RECENT IMPROVEMENTS IN OIL BURNING EQUIPMENT.*

— PART II —

Initial trials of the 1943 register were carried out with the 12 in. diameter design at Haslar. Two registers were used on the boiler in order to obtain comparative data while making the numerous alterations in design as devepment work proceeded. The combustion obtained was considered so successful that it was decided to embody the same principles in a 16 in. diameter register, intended to be suitable for fitting in all classes of ships having large boilers up to the highest output.

The 16 in. prototype register, designed according to the principles described in Part I of this paper, gave satisfactory combustion at A.F.E.S. when burning with all sizes of sprayer cap from No. 2A to No. 6 (750 to 1,850 lbs. oil per hour). When burning 1,850 lbs. oil per hour in this boiler, a draught loss of 3.5 in. water gauge was required, but with only one register in use it was not possible to get accurate data for flame/tube clearances, or for the draught loss required at various forcing rates. It was decided, therefore, that a full scale trial should be carried out with a battery of these new burners fitted to the test boiler from *H.M.S. Vanguard* during shore trials at Clydebank. As the first series of trials for ascertaining the performance of the boiler was carried out using the 1941 modified open fronts, a useful opportunity was provided for comparing the two designs of burner.

Shore trials in "Vanguard" test boiler

The general arrangement of the battery of seven 1943 Admiralty burners fitted to this boiler is shown in Fig. 1. The registers were fitted on the boiler front in the same position as the modified open fronts, the standard Admiralty pitching for this front being maintained. Trials were carried out with the same size of sprayer cap as with the modified open fronts, and for corresponding loads the same oil fuel pressures and temperatures were used. The first trials with the new burners indicated that the flame obtained was shorter and wider than with the usual Admiralty burning equipment.

As the registers were located close to the furnace floor, there was a certain amount of impingement by the wider flame and a quantity of carbon up to 4 in. thick built up on the floor bricks.

The whole of the burner front carrying the registers was then raised by 9 in. Raising the burners this amount from the furnace floor, cured the trouble of carbon deposits, but in doing so, the burners had been brought nearer to the water tubes and the top wing registers had not now sufficient clearance to allow for combustion to be completed before the flame impinged on the tubes. The impingement of flame from these wing burners caused a certain amount of smoke, which could not be entirely cleared by increasing the air pressure. Consequently when trials were carried out with seven burners in use on the boiler, unduly high air pressures were recorded. In order to narrow the flame and cut down air resistance, the air swirl was reduced by decreasing the depth of the vanes. This modification gave a certain amount of improvement but was not sufficient to completely prevent flame impingement. Trials were carried out at various loads up to full power with the new burners while draught loss readings with different sizes of sprayer caps and at different oil fuel pressures were obtained. The new burners gave a very short and intense flame and it was possible to burn continually with complete absence of carbon deposits on the brick tubes and tip plates. The draught loss trials indicated

*The first part of this article appeared in *Papers on Engineering Subjects No.* 18.

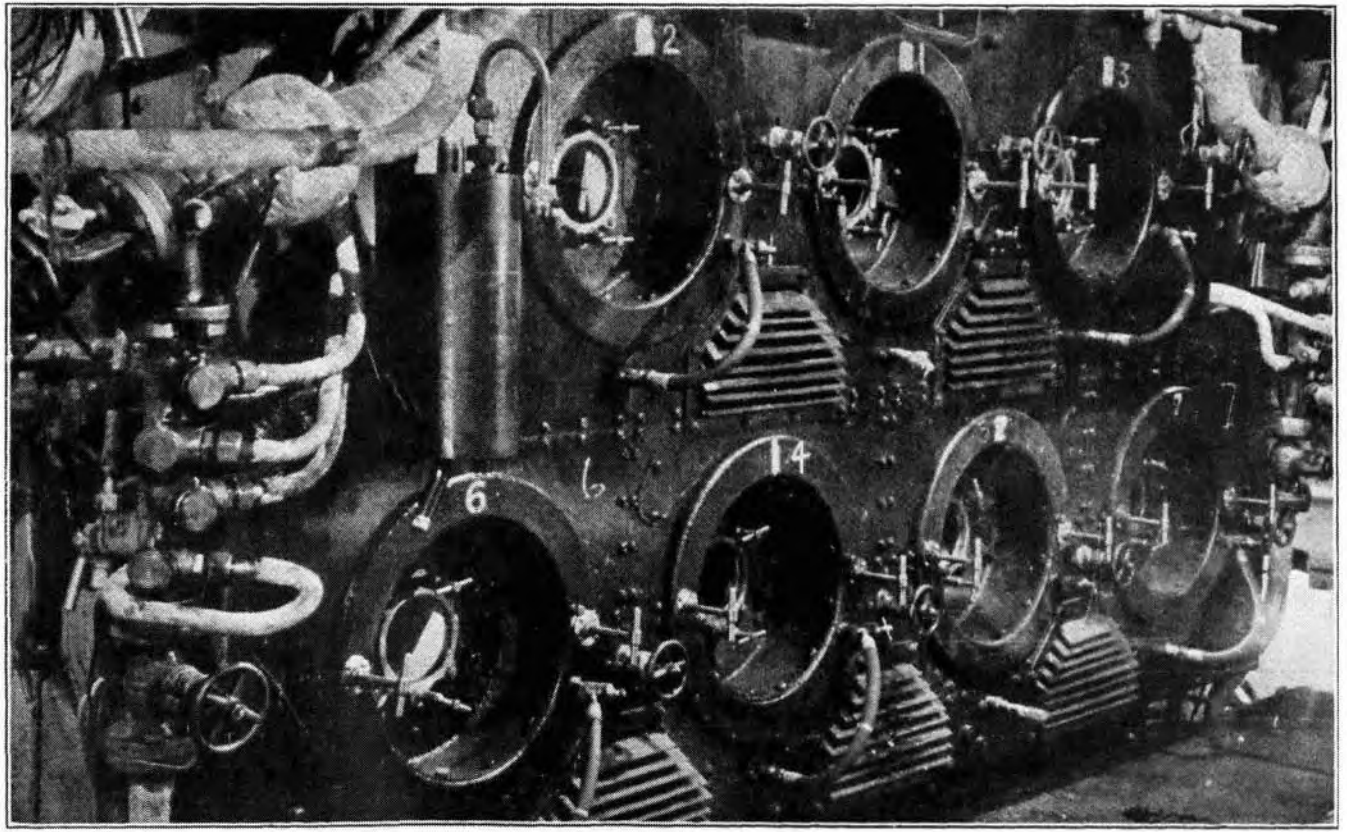


FIG. 1.—ARRANGEMENT OF ADMIRALTY 1943 REGISTERS ON TEST BOILER OF H.M.S. "VANGUARD"

that for the same forcing rate the air pressure required with seven No. 4 sprayer caps in the new registers was approximately equal to that required with five No. 6 caps in the old type of burner.

