RECENT IMPROVEMENTS IN OIL FUEL BURNING EQUIPMENT.*

PART III

As a result of the satisfactory combustion achieved with the 1943 Admiralty register (already described in Part I of this paper) when fitted to the prototype Foster Wheeler controlled superheat boiler during shore trials at Clydebank, approval was given for one boiler room of *H.M.S. King George V* to be fitted with the 1943 Admiralty registers. An opportunity was thus provided not only of testing the new burners under sea-going conditions but also of making a direct comparison with the original closed front burners remaining in the other boiler rooms.

Some trouble had been experienced in the past in this class of ship owing to distortion of the boiler tubes towards the rear of the tube banks. This may have been caused either by having to force the boilers above a safe limit, or by increasing generally the temperature of the gases through the tube banks by using a high percentage of excess air in order to steam without smoke. Observations made in a sister ship during a passage under operational conditions revealed that 100% to 200% excess air was required for a clear funnel.

Conversion of " X " boiler room

As originally fitted, the boilers of *H.M.S. King George V* had nine 17⅞ in. closed front registers with No. 5 sprayer caps. The full power of the ship, 110,000 s.h.p., was obtained when burning 11,000 lbs. of oil per hour under each boiler, which corresponded to eight No. 5 sprayers at an oil pressure of 110 lbs. per sq. in. or seven at 145 lbs. per sq. in.

With the new burning equipment, the combustion of the fuel is complete well within the confines of the furnace proper, which results in more even distribution of steam generation along the length of the tube banks. As the formation of carbon deposits on the brick tubes has been eliminated there should be no occasion to burn with a high percentage of excess air in order to obtain smokeless combustion. These two factors should appreciably reduce the risk of the tube distortion referred to above and a considerable saving of fuel should be effected by the increased efficiency of the boiler.

As already stated in Part II of this paper, the 1943 Admiralty register, on account of the air swirl giving more intimate air/oil mixing, produces, when burning comparative amounts of oil, a flame which is shorter but wider than that obtained with the closed front or the 1941 modified open front. It is therefore necessary to have greater tube/flame clearances to prevent impingement. Greater flame/tube clearances were obtained by angling the burners to a focal point in the combustion chamber and the total flame envelope was reduced in volume by increasing the rate of combustion. The combustion rate is increased by using high oil pressures and so improving the atomisation.

In order to obtain full power with approximately the same boiler room air pressure as with the closed fronts it was necessary to have nine of the new pattern registers. All nine burners were used at full power with No. 3A sprayer caps at an oil pressure of 210 lbs. per sq. in. With the new burner, arrangements are made whereby the sprayer cap is prevented from becoming " carboned " and there should be little need to have an additional sprayer on the boiler to allow for cleaning purposes at full power. Further, a defective sprayer can be changed in a matter of 30 seconds.

---

*PARTS I and II of this article were published in *Papers on Engineering Subjects* Nos. 18 and 19.

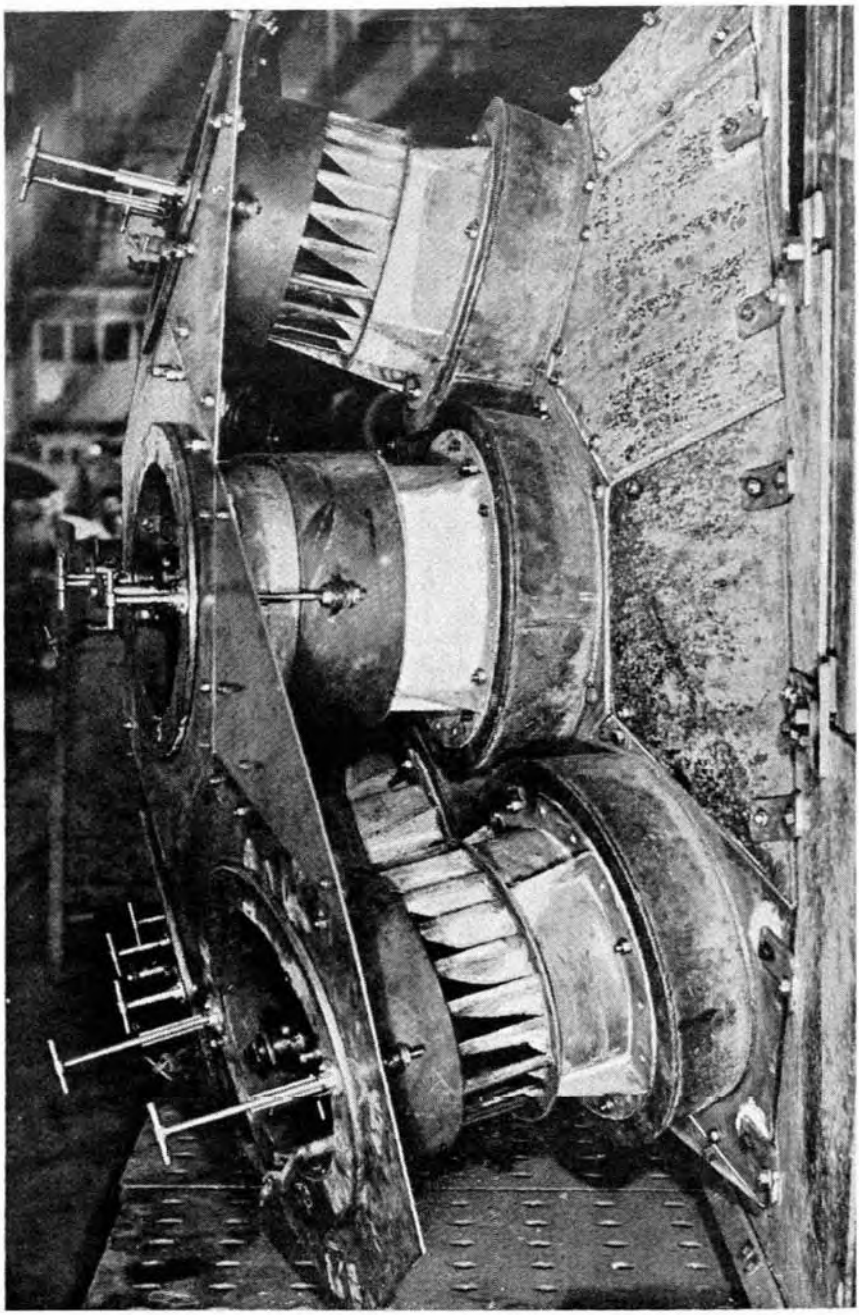


FIG. 1.—SHOWING THE CLOSE PITCHING OF REGISTERS AND AMPLE ROOM FOR THE FREE PASSAGE OF AIR AROUND THE BURNERS

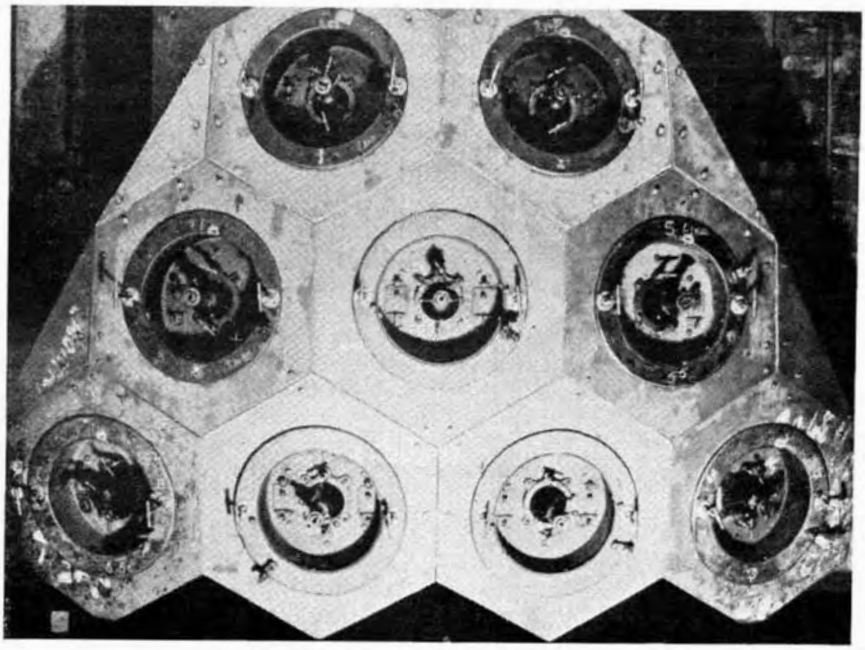


FIG. 2.—THE HEXAGONAL PLATES FORMING THE AIR CASING FOR THE BOILER FRONT OF H.M.S. KING GEORGE V BOLTED TOGETHER BEFORE WELDING

