the same high powers.

(*c*) Phase the fuel pump drive.

(*d*) Check injector sprays and correct lifting pressures.

Static Settings

(*a*) Set induction valve clearance at 25/1000″ and exhaust valve clearance at 40/1000″ to 45/1000″.

(*b*) Take and record valve openings and closings.

(*c*) Set fuel pumps by spill test.

ENGINE SETTING INDICATOR

INSTRUCTIONS

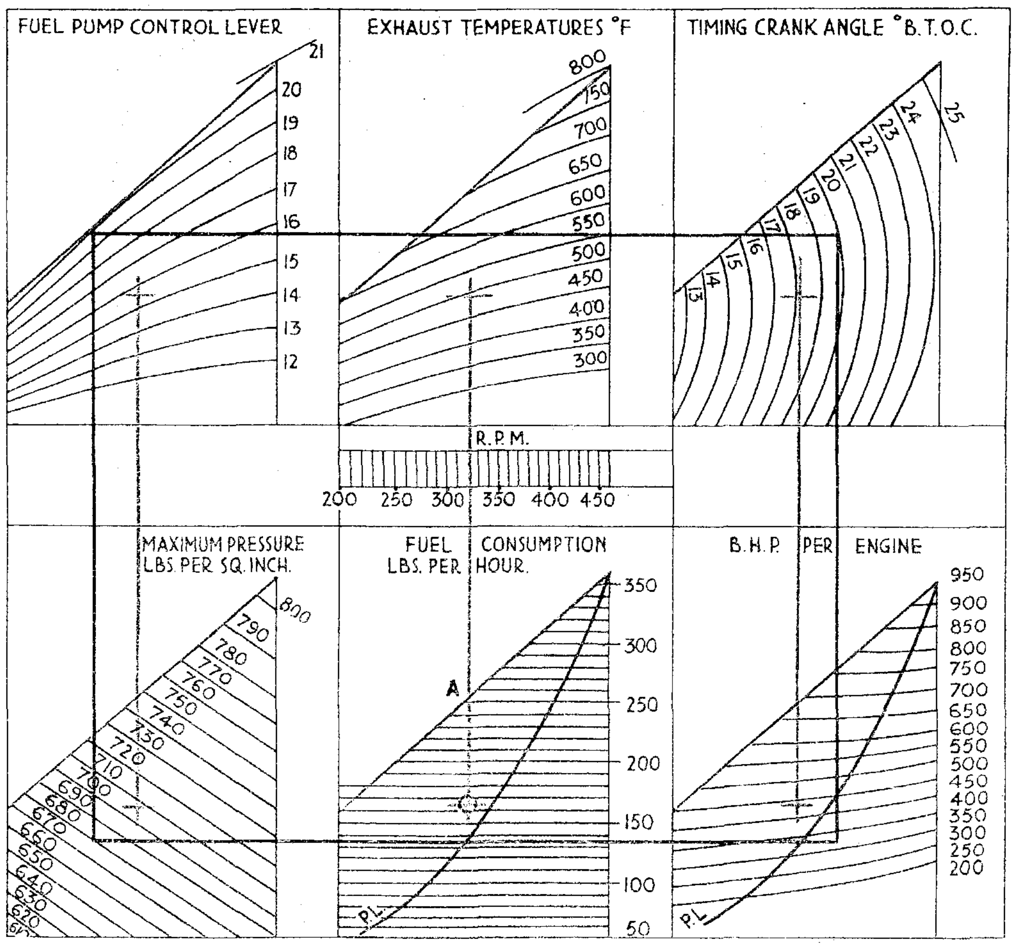
Slide the glass horizontally till the middle hair line is at engine speed on R.P.M. scale. Then slide frame vertically till the cross in the red circle is at the " consumption per hour." This must never be above the red line which shows the maximum permissible fuel at any R.P.M. The engine settings are then indicated by the crosses.

The propeller law (P.L.) and the B.H.P. chart is for twin screw, clean bottom, fair weather, without charge under these conditions, and assuming a motor generator efficiency of 90%. The maximum amps. charge available are :—

Revs. ...	250	275	300	325	350	375	400	425	450
250 Volts ...	1,000	1,008	1,000	945	860	721	561	340	120
310 Volts ...	808	814	808	762	694	581	452	274	97

Note.—When fuel consumption cannot be readily measured, engine setting should be determined by placing the top left hand cross over the fuel lever setting.

The outline of the movable cursor is shown by a thick black line ; the green lines are on the cursor.



FUEL PUMP CONTROL LEVER
21
20
19
18
17
16
15
14
13
12
EXHAUST TEMPERATURES °F
800
750
700
650
600
550
500
450
400
350
300
TIMING CRANK ANGLE °B.T.O.C.
13
14
15
16
17
18
19
20
21
22
23
24
25
R.P.M.
200 250 300 350 400 450
MAXIMUM PRESSURE
LBS. PER SQ. INCH.
800
790
780
770
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
FUEL CONSUMPTION
LBS. PER HOUR.
A
350
300
250
200
150
100
50
P.L.
B.H.P. PER ENGINE
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
P.L.

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Running Settings

The object of these settings is to get equal power from each cylinder and the method of measuring these powers is by exhaust temperature and maximum pressure only—if these are level the powers will be level.

(*a*) After preliminary running to check the bearings, etc., compression cards using a Dobbie McInnes indicator are taken at approximately 300 r.p.m. In some cases it may be found necessary to adjust the compression plate thicknesses to balance the compression pressures.

(*b*) Run the engine up to three-fifths full power and balance the exhaust temperatures to the average by the individual fuel pump adjustments, increasing or decreasing fuel as necessary. The mercury-in-steel exhaust gas thermometers are simple and reliable and can be depended upon.

(*c*) Having balanced the exhaust temperatures take a set of maximum pressure cards. For ease of analysis, records of all cylinders covering a band about $\frac{1}{8}''$ thick for each should be on one card. An example of maximum pressures, after the exhaust gas temperatures had been "levelled off" is as follows :—

Cylinders ...	1	2	3	4	5	6	7	8	
Temperatures ...	840	840	860	860	840	860	880	850	°F.
Max. Pressures from Card ...	800	760	830	790	810	800	840	770	lb./sq. in.
Mean				800					lb./sq. in.
Difference ...	0	−40	+30	−10	+10	0	+40	−30	lb./sq. in.
Therefore :— Adjust timing ...	0	+2°	−1½°	+½°	−½°	0°	−2°	−1½°	

If the slide rule indicates the maximum pressure should be 780 lb./sq. in., all pumps should be retarded 20 lb./sq. in. which usually approximates to 1°.

After this, exhaust gas thermometers should be inspected, levelled off once more as alteration to timing will slightly modify the temperature. Advance of timing for instance will decrease the exhaust gas temperature.

(*d*) Run the engine up to four-fifths full power and repeat as for (*c*). During the course of these tuning operations it must be clearly understood that major alterations necessary to *exhaust temperatures* are made by *fuel adjustments*, and to *maximum pressures by timing.*

(*e*) Having tuned for four-fifths power it is rarely necessary to make further adjustments at full power. It must be borne in mind that having tuned at full power, slight out-of-tune conditions may prevail at the lower powers, but these conditions must be accepted.

(*f*) Finally, with the engine in tune, under operational conditions, the exhaust temperatures which are instantaneous recordings, give the immediate indications to the watchkeeper of the load on the engines. When running the engines up to full power the load is increased until the exhaust temperatures approximate to the loading curves for the particular conditions, then check is made on the fuel consumption and minor adjustments made, as found necessary, bearing in mind that the fuel consumption is the final yardstick.