5.

NOTES ON BURNING OF FUEL OIL.

In order that any fuel shall burn, it must be raised to the temperature of ignition and if it is to burn rapidly it must present a large surface of contact to the air. Liquid Fuel cannot burn satisfactorily as a liquid and hence it must be completely vapourized, in which condition the vapour will present the necessary surface of contact to the air.

The conditions for burning fuel oil in the Merchant Service differ very considerably from those prevailing in H.M. Ships, where, owing to the high rate of forcing and to the relatively small combustion space volume, it is necessary for the oil to burn extremely rapidly if the combustion is to take place entirely in the furnace and not partially in the uptakes and funnels. Under Naval conditions, therefore, it is necessary that the oil shall be completely mixed with the air as quickly as possible; otherwise loss of efficiency and, in extreme cases, damage will occur. It is on account of the foregoing reasons that under highly forced conditions only high grade oils with low water percentages can be burned, and so an oil which might be satisfactorily commercially may be unfit for use in H.M. Service.

Generally speaking, there are four main factors in the burning of Oil Fuel which are under the control of the personnel :—

(1) Pressure of the oil.
(2) Temperature of the oil.
(3) Setting of the sprayer.
(4) Pressure of air used in the stokeholds.

It is only by the correct adjustment of these factors that efficiency in burning can be obtained.

Numbers 1 and 2, the pressure and temperature of the oil, are comparatively easy to deal with and slight variations of these two factors do not materially affect the efficiency.

No. 1.—The Pressure of the Oil.—Many experiments have been tried to determine the efficiency of a 900 lb. sprayer at different pressures and the results tend to show that pressures of from 70 lbs. to 125 lbs. should be used with a Texas Oil, as the efficiency falls off slightly outside these limits. Heavier oils, or those containing slight percentages of water, require the use of somewhat higher pressures, as a bad spray may be obtained at any pressure below 100 lbs. in such cases.

Too low a pressure is always to be avoided as the oil is not so well atomised and takes longer to burn. It is more economical to burn several small output sprayers at about the middle of their range, rather than one 900 lb. sprayer at a very low or very high output.

No. 2.—The Temperature of the Oil.—This differs with type of oil being burnt and is determined chiefly by viscosity. No definite rule can be laid down regarding the best temperature at which to burn an oil, but generally a temperature corresponding to a viscosity of 40, Redwood II Seconds gives good results. The flash point, however, must be taken into consideration, and it is not desirable to burn an oil at more than 20° F. above the flash point, although there is no danger in so doing. The risk of the oil "cracking" before being sprayed is negligible if a moderately high pressure is maintained.

There appears to be a tendency, however, to burn oils at too low a temperature, generally due to the fear of "pulsation." The effect of too low a temperature is similar to that of too low a pressure, *i.e.*, the oil is not so completely atomised and the temperature of the vapour is lower; thus the fuel requires more time for its combustion, with the result that unduly high temperatures are experienced in the uptakes and funnels, and a consequent falling off in boiler efficiency is experienced. In extreme cases wet cones will result, while oil passes in liquid form to the furnace without "flashing," and thus overheating of uptakes and possible damage may be caused. The reduction in efficiency due to this cause may be very appreciable and in practice it will generally be found desirable to work with the highest possible temperature consistent with avoiding pulsation.

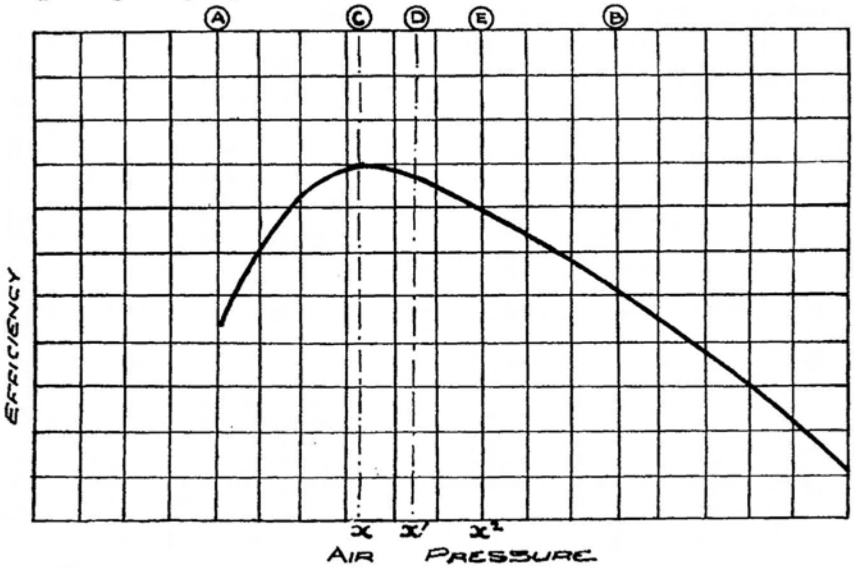
No. 3.—*Setting of Sprayers.*—With the ordinary service type of sprayer bracket, adjustment is provided in two directions only, viz. :—axially and, to a limited extent, across the boiler front horizontally. Owing to the thin plating of the air boxes becoming distorted from expansion, to small variations in the attachments of the combustion tubes and to careless treatment of the brackets, it is found in practice that an adjustment in the vertical direction is also required if the correct setting of the sprayers is to be maintained.

