INSTITUTE OF MARINE ENGINEERS
INCORPORATED.

Patron: HIS MAJESTY THE KING.

SESSION 1930.

President: ENGINEER VICE-ADMIRAL SIR ROBERT B. DIXON, K.C.B., D.Eng.

VOLUME XLII.

Water-Tube Boilers for Merchant Ships

BY ENGINEER REAR-ADMIRAL W. M. WHAYMAN, C.B., C.B.E. (Vice-President)

READ

Tuesday, January 14, 1930 *at* 6.30 *p.m.*

CHAIRMAN: MR. H. J. VOSE (Vice-Chairman of Council).

The CHAIRMAN: We have come to hear Admiral Whayman read his paper on water-tube boilers for use in the Merchant Navy. I take it that he is an authority on boilers in the Royal Navy and perhaps he can tell us something we can do to introduce water-tube boilers into the Merchant Navy. You may remember that well-known picture of Turner's, "The Passing of the Temeraire," and one almost might think of the water-tube boiler and the old Scotch boiler when one thinks of that picture from the engineering point of view. However, Admiral Whayman will present the picture in his own colours to-night.

In preparing a paper on the above subject for this Institute it occurred to the writer that it would be of increasing interest to discuss the problem from the time that it was last reviewed by papers at this Institute. It will be remembered that in

October, 1924, a paper was read by the late Sir James Kemnal on "The Present Tendencies of Steam Generation," and that in February, 1926, a paper was read by Mr. Stanley S. Cook on "High Efficiency Steam Installations for Ship Propulsion —With Special Reference to the Question of Auxiliary Machinery."

Sir James Kemnal stated that the adaptation of steam turbines to higher pressures and higher superheats has led to improvements in boiler construction which have already been brought before the public as applied to land installations, and anticipated that the application of higher pressures and superheats for marine purposes would eventually follow, if only to compete with the Diesel engine. Sir James Kemnal concluded his paper with the following words:—

"As things are at present, marine installations have to be "operated at maximum economy if ships are to go to sea and "obtain freights at all. Diesel oil engine installations have "made notable strides within the last few years, and many "installations are giving the greatest satisfaction to their "owners. Having regard, however, to first cost and maintenance charges, including depreciation, I am of opinion "that a high pressure steam installation could be made to "compete with the marine Diesel oil engine installation in "operating costs.

"As far as reliability is concerned, it is not probable that "the most enthusiastic Diesel engine advocate would claim "that the steam installations have yet been equalled."

Mr. Cook, in his paper in 1926, gave the Institute a very interesting paper on the results that might be anticipated to be obtained from a steam installation working at 500 lbs. pressure and an initial temperature of 700° F. with various methods of working the auxiliary machinery. The figures quoted by Mr. Cook were:—

1. With steam driven auxiliaries—·667 lbs. of oil per s.h.p./hr. for all purposes.
2. With motor driven auxiliaries—·648 lbs. ditto
3. With motor driven auxiliaries and Diesel generators — ·62 lbs. ditto

It is desired now to bring before the Institute the experience which has been obtained up to the end of 1929, from the steam propelling machinery equipments of a number of different types of vessels, and to show how far the anticipated performances quoted by the late Sir James Kemnal and Mr. Cook have been realised.

The marine steam machinery available to-day is low in first cost and operating cost. It operates at high efficiency, its reliability is unsurpassed, and the low upkeep and maintenance cost render it advantageous to other types. It has the added advantage that it can use any kind of fuel.

A list of ships which have been completed or are being built with one type of water-tube boiler in the last five years is given in Table 1 to illustrate the advance in pressure and superheat which has taken place in some of these vessels. It will be noted that whereas in 1925 the usual pressure was 200 lbs., in the case of ships ordered in 1927 the pressures had been advanced in some cases to 250 lbs., 290 lbs., and even 430 lbs., and in other cases of ships ordered in 1928 to 370 and 550 lbs. pressure. The amount of superheat in use in 1925 was about 180° F., which has remained somewhat of an average figure though there had been cases in which a higher temperature of 260° F. has been used.

TABLE I.

YEAR.	Number of Vessels.	Number of Boilers.	Pressures lbs.	Superheat °F
1925	9	18	200	0 and 182
1926	15	50	200, 206, 220, 225, 230 and 265	0, 144, 180, 200 and 250
1927	16	41	200, 250, 290 and 430	100, 185, 200 and 263
1928	13	37	130, 190, 200, 225, 250, 370 and 550	100, 185, 220 and 256
1929	11	27	180, 200, 370 and 400	0, 180, 190 and 264

To illustrate more clearly the trend of boiler pressure and superheat during the last five years the experience available to the writer which is included in Table I has been indicated in the form of curves showing the pressures and superheats adopted for the vessels referred to.