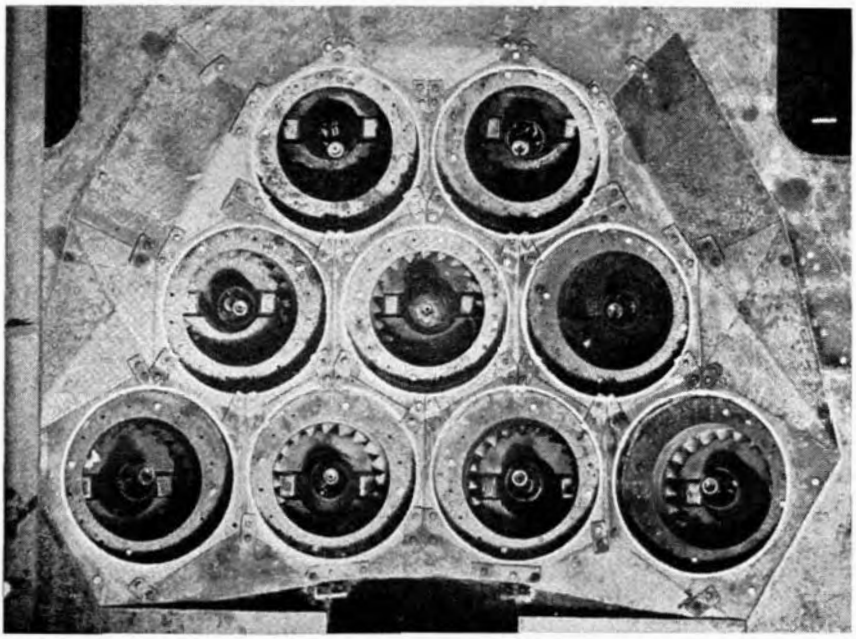


FIG. 3.—THE HEXAGONAL PLATES FORMING THE BURNER SPECTACLE PLATE OF THE BOILER FRONT FOR H.M.S. KING GEORGE V

As stated above, the burners were arranged so that they focus on a common point in the furnace. They were arranged so that their centres lie upon the surface of a sphere of radius equal to the focal length. Angling the burners in this manner in addition to giving increased clearances between the flames and the boundaries of the furnace allows for a very close pitching at the furnace face while still maintaining ample room for the free passage of air around the burners (see Fig. 1).

In the case of *King George V* class boilers, the focal point was chosen as being about 5 ft. from the back wall of the furnace, and the fabricated brick plate approximated therefore to a section of the surface of a sphere of 7 ft. 6 in. radius. This radius gave the necessary degree of angling, while the "bowing" of the fronts did not encroach too much on the stokehold space.

The ideal construction for focused burners is a spherical brick plate, which, in fact, is being fitted in new construction. In the case of conversions in existing ships, however, where the size of the plate that can be easily taken into the stokehold through the boiler room approaches is limited, the brick plate has to be composed of a number of separate pieces. In this instance the spherical plate is approximated to by a number of irregular hexagons, each of which forms a base for the brick ring and burner.

It will be appreciated that if these hexagons were regular figures then gaps would occur between them, and filling pieces would be needed. This was avoided by calculating the filling pieces required and cutting the plates accordingly. Having fixed the position of the basic hexagon and set its adjacent plate at the correct angle, then when all the plates are fitted together such that all their sides are touching, each burner will automatically take on its correct axial relation to the focal point. The new fronts for *H.M.S. King George V* were made by Devonport Dockyard and Figs. 2 and 3 show the hexagonal plates bolted together before welding.

Air and screen casings

These casings also lie on the surface of a sphere. The hexagons of the screenplate, are generated by the radials from the focal point through the corners of the hexagons on the inner brick plate, their size depending, of course, upon the distance between this casing and the brick plate.

A sixth scale model made at A.F.E.S. was found most useful in planning the nine-burner arrangement for *H.M.S. King George V*. Various views of this model are shown in Figs. 4, 5 and 6. One of the boiler fronts for *H.M.S. King George V* after all the various plates had been welded together is shown in Fig. 7.

The new fronts for X boiler room were the first to be made with the above construction. No difficulty was found in manufacturing or welding the fronts and when completed the whole assembly fitted together extremely well. In this case the bowed portion of the brick plate surrounding the burners was lined with a good quality of plastic refractory, as shown in Fig. 8. It is not generally recommended that such large areas should be lined with plastic but at this time no suitable bricks for use in the overhanging portions were available.

Performances during sea trials

The boilers with the new burners were lit from cold without any carbon being formed or any oil dripping from the register. After a few hours auxiliary steaming the boiler room staff had become familiar with the new apparatus and found it easy to maintain a perfectly clear funnel over an indefinite period.

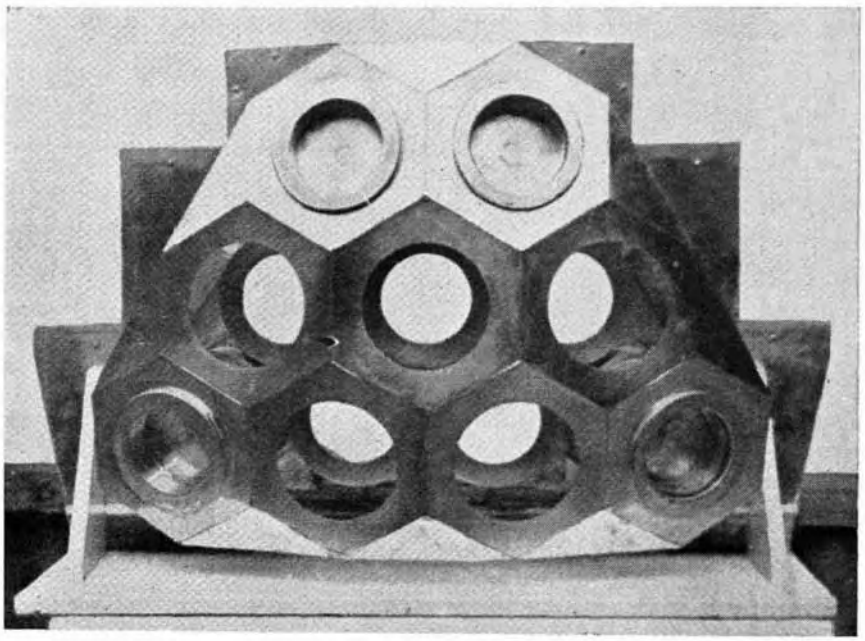


FIG. 4.—FRONT VIEW OF 1/6TH SCALE MODEL OF BOILER FRONT FOR H.M.S. KING GEORGE V

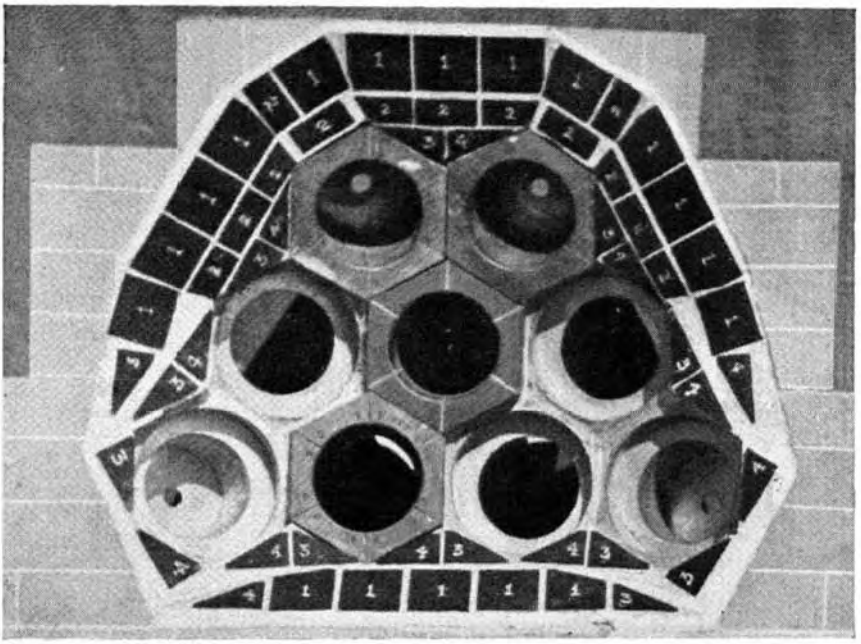


FIG. 5.—VIEW OF BOILER FRONT FROM FURNACE—1/6TH SCALE MODEL OF BOILER FOR H.M.S. KING GEORGE V

They had no difficulty in going through the various movements necessary for putting sprayers on and off.