Under conditions of continuous steaming, not only is it necessary to change the sprayers at intervals, but also the distortion of the air boxes, spectacle plates, &c., is found to vary with the output of the boiler and according to the positions of the sprayers alight. Initial setting of the sprayers before steaming is therefore of little practical use, and the best solution appears to lie in providing means for making the necessary adjustments while the sprayers are actually in use.

The required adjustment can be given by a very simple alteration to the attachment of the bracket, and it will be found that its use results in a considerable economy in combustion tubes and also reduces the work involved in cleaning the cones, with consequent lengthening of the life of the brickwork—these advantages are very substantial, especially when added to the better economy obtained from correct settings.

In order to realise fully the benefits of this alteration, it is necessary when burning heavy oils to arrange for one rating to be responsible for the setting of the sprayers and also for their condition; the petty officer in charge of the boiler room cannot efficiently perform these duties under normal conditions when steaming in company.

No. 4.—The Pressure of Air in the Stokehold.—This is the most important factor of the three and, as will be shown, a small variation of air pressure has a very marked effect on the efficiency of combustion. For complete combustion just sufficient air must be supplied to burn the fuel to CO_2; insufficient air will cause burning to CO, a combustible gas, whilst too much air will result in CO_2 and excess oxygen. A slight excess of air over that theoretically required to burn the fuel is of course necessary in order to avoid any risk of incomplete combustion, with the consequent heavy loss of efficiency due to combustible gases passing away up the funnel.



(*a*)

A.F.O. 2080/26 and the accompanying sketch is of interest in connection with the question of air supply. For maximum efficiency of combustion we see that ((x) is the ideal air pressure, and that with either more or less air pressure the efficiency falls off—much more steeply towards " A " due to incomplete combustion than towards " B " (too much air pressure).

In H.M. Service it is not practicable to burn oil at the maximum efficiency, as too much smoke will be formed under this condition; a slightly higher air pressure (x^1) is therefore used, thus reducing the smoke to a light haze. A clear funnel can of course be obtained by increasing the air pressure to (x^2), but, as shown, this will result in a further fall in efficiency.

Thus we see that—

(*a*) Increase of air pressure causes—

Larger percentage of CO_2 in funnel gases, more oxygen and less risk of CO.

Higher temperature of uptakes.

Less smoke.

Lower efficiency.

(*b*) Decrease of air pressure causes—
More percentage of CO_2 in uptakes and less oxygen and more risk of CO.
Lower temperature of uptakes.
More smoke.
Increased efficiency.
(*c*) Too low an air pressure may cause pulsation.

The percentage of CO_2 in the funnel gases thus forms a guide to the correct air pressure and the fitting of CO_2 recorders in modern construction should prove of great value and promote economy, provided that the difficulties involved in obtaining consistent samples of flue gas can be satisfactorily surmounted. These recorders do not form reliable indicators of the boiler efficiency as they take no account of incomplete combustion, but should nevertheless be of real assistance in practice provided that due regard is paid to the conditions of burning, *i.e.*, temperature and pressure of the oil, the setting of the burner and the fineness of the spray.

Apparatus has been devised for indicating the amount of combustible matter remaining in the flue gases, but it remains to be proved whether a satisfactory design of the instrument can be produced to meet Naval requirements.

The temperature of the gases in the uptakes also provides an indication of efficiency, and in general it may be said that the higher the temperature of the gases the more the heat passing away to waste; pyrometers are being fitted in the latest ships for recording these temperatures.

The efficiency of combustion cannot be gauged by observation of the smoke alone, as one faulty sprayer in a boiler will cause excessive smoke and if the air pressure is increased to clear the smoke the boiler efficiency is lowered. If excessive smoke is observed under conditions of normal air pressure, attention should immediately be directed to the sprayers; the air pressure should only be increased as a last resort.

Some actual figures taken from recent trials are of interest as substantiating the foregoing statements. Temperature of Oil, Constant, at 200°. Rate of Forcing about ·5 per square foot of heating surface.

Air Pressure.	CO_2 in Uptake Gases.	Temperature of Uptakes.	Oil Consumption per H.P.
1·6	10·4	752	1·0*
1·4	11·0	695	·95*
1·3	11·8	625	·88*

* Not very reliable but gradually falling.

Unduly high gas temperatures will be experienced in the uptakes if excessive quantities of air are employed: this effect is probably due to two causes, viz. :—(1) lowered temperature of mixture and slow rate of burning, combustion thus taking place late in the uptakes; (2) increased speed of flow of the gases, resulting in the "centre of heat" being moved further up the funnel.