It will be seen from the curve indicating the boiler pressures that although the general average may be said to have been retained at or about 200 lbs. per sq. in., there is a definite trend as experience is obtained in the direction of higher pressure.

With regard to the degree of superheat, however, this has not altered very much, but has been varied slightly up and down. In all cases, however, the amount of superheat employed in connection with marine installations has been moderate and such as can be dealt with, with the usual quality steel material for superheater tubes and steam pipes.

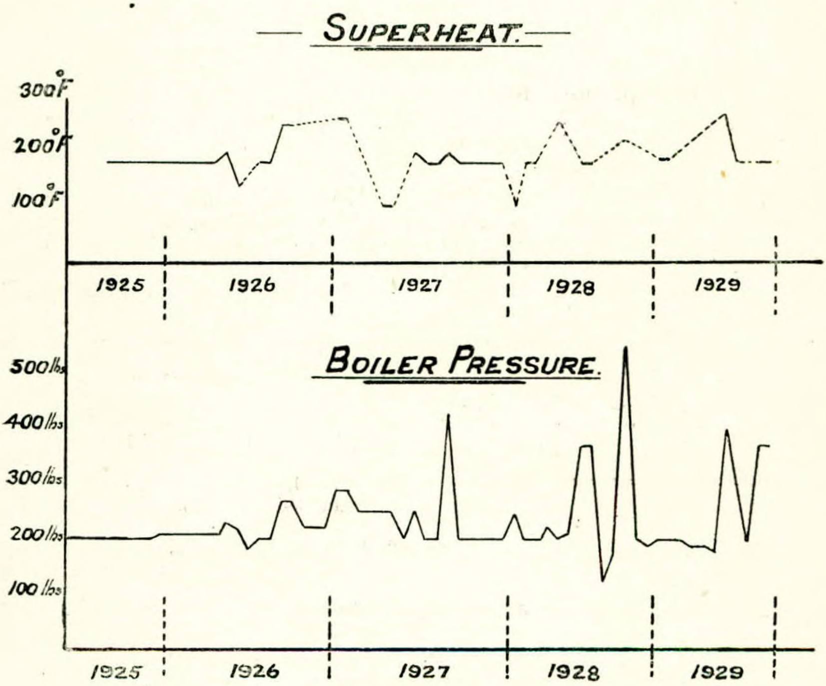


DIAGRAM NO. I

Economy in Fuel.—As illustrating the advantages which have been obtained in fuel economy in recent ocean-going passenger liners with the introduction of water-tube boilers with higher pressures and superheat temperatures in association with turbine machinery, we had a most instructive paper presented by Mr. J. Johnson, the Chief Superintendent Engineer of Canadian Pacific Steamships Ltd., before the Institution of Naval Architects in the spring of 1929.

The best result published by Mr. Johnson at that date was that obtained in the *Duchess of Bedford*, which is fitted with Parsons turbines and Yarrow boilers. The major portion of the auxiliary machinery is motor driven, the energy being supplied by Diesel and turbo generators.

The figures published were a consumption of ·57 lbs. of oil fuel per s.h.p. hour for propulsion and ·625 lbs. for all purposes.

We have recently had presented to this Institute a paper by Mr. Eskil Berg on "Electric Propulsion as applied to Passenger Liners," describing in particular the installation in SS. *Virginia*.

Mr. Eskil Berg informs us that the published data of SS. *Bremen* credits her with a fuel consumption of ·685 per s.h.p. for all purposes, which compares with a figure of ·715 lbs. of oil per s.h.p. for all purposes in the SS. *Virginia*.

Mr. Eskil Berg anticipates that the figure of ·715 lbs. could be improved upon by a similar installation to that in the *Virginia* if the installation were of larger power so as to enable more efficient turbines to be installed.

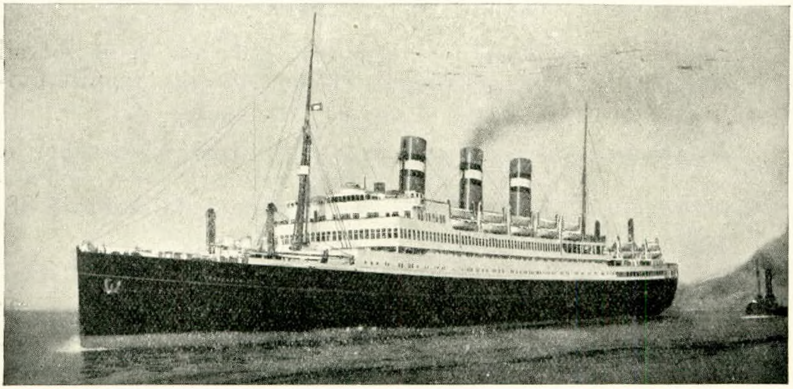
Equally good performances have, it is understood, been obtained in the new P. and O. steamer, *Viceroy of India*, but the writer has not learnt any actual results.