Rapid manoeuvring trials showed that the ease of manoeuvrability was remarkably good and complete control could be maintained over the boiler in going from practically zero load to full power in a matter of seconds, only five seconds being required for the correct operation of a register.* No maintenance was necessary and after many hours steaming the registers and quarls were in good condition. For these trials the quarls were made from various trade brands of plastic refractory material. All gave a satisfactory performance and their condition on the completion of the trials is shown in

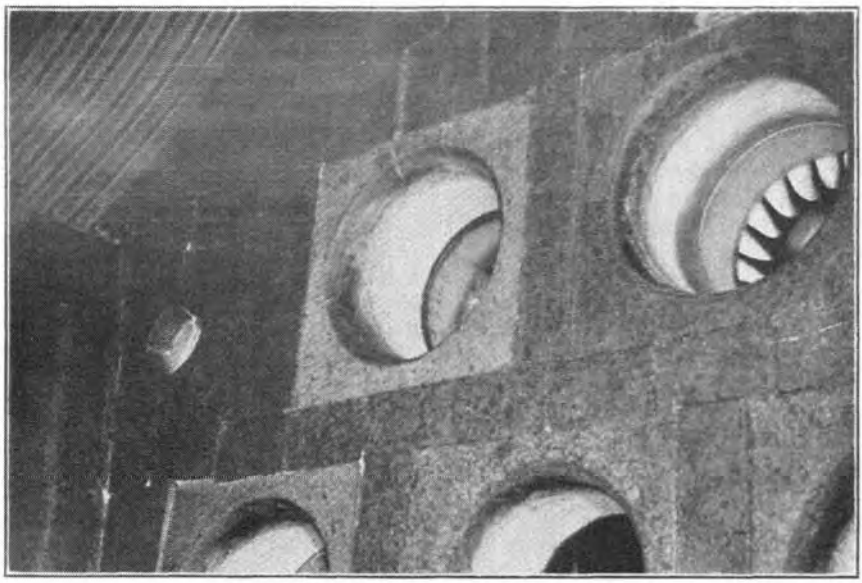


FIG. 2.—CONDITION OF PLASTIC QUARLS AFTER STEAMING TRIALS

Fig. 2. It was thought, however, that the structure could be more easily made with fire bricks. The plastic material was used primarily because no bricks of the correct shape were available at that time and also in order that experience might be gained with this material.

From the trials carried out in the test boiler of *H.M.S. Vanguard* it was thought that improvement might be made in the new register by—(a) reducing the draught loss through the register and (b) obtaining a more compact flame with a view to increasing flame/tube clearances.

Experiments were continued at Haslar with the object of producing an 18-in. diameter register and brick quarl for operating with a lower draught loss. These showed, however, that if the air velocities through the register were reduced, then less satisfactory combustion resulted and the flame was even wider than before. It became apparent that the only way of reducing the air pressure required with the new type of burner was to use a smaller size sprayer cap in the register and arrange for a greater number of sprayers to be fitted on the boiler front. By this means, boilers could be operated at

*See note at bottom of page 13.

full power under existing ideas of the maximum amount of air pressure permissible in ships' boiler rooms.

Although, in the light of further knowledge of the 1943 burners, it has now been decided to fit these registers to the boilers of *H.M.S. Vanguard*, at the time of the shore trials of the test boiler it was thought impossible to do so as the large number of sprayers required with the 1943 burners, could not be fitted to the boiler front and still maintain adequate flame/tube clearances. The original decision was that the *Vanguard* should be fitted with modified open front registers.

About this time, the Foster Wheeler controlled superheat prototype boiler was being designed for the Weapons Class destroyers. There were indications that neither the closed type of front nor the modified open front system would enable optimum conditions to be obtained. This boiler has two furnaces and consequently each furnace must necessarily be narrow. Messrs. Foster Wheeler Ltd. suggested that closer pitching of the burners and consequently improved flame/tube clearances could be obtained by angling the burners to a focal point in the combustion chamber, so it was decided to do this irrespective of the type of burner to be used.

It was realised that although the modified open fronts gave good combustion under normal conditions, in a two furnace boiler there would be times when all burners might be alight in one furnace and only one in the other, e.g. at full output of saturated steam. Under these conditions when there would be a high air pressure in the boiler room, complete stability of the single burner, which is difficult to attain in the combustion tube type of register, would be a most important feature, for in a water walled boiler, such as the Foster Wheeler, it might be dangerous if the only sprayer alight in one furnace became extinguished.

If the 1943 burners were to be fitted to this boiler, then it was apparent that a smaller quantity of oil would have to be used through each burner. Consequently more of these registers would have to be fitted than if the modified open fronts were used, but it could be seen that this would prove an advantage for the greater the number of registers the more easily could a constant superheat be maintained. It was therefore decided that two series of tests should be carried out during the shore trials of this boiler at Clydebank. The first series to be with a boiler front using eleven 1943 burners (five on the saturated furnace and six on the superheat furnace). The data obtained during this series would then be compared with the results from the second series of trials carried out with an arrangement incorporating nine modified open fronts.

Shore trials of Foster Wheeler boiler

The burners of the Foster Wheeler prototype boiler were angled towards a focal point in the combustion chamber and despite the fact that the furnaces were very narrow greater flame/tube clearances were obtained than in the normal Admiralty three-drum boiler. The layout of the front when fitted with 1943 registers is shown in Fig. 3. It was found, however, that the flame produced with the new burners when burning No. 5 sprayer caps at 110 lbs. per sq. in. oil pressure impinged on the boiler tubes and a large amount of carbon was formed on them in a very short time.

The best and simplest way to increase the rate of combustion and so decrease the flame envelope size when burning fuel oil is to decrease the particle size of the oil spray. It is well known that the higher the oil fuel pressure, the better the atomisation.

The fact that considerably improved atomisation is obtained by using higher oil pressures is very clearly indicated by the illustrations on pages 20-21, which

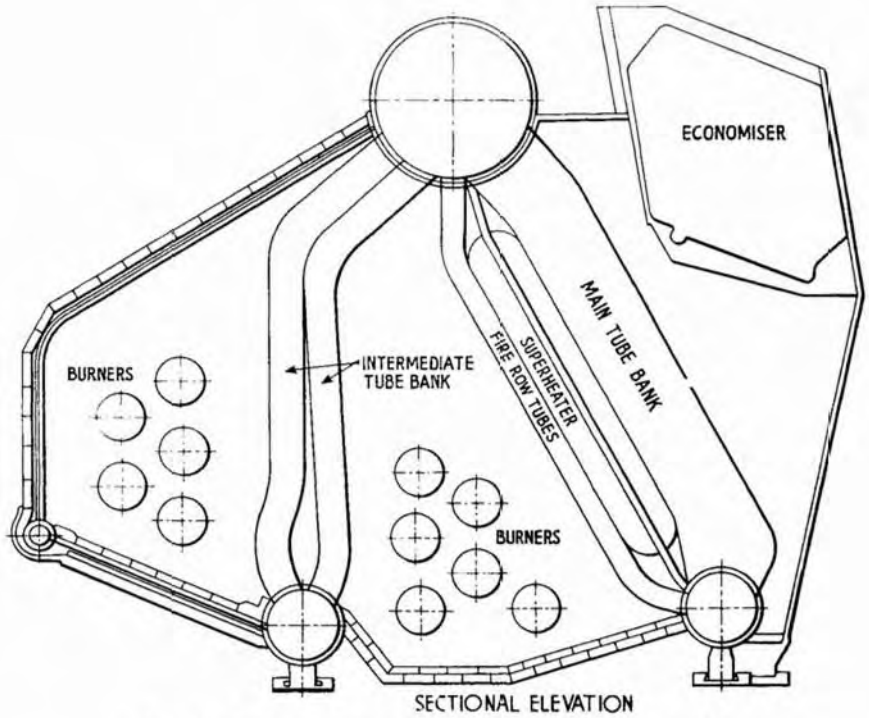


FIG. 3.—FOSTER WHEELER CONTROLLED SUPERHEATER BOILER

show a No. 3A and No. 6 sprayer under various pressures from 50 to 200 lbs. per sq. in. On page 21 a No. 3A cap and a No. 6 cap each delivering 1,500 lbs. of oil at 300 and 100 lbs. pressure respectively are illustrated. These last two photographs give a very clear indication of the improved atomisation to be obtained by using higher oil pressures.

Trials were therefore carried out using smaller sprayer caps at higher oil fuel pressures and it was found that when working at full power with 10 in number No. 3A sprayer caps at 240 lbs. per sq. in. oil fuel pressure there was no flame impingement on the tubes. Combustion data obtained showed that burning was completed in the furnace and subsequent examination revealed the fact that no carbon deposits were formed either on the boiler tubes or the brickwork.