The effect of excessive air pressure on efficiency is shown from some figures taken from a Destroyer. One boiler at maximum output :—

Air Pressure.	*Boiler Efficiency.*	CO_2.
5·5 in.	63 per cent.	11·0 per cent.
3·5 in.	72 ,,	13·0 ,,

Position of the Sprayers.—The position of the sprayers, relative to the comparatively cool brick and tube surfaces, exercises some effect upon the boiler efficiency. Thus if a wing sprayer is used the efficiency may be as much as 3–4 per cent. less than that realised when a centre sprayer is employed. When therefore the conditions of burning permit of a choice of sprayers being made, it is preferable to use those situated in the centre of the boiler front.

Pulsation.—The principal difficulty to be overcome in burning oil in highly forced boilers is the control of pulsation. Many theories have been advanced regarding the cause of this phenomenon, while an equally large number of specifics have been proposed for its prevention; it is probable therefore that pulsations are due not to one alone but to several causes, some of which will now be briefly mentioned.

Incorrect setting of the burner is a frequent cause of pulsation in individual cases, although the reasons advanced to account for this effect do not appear conclusive in the light of the latest developments, which will be referred to later.

Pulsations may also be caused by irregularities in the supply of the oil or of the air to the furnace.

The former is almost entirely a question of oil temperature and may be due to the fact that at a certain temperature (varying with every oil) the character of the flow changes, with the result that the oil issues in irregular gusts rather than in a steady spray. The remedy is obviously to lower the oil temperature till pulsation ceases. Irregular working of the oil fuel pumps also undoubtedly tends to cause pulsation, and attention to the air vessels will often effect a cure.

Pulsations due to variation in the air supply are in general due to three causes, viz. :—

(*a*) Unsuitable type of fan propeller, giving a discontinuous (and periodic) air flow at high speeds. Fan impeller design is still too imperfectly understood for this to be entirely avoided under all conditions.

(*b*) Unsteady running of the fan engines.

(*c*) Fans badly placed with regard to the boilers they supply, and also the existence of obstructions to the air flow between fan and sprayers.

The two former are, of course, not under the control of the operator, but the last may be influenced by an alteration in the conditions of the air supply to the boiler-room either by a general variation in the speed of all fans or by adjustment of that of a few fans only; this last is not desirable in view of the accompanying loss in efficiency. Disturbances in the air supply are usually of a periodic nature, and pulsation due to such causes is likely to occur at a few frequencies only : a remedy that is sometimes effective consists in altering the air path to the sprayers by means of baffles, this being particularly suitable when individual sprayers are prone to pulsation.

It has been known for some years that pulsation may frequently be prevented by slightly closing the air flaps, and this procedure is strongly recommended for general adoption when working up to high powers. The effect, however, is to increase the pressure in the stokehold ; when the boiler is properly warmed up, the flaps must be gradually reopened to the limits imposed by pulsation, thus reducing the air pressure and lessening the work of the fan engines.

It has been suggested that the effect of closing the air flaps is to damp out the pressure variations in the air supply, thus preventing pulsation. It is, however, possible that such adjustments effect their purpose by altering the relative distribution of the air supplies to the centre and to the slots of the combustion tube, and evidence is not wanting to indicate that this is the case.

Any means whereby higher oil temperatures and lower air pressures can be utilised without the risk of pulsation may well exercise far-reaching effects, and possibly alter many views at present held upon the subject of burning oil fuel. The opinions expressed in this article must, therefore, be read as applying strictly to the present Service design of oil fuel apparatus only, and may require revision in the light of any possible future developments.

Harbour Conditions.—It is when steaming under these conditions that the effects of uncontrolled excess air become most marked, and if economy is then to be achieved it is essential that the boiler casings should be airtight, and that the flaps on the airboxes not in use should fit properly and be secured shut. The correct setting and working of the sprayers is also of great importance.

It is obviously desirable that the air pressure should be a minimum under these conditions, not only in order to minimise the steam consumption of the fan engines, but also in order to reduce the amount of air leaking into the gas path of the boiler or passing to waste through other avenues.

The best solution appears to lie in working the boilers under natural draught: some remarks in this subject are given in Engineering Papers No. 6.

From such information as is available it appears that ½ ton of oil per hour can be successfully burned in a T.B.D.'s boiler, using 6–400 lbs.-per-hour "lighting-up" sprayers with natural draught alone. In larger vessels it should be possible to burn a greater quantity of oil, in view of the better "draught" available owing to the increased funnel height.

The following general observations on burning oil with natural draught may be found of interest:—

(1) Sprayers should not be worked at a rate exceeding about one-half their rated output—the actual proportion depends upon the height of funnel and upon atmospheric conditions.

(2) Smoke must be expected till the boiler brickwork is thoroughly heated up.

(3) The larger the number of sprayers that can be used the better.

(4) Loose soot deposits occur, but running the fans for short periods should be sufficient to remove these.

(5) Except in ships with greatly cramped boiler rooms, there is little to choose between "open" and "closed" stokeholds as regards the temperature conditions on the floor plates: in at least one case, during hot weather, the stokehold was actually cooler when working on natural draught than when one fan was in use.