RECENT IMPROVEMENTS IN OIL-BURNING EQUIPMENT.

In the summer of 1942 it was becoming more and more apparent that a change in the quality of the boiler fuel oil being supplied to the fleet in home waters was causing a good deal of difficulty in the boiler room in ships of all classes. No precise information has been obtained regarding the reason for the change in the oil, but it may well be that the higher demand for the lighter oils, coupled with the greatly increased expenditure of boiler fuel in the Naval service, had resulted in an inability on the part of the oil companies to obtain a sufficient quantity of the high grade fuel formerly supplied to the fleet.

This contention is supported by the fact that in September, 1941, the Admiralty specification for boiler fuel oil was amended and the permissible viscosity at 70° F. was limited to 1,500 seconds Redwood I, whereas prior to this date a typical Admiralty fuel showed a viscosity of 800 seconds at this temperature. Owing to more vicious cracking, and possibly aggravated by the particular type of crude oil in common supply, it is probable that the higher viscosity oils contain a smaller percentage of the volatile fractions, a large content of compounds of high molecular weight, and a greater amount of unstable substances such as hard asphalt.

The difficulties encountered in the boiler rooms were due chiefly to greatly increased carbon deposits on the brick throats or quarls through which the oil is sprayed into the furnace and to an instability of the primary flame in the register, especially when low oil pressures were used.

Increased carbon deposits cause a great deal of arduous work for the watchkeepers, damage to the brick quarls, and necessitate excess air being used to counteract black smoke. Burning with excess air, apart from being uneconomical, is liable to cause distortion of the boiler tubes, especially after the superheater, and may also cause undue wear of the furnace refractories. Instability of the primary flame often results in the flame becoming extinguished, unknown to the watchkeepers, and this again causes black smoke, deterioration of brickwork and risk of damage to the boiler tubes and uptakes.

Causes of carbon deposits.

Carbon deposits are caused by impingement of oil particles on any comparatively cold surface such as brick quarls, boiler tubes, and sometimes furnace floors and walls. This effect can be aggravated by polymerisation of the unsaturated compounds as the result of heating the oil either before burning or during the initial stages of combustion. The amount of polymerised products formed depends to some extent upon the length of time for which the oil is heated, but it has been found that temperature is the most critical factor, and above a certain temperature a " breakdown " occurs when the quantity of carbonaceous matter produced rises very rapidly. This temperature varies with different grades of fuel oil, but is usually higher than the temperature required for good burning, consequently, should the oil temperature be inadvertently allowed to rise to a high figure, increased carbon deposits may result.

One of the main essentials of any oil-burning equipment is that there shall be a permanent point of ignition close to the sprayer cap. This point of ignition is often referred to as the primary flame, or, in Admiralty registers, as "drawback."

If, in the region of the sprayer cap, the air velocity exceeds the actual rate of flame propagation, then this ignition point is lost. The smaller the oil particle size the greater will be the absolute rate of flame propagation, consequently, the finer the particle size the easier it is to obtain a stable point of ignition with high air velocity. Thus it is not the main spray, composed of relatively large droplets, but the fine mist which surrounds it near the sprayer which is responsible for maintaining the stability of the primary flame.

With the heavier oils, and especially when sprayed at low pressures, there will be a dearth of this fine mist, and, furthermore, it will break off from the oil film at a point more remote from the sprayer cap. In order to regain stability under these conditions it becomes necessary to move the sprayer to a position where the air velocity does not exceed the new slower rate of flame propagation.

In the Admiralty closed front register that stability of the primary flame, which is necessary for good combustion, can be restored to some extent by retracting the sprayer in its carriage and so bringing the fine oil particles back into the low pressure zone at the small end of the combustion tube. This, however, increases the likelihood of the main spray striking the brick quarl and building up carbon deposits.

It is apparent, therefore, that the heavier the grade of oil the more difficulty there will be in achieving good combustion and trials showed that the fuel supplied could not be burnt satisfactorily in the Admiralty closed front register, which was designed when high grade oil was plentiful.

An essential factor making for good combustion is that the air distribution across the boiler front shall be even, or, in other words, that each register shall receive the same quantity of air. Owing to the necessary design of the air supply casings in the Admiralty closed front, and to the unrestricted air flow through the registers which were designed for the lowest possible draught loss, the air distribution between the registers is far from even.

Damage to orifices.

Prevention of the sprayer caps from becoming dirty is another important factor in producing good combustion, by maintaining the quality of the atomisation. This also helps to prolong the life of the cap as frequent cleaning is apt to damage the tangetial and exit orifices. Most of the fouling of sprayer caps is not due to adventitious matter in the system, but to the coking of the oil left lying in the cap when the sprayer is shut off, the cap still being exposed to the radiant heat from the furnace. The existing mechanism for retracting the sprayer under these conditions is unsatisfactory.

It seemed apparent that combustion might be improved by giving attention to the following main points :—

(1) Arranging to burn with the sprayer further forward so as to reduce the risk of the oil spray impinging on the brick quarls.

(2) Devising some mechanical means of increasing the intensity of the primary flame so that the point of ignition is perfectly stable when the sprayer is advanced even further than is required to eliminate carbon deposits.

(3) Improving the atomisation of the oil spray.

(4) Improving the admixture of the oil and air in the register.

(5) Equalising the distribution of the air supply across the boiler front so that each register should receive the same quantity of air under all conditions of burning.

(6) Devising some method whereby the sprayers not in use would be protected from the radiant heat from the furnace to prevent fouling of the sprayer cap by coking.

(7) Ensuring that the oil is burnt in the available furnace volume.

SHORT-TERM REMEDY

Gaiters and extensions.

A simple modification to the closed front register is shown in Fig. 1, whereby it was found possible by fitting an extension piece to the sprayer and a sheet metal gaiter to the combustion tube to burn with the sprayer set considerably further forward than had previously been possible. The stability of the primary flame is restored by restricting the amount of air flowing through the combustion tube. The atomisation of the oil can be improved by impressing upon ships' staffs the desirability of burning the oil at the highest pressure possible under the circumstances prevailing, and by bringing to their notice the necessity for keeping the oil at the correct temperature. A.F.O. 250/44 has been issued for their guidance.

No easy method could be devised for modifying this register so as to improve the oil/air admixture or to equalise the air supply to all burners.

The fitting of extension pieces to the sprayer body, while considerably reducing the deposit of carbon on the quarls and combustion tubes, rather accentuated the troubles due to the coking of the sprayer caps when not in use.

When properly fitted and operated this device has given improved burning in a number of ships. There have also been failures, and these may have been due to the fact that the correct distance between the gaiter and the end of the combustion tube was not always maintained. Further, the dangerous but common practice of improving the flame stability by using the air shut off tube as an adjustable damper, was no doubt responsible for a frequent complaint that the gaiters quickly burnt out. The greatest objection to the use of gaiters on the registers of large boilers is perhaps the fact that owing to the air distribution across the front being uneven, it would be necessary to adjust the axial position of each sprayer separately in order to obtain stability of all burners and to make this adjustment every time the conditions of air pressure changed. To expect to make such an adjustment rapidly with existing fittings is out of the question, and this probably accounts for some of the adverse reports received on the fitting of gaiters and extensions to multi-sprayer boilers.