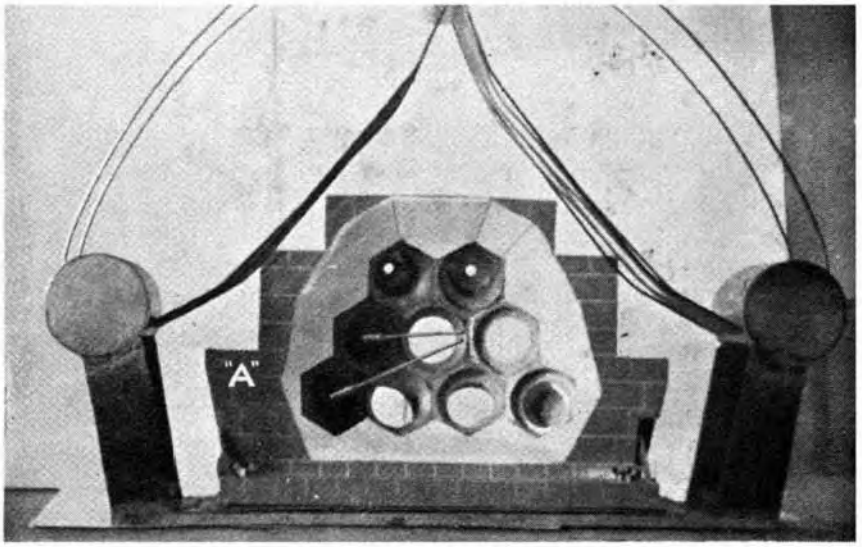


FIG. 6.—1/6TH SCALE MODEL OF BOILER FOR H.M.S. KING GEORGE V

For the basin trial, steam was raised in both X.1 and X.2 boilers. With auxiliary machinery running and the inboard shafts turning at 30 r.p.m. ahead and the outboard shafts at 30 r.p.m. astern, it was possible to take each boiler in turn to an output equivalent to full power. With nine No. 3A sprayers in use at an oil pressure of 220 lbs. per sq. in. (equivalent to 11,100 lbs. of oil per boiler) a clear funnel was obtained at 8.5 in. w.g. air pressure with a CO_2 content in the funnel gases of 13.6%. Each boiler was steamed at full power for approximately 40 minutes, during which time a set of readings was taken. These are shown in Table I.

During the basin trial, the temperature at the floor plates of the boiler room was high, but this was mainly due to a number of steam leaks, and to lagging missing from various auxiliary engines which raised the temperature of the air at the top of the boiler room to such an extent that the discharge from the motor driven fan into the firing space was above 100° F.

An examination of the furnace of X.2 boiler after the basin trial showed there had been no impingement of flame on the boiler tubes. The condition of the plastic refractory was satisfactory, and there were no carbon deposits, either on the furnace floor or on the brick quarls.

During passage to the Fleet Base the ship was working up to full power. Compared with the usual difficulties experienced in steaming the other boilers it was noticeable that in X boiler room there was little for the watchkeepers to do. Throughout the whole period at sea a clear funnel was maintained from X.1 to X.2 boilers.

Full Power Trial

Subsequently, a full power trial of 4 hours duration was carried out, during the first three hours of which X boilers were steamed at a forcing rate

TABLE I
H.M.S. "KING GEORGE V"
TRIALS IN "X" BOILER ROOM WITH HASLAR 1943 REGISTERS
19th JULY, 1944

		X.1 Boiler	X.2 Boiler
Duration of trial		1140—1210	1530—1610
Drum Pressure, lbs./sq. in.		395	400
Superheater Outlet Pressure, lbs./sq. in.		390†	390†
Steam Temperature, ° F.		685	710
No. of Sprayers in use		9	9
Size of Sprayers		3A	3A
Oil Fuel Pressure, lbs./sq. in.		225	222
Oil Fuel Temperature, ° F.		205	202
Air Pressure in Boiler Room, " W.G.		Gauge not working	8.7
Air Temperature in Boiler Room, ° F.		110	112
Air Temperature in Casings, ° F.		275	284
Draught Loss across Registers		6.0" *	6.3" *
Calculated Furnace Temperature, ° F.		2960	3020
Feed Temperature, ° F.		200	200
Funnel Temperatures :	Above Pre-heaters, ° F.	405†	641
	Below Pre-heaters, ° F.	780	762
Gas Analysis :	Percentage CO_2	13.0	(i) 13.0 (ii) 13.4
	Percentage O.2	3.8	3.6 3.0
	Percentage C.O.	Nil	Nil Nil
Funnel seen from Quarterdeck		Clear	Clear
Oil Fuel Consumption by Sprayers, lbs./hour		11,700	11,660
Forcing rate, lbs./sq. ft. T.W.A.		49.6	49.6
Temperature of firing space, ° F.		115	120
Temperature at grating, ° F.		128	134
No. of sprayers alight on opposing boiler		2	3
Tube Wall Area, sq. ft.		235	235
Combustion Chamber Volume, cu. ft.		1008	1008
Oil burnt, lbs./cu. ft.		11.6	11.5
Heat release, B.T.U's/cu. ft.		215,760	213,900

NOTES :—Each boiler was steamed in turn at an output equivalent to Full Power.
† Doubtful figures. * Includes loss through pre-heater and casings.