Trials at Haslar had shown that with the 1943 register a parallel brick tube gave better air/oil mixing and a flame more suited to present day furnace shapes than the original conical brick tube which opened out to a larger diameter at the furnace face. With a parallel brick tube it was found easier to adjust the flame so that the quarl could be completely filled and yet avoid the building up of carbon deposits at this point. The brick tubes in the Foster Wheeler prototype boiler were therefore modified in this manner with satisfactory results. In order to obtain the closest possible pitching of the registers the brick rings were made hexagonal in shape and arranged in a honeycomb formation on the surface of a sphere ; each burner was therefore focused on a point close to the back of the furnace.

The quarls in this case were made up of six self-locking bricks of special form. Bricks were considered preferable to the plastic material used in th

TABLE I

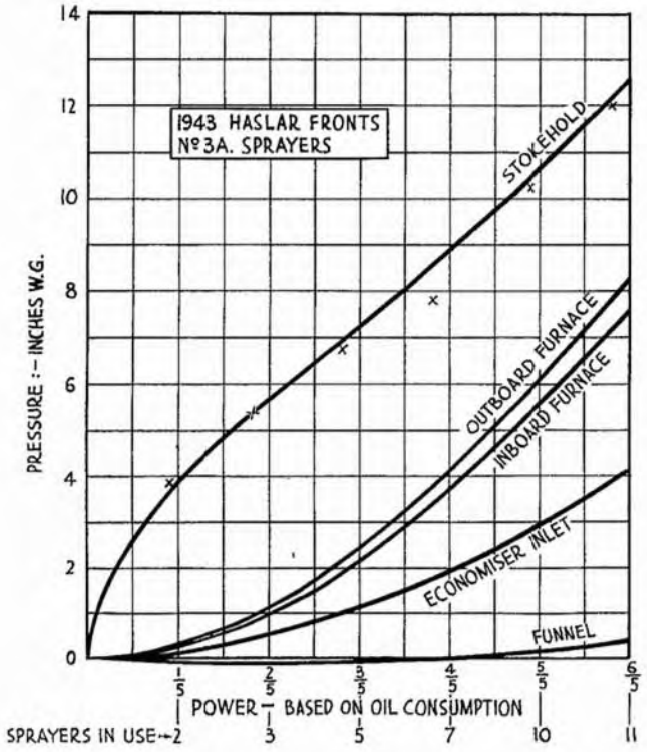
FOSTER WHEELER PROTOTYPE CONTROLLED SUPERHEAT BOILER. SOME DATA AT VARIOUS POWERS WITH ADMIRALTY 1943 BURNERS.

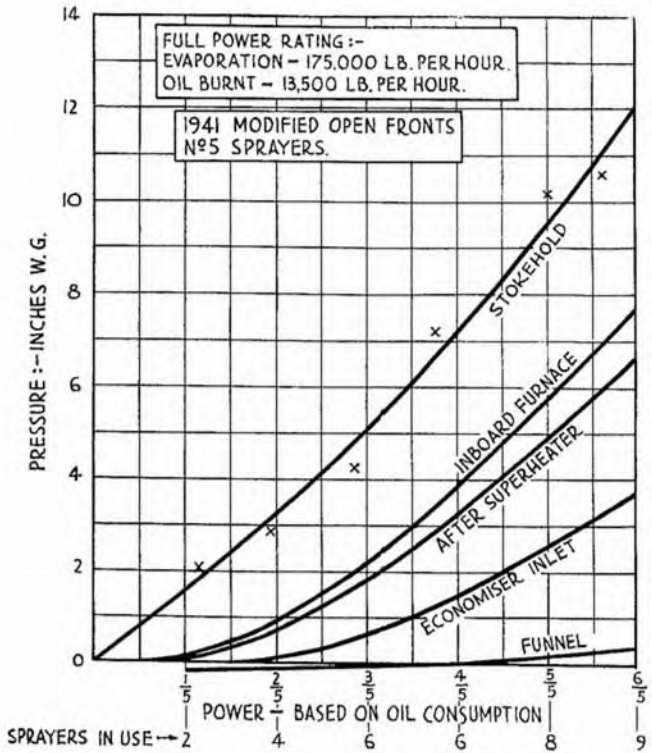
Condition		Normal Superheat						Minimum Superheat			
Load of full power ..		1/5th	2/5th	3/5th	4/5th	5/5th	6/5th	1/5th	2/5th	3/5th	Max. at Min. Temp.
Evaporation × 10-³ lbs./hr.	Total	36.1	70.6	102	141	174	213	36.9	78.0	102	107
	Superheated ..	31.1	61.9	92.4	129	163	201	31.5	70.5	93.4	95.3
	Saturated ..	5	8.7	10.5	12.0	11.2	12.4	5.5	7.5	8.9	12.2
No. of Burners in Use	Outboard furnace	1	1	2	3	4	5	1	3	4	5
	Inboard furnace	1	2	3	4	6	6	1	1	1	1*
Size of Burner .. .. * standard burner modified		4*	4*	4*	4*	3A	4*	4*	4*	4*	3A
Oil Fuel Pressure lbs./sq. in.		123	210	170	160	240	150	125	133	150	265
Oil Fuel Temperature ° F.		209	199	199	197	190	207	205	200	205	195
Oil Burnt lbs./hr. × 10-²		26.2	50.1	76.1	104	130	157	26	55.2	72.1	72.1
B. R. Air Pressure " W.G.		3.9	5.4	6.8	7.8	10.0	12.0	3.7	5.0	6.5	7.3
Gas Pressures " W.G.	Outboard Furnace	0.36	0.98	2.1	3.4	6.0	7.7	0.33	1.3	2.1	—
	Inboard Furnace	0.31	0.94	1.9	3.1	5.5	7.1	0.28	1.0	1.7	—
	Before Economiser	0.13	0.44	1.01	1.65	3.05	3.75	0.1	0.6	0.93	—
	After Economiser	-0.1	-0.1	-0.1	0.02	0.25	0.3	-0.15	-0.1	-0.05	—
Pressure Drops " W.G. (fine'd gauge)	Across Burners ..	3.55	4.55	4.8	4.5	4.5	4.6	3.4	3.9	4.5	—
	Across Main Bank	0.17	0.4	0.8	1.3	2.4	3.15	0.15	0.42	0.7	—
	Across Economiser	0.24	0.6	1.03	1.6	2.75	3.4	0.24	0.62	1.0	1.1
Smoke Density		faint haze	faint haze	faint haze	slight sm'ke	faint haze	slight sm'ke	faint haze	faint haze	faint haze	haze
Funnel Temperature ° F...		277	299	327	353	422	418	279	292	350	325
% CO_2 Econ. Outlet		7.1	11.3	12.0	13.2	12.2	12.9	7.0	10.9	10.1	10.9
Feed Temp. from Heater ° F.		210	204	206	202	198	206	207	191	191	220
Feed Temp. from Econ. ° F.		323	313	320	317	352	330	320	292	292	309
Percentage Efficiency ..		85.6	88.0	87.7	87.0	86.0	85.0	86.0	87.0	87.0	87.5
Atmospheric Temp'ture °F.		47	51	44	52	44	34	48	48	50	—
Stokehold Temperature °F.		84	86	79	86	78	71	84	80	79	75
Oil Fuel Burnt lbs./cu. ft.	Outboard Furnace	2.7	3.5	6.3	9.2	10.8	14.8	2.7	8.6	12	14.2
	Inboard Furnace	2.1	5.4	7.3	9.5	12.5	13.7	2.1	2.2	2.3	0.62
Steam Temperature °F. ..		660	755	760	757	746	694	663	632	627	590

TABLE II.

FOSTER WHEELER PROTOTPYE CONTROLLED SUPERHEAT BOILER. SOME DATA AT VARIOUS POWERS WITH MODIFIED OPEN FRONTS.

Condition		Normal Superheat						Minimum Superheat			
Load of Full Power ..		1/5th	2/5th	3/5th	4/5th	5/5th	6/5th	2/5th	3/5th	4/5th	Max. Ld. at Min S.H.
Evaporation $\times 10^{-3}$ lbs./hr.	Total	39.2	70.4	104	136	177	211	72.7	110	140	127
	Superheated ..	34.7	66.5	99.7	128	169	203	67.4	105	132	120
	Saturated ..	4.5	4.0	4.6	7.3	8.4	8.4	5.2	4.6	7.9	7.8
No. of Burners in use	Outboard Furnace ..	1*	1	2	2	3	4	3	4	4	4
	Inboard Furnace	2	3	4	4	5	5	1	1	2	1
Size of Burner .. No.		5	5	5	5	5	5	5	5	5	5
Oil Fuel Pressure lbs./sq. in.		98	100	99	177	176	176	90	135	178	195
Oil Fuel Temperature ° F.		180	172	175	170	172	169	176	175	167	165
Oil Burnt lbs./hr. $\times 10^{-2}$		28.4	51.2	77.1	102	135	152	50	75.4	100	88.9
B. R. Air Pressure " W.G.		2.1	2.9	4.2	7.3	10.2	10.6	3.6	5.1	8.1	8.1
Gas Pressures " W.G.	Outboard Furnace..	←	—	—	—	not r	ecord	ed	—	—	→
	Inboard Furnace ..	0.4	1.0	2.0	3.5	6.2	6.5	1.1	2.0	3.6	4.1
	Before Economiser .	0.03	0.4	0.97	1.75	3.3	3.6	0.51	0.87	1.93	1.58
	After Economiser ..	-0.2	-0.1	-0.1	0.5	0.3	0.34	-0.01	-.05	0.1	0.06
Pressure Drops " W.G.	Across Burners ..	1.7	1.9	2.2	3.8	4.0	4.1	2.5	3.1	4.5	4.0
	Across Main Bank..	0.17	0.58	1.1	1.8	3.0	3.25	0.62	1.1	1.8	1.6
	Across Economiser	0.23	0.39	0.89	1.63	3.0	3.36	0.5	0.82	1.8	1.4
Smoke Density		faint haze	faint haze	slight sm'ke	haze	slight sm'ke	slight sm'ke	faint haze	slight sm'ke	slight sm'ke	slight sm'ke
Funnel Temperature ° F...		271	292	329	357	400	411	304	322	364	350
% CO_2 Econ. Outlet		9.5	10.2	10.5	11.5	11.4	13.2	9.3	10.9	11.2	10.0
Feed Temp. from Heater ° F.		212	204	197	195	193	204	211	202	193	203
Feed Temp. from Econ. °F.		308	307	314	320	327	329	309	299	307	307
Percentage Efficiency ..		87.5	88.0	87.5	87.5	85.5	86.0	87.5	88.0	87.0	86.5
Atmospheric Temp'ture °F.		38	43	40	45	46	46	43	45	48	47
Stokehold Temperature °F.		86	85	79	80	79	81	71	75	73	71
Oil Fuel Burnt lbs./cu. ft.	Outboard Furnace	0.65	2.7	5.4	7.1	10.6	14.1	7.8	12.6	13.9	14.8
	Inboard Furnace	4.06	6.2	8.2	10.9	13.6	13.6	2.0	2.4	5.35	2.85
Steam Temperature ° F. ..		746	750	739	746	734	669	602	608	648	604





FIGS. 4 AND 5.—FOSTER WHEELER CONTROLLED SUPERHEAT BOILER FOR WEAPONS CLASS DESTROYERS. AIR AND GAS PRESSURES FOR FULL SUPERHEAT

Vanguard boiler trials, but plastic material was extensively used to fill up the gaps between adjacent quarls and between the quarls and the surrounding bricks.

Throughout the whole series of trials very satisfactory combustion was obtained and a constant steam temperature was maintained at all loads from a little over 1/5th power up to full power by using oil fuel pressures from 150 to 270 lbs. per sq. in. and varying the number of sprayers in use. With one man per furnace, manoeuvring was carried out rapidly. It had been anticipated that this would have been slowed up owing to the fact that the number of burners alight in each furnace must be controlled in order to maintain superheat conditions.

Complete flame stability was maintained at all powers, and good funnel gas analyses were recorded. Some data obtained relevant to combustion is shown in Table I, and the curves shown in Figs. 4 and 5 show the air pressures required with the 1943 registers at various powers of the boiler compared with those obtaining with the modified open fronts. It is interesting to note that the air pressure in the boiler room at full power with 10 of the new burners in use, was the same as with 8 of the modified open fronts which were fitted during the second series.

The 1943 registers gave the following advantages over the modified open fronts :—

(1) No carbon deposits on the brick tube.
(2) Complete flame stability.
(3) No glare, and registers maintained lower metal temperatures both when in use or shut off, while burning and coking of the sprayer cap was entirely eliminated. After washing in light oil, the caps were as new, even after the whole of the first series of trials.
(4) The larger number of burners enabled the superheat temperature to be maintained more constantly throughout the whole power range.

It was therefore decided to fit the 1943 register to these boilers for the Weapons Class of destroyers.

As the result of these trials with the Foster Wheeler boiler it was decided to construct a boiler front having 1943 registers angled to a focal point to fit to the normal Admiralty three-drum boiler. Combustion troubles had been occurring with the K.G.V. class of battleships and the first design of front for "A" type boilers was fitted in "X" boiler room of *H.M.S. King George V.* Trials showed that excellent combustion was achieved, and later all the boilers in other ships of the class were modified in a similar manner. Improvements were introduced into the construction of these new fronts and to the brick rings and brick tubes. These will be described in Part III of this paper which will deal with experiences encountered, and results obtained during trials at sea with a number of ships to which the 1943 registers have been fitted.

Yarrow prototype controlled superheat boiler

The layout of this boiler is shown in Fig. 6. It can be seen that the superheat in this case is controlled by an adjustable baffle in the uptake.

By the time of the shore trials of the Yarrow prototype controlled superheat boiler the 1943 registers had become established and it was not considered necessary to try any other type of burner. As the sprayer caps never became dirty with these registers, there was no need to fit an additional register to allow for cleaning at full power, and a front having 10 burners and embodying all the latest improvements was designed. A pressed spherical plate was used to locate the burners instead of using the angled hexagon arrangement. A spherical plate gives a much simpler construction and will

be used in all new work. The hexagon construction is usually necessary when converting existing ships, as it is easier to pass the plates through the boiler room doorways and passages.

In the Foster Wheeler boiler some trouble was experienced by the fracturing of the overhanging bricks outside the tubes forming the roof wall of the outboard furnace. Consequently a new form of brick and brick bolt known as the " Anchor " brick and bolt, was devised and used in the Yarrow

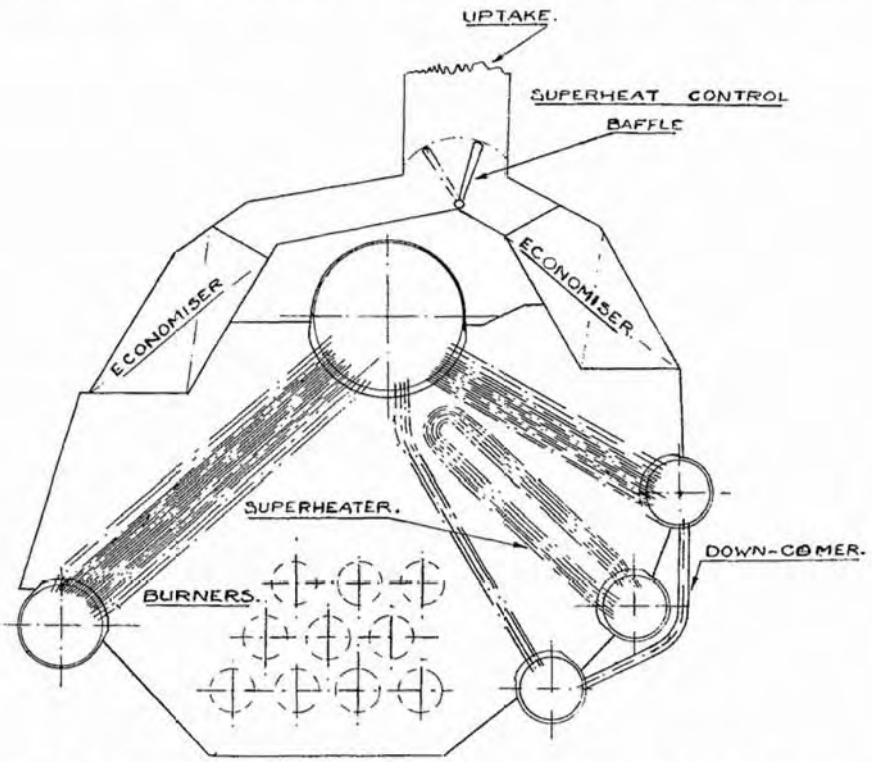


FIG. 6.—YARROW FIVE-DRUM PROTOTYPE CONTROLLED SUPERHEAT BOILER, SHOWING SPRAYER ARRANGEMENT.

boiler to line the portions of the sperical bowl around the brick quarls, where at the top, a certain number of bricks are overhanging. These bricks can be seen in the illustration of the furnace side of the boiler front shown in Fig. 7.

A new method for improving flame/tube clearances and producing greater flame turbulence and air mixing may also be seen in Fig. 7. The vanes of the registers are arranged clockwise on one side of the boiler, and anti-clockwise on the other so that in all cases an air swirl is produced which throws the top of the flame away from the tubes.

A very comprehensive series of trials was carried out with this boiler and excellent combustion was obtained throughout. No trouble of any kind was experienced with the burning equipment and although a period of time was allowed at the beginning of the trials for burner adjustments, etc., it was not required. High CO_2 figures were obtained and little excess air was used for

smokeless combustion. It was thought that higher furnace temperatures were obtained during these trials than ever before with an Admiralty boiler. Manoeuvring trials were successfully carried out and it was possible to manoeuvre

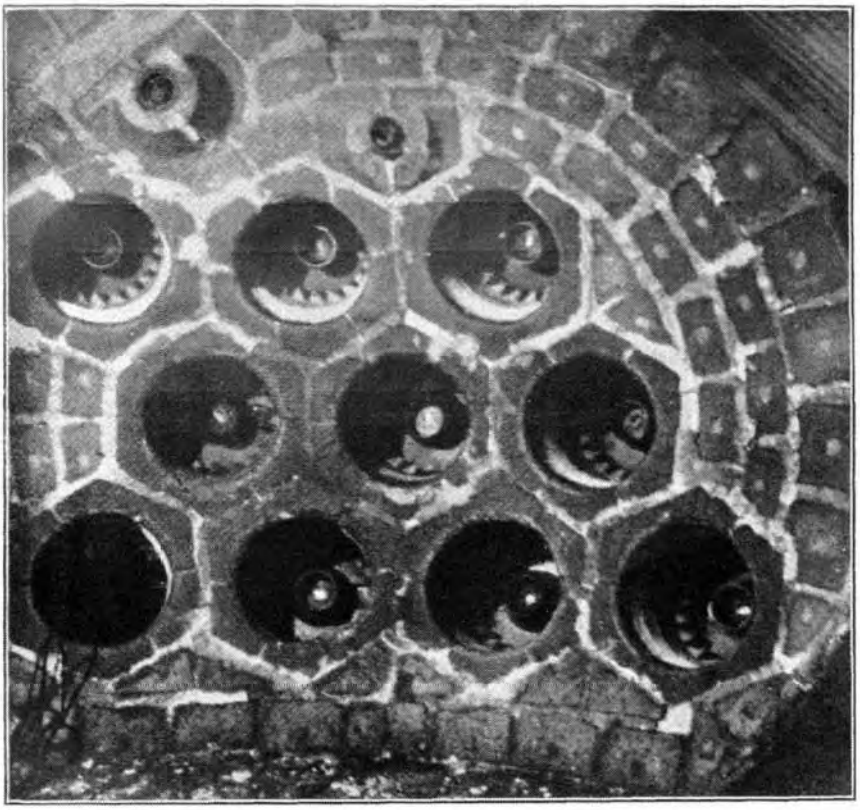


FIG. 7.—FURNACE SIDE OF YARROW PROTOTYPE BOILER SHOWING (a) ANCHOR BRICKS FORMING BOWL SURROUNDING BURNERS AND (b) VANES PRODUCING OPPOSING AIR SWIRL ON EITHER SIDE OF FURNACE

from one sprayer to full power in 30 seconds, and reduce from full power to one sprayer in 25 seconds.*

A number of experiments to determine draught loss through the 1943 burner with different sizes of sprayer caps at various forcing rates, were carried out. The results obtained are shown in an empirical manner in Fig. 8, while Fig. 9 shows the variation in draught loss through the burner and various sections of the boiler when fitted with 3A sprayers.

Readings obtained at various boiler outputs are shown in Table III.

Further shore trials have been carried out with the Eagle test boiler and similar results obtained. This boiler is of normal Admiralty design but fitted with an economiser and downcomers. Curves showing variation of air and gas pressures, with power, are illustrated in Fig. 10.

* NOTE.—The rapid manœuvring trials of the *Vanguard* test boiler and of the Yarrow controlled superheat boiler were carried out to test the ability of these boilers to withstand rapid changes of output. In each case the feed pump in use was that designed to supply the boilers. Such rapid changes are not advisable as a general practice.

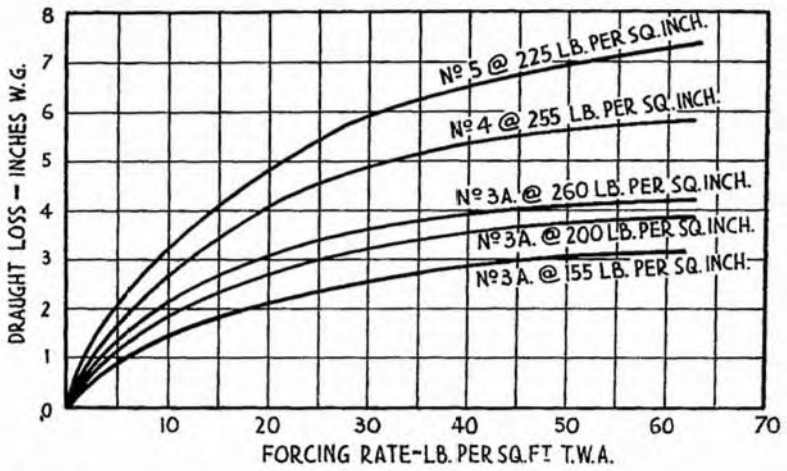


FIG. 8.—DRAUGHT LOSS ACROSS 1943 ADMIRALTY REGISTER WHEN USING DIFFERENT SIZES OF SPRAYER CAP AT VARIOUS FORCING RATES

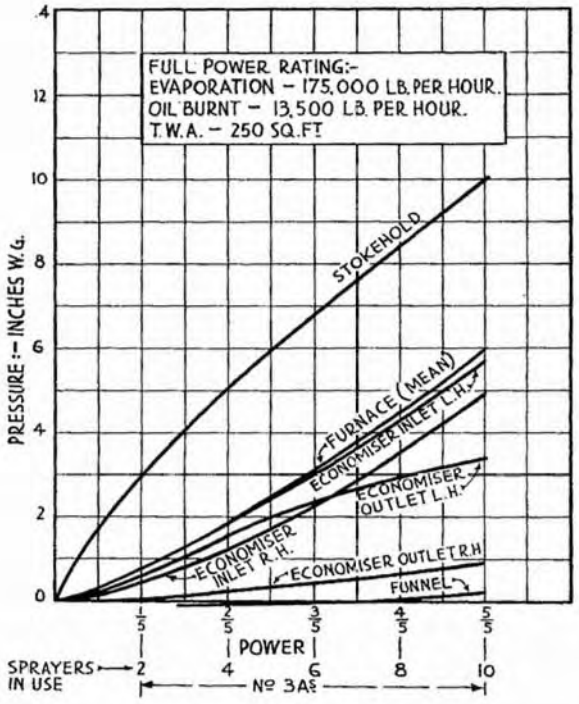


FIG. 9.—AIR AND GAS PRESSURES THROUGH YARROW CONTROLLED SUPERHEAT BOILER FOR WEAPONS CLASS DESTROYERS (BAFFLE SET FOR 750° F. STEAM TEMPERATURE). THE DRAUGHT LOSS THROUGH BURNER IS THE DIFFERENCE BETWEEN STOKEHOLD AND FURNACE PRESSURES.