In sloops and corvettes, where only a small number of sprayers are fitted to each boiler—usually three—the air distribution is reasonably good and gaiters and extension have found a good deal of favour. Burning with the sprayers further forward not only prolongs the life of the throat bricks, but also that of the furnace lining generally, as the oil burns with a shorter flame, and, consequently, there is less impingement on the refractories; while the amount of a carbon deposits, smoke, and the work of the watchkeepers, may all be very much reduced.

This is clearly shown by reference to the illustrations on pages 8 and 9. In Fig. 2, the type of flame obtained from the standard Admiralty closed front register after carbon deposits have built up on the brick tube is shown. The flame had been alight for 40 minutes without cleaning the brick tube when the photograph was taken. It will be seen that the flame is long and smoky and tends to be unstable at the entrance to the quarl. Burning oil and carbon will be noted pouring down the furnace wall. Fig. 3 shows the nature of carbon deposits on the brick tube after steaming for just over 40 minutes without cleaning.

The type of flame obtained from the Admiralty closed front register modified with 'gaiters' and 'extensions' is shown in Fig. 4, after 60 minutes steaming without removing any carbon deposits from the brick tube. It will be seen

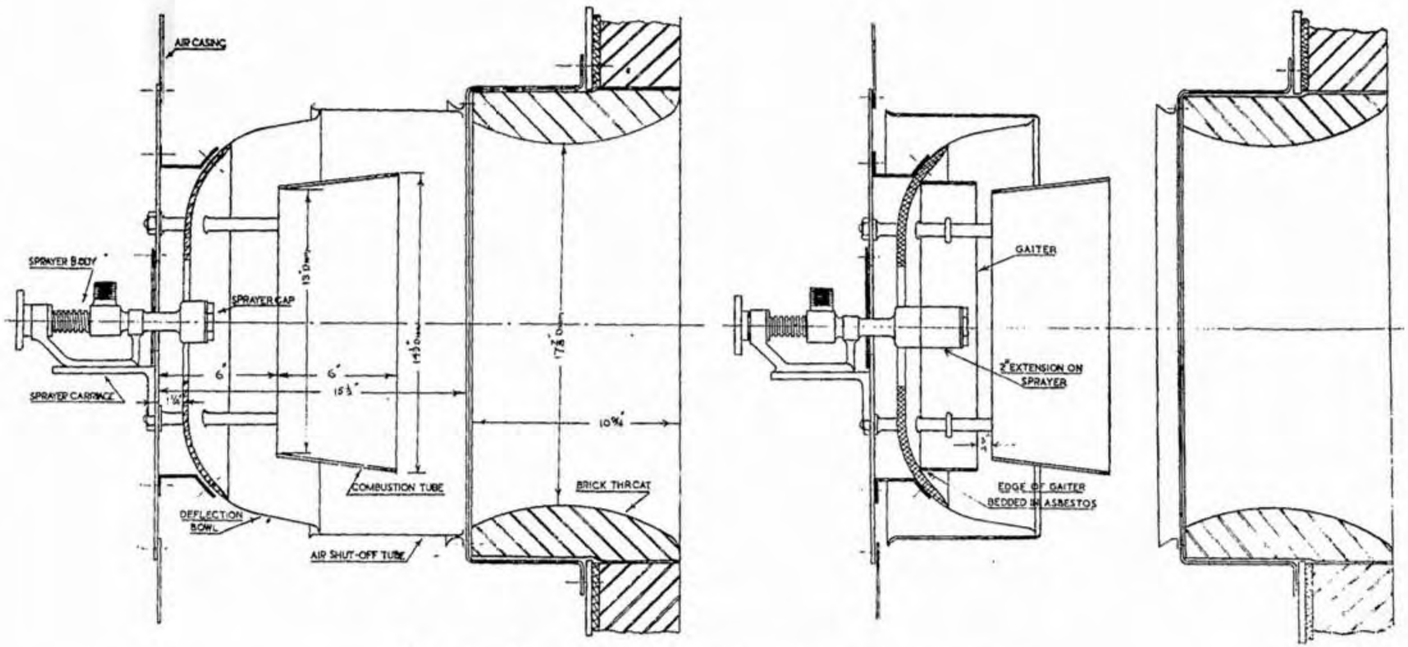

FIG. 1.—MODIFICATION TO CLOSED FRONT REGISTER.

ON THE RIGHT THE "GAITER" AND A 2-IN. EXTENSION PIECE TO THE SPRAYER BODY ARE SHOWN.

that the flame is short and clear. The brick tube of the modified register after more than one hour's steaming without cleaning is illustrated in Fig. 5. Only light carbon deposits due to slight irregularities in the spray can be observed.

The use of gaiters and extensions as a remedy may, however, only be looked upon as a simple and quick modification to give a certain amount of improvement in combustion with present burning equipment, and was never intended to be a permanent arrangement for obtaining satisfactory combustion.

MEDIUM-TERM REMEDY.

1941 Modified open front.

By using an open front register where the air supply is taken straight into the register from the firing space, casings to direct the air supply to the burners are eliminated, and an even supply of air to each register is obtained. The original open front register was clumsy to operate and, as in the closed front register, the sprayer could not be carried in a forward position without risk of losing the ignition point.

An improved type, known as the 1941 Modified Open Front, was designed, and was first successfully used in a steam gunboat.

Fig. 6 shows the general arrangement of this register, while Fig. 7 shows the registers fitted to a La Mont boiler of a steam gunboat. Certain modifications to improve the air flow through the register by fitting doors symmetrically placed around the sprayer, shielding the combustion tube from direct draught, and the adoption of a device for rapidly opening and closing the doors, have been incorporated.

The stability of the flame is assured by the action of the shield fitted before the combustion tube to restrict the quantity of air flowing through it in much the same manner as with the gaiter. This permits the use of a three-inch extension on the sprayer body. It is usually possible with this arrangement to burn with all sprayers fully advanced under all conditions of air pressure.

Prolonged tests of this burner were carried out at the Admiralty test house at Clydebank during the trials of a boiler for H.M.S. *Vanguard,* and also of the Foster Wheeler prototype boiler for the "Weapons" Class destroyers. Generally, it can be said that this register gives efficient combustion up to very high loads, is thoroughly stable, and prolongs the life of furnace refractories.

The re-introduction of this front, however, cannot be said to have improved the habitability of the boiler room, as it is apt to be uncomfortably hot when steaming at low powers or for auxiliary purposes in harbour; but it has definitely reduced the amount of work for the men on watch. These registers are now being fitted in a large number of vessels in the new construction programme, and in the case of H.M.S. *Achilles*, a conversion to this type was recently carried out at Portsmouth Dockyard with satisfactory results.