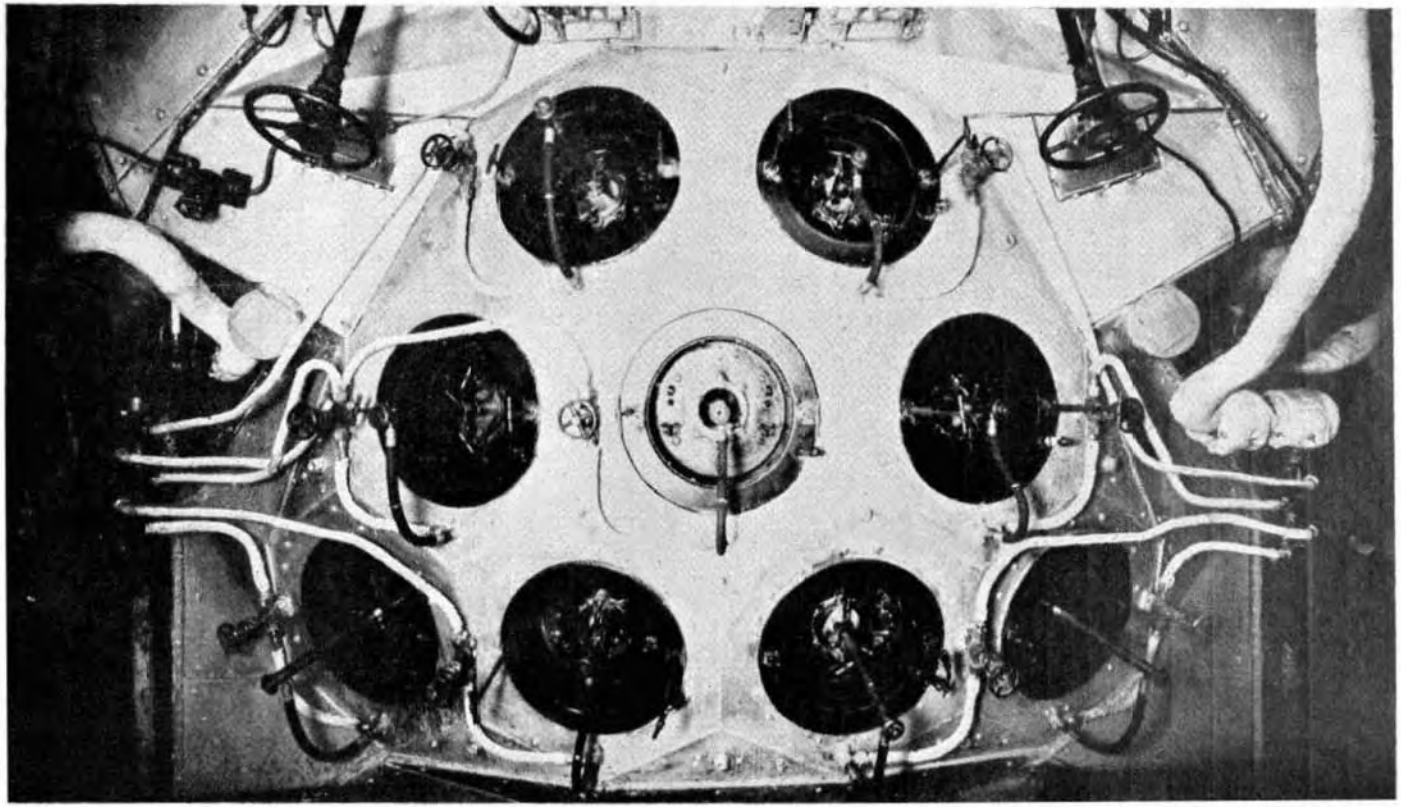


FIG. 7.—BOILER FRONT IN X BOILER ROOM OF H.M.S. KING GEORGE V COMPLETE AND READY FOR STEAMING

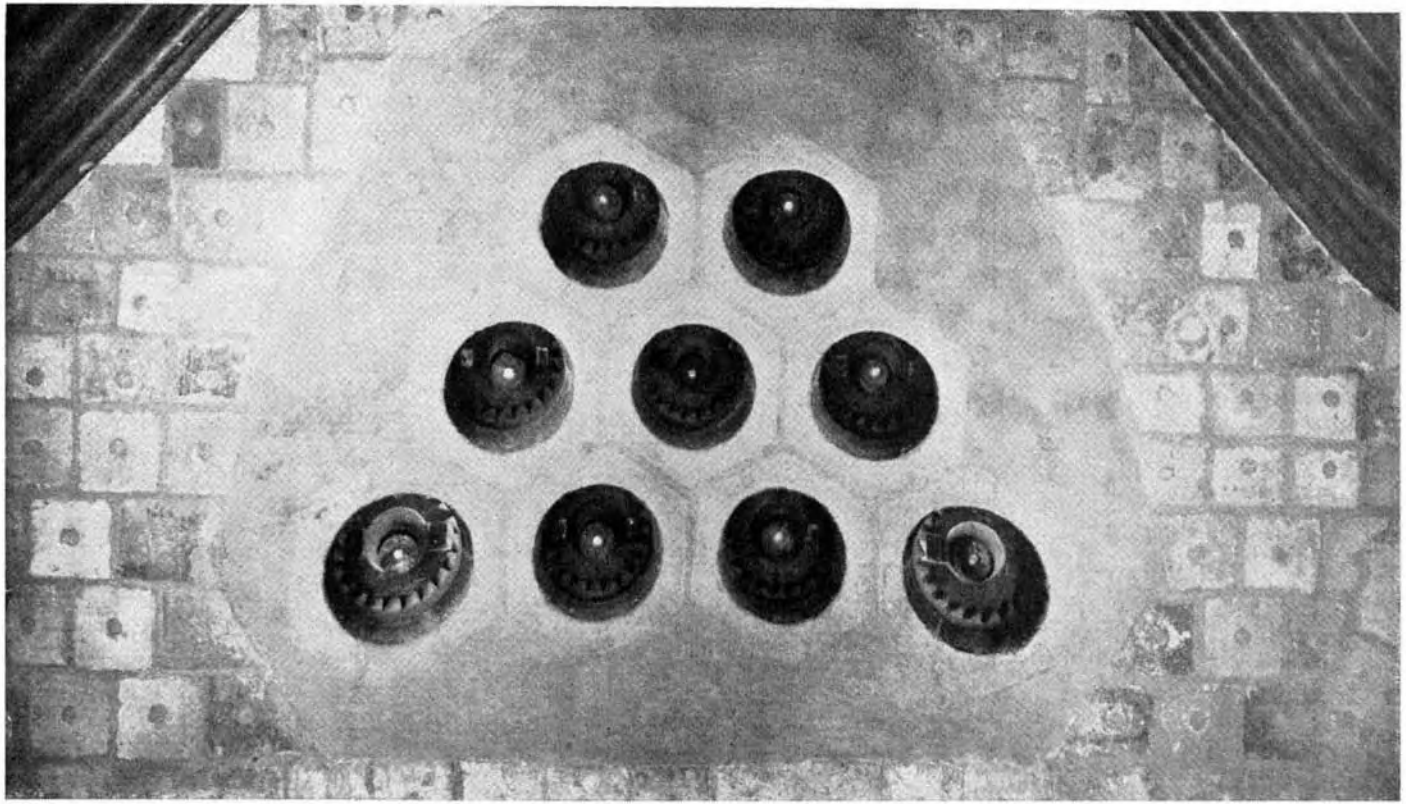


FIG. 8.—VIEW OF BOILER FRONT IN X BOILER ROOM OF H.M.S. KING GEORGE V SHOWING THE NEW TYPE BRICK TUBES AND THE PLASTIC REFRACTORY LINING OF THE BOWED PORTION OF THE FRONT

sufficient to develop 27,500 s.h.p., i.e. the maximum full power of the unit. During the last hour of the trial, however, the speed of the main circulating pump of X unit was reduced, until the vacuum dropped to 25 in. This was done to simulate tropical conditions of sea water temperature and the forcing rate of the boiler was then increased, in order to maintain the S.H.P. of the unit at the same figure.

Under these overload conditions the following figures were recorded during the last hour of the trial.

X-Unit

S.H.P.	27,275
Vacuum	25.0 in. h.g.
Sprayers in use	9 No. 3A.
Oil fuel pressure	250 lbs. per sq. in.
Air pressure in boiler room	8.5. in. W.G.
CO_2 in funnel gases	13.5%
Forcing rate	54 lbs. of oil per sq. ft. t.w.a.

Table II shows the figures recorded in X boiler room during the whole of the trial together with mean figures from other boiler rooms taken over the same period.

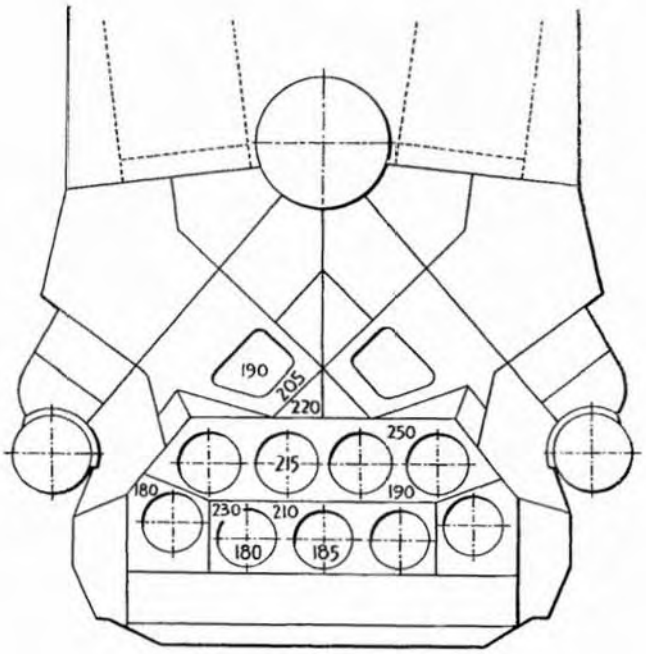
It was found that rather more carbon was made on the brick quarls during the full power trial in *H.M.S. King George V* than is normal with this type of register. It is thought that this may have been due to the fact that throat bricks were not of the correct size, the diameter of the quarls being generally $\frac{1}{2}$ in. too small, and the length too great. In addition the furnace end of the bricks was not sufficiently radiused. An examination of the furnace of X.2 boiler after the full power trial showed that very high furnace temperatures had been attained, but all the brickwork had stood up well and the boiler tubes were perfectly clean with complete absence of unburnt oil. An interesting feature was the fact that no glazing had taken place on the plastic refractory used to line the burner bowl, showing that the percentage of flux in the brand of plastic material used was extremely small.

The temperature of the front casing was of the order of 170° F. This is considerably lower than that which obtained in the other boiler rooms (see Fig. 9). It was found in later conversions of ships of this class that an improvement on this temperature was made by increasing the depth of the lagging behind the front air casing.

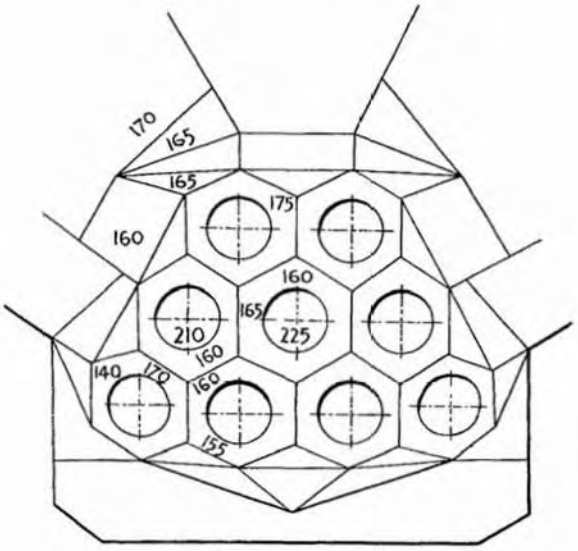
Maintenance of the oil burning equipment

Over a period of some 200 hours steaming at various loads with the new burning equipment, very little maintenance was necessary. Sprayer caps and tip plates were inspected every 24 hours, but on no occasion was it found necessary to clean a sprayer cap and only after a period of steaming at very low oil fuel pressure was any deposit found on the tip-plate. Several of the studs used for securing the register to the spectacle plate sheered when the register was removed for giving access to the furnace. This was attributed to heat fatigue, and arrangements were made to replace these studs with H.T. steel.

After 700 hours steaming no trouble was reported by ship's staff except that a certain amount of spalling had taken place at the furnace face of the throat bricks. An examination showed that these bricks had not stood up well which was rather disappointing, as similar bricks used for the prototype Foster Wheeler Boiler showed little effect after the whole extended series of trials. A subsequent test, however, showed that the material was not up to



Y1. BOILER



X1. BOILER

FIG. 9.—TEMPERATURE IN DEGREES F. OF FRONT CASINGS OF BOILERS OF H.M.S. KING GEORGE V AT FULL POWER

Admiralty Grade A standard. Further sets of correct quality bricks have not caused anxiety, although the spalling is not entirely eliminated. Fig. 10 shows the type of surface crack which develops. In this case, the burner had been in constant use for 300 hours.

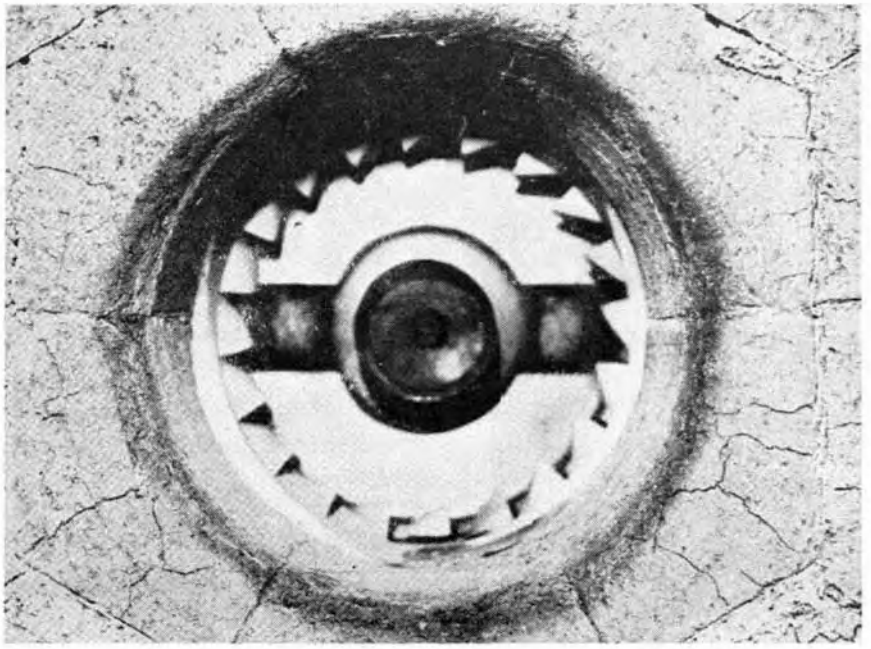


FIG. 10.—THE TYPE OF SURFACE CRACKING WHICH DEVELOPED IN THE QUARL BRICKS OF THE 1943 REGISTERS AFTER 300 HOURS CONTINUOUS USE

Reports received from ships have indicated that the new burners are undoubtedly a success, and it has been estimated that a saving of 5% in fuel consumption has been effected with the boilers converted.

Comparison of combustion in A, B and Y boiler rooms

A, B, and Y boiler rooms were fitted with the standard burning arrangements for this class of ship. The average conditions in these boiler rooms during the trial were 8 No. 5 sprayers burning at 130 lbs. per sq. in. oil pressure and 170° F. oil temperature, with a boiler room air pressure of 9.0 in. w.g.

Table II shows the mean of relevant figures obtained in A and Y boiler rooms for comparison with those taken in X. The usual type of carbon deposits was made by the burners in A, B, and Y. A and B boilers usually showed from a light to a heavy haze at the funnel at full power. Y boilers maintained a clear funnel throughout the trial, but under this condition even after making all possible adjustments for optimum burning the highest CO_2 recorded was of the order of 9.6%.

H.M.S. Duke of York and H.M.S. Anson

The conversion of *H.M.S. King George V* proved sufficiently successful to warrant the conversion of all boilers in *H.M.S. Duke of York* and *H.M.S. Anson* to the 1943 type of register.

TABLE II

H.M.S. "KING GEORGE V"

DATA OBTAINED DURING FOUR HOURS FULL POWER TRIAL

	Boiler	1st hr.	2nd hr.	3rd hr.	Over-load 4th hr.	Mean Conditions in other Boiler Rooms.			
						Y1	Y2	A1	A2
Steam Pressure in Drums lbs./sq. in.	X1 X2	392.5 397.5	400 397.5	396.5 395	395 395	390	400	400	400
Steam Pressure at Superheater Outlet	X1 X2	387.5 392.5	390 392.5	383.5 386	382.5 385	—	—	—	—
Steam Temperature ° F.	X1 X2	685 685	670 680	687.5 687.5	675 672	685	677	700	692
No. and Size of Sprayers in use	X1 X2	9 No. 3A	9 No. 3A	9 No. 3A	9 No. 3A	8 No. 5		8 No. 5	
Oil Fuel Pressure lbs./sq. in.	X1 X2	220 222.5	215 215	197.5 200	238 243	— —	— —	— —	— —
Oil Fuel Temperature	X1 X2	197.5 193.5	192.5 188	178 186	185 186.5	177	177	177	175
Boiler room Air Pressure " W.G.	X1 X2	8.7	8.7	7.6	8.3	9		8.9	
Draught loss across Register " W.G.	X1 X2	4.6	4.8	4.2	4.5	—	—	—	—
Gas Analysis % CO_2	X1 X2	11.5 12.8	12.0 13.0	13.2 13.5	13.05 13.5	9.5	9.7	—	—
Funnel	X1 X2	Clear	Clear	Slight haze	Clear	Slight haze		Slight haze	
Gas Temperature above Preheater ° F.	X1 X2	625	620	592.5	611	630	625	692	—
Gas Temperature below Preheater ° F.	X1 X2	795 770	835 770	755 730	755 752	—	—	773	765
Temperature at Gratings ° F.	X1 X2	88	92	95	97	—	—	—	—
Temperature at Firing Space ° F.	X1 X2	108	103	106	107	99	—	—	—
Feed Pump Discharge Temp ° F.	X1 X2	190	191	190	197	150	—	195	—
Oil Consumption lbs./hr.	X1 X2	11,760 11,635	11,610 11,505	10,975 11,120	12,220 12,340	12,000 per boiler		12,320 per boiler	
Forcing Rate	X1 X2	49.8 49.4	49.7 49.0	46.6 47.2	51.6 52.3	50.8		52.2	