TABLE III.

YARROW CONTROLLED SUPERHEAT BOILER.

SOME DATA AT VARIOUS POWERS WITH ADMIRALTY 1943 BURNERS.

Condition			Normal Superheat						Minimum Superheat			
Load Fraction of Full Power			1/5th	2/5th	3/5th	4/5th	5/5th	6/5th	1/5th	2/5th	3/5th	5/5th
Total Evaporation $\times 10^{-3}$ (lbs./hr.)			36.0	71.5	103.2	142	172	201.7	41.0	80.2	109	185.5
Superh't'd Steam Temp. °F.			684	747	740	747	743	738	498	520	540	615
Number of Burners in use			2	4	6	8	10	10	2	4	6	9
Size of Burner .. No.			3A	3A	3A	3A	3A	4	3A	3A	3A	4
Oil Fuel Pressure lbs./sq. in.			276	270	245	270	266	277	277	268	249	246
Oil Fuel Temperature ° F.			202	200	201	200	200	193	196	210	194	197
Total Quantity of Oil Burnt $\times 10^{-2}$ (lbs./hr.)			27.1	53.9	79.5	108.8	134.7	162	27.3	53.8	78.6	130
B. R. Air Pressure " W.G.			3.0	5.1	6.0	8.4	10.0	15.9	3.4	4.9	8.0	17.2
Gas Pressures " W.G.	Furnace		0.7	2.2	2.9	4.75	6.6	11.0	.9	2.2	4.8	12.3
	R.H. Bank	Before Economiser	0.45	1.7	2.0	3.45	4.9	8.5	.77	2.0	4.4	11.2
		After Economiser	0.05	0.4	0.2	0.6	0.9	3.3	.75	1.92	4.2	9.5
	L.H. Bank	Before Economiser	0.7	2.03	2.6	4.31	5.7	9.6	.75	1.8	4.0	10.5
		After Economiser	0.6	1.93	2.0	2.99	3.37	6.0	.03	0.7	1.7	5.15
Pressure Drops " W.G.	Across Burners ..		2.3	2.9	3.1	3.6	3.4	4.9	2.5	2.7	3.2	4.9
	R.H. Bank	Across Banks ..	0.25	0.5	0.9	1.3	1.7	2.5	.12	0.2	0.6	1.1
		Across Economiser	0.4	1.25	1.8	2.85	3.9	5.3	.02	0.6	0.2	1.7
	L.H. Bank	Across Bank ..	Nil	0.15	0.3	0.44	0.9	1.4	.15	0.4	0.8	1.8
		Across Economiser	0.1	0.3	0.6	1.31	2.35	3.6	.72	1.1	2.3	5.35
Position of Damper (Mid. Pos.=0, Mx.=$\pm$5 if L.orR)			$+5\frac{1}{4}$	$+4\frac{3}{4}$	$+3\frac{3}{4}$	$+3\frac{1}{4}$	$+3\frac{1}{2}$	$+2\frac{1}{2}$	—5	—5	—5	—5
Smoke Density			very faint haze	very faint haze	faint haze	haze	faint haze	faint haze	very faint haze	faint haze	faint haze	very faint haze
Funnel Temperature ° F...			287	335	353	395	442	490	282	334	387	477
Percentage CO_2 at Funnel			12.4	14.0	13.95	13.54	13.95	13.94	10.5	13.8	13.82	13.4
Feed Temp. from Heater, ° F.			210	207	193	202	201	203	205	198	196	195
Feed Temp. from Econ.° F.			277	277	280	294	308	314	291	261	302	317
Atmospheric Temp'ture °F.			48	54	53	53	56	51	48	53	53	53
Stokehold Temperature °F.			107	114	103	92	92	90	95	105	90	93

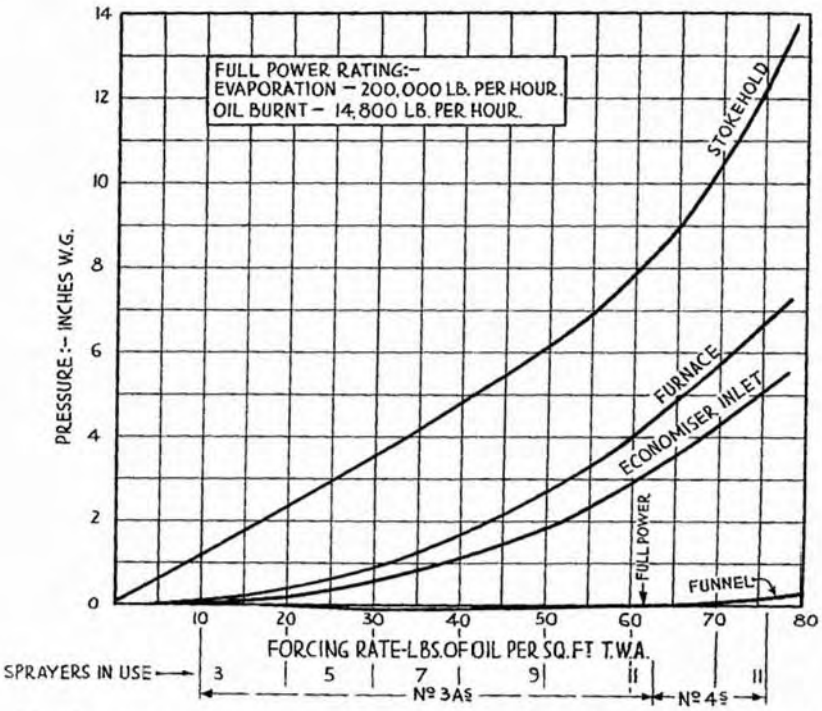


FIG. 10.—AIR AND GAS PRESSURES OF TYPICAL ADMIRALTY 400 LB./SQ. IN. THREE-DRUM BOILER FITTED WITH ECONOMISERS. THIS BOILER WAS PROVIDED WITH FOUR DOWNCOMERS TO ENSURE SAFETY OF CIRCULATION AT THE HIGHEST FORCING RATES

Trials with heavy fuel oil

A number of readings were taken during the trials of the Foster Wheeler Weapons class boiler using Pool heavy oil of viscosity approximately 1,000 secs. R.I. at 100° F., when it was found that the air pressures and burner settings were very similar to those when using Admiralty grade fuel oil. Although the test was only of short duration, it could be seen that the new register was fully capable of dealing with heavy oil of this nature without forming any carbon deposits.

More comprehensive trials were carried out burning grades of heavy fuel oil through the 1943 burners during the shore trials of the Yarrow controlled superheat boiler.

Satisfactory results were obtained with Pool heavy oil, similar to that used in the Foster Wheeler trials. Combustion was good and no carbon deposits were made.

Trials were continued using a grade of oil equivalent to " Bunker ' C ' " (viscosity approximately 3,000 secs. Redwood I at 100° F.). It was satisfactory to find that no trouble was experienced in burning this grade of oil, as no heavier oil is likely to be encountered at sea.

With the heavier grades of oil, however, it was found that in order to achieve optimum results it is more than ever necessary to maintain the oil fuel pressure as high as possible, and to ensure that the correct oil temperature

TABLE IV.

FOSTER WHEELER PROTOTYPE CONTROLLED] SUPERHEAT BOILER.

SOME DATA AT VARIOUS POWERS WITH ADMIRALTY 1943 BURNERS WHEN BURNING POOL HEAVY FUEL OIL.

Specific Gravity of oil at 60° F. .. 0.955
Viscosity Redwood No. 1 at 70° F. : 3165 ; at 100° F. : 961.
Calorific value BTU/LB. 18345

Condition		Normal Superheat				
Load of Full Power		1/5th	2/5th	3/5th	4/5th	5/5th
Number of Burners in use	Outboard Furnace ..	1	2	3	3	4
	Inboard Furnace ..	2	3	4	5	6
Size of Burner		3A	3A	3A	3A	3A
Oil Fuel Pressure lbs./sq. in. ..		100	150	150	225	240
Oil Fuel Temperatures ° F. ..		239	245	240	242	242
Boiler Room Air Pressure " W.G.		3.3	3.1	4.8	7.4	9.8
Gas Pressures " W.G.	Outboard Furnace	.53	.93	2.03	3.9	5.95
	Inboard Furnace	.42	.80	1.9	3.6	5.5
	Before Superheater ..	.40	.75	1.66	3.22	5.1
	After Superheater	.36	.70	1.59	3.02	4.95
	Before Economiser	.16	.4	1.0	1.82	2.96
	After Economiser	-0.16	-0.05	0	0.05	0.1
Pressure Drops " W.G.	Across Burners	2.8	2.2	2.8	3.6	4.1
	Across Main Bank	0.26	0.4	0.9	1.78	2.54
	Across Economiser ..	0.3	0.45	1.0	1.77	2.86
Smoke density		light haze	light haze	light haze	light haze	light haze
Steam Temperature ° F.		690	750	748	765	752
Percentage CO_2 Econ. Outlet ..		7.0	13.0	12.0	12.0	12.5
Feed Temp. from Feed Heater ° F.		215	215	215	211	212

was adhered to on all occasions. The burning became unsteady when a large number of sprayers were in use at low oil pressures, and pulsation occurred, but was quickly overcome by shutting off a sprayer and increasing the oil pressure to give the corresponding steam output.

It was demonstrated, however, that while optimum combustion is obtained with the better grades of fuel oil, the 1943 register is capable of dealing satisfactorily with any grade of fuel oil without the formation of carbon deposits. Tables IV, V and VI set out results obtained at various powers with the Foster

TABLE V.

YARROW CONTROLLED SUPERHEAT BOILER

SOME DATA AT VARIOUS POWERS WITH ADMIRALTY 1943 BURNERS WHEN BURNING POOL HEAVY OIL.

Specific Gravity of Oil at 60° F. .. 0.956 Viscosity Redwood No. 1 at 100° F. .. 936
Calorific Value BTU/LB. .. .. 18720 Hard Asphalt 6.26%

Condition			Normal Superheat				
Load Fraction of Full Power ..			1/5th	2/5th	3/5th	4/5th	5/5th
Total Evaporation lbs./hr. $\times 10^{-3}$ ..			—	—	105	135	172
Superheat Steam Temp. ° F. ..			697	744	734	728	740
Number of Burners in use ..			2	4	6	8	10
Size of Burner .. .. No.			3A	3A	3A	3A	3A
Oil Fuel Pressure lbs./sq. in. ..			275	275	274	276	273
Oil Fuel Temperature ° F. ..			241	247	247	247	241
Oil Burnt lbs./hr. $\times 10^{-2}$			28.4	54.6	84.3	112.3	142.8
Boiler Room Air Pressure " W.G.			2.8	4.9	6.5	8.4	11.9
Gas Pressures " W.G.	Furnace		0.52	1.98	3.55	5.3	8.3
	R.H. Bank	Before Economiser ..	0.4	1.43	2.57	4.07	6.5
		After Economiser ..	0.4	1.0	1.5	2.1	3.1
	L.H. Bank	Before Economiser ..	0.6	1.93	3.17	4.8	7.4
		After Economiser ..	0.6	1.9	3.1	—	—
Pressure Drops " W.G.	Across Burners		2.15	2.9	3.0	3.1	3.5
	R.H. Bank	Across Banks	0.1	0.5	1.0	1.3	1.8
		Across Economiser ..	Nil	0.4	1.0	2.0	3.4
	L.H. Bank	Across Bank	Nil	0.05	0.38	0.5	0.9
		Across Economiser ..	Nil	0.03	0.04	—	—
Position of Damper (Mid. Pos.=0, Max.=±5 if L. or R.)			+5	+5	+4.2	+3.8	+3.5
Funnel Temperature °F			275	320	355	403	451
Smoke density			faint haze	faint haze	faint haze	faint haze	faint haze
Percentage CO_2 at Funnel ..			13.0	13.9	14.0	14.2	14.07
Feed Temp. from Feed Heater ° F.			160	157	172	190	196
Feed Temp. from Economiser ° F.			265	248	261	284	298
Atmospheric Temperature ° F. ..			49.8	52.4	53.8	55.6	56.2
Stokehold Temperature ° F. ..			83	82	80	81	80.5

TABLE VI.

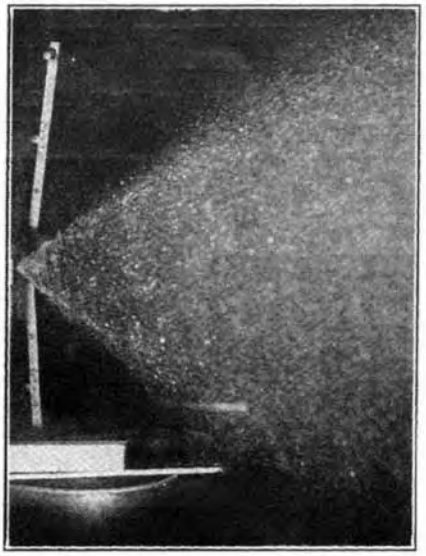
YARROW CONTROLLED SUPERHEAT BOILER.

SOME DATA AT VARIOUS POWERS WITH ADMIRALTY 1943 BURNERS WHEN BURNING BUNKER "C" FUEL OIL.

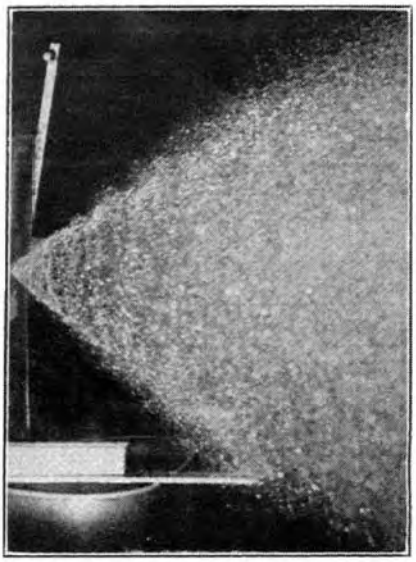
Specific Gravity of oil at 60° F. .. 0.966 Viscosity Redwood No. 1 at 100° F. .. 2,910
Calorific value BTU/LB .. .. 18420 Hard asphalt 7.7%

Condition			Normal Superheat				
Load Fraction of Full Power ..			1/5th	2/5th	3/5th	4/5th	5/5th
Total Evaporation lbs./hr. × 10^{-3}			—	—	106.5	138	173
Superheated Steam Temp. ° F. ..			677	737	739	747.5	742
Number of Burners in use.. ..			2	4	6	8	10
Size of Burner .. .. No.			3A	3A	3A	3A	3A
Oil Fuel Pressure lbs./sq. in. ..			274	274	275	276	286
Oil Fuel Temperature ° F. ..			274	261	262	265	259
Oil Burnt lbs./hr. × 10^{-2}			30.06	55.6	87.3	116.1	143.6
Boiler Room Air Pressure " W.G.			2.65	5.15	6.85	9.55	12.45
Gas Pressures " W.G.	Furnace		0.53	2.07	3.73	5.93	8.68
	R.H. Bank	Before Economiser ..	0.35	1.6	2.8	4.5	6.8
		After Economiser ..	0.15	0.9	1.4	2.0	3.1
	L.H. Bank	Before Economiser ..	0.53	2.0	3.4	5.3	7.8
		After Economiser ..	0.48	1.95	3.0	4.25	5.71
Pressure Drops " W.G.	Across Burners		2.12	3.08	3.12	3.62	3.8
	L.H. Bank	Across Banks	0.18	0.47	0.93	1.43	1.88
		Across Economiser ..	0.2	0.67	1.33	2.5	3.7
	R.H. Bank	Across Bank	Nil	0.07	0.33	0.63	0.88
		Across Economiser ..	0.05	0.05	0.4	1.05	2.1
Position of Damper (Mid. Pos.=0, Max.=±5 if L. or R.)			+5	+4¾	+4½	+4	+3
Smoke density			faint haze	faint haze	faint haze	faint haze	faint haze
Funnel Temperature ° F.			260	311	347	388	445
Percentage CO_2 at Funnel ..			13.0	13.0	13.4	14.0	14.0
Feed Temp. from Feed Heater ° F.			176	180	189	187	196
Feed Temp. from Economiser ° F.			251	253	265	275	294
Atmospheric Temperature ° F. ..			51.5	50.5	51	51	51.7
Stokehold Temperature ° F. ..			96	87	85	82	81.4

COMPARISON BETWEEN DIFFERENT SIZES OF ADMIRALTY



No. 3A AT 50 LB./SQ. IN.



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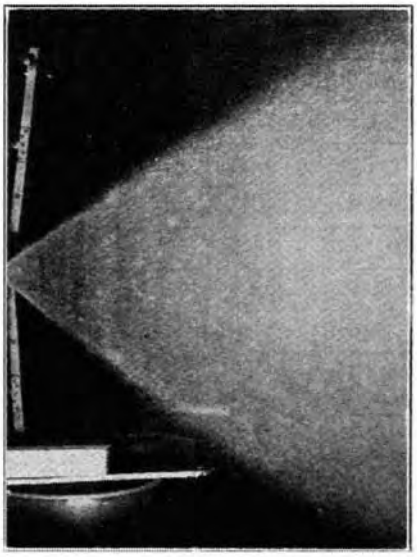

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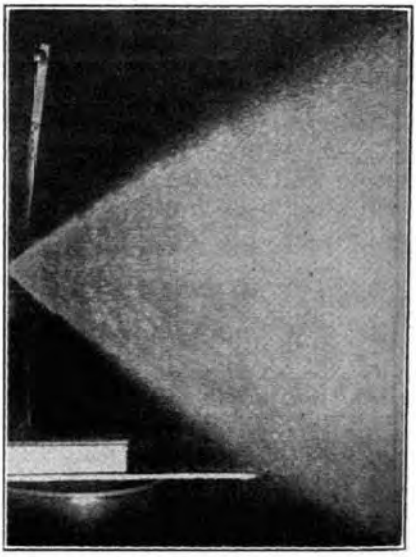
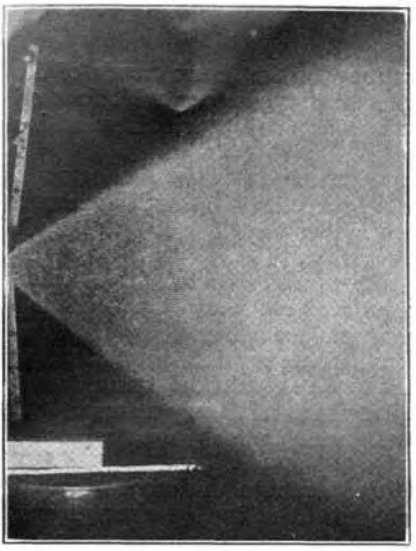


No. 6 AT 150 LB./SQ. IN.

It can be seen from the illustrations on these pages that the Admiralty No. 3A Sprayer Cap gives at corresponding pressures slightly better atomisation than an Admiralty No. 6 Spr ayer It is also apparent that atomisation is considerably improved at the higher oil pressures The mist which is——

SPRAYER CAPS AT VARIOUS OIL FUEL PRESSURES.



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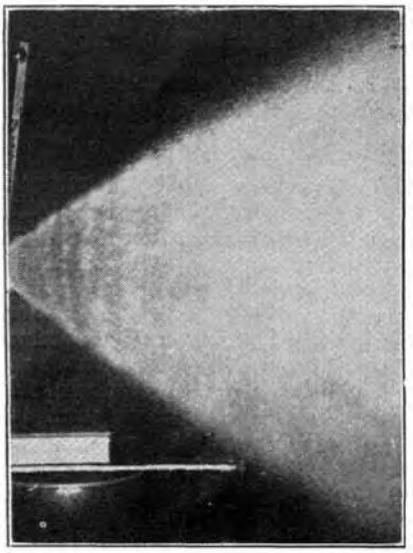

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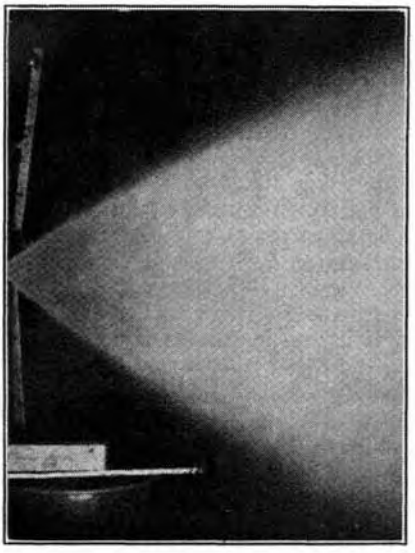
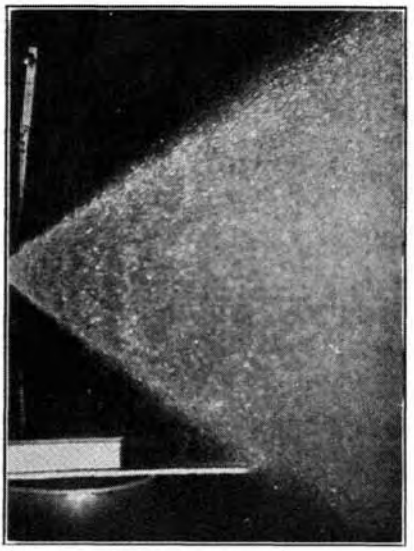


No. 3A AT 300 LB/SQ. IN.



No. 6 AT 100 LB/SQ. IN.

——thought to be responsible for primary combustion can be seen at the edge of the spray. No. 3A Sprayer Cap has the same output at 300 lb./sq. in as a No. 6 Cap at 100 lb./sq. in. The improved atomisation obtained by using higher oil fuel pressures is clearly shown in the lower illustrations on this page.

Wheeler prototype boiler on Pool heavy oil, and with the Yarrow boiler on Pool heavy and " Bunker ' C ' " fuel oil.

Future developments

All the foregoing trials gave clear indications for the future trends of oil burning. Boiler design is demanding a greater heat release per cubic foot of furnace volume, and to achieve this, better atomisation and higher air velocities will be required.

Not only will it be necessary to increase the air velocities through the register, but also in order to effect a high rate of heat transfer from the increased heat release, boiler room air pressures much higher than the accepted limit from the point of view of comfort will be required. The air to the burners will therefore have to be enclosed in a separate trunk or casing. Trials with the 1943 register modified for use with trunked air have recently been carried out at Clydebank. Good combustion was obtained when burning up to 2,000 lbs. of oil per hour through each register. There is evidence that further experimental work is required if this figure is to be exceeded. Increased heat release will impose further strain on brickwork which is already a formidable problem with the higher furnace temperatures which are involved with the improved combustion with the new burners.

An investigation both theoretical and practical into the mechanism of atomisation and for sprayer design is now in progress at Haslar. Mathematicians and experts in sprayer design are co-operating in this work in an endeavour to produce the optimum design of sprayer cap. It cannot be over-emphasised that whatever type of burner or register is used with any mechanical pressure jet, really good combustion is only obtained at the higher oil fuel pressures. It therefore follows that at all powers the highest fuel oil pressure possible in the circumstances should be used.