Plate I shows a picture of the new Holland-America Line twin-screw steamer, *Statendam*, which is equipped with turbines and water-tube boilers.

Plate II shows front and side views of the boilers, superheaters and air-heaters fitted in this vessel, and Plate III shows the arrangement of the after boiler room.

The ship has six large tube water-tube boilers designed for a safety valve load of 430 lbs. per sq. in. and to give a steam temperature at the superheater outlet of 650° F. The design service s.h.p. with single reduction Parsons type geared turbines is 22,000. This vessel has now performed several Atlantic crossings on service at an average total consumption of ·61 lbs. of oil per s.h.p. for all purposes. Only five boilers are required for the full output and one boiler is, therefore, always available for a stand-by or for cleaning if desired.

PLATE I.



S.T.S. "STATENDAM."

Built by Harland & Wolff Ltd., Belfast, and completed by Wilton's Engineering and Slipway Co., Rotterdam.

28,150 gross tons. 22,140 S.H.P. Speed 19 knots.

Fitted with six Babcock and Wilcox Oil-fired Water-tube Boilers, Superheaters and Airheaters.

The boilers are oil-fired and the accompanying drawings show the boiler construction and the boiler arrangement in the vessel.

A most noticeable feature of this boiler installation is the extremely low temperature of the boiler rooms even when running at maximum power. Even with upper platforms and gratings in the vicinity of the uptakes and air-heaters the temperature is never sufficient to cause the slightest inconvenience or discomfort to the boiler-room staff. Having in view the high pressure and temperature employed, the coolness of the boiler casings themselves and all working spacings around the boilers is very marked.