An exactly similar arrangement of burners and casings was installed. In this case, however, the new pattern anchor bricks were used to line the bowl surrounding the burners instead of the plastic, and the vanes of the burners were fitted so that half the register gave a clockwise and half an anti-clockwise

air swirl. The clockwise and anti-clockwise registers were arranged so that the tops of the flames were swirled away from the adjacent tubes. This feature can be seen in Part II, Fig. 7. It is thought that contra rotating flame swirl not only provides increased flame/tube clearance but also produces more intimate air/oil mixing. This was shown during the basin trials in both *Duke of York* and *Anson* where a clear funnel was obtained at the full power of the boilers with a gas analysis of 14.0 to 14.5% CO_2, an improvement on the figure obtained in *H.M.S. King George V.*

H.M.S. "Manxman"

The boilers of the fast minelayers have given considerable trouble with tube distortion. Here it was found that it was not possible to steam at full power without making smoke. These boilers are very highly forced and at full power the circulation was nearing the critical point even with good combustion. When the burning was such that the combustion was not completed in the furnace it was possible that conditions would arise when the circulation became unsafe. It was decided therefore that the boilers of this class should be fitted with unheated downcomers, and that *H.M.S. Manxman*, which was refitting at the time, should have her burning equipment converted to the 1943 burners.

The fronts for these boilers were originally fitted with nine closed type registers and No. 5 sprayer caps. Full power was obtained with all sprayers in use at 200 lbs. per sq. in. oil pressure. Under these conditions, the fans were usually working at their maximum load.

In order to obtain smokeless combustion at full power with the same fans

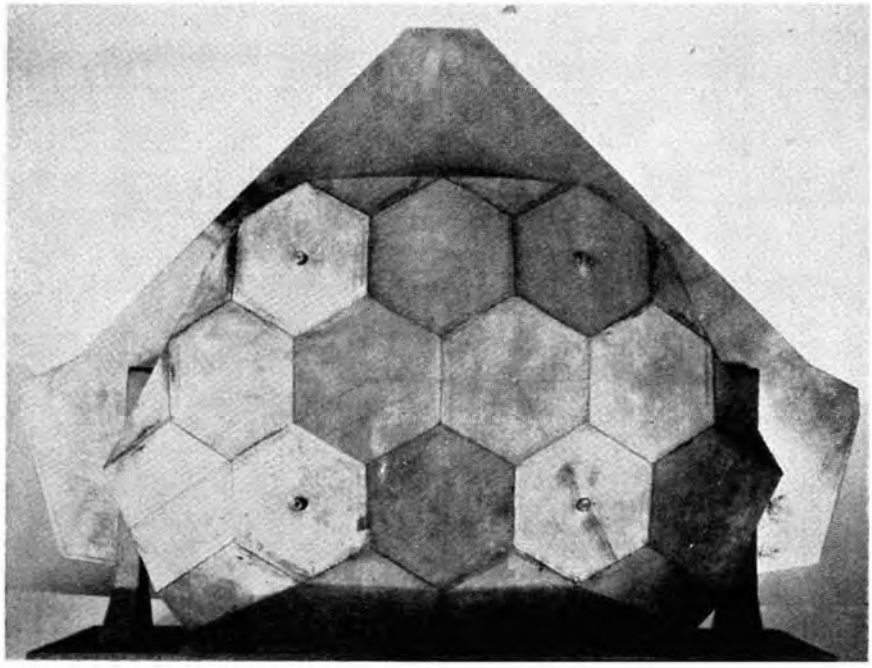


FIG. 11.—FRONT VIEW OF EIGHTH SCALE MODEL OF TWELVE BURNER FRONT FOR H.M.S. MANXMAN

it was necessary to fit twelve of the 1943 registers. The burners were angled to a focal point in the combustion chamber.

These ships have two boilers in each boiler room and there is very little room on the firing space as most of it is taken up with pumps and auxiliary machinery. The dimensions of the boilers are small, and the furnace short. To have angled the burners to the optimum amount for tube clearances would, with a twelve-burner front, have resulted in the bowed front air casing encroaching too much on the firing space. A compromise had to be made, and it was found that the same degree of angling as used for the *King George V* class of ship was the most suitable. The burners were therefore arranged on a section of a sphere of radius 7 ft. 6 ins. As before, the burner plate was made of a series of irregular hexagons, the arrangement being shown in Fig. 11, which is a photograph of an eighth scale model.

Sea trials proved successful, full power being obtained with twelve No. 4 sprayers at 200 lbs. per sq. in. and 205° F. with 7.5 in. of air pressure in the boiler room. There was no flame impingement on the tubes, and the ship was steamed at full power without any smoke from the funnels. It was unfortunate that the Orsat for CO_2 measurements was broken during transit to the ship, but figures obtained for draught loss across the registers indicated that very little excess air was needed for smokeless combustion.

H.M.C.S. Ontario

Although it was originally intended to fit this vessel with the standard closed front arrangement of the improved *Fifi* class, the sea trials in the foregoing ships had shown such successful combustion that a last minute change to the new burners was made.

TABLE III

H.M.C.S. "ONTARIO"

DATA OBTAINED DURING SEA TRIALS

Duration of trial ..	2 hours	1 hour	2 hours	2 hrs. full power
S.H.P.	20,000	23,000	72,500	77,600
Fuel Consumption all purposes, lbs./S.H.P./hr.	1.11	1.21	.735	.732
Steam Pressure, lbs./sq. in.	394	396	401	401
Steam Temperature, ° F.	592	606	630	633
Sprayers in use No. 5 caps	F A 8 7	F A 10 8	F A 18 17	F A 18 18
Oil Temperature, ° F.	179	184	194	189
Oil Pressure, lbs./sq. in.	F A 202 198	F A 160 187	F A 251 258	F A 270 258
Fuel Oil Consumption tons per hr.	9.94	12.58	12.2 11.89	12.59 12.45
Air Pressure, " W.G.	7.0 4.2	7.0 5.1	11.0 11.5	10.9 11.5

The boilers are approximately of the same dimensions as the *King George V* class and exactly the same burner arrangement and type of front were used. The boilers are, however, more highly forced and it was found necessary to use No. 4 size sprayer caps in order to obtain full power. With these caps full power was obtained at 260 lbs. per sq. in. oil fuel pressure.

Under these conditions the amount of oil passing through each burner was 1,600 lbs. per hour and naturally a high draught loss was required across the burner. The fan power of the ship was adequate, however, and full power was obtained with 11.0 in. w.g. air pressure in the boiler room. The combination of high oil fuel pressure and high draught loss resulted in excellent combustion at full power. Readings obtained during sea trials at various powers with this vessel are shown in Table III.

" Black Swan " Class sloops with Foster Wheeler boilers

Several of the *Black Swan* class sloops are fitted with Foster Wheeler " D " type boilers. These boilers were designed with three 17⅜ in. diameter quarl closed front registers fitted with No. 3 size sprayer caps. Sea trials in the first ship of the class, *H.M.S. Woodpecker*, showed that the combustion was not good. At all powers very heavy carbon deposits built up on the brick quarl and there was a continuous mild form of pulsation of the boiler front. Similar conditions occurred in *H.M.S. Wren* ; and although the gaiters and sprayer extensions fitted to *H.M.S. Chanticleer* considerably reduced the carbon deposits, the combustion was still considered unsatisfactory.

The next ship of the class, *H.M.S. Hind*, was fitted with 1941 modified open fronts. Combustion was good, and there was a notable reduction in carbon deposits, but the slight pulsation persisted at certain powers. The 1943 registers were fitted in *H.M.S. Mermaid*, which was in fact the first ship to go to sea with this type of burning equipment.

The registers were of 12 in. diameter, four in number, with No. 2 size caps. In this case, the original flat front was retained, and there was some evidence at the higher powers of flame impingement on the tubes. These furnaces are narrow, consequently future ships will have the same arrangement of burners except that they will be angled to a focal point in the furnace.

H.M.S.s Alacrity and *Opossum* have the same arrangement as *H.M.S. Mermaid. H.M.S. Snipe* and *H.M.S. Sparrow* will be the first ships with the angled burners. Fig. 12 illustrates the arrangement.

Trials in H.M.S. " Mermaid "

With the 12 in. 1943 burners, satisfactory combustion was obtained, carbon deposits were negligible, and the pulsation experienced in previous ships of the class were absent.

Although there is a higher draught loss through the register with the new burners, it was found possible to bring the air pressure required in the boiler rooms at full power to that of the previous ship of the class (*H.M.S. Hind*) by removing the gas deflection baffles in the boiler. These baffles were included in the original design to increase the boiler efficiency by increasing the draught loss through the tube bank. When the new burners were fitted, it was interesting to note that from the funnel temperatures and CO_2 figures recorded, removing the gas baffles made little difference to the boiler efficiency, and did not result in hot spots on the boiler casings. It was noticeable that successive ships of the class required to burn more and more oil in order to obtain their full power R.P.M. This was no doubt in some degree due to an increase in the number and size of the auxiliaries, and ship's draught.

While the new burners were designed for the combustion of 2,140 lbs. of

oil/hour/boiler, which gave the nominal designed full power of the boiler, the actual amount of oil burnt during the full power trial of *H.M.S. Mermaid* was of the order of 2,800 lbs. of oil per hour per boiler. Hence, the registers and fans were capable of giving smokeless combustion at about 30% above the rated full power.

After trials in other ships of the class, the absence of carbon deposits with the new burners was most marked, and it was significant that during the whole of the four hours full power acceptance trial a clear funnel to a very slight haze was maintained, and although the brick quarls were not cleaned during the period, no change in air pressure was necessary.

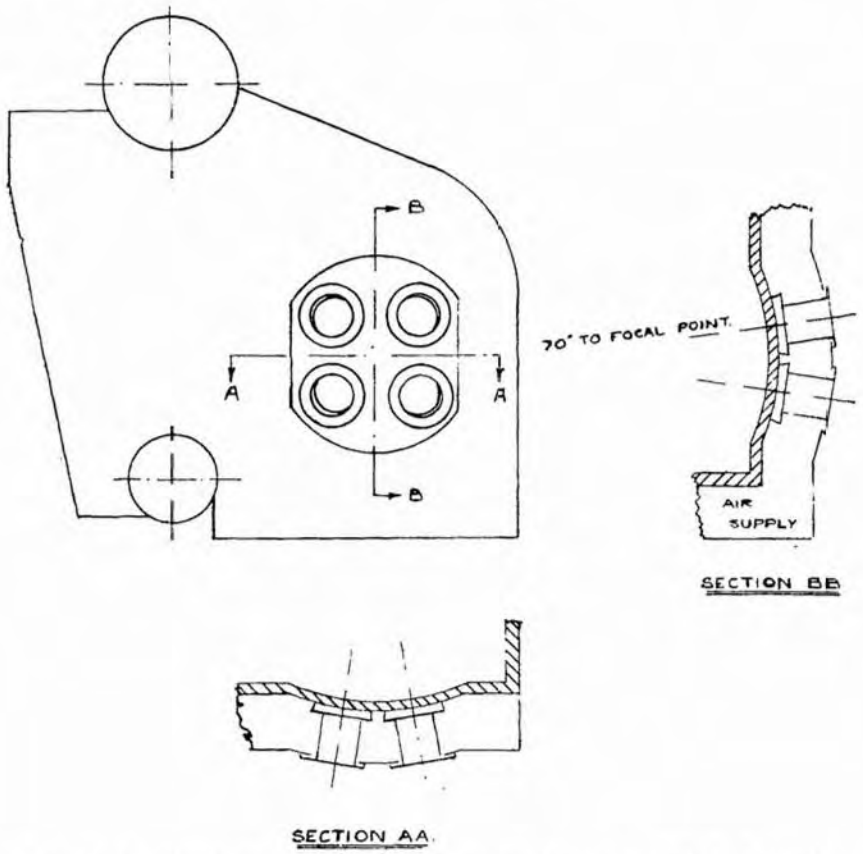


FIG. 12.—ARRANGEMENT OF 1943 REGISTERS ON THE BOILERS OF H.M.S. SNIPE AND H.M.S. SPARROW

Table IV sets out the mean of readings obtained during the full power trials of ships of this class fitted with Foster Wheeler boilers.

It is interesting to note the differences in the percentage of CO_2 in the funnel gases of this class of ship compared with the *King George V* class ; and to observe that the reciprocating oil fuel pumps in these ships were fitted with air vessels which were hardly large enough for the increased amount of oil

TABLE IV

DATA OBTAINED DURING 4 HOURS FULL POWER ACCEPTANCE TRIALS OF VARIOUS "BLACK SWAN" CLASS SLOOPS WITH FOSTER WHEELER "D" TYPE BOILER

Ship	No. and size of sprayers	Oil Fuel Pressure lbs./sq. in.		Oil Fuel Temperature ° F.		Air Pressure " W.G.		Feed Temperature ° F.		Funnel Temperature ° F.		CO_2 Percentage		Vacuum ins. H.G.		R.P.M.		Remarks
Boiler No.	..	1	2	1	2	1	2	1	2	1	2	1	2	P	S	P	S	
H.M.S. Woodpecker	3 No. 3	92	125	180	—	2.5	3.0	206	194	572	612	12.7	12.7	—	—	—	—	Total S.H.P., 4,475
H.M.S. Wren ..	3 No. 3	110	115	176	170	3.2	3.4	—	—	630*	670	—	—	—	—	—	—	* Unreliable thermometer
H.M.S. Chanticleer	3 No. 3	139	147	184	184	4.1	3.8	155	157	775	710	12.6	12.8	—	—	—	—	Feed temperature low (leaky exhaust vv. to condenser).
H.M.S. Hind ..	3 No. 3	151	143	168	174	4.7	5.1	207	203	731	755	11.3	10.9	28.0	28.1	301	305	Ship 100 tons lighter in water than others, but fuel consumption high.
H.M.S. Mermaid..	4 No. 2	209	211	190	197	4.7	5.1	183	196	788	741	11.5	10.8	27.5	27.5	298	298	Ship fully laden.
H.M.S. Mermaid..	4 No. 2	135	134	196	215	3.0	3.3	—	—	652	683	10.7	10.5	—	—	260	260	Nominal F.P. oil consumption for each boiler.
H.M.S. Alacrity ..	4 No. 2	204	247	192	197	4.8	5.4	186	199	760	730	—	—	27.3	27.7	294.3	295.2	Total oil fuel consumption, 5,660 lbs./hr./boiler.
H.M.S. Opossum	4 No. 2	229	248	205	200	4.7	4.6	201	189	791	786	—	—	27.5	27.5	300	300	Total oil fuel consumption, 5,720 lbs./hr./boiler.

Oil fuel used in H.M.S. "Mermaid" at full power, 5,480 lbs./hr. compared with 5,286 lbs./hr. in H.M.S. "Hind" and 4,425 lbs./hr. in H.M.S. "Woodpecker." H.M.S. "Chanticleer's" oil consumption was heavier than her predecessors owing to low feed temperature.

required. Consequently, the oil fuel pressure was fluctuating widely during the trials, and in order to maintain a mean of say 210 lbs. per sq. in., a continual swing in pressure from 190-230 lbs. per sq. in. was recorded. This was a severe handicap to combustion and had an adverse effect on the percentage of CO_2 : as in order to maintain a clear funnel at all times it was necessary to supply sufficient air for the maximum oil output with consequent excess air at the lower swing of the pump.

It is considered that the following advantages have been obtained by fitting the 1943 burners :

(1) Improved operational conditions by eliminating funnel smoke and sparks.
(2) Enabling a higher forcing rate to be achieved with less risk of damage to boiler tubes.
(3) A longer life to furnace refractories.
(4) A saving of fuel, probably of the order of 5% or more.
(5) Less arduous work for the men to maintain correct combustion.
(6) Greater comfort and cleanliness in boiler rooms.
(7) A reduction of external deposits and of birds-nesting in the tube banks and superheaters.

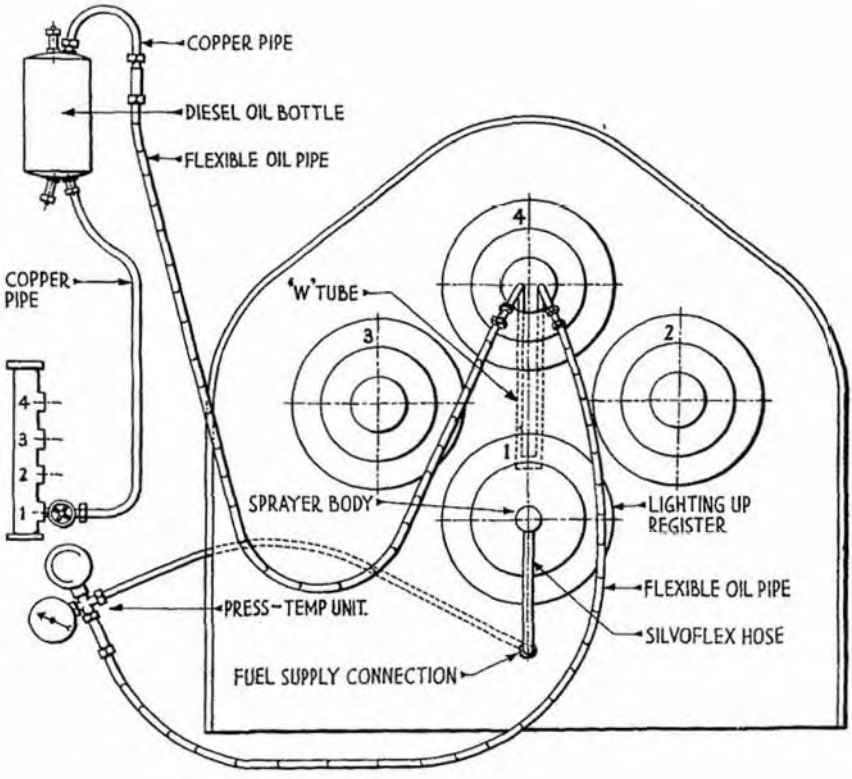


FIG. 13.—ARRANGEMENT FOR LIGHTING UP FROM COLD

Concurrently with the above burner conversions, a new method has been devised for lighting up boilers from cold.

Lighting up a boiler from cold

The normal method of lighting up when no steam is available, which involves the crude and dirty practice of building a bonfire of oily waste around the U-tube called for revision. By inserting the U-tube through the brick tube of the burner to be used for lighting up, the oil spray is interrupted and results in a great deal of oil dripping both inside and outside the furnace, the former causing damage to brickwork and the latter constituting a danger of fire. Other objections are large quantities of unburnt oil forming deposits on the brickwork and boiler tubes, the production of much black smoke, and heavy deposits of carbon on the brick tubes and elsewhere.

The newer method of lighting up from cold employs :—

(1) A Diesel bottle.
(2) A " W " Tube.
(3) A combined pressure and temperature unit.
(4) A small portable electric-driven fan.

A typical layout of the arrangement is shown in Fig. 13.

The Diesel bottle is inserted in the line between the manifold and the cold leg of the " W " tube. The bottle is filled with approximately 1½ gallons of Diesel oil and the " W " tube is inserted through the brick tube of a register above that to be used for lighting up. Heavy oil is supplied in the ordinary manner by the hand or electric pump to the manifold and by following the diagram it will be seen that the Diesel oil will be forced from the bottle to the sprayer. As Diesel oil requires no preheating it can be lit at once by a torch provided the pressure from the pump is well maintained. The quantity of Diesel oil is sufficient to provide enough heat to bring the whole to a working temperature before the heavy oil reaches the system, so the gradual transition from light to heavy oil has no ill effects upon the combustion.

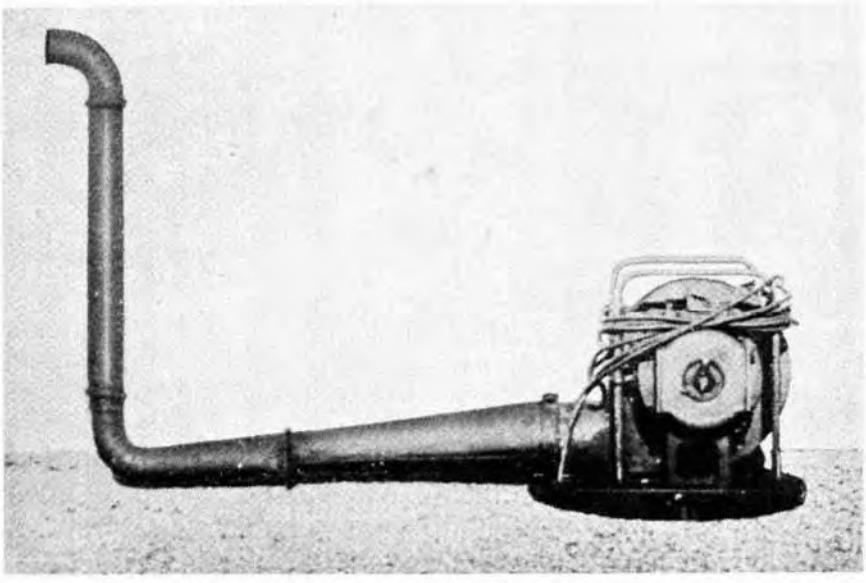


FIG. 14.—PORTABLE FAN FOR LIGHTING UP FROM COLD

In order to establish a positive draught in the right direction and to complete the combustion as far as possible, a small portable fan fitted with a 3 in. diameter trunk on the discharge, as shown in Fig. 14, is so placed that the air is directed into the centre of the register used for lighting up. The size of the sprayer caps used for lighting up will depend, of course, on the boiler, but in no case should it ever be necessary to use a cap larger than No. 2 size, for provided the oil pressure is kept high this size of cap will pass the maximum quantity of oil (700 lbs./hr.) which the " W " tube is capable of heating to the correct temperature.

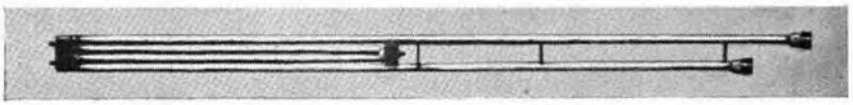


FIG. 15.—" W " TUBE FOR LIGHTING UP FROM COLD WITH 1943 REGISTER

When using this method particular attention must be paid in the initial stages when the oil temperature will rise very rapidly; it should not be allowed to exceed 200° F., and the position of the " W " tube should finally be adjusted to maintain a steady temperature of from 180 to 190° F. The " W " tube, illustrated in Fig. 15, gives an increased total heating surface without extending the overall length of the tube. It will be noted that cleaning plugs are provided. The illustration on page 4 of *Papers on Engineering Subjects No.* 19 shows a Diesel bottle mounted on a prototype boiler.

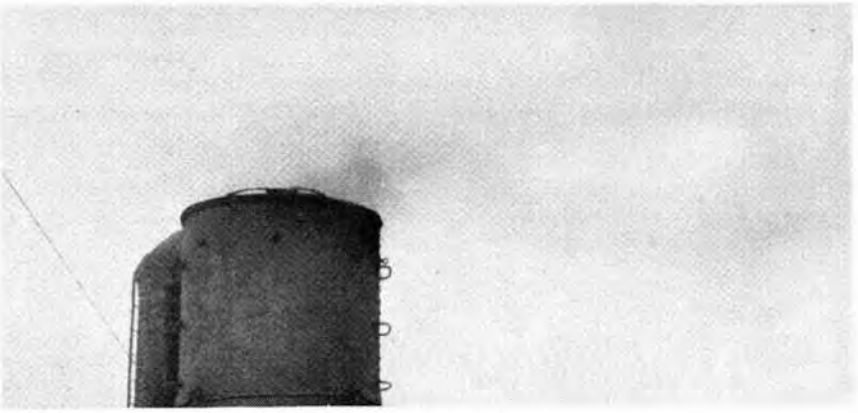


FIG. 16.—ALMOST COMPLETE ABSENCE OF SMOKE WHEN LIGHTING UP FROM COLD WITH DIESEL FUEL USING " W " TUBE AND PORTABLE FAN

Very clean and efficient lighting up with almost a complete absence of smoke can be obtained when using the above method. This is clearly illustrated in Fig. 16, which was taken during lighting up operations with the new equipment.