The fitting of an extension to the sprayer body has not improved the situation regarding the overheating of the sprayers not alight, but a new type of sprayer and sprayer carriage has been designed and will shortly be available for service with these registers. This design allows for an easy axial adjustment of the sprayer and for ample retraction in its carriage when not in use. It also provides for the aligning of the sprayer while burning.

LONG-TERM REMEDY.

Admiralty 1943 Type register.

Further experiments carried out with a view to modifying the existing Admiralty oil-burning equipment to give satisfactory combustion with the

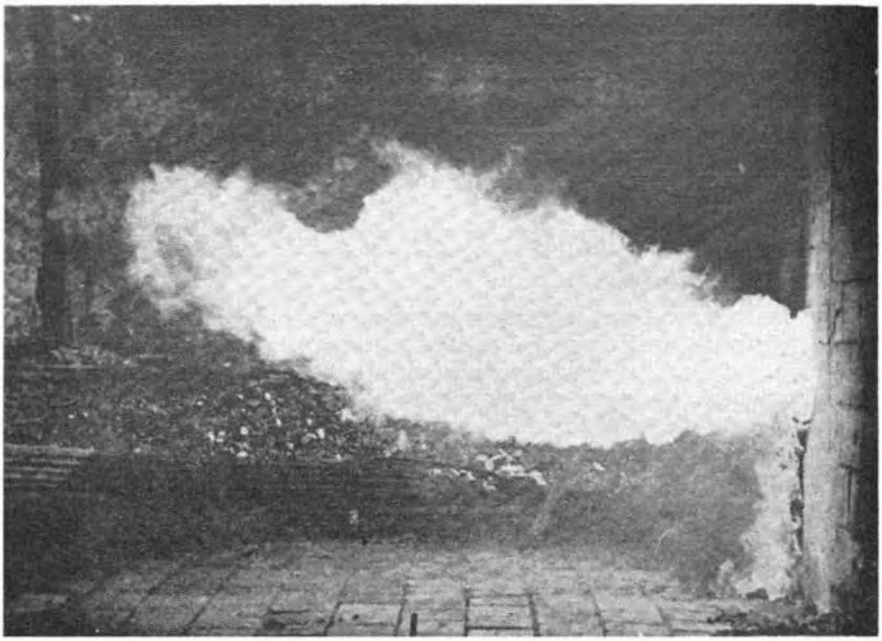

FIG. 2.—(ABOVE) FLAME FROM ADMIRALTY CLOSED FRONT REGISTER AFTER CARBON DEPOSITS HAVE BUILT UP ON THE BRICK TUBE.

FIG. 3.—(LEFT) NATURE OF CARBON DEPOSITS ON THE BRICK TUBE OF AN ADMIRALTY CLOSED FRONT REGISTER AFTER 40 MINUTES' STEAMING.

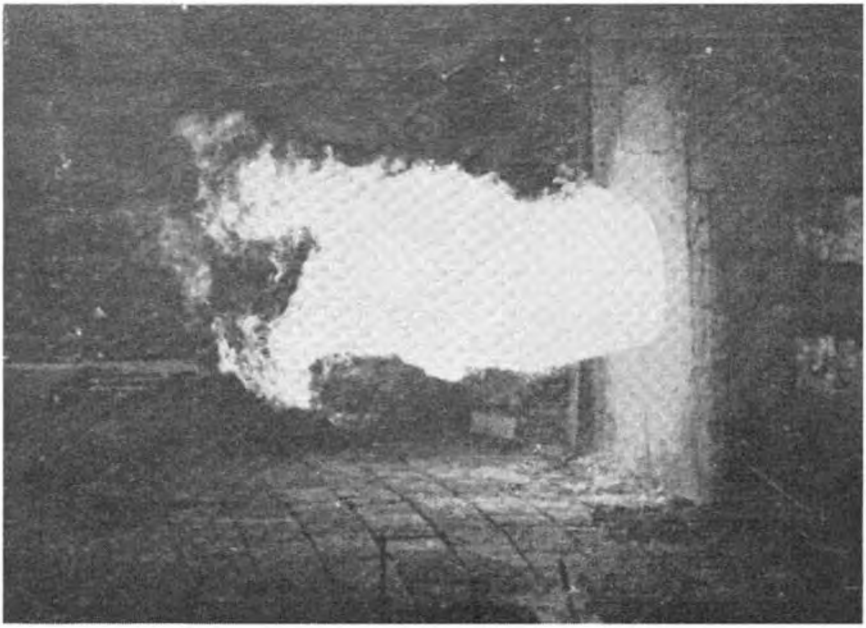

FIG. 4.—(ABOVE) FLAME FROM ADMIRALTY CLOSED FRONT REGISTER FITTED WITH "GAITERS" AND "EXTENSIONS."

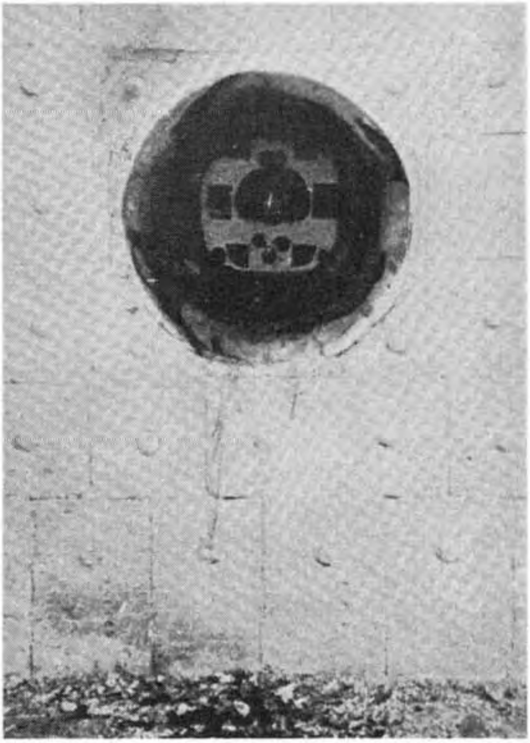

FIG. 5.—(RIGHT) NATURE OF CARBON DEPOSITS ON THE BRICK TUBE OF REGISTER FITTED WITH "GAITERS" AND "EXTENSIONS" AFTER 1 HOUR'S STEAMING.

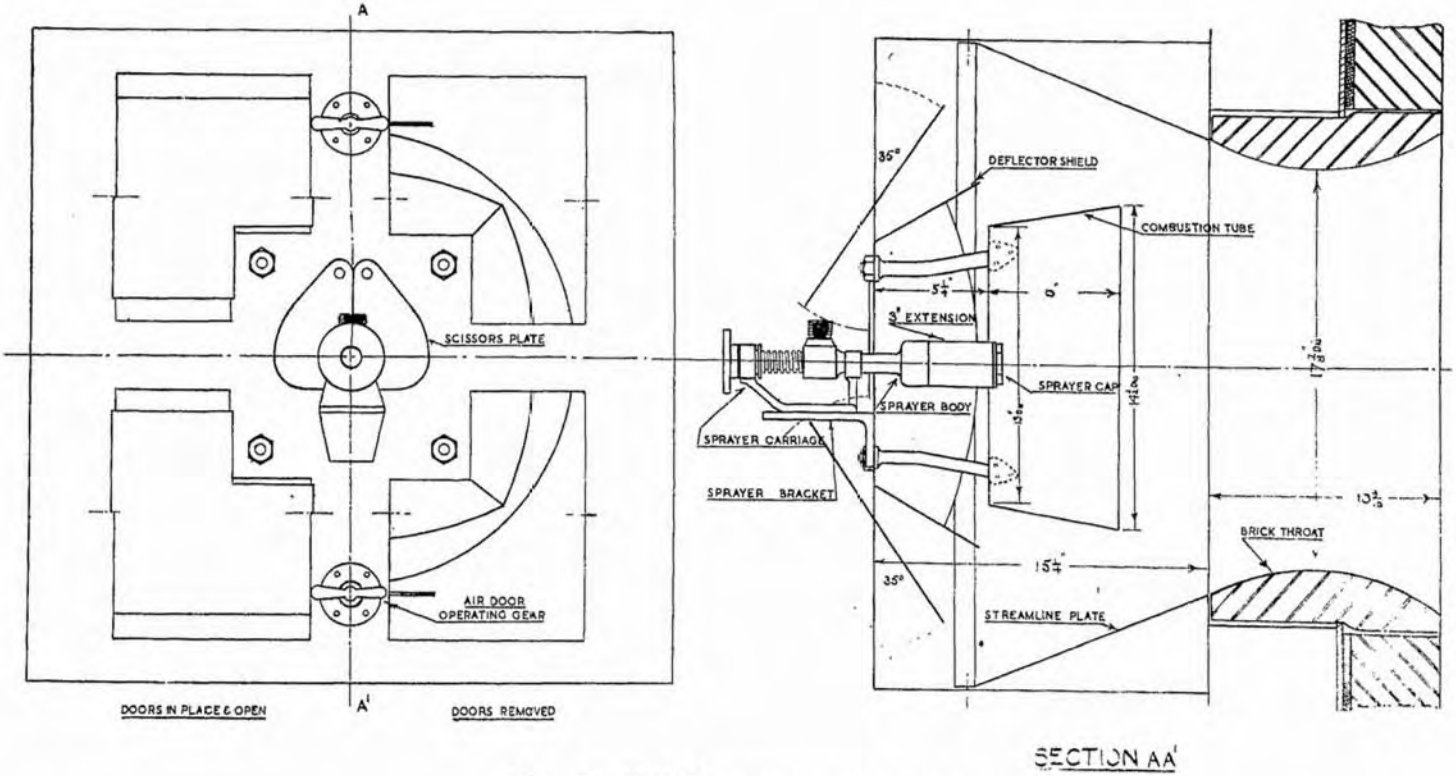

FIG. 6.—1941 MODIFIED OPEN FRONT

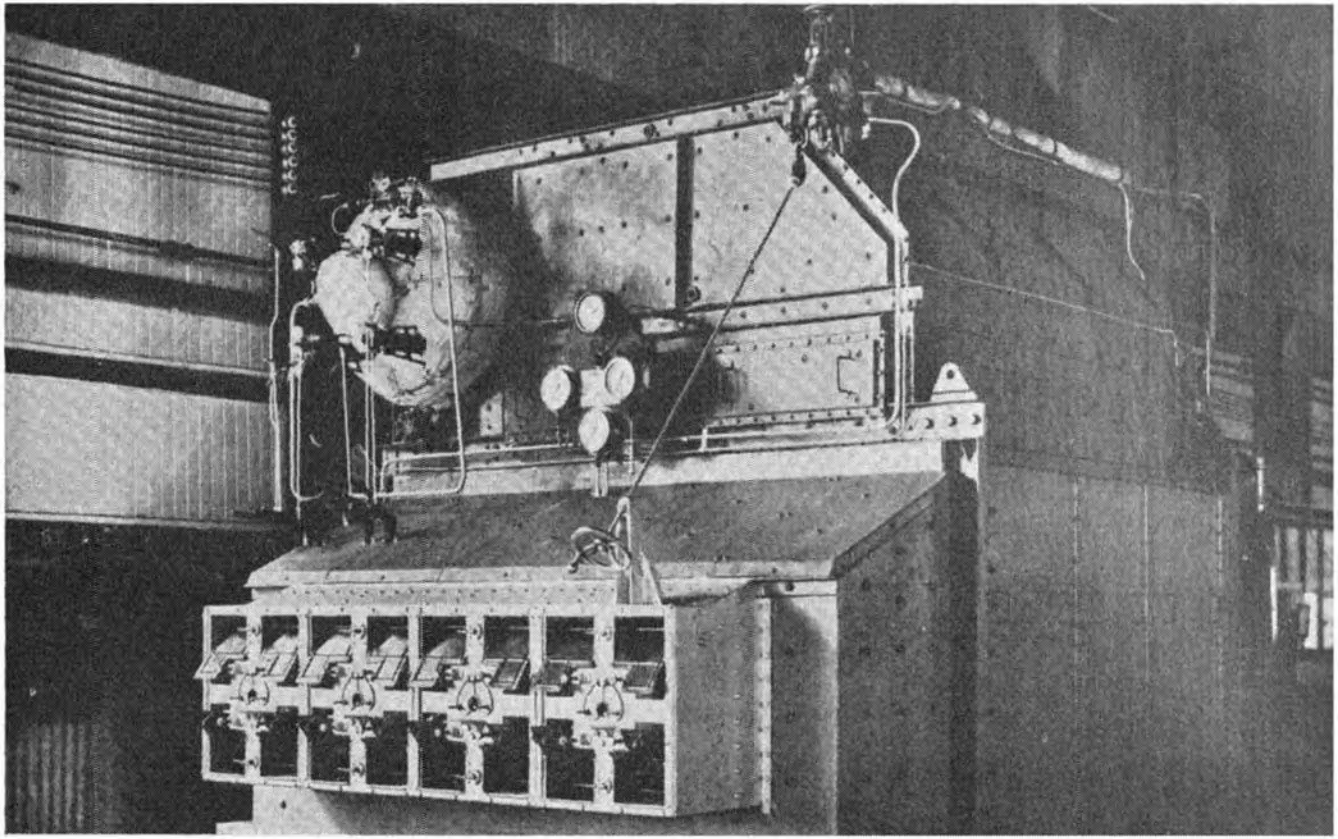

FIG. 7.—LA MONT BOILER FITTED WITH 1941 MODIFIED OPEN FRONTS (AIR DOORS OPEN)

heavier grades of fuel oil, showed beyond doubt that a permanent cure for the trouble experienced at sea could only be achieved by designing an entirely new register not only embodying the basic principles of oil burning, but also those items set out on page 4, to which it was considered necessary to give special attention in order to obtain optimum combustion.

It has long been apparent that a large amount of the trouble experienced with oil fuel burning can be attributed to the mechanical defects in the register, such as sprayers becoming out of line, distorted air—shut off tube, etc. Thus, second only to the theoretical correctness of design comes the practical correctness of the mechanics of the register, and in designing the new equipment as a long-term remedy, this point has been kept well to the fore, and a number of novel features incorporated.

Initial experiments carried out at Haslar showed that large quantities of oil can only be burnt correctly in small combustion spaces, or at a high forcing rate as required in naval boilers, by arranging for high air velocities through the register. To achieve this, it has been found necessary to design the diameter of the register according to the quantity of oil to be burnt, such that higher air pressures than heretofore are necessary for supplying the correct amount of air for combustion.

Conditions fulfilled.

As, in existing ships, the air pressure is limited by the machinery provided it has been found necessary to limit the amount of oil to be burnt through each register so that the draught loss through the burner with the smaller quantity of oil was not appreciably greater than that with standard equipment when burning a larger amount of oil. In order to burn the same total quantity of oil under the boiler, it is therefore necessary to have a greater number of burners. Thus, an essential feature of the new burning equipment is that it should be compact and that the diameter of the register should be kept to a minimum. The 1943 Admiralty register fulfils these conditions as it has been found possible to design boiler fronts for converting existing ships to the new burners. Despite the introduction of vanes to produce an air swirl and the smaller diameter brick throats, full power may be achieved with air pressures even lower than used with the equipment at present fitted, but still maintaining a high air velocity through the register.

The 1943 register can be easily modified for use with trunked air, and it is anticipated that future designs may incorporate much higher air pressures in the trunking so that large quantities of oil may be burnt through small diameter registers giving still more efficient combustion.

After prolonged experimental work at Haslar, the Admiralty 1943 Type register has been produced to incorporate the essential points referred to above. Results of trials ashore and at sea have been sufficiently successful, both in existing ships which have been converted and in new construction, to justify the hope that the new burners will be regarded as a long-term remedy for the oil fuel burning difficulties of the Navy.

Trials have been carried out when burning various grades of fuel oil and the new register has given trouble-free combustion with oils up to 1,000 secs. R.I at 100° F. (3,400 secs. at 70° F.), so no reason can be seen why even heavier oils could not be dealt with successfully.

The Admiralty 1943 Type register has been designed and tested in three sizes.

(1) 12 in. diameter register with 12-in. brick tube for use with No. 1 sprayer caps at all oil fuel pressures or No. 2 sprayer caps up to 150 lb./sq. in. and in ships with an ample margin of fan power up to 250 lb./sq. in. oil fuel pressure.

(2) 14 in. diameter register with 14-in. brick tube for use with No. 2 size sprayer caps where only low air pressures are available, and No. 2A and 3 sprayer caps at oil pressures up to 150 lb./sq. in.

(3) 16 in. diameter register with 16-in. brick tube for use with sprayer cap size Nos. 3 and 4 at all oil pressures.

Larger quantities of oil may be burnt through each register provided that the necessary air pressure is available. (A No. 5 cap at 250 lb./sq. in. oil pressure, representing approximately 2,000 lb. of oil an hour, has actually been burnt satisfactorily through a 14-in. register in a small boiler at Haslar using a draught loss of 10 in. W.G. through the register.)

The general arrangement of the register, complete with sprayer and tip plate in its carriage is illustrated in Fig. 8.

The essential components are :—

(*a*) A series of radial vanes arranged so that the air entering the register is given a swirling motion and forms a vortex with a low pressure zone in the centre.

(*b*) A parallel brick quarl, of sufficient length to enable the rotating air to take up its true free vortex form.

(*c*) A new device for creating a stable ignition point referred to as the " Tip Plate " is situated at the end of the sprayer and over which flows a current of air supplied from the front of the register through a centre tube. The air supply through the centre tube is shut off by the tip plate when the sprayer is fully retracted.

(*d*) An air shut off tube for closing the air supply to the vanes when the register is not in use. This shut off tube closes against flat surfaces and the manipulating mechanism is arranged so that it can be locked in both the open and closed positions.

(*e*) A sprayer body, cap and carriage. After many experiments with various designs of sprayer caps, it was decided that the standard Admiralty sprayer cap possessed a number of desirable features and this cap has been used with the new register.

The sprayer body is of such length that in the fully forward position the spray will miss the brick tube. By observing the flame through the sight doors, the brick tube can be kept filled with flame by the ready means provided for adjusting the axial position of the sprayer body in its carriage. A small gap is left between the sprayer cap and the tip plate. When the register is alight, air passes through this gap, thus assisting the initial combustion and by breaking down the low pressure zone in the vicinity of the orifice in the cap, prevents the face of the cap becoming fouled by partially burnt oil particles being drawn back on to it. When not alight this current of air helps to keep the cap cool.

The illustrations on pages 15 to 19 show views of the register, and details of the sprayer and carriage.

A number of novel features have been incorporated in the register as may be seen from the illustrations. These features include the mechanism by means of which the sprayer may be changed in a very short time, the method of securing the sprayer in any desired axial position, the locking device for the air shut off tube, the method of construction of the brick quarl, etc.

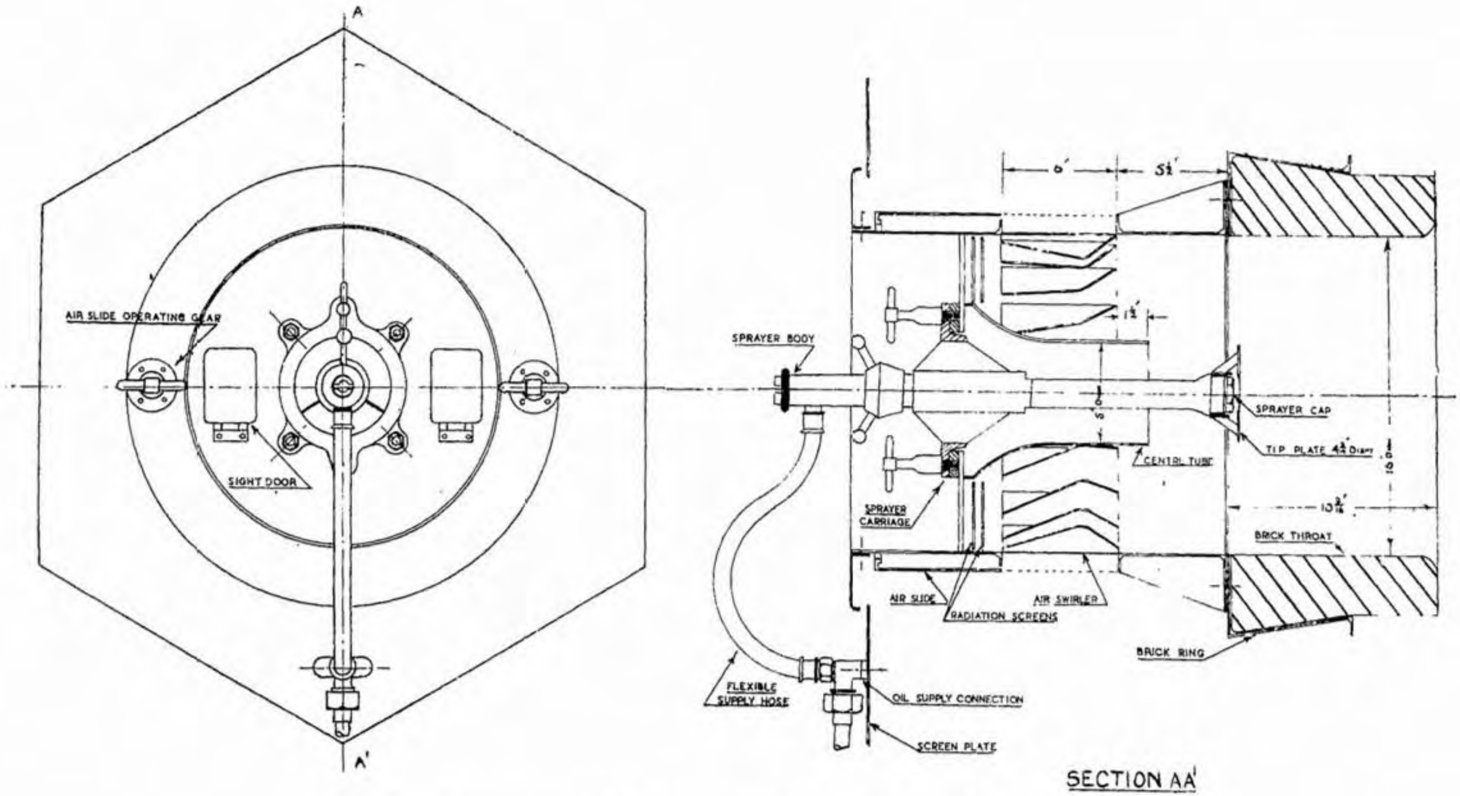

FIG. 8.—ADMIRALTY 1943 REGISTER AS USED IN CLOSED STOKEHOLD.

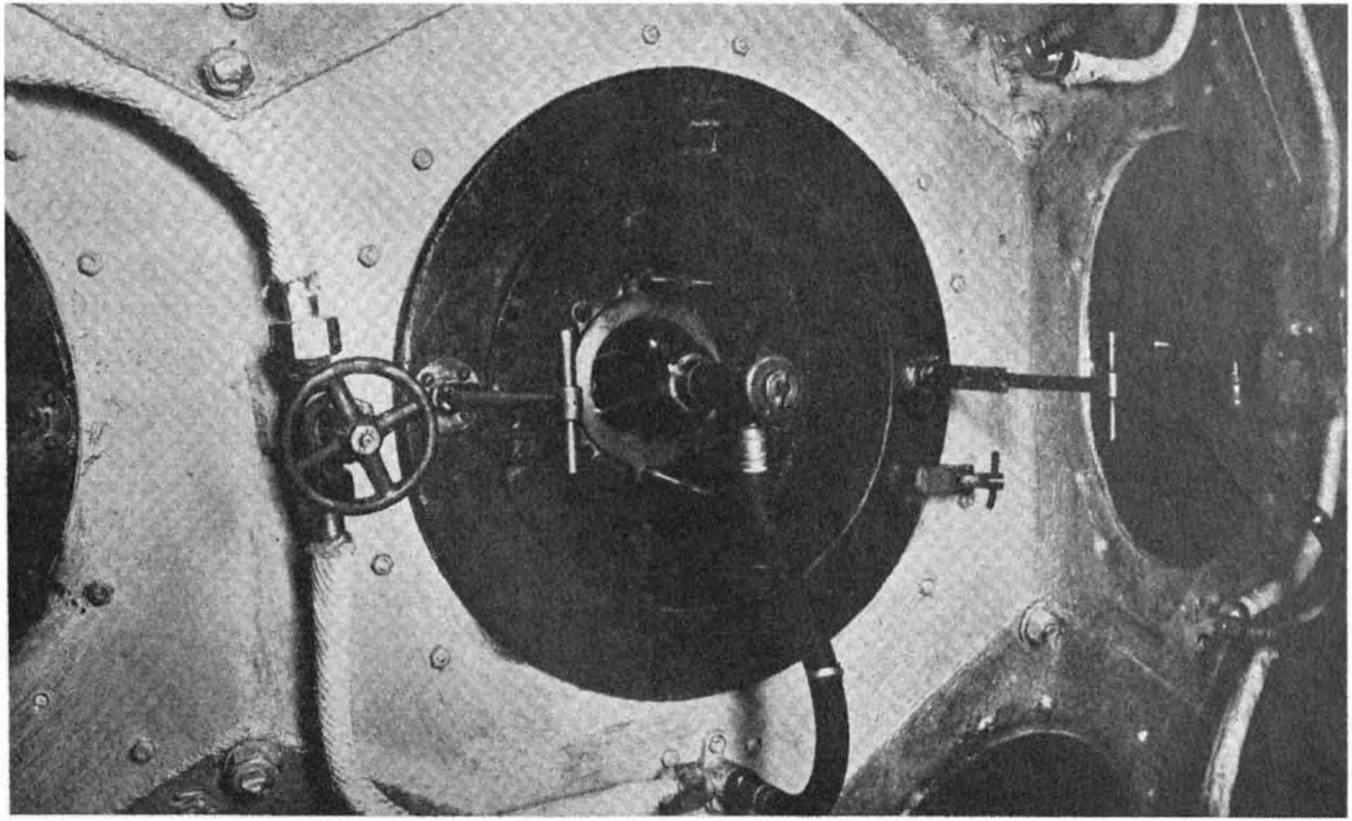

FIG 9.—VIEW OF BOILER FRONT SHOWING ADMIRALTY 1943 REGISTER AND DETAILS OF SPRAYER ASSEMBLY

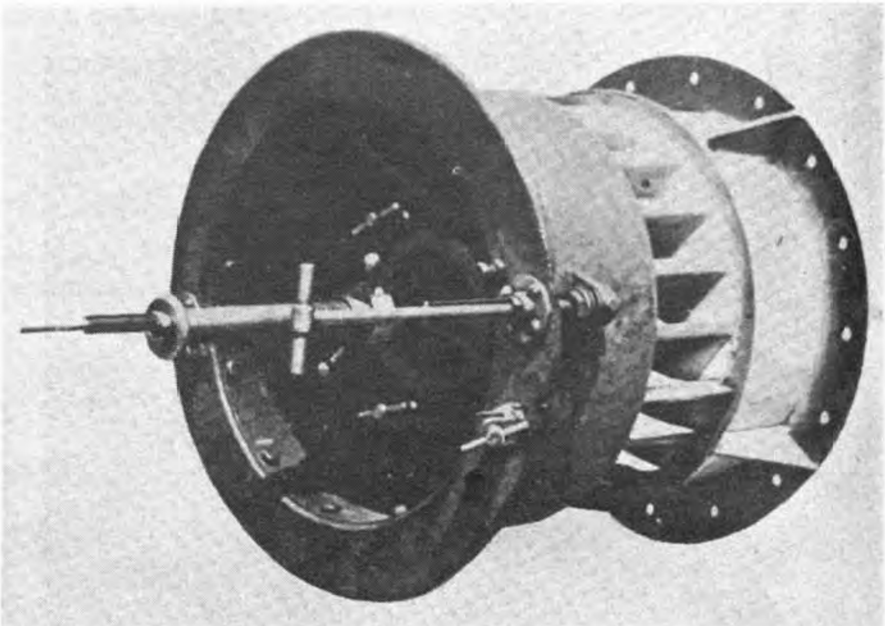

FIG. 10.—REGISTER WITH AIR SLIDE LOCKED IN OPEN POSITION

It will be seen from Fig. 8 that special attention has been given to the seven points enumerated on page 4 by :—

(1) Arranging the sprayer well forward in order that the oil spray does not impinge on the brick tube, the tube being of such a shape that it may be kept filled with flame without oil impingement occurring.

(2) Arranging a primary flame or point of ignition which will remain stable under all conditions and which will not be lost during rapid changes of load.

To maintain a stable point of ignition it is necessary to have a low air velocity in the region of the sprayer cap. Within the 1943 register the swirling air forms a free vortex in the centre of the register and a stable point of ignition could be formed in this region of low pressure without any other devices. It would then be found, however, that as the air pressure varied, the apex of the vortex would shift and to obtain optimum conditions, adjustments would have to be made to the position of the sprayer body every time the air pressure or load is changed. Such a condition would be impossible in a warship, where rapid manœuvrability is essential. In the 1943 register, a strong and stable point of ignition is maintained even when large and rapid changes of air pressures occur, by arranging for air to pass through the centre tube and to strike the back of the tip plate with high velocity, so that a depression is created in front of it. A low pressure area is thereby formed around the sprayer cap whatever its position in the main air vortex. In fact, the greater the velocity of the air striking the back of the tip plate, the greater will be the depression in front of it and the more stable the primary flame.

(3) Improving the atomisation of the oil spray by arranging to burn at higher oil fuel pressures and temperatures. The recommended burning temperature for present day Admiralty fuel oil with the new register is 200° F., compared with the average figure with the old type of register of 165° F. Oil fuel pressures of 200 lb./sq. in. are used for normal steaming. The use of higher oil fuel pressures

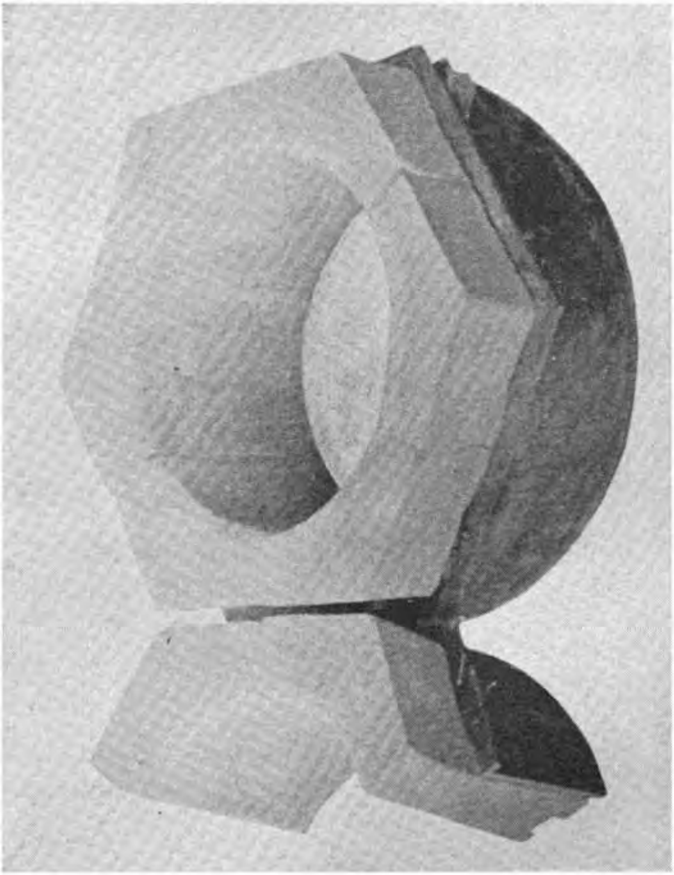

FIG. 11.—BRICK TUBE WITH PART OF ADJACENT QUARL AS POSITIONED FOR BURNERS ANGLED TOWARDS A FOCAL POINT

and temperatures is possible with the new register as it does not depend on the spray angle in order to fill the brick tube with flame, as is the case with the present design of Admiralty registers, where trials have shown that oil pressures over 185 lb./sq. in. are liable to close the spray in to an extent which will cause the flame to miss the brick tube.

(4) Improving the mixture of the oil and air by arranging for the air to be given a swirling motion by the vanes in the register, and by arranging for higher air velocities for a given quantity of fuel by using a smaller diameter brick quarl.

(5) Equalising the air distribution across the boiler front by providing a freer entry for the air to the casings surrounding the burners and by

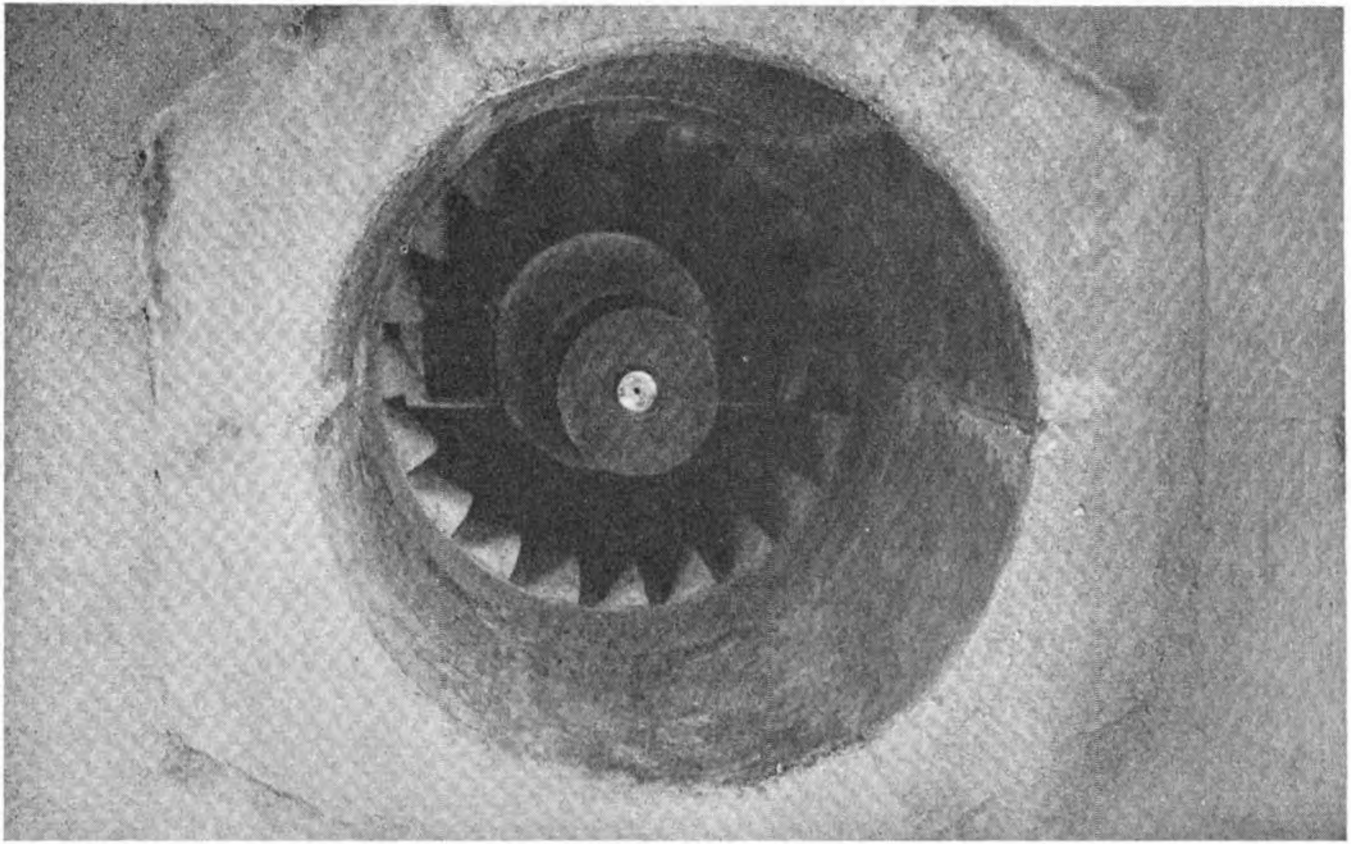

FIG. 12.—REGISTER AND BRICK TUBE AS SEEN FROM INSIDE COMBUSTION CHAMBER. THE SPRAYER CAP SHOWN HAD BEEN IN USE FOR MANY HOURS BUT THERE IS NO EVIDENCE OF CARBON DEPOSIT

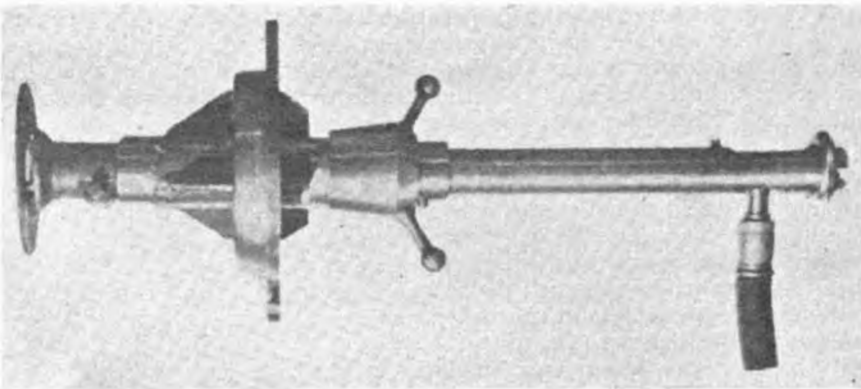

FIG. 13.—SPRAYER ASSEMBLY IN PARKED POSITION, SHOWING TIP PLATE, SPRAYER CARRIAGE AND FLEXIBLE HOSE

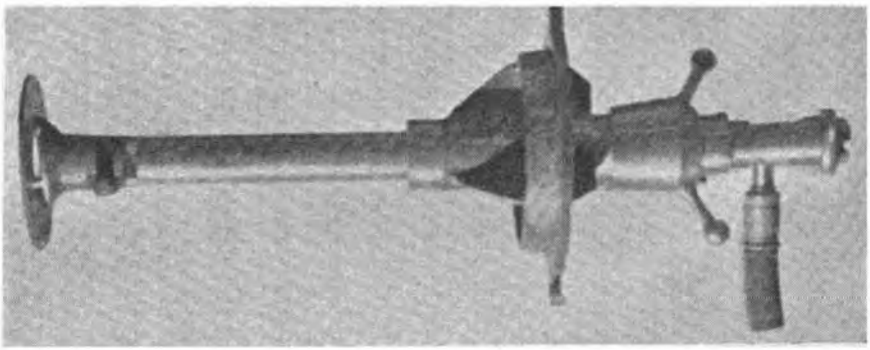

FIG. 14.—SPRAYER ASSEMBLY IN WORKING POSITION. NOTE SMALL GAP BETWEEN SPRAYER CAP AND TIP PLATE

utilising the nozzling effect provided by the resistance to the air passage through the registers. Although very close pitching is used with the new register on the boiler spectacle plate, increased air space is available around the registers by angling them to a focal point situated in the combustion chamber.

(6) Preventing coking of the sprayer caps by arranging for the sprayer and tip plate to be easily retractable when the sprayer is not alight. The sprayer and tip plate can easily be withdrawn into the centre tube and are thereby largely protected from the radiation from the furnace while the slight air leakage allowed protects the sprayer still further from damage by heat.

(7) Burning the oil completely in the available furnace volume is achieved by virtue of the improved atomisation and more intimate air/oil mixing, thereby increasing the rate of combustion. This results in a smaller volume of flame for a given rate of oil being burnt.

When using the new burners, arrangements are made for the boiler front to form a part of the surface of a sphere, and the registers are angled to a focal point in the combustion space. The flames are thus directed away from the water tubes, floor, etc., and clearances are increased. Further, it has been found that one flame supports the other and an increased rate of combustion results. It has also been found advantageous for the proper distribution of the flames in the furnace to vary the direction of rotation of the air through the registers, e.g., in a standard three-drum Admiralty boiler a clockwise rotation of the air for left-hand burners, and an anti-clockwise rotation for those on the right of the boiler tend to give more clearance between the flame and the tubes.

The 1943 register has been designed for use in conjunction with all types of air supply. The original design was intended for use in a stokehold under pressure, and can be used either with the register open to the boiler room, or enclosed in a casing such as is used when the air supply is preheated. In these cases, the supply of air through the centre tube for creating the stable point of ignition is taken direct from the boiler room and enters the register through passageways in the sprayer carriage.

The register may be very easily modified for use in an open stokehold, where the air used for combustion is supplied under pressure through trunking leading to the registers. The air supply to the centre of the register in this instance is taken from ports situated immediately behind the main air supply to the vanes, and the openings in the sprayer carriage are blanked.

(*To be continued*).