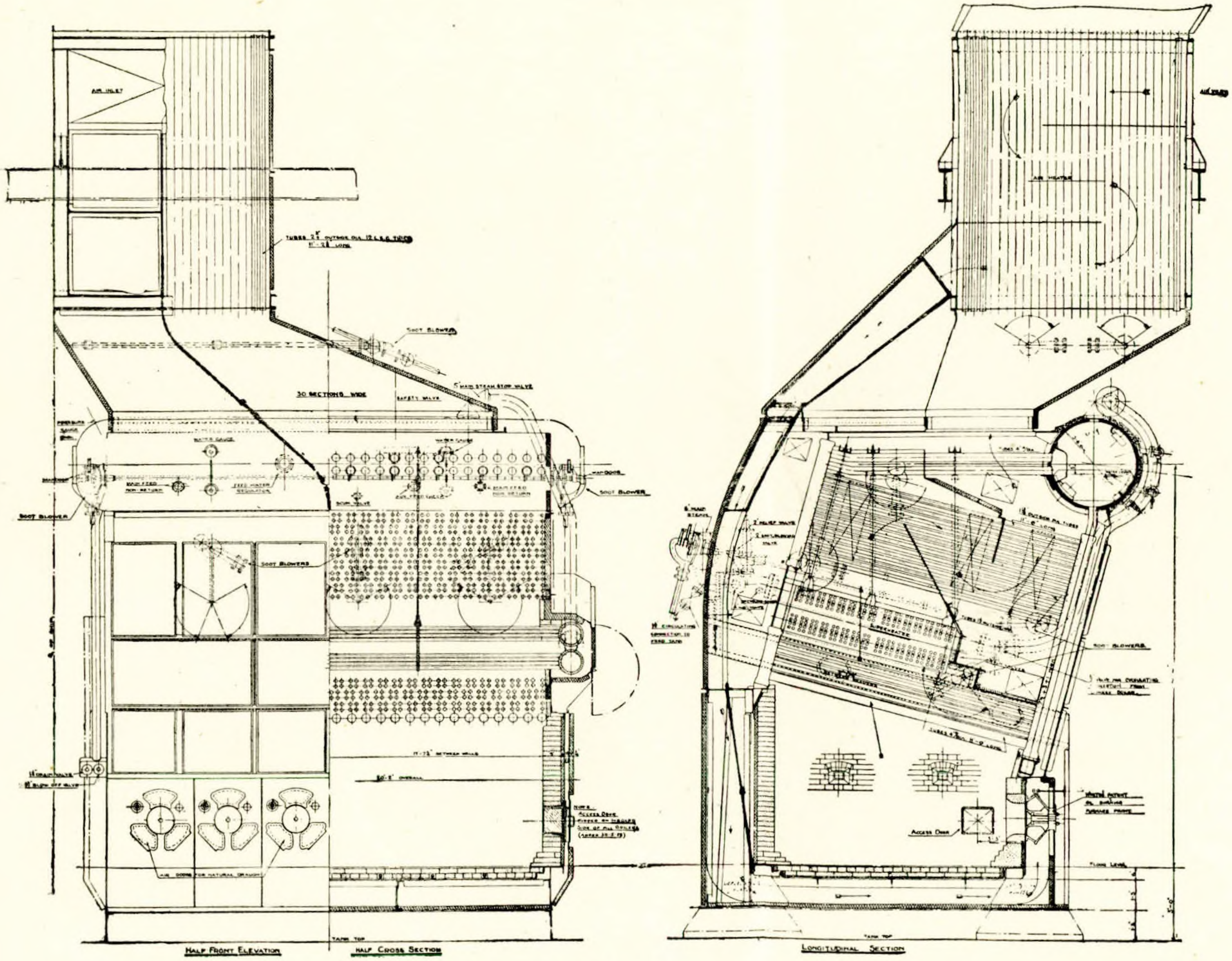

AIR INLET
TUBES 2½" OUTSIDE DIA. 12 L.S.G. THICK 11'-2¾" LONG
SOOT BLOWERS
30 SECTIONS WIDE
SAFETY VALVE
5" MAIN STEAM STOP VALVE
PRESSURE GAUGE
WATER GAUGE
MAIN FEED NON-RETURN
FEED WATER REGULATOR
SOOT BLOWER
SCUM VALVE
AUX. FEED CHECK
MANHOLE
SOOT BLOWERS
1½" DRAIN VALVE
1½" BLOW OFF VALVE
AIR DOORS FOR NATURAL DRAUGHT
17'-7½" BETWEEN WALLS
20'-2" OVERALL
NOTE. ACCESS DOOR FITTED ON HEADER SIDE OF ALL BOILERS
TANK TOP
HALF FRONT ELEVATION
HALF CROSS SECTION
AIR HEATER
6" MAIN STEAM
2" RELIEF VALVE
2" ANTI-BLOWING VALVE
1½" CIRCULATING CONNECTION TO FEED TANK
SUPERHEATER
SOOT BLOWERS
1¾" OUTSIDE DIA. TUBES
TUBES 4" DIA. 18'-0" LONG
WHITE'S PATENT OIL BURNING FURNACE FRONT
ACCESS DOOR
FLOOR LEVEL
TANK TOP
LONGITUDINAL SECTION

PLATE II.

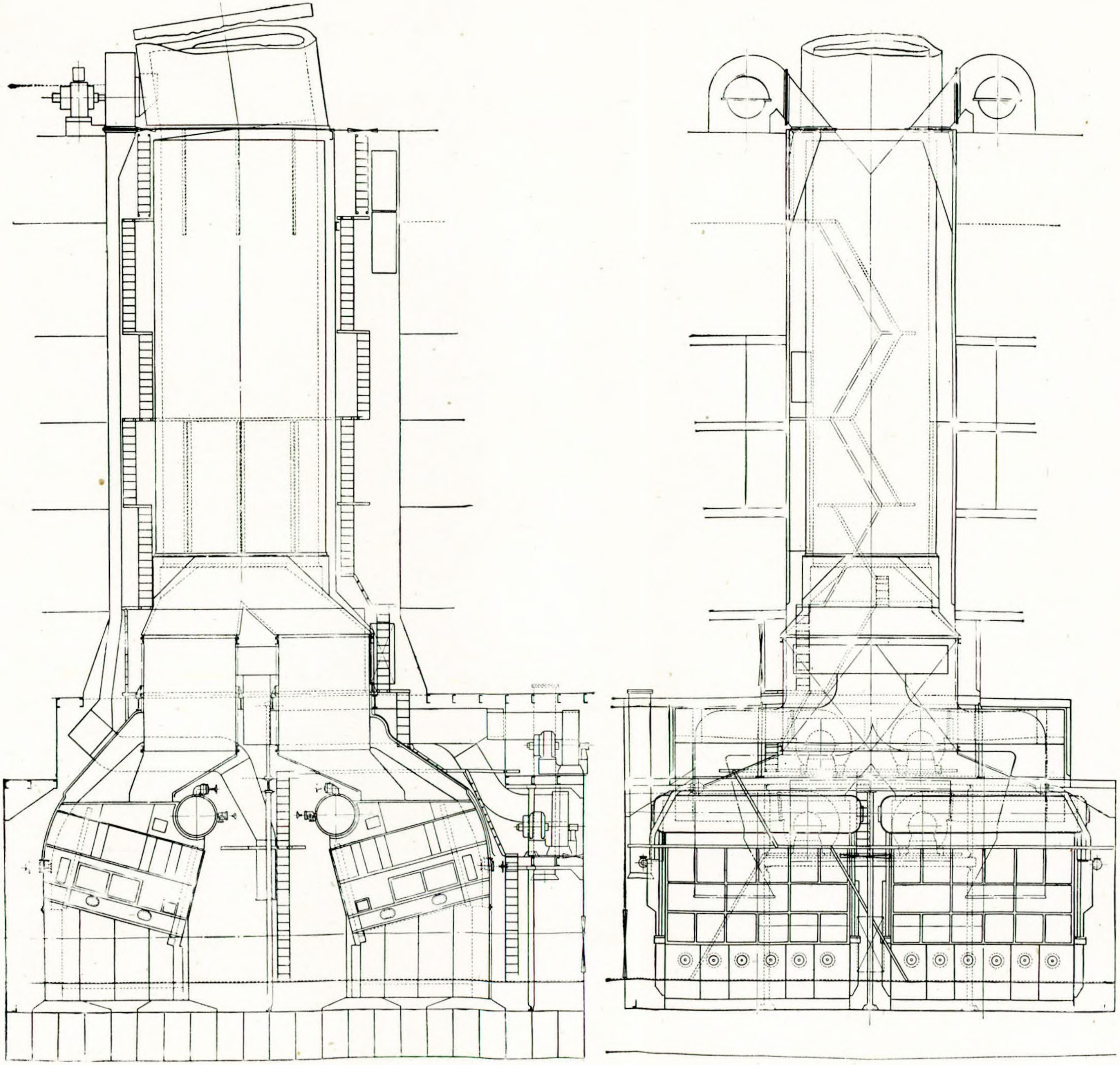


PLATE III.

The steam trial results recorded on the machinery trials in March, 1929, were as follows:—

Mean R.P.M.	124½
Mean S.H.P.	20,400
Steam press. boilers	405 lbs.
Steam press. engines	394 lbs.
Steam temp. boilers	675°F.
Steam temp. engines	658°F.
Vacuum	28·6 in.
Water per hour	192,500 lb.
Fuel Oil per hour	13,750 lbs.
Feed Temperature	270°F.
Gas Temperature into Superheater	1,310°F.
Gas Temperature out of Superheater	820°F.
Gas Temperature out of boiler	535°F.
Gas Temperature out of Airheater	360°F.
Air Temperature Fan Inlet	105°F.
Air Temperature out of Heater	285°F.
Air Temperature into O.F. Air Register	300°F.
Air Pressure at Fan delivery to Airheater	+·709 in.
Air Pressure out of Airheater	+·354 in.
Air Pressure at Oil Burner	+·04 in.
Gas Pressure into Airheater	—·47 to—·51 in.
Gas Pressure out of Airheater	—·47 to—·51 in.
CO_2 at Boiler exit	11%.

The air-heaters were designed to raise the temperature of the combustion air to 300° F.

Particular attention was paid in the design of the air supply and the air trunking from the forced draught fans to the oil-fuel burners to give an efficient and easy flow of air from the fans to the boiler fronts.

Similar attention was given to the design of the uptakes and air-heaters to provide an easy flow for the furnace gases from the boiler through the air-heater to the funnel.

The results of the machinery trials and subsequent service at sea indicate a very satisfactory performance of this part of the installation.

The boiler efficiency assuming fuel oil value of 18,500 B.T.U.'s on the above figures is 84% of the gross value of the fuel. Boiler efficiencies of 87 and 88% have been recorded on service.

The foregoing results show that the forecast made by Mr. Cook in 1926 was very soon realised in actual service, and even more economical figures may be anticipated in the future, although the rate of advantage which has been obtained during the last five years cannot be expected to be sustained.

MARINE BOILER INSTALLATIONS.

It is now desired to illustrate the progress in boiler design which has occurred during the last five years, and it is proposed to do this by illustrating examples of representative boiler installations which have been installed in ships during these years. Three examples have been chosen from boiler installations commenced in 1926.

Plate IV shows the boilers fitted in the passenger steamer *Op ten Noort,* of the Royal Packet Navigation Company of Holland. This vessel has five boilers with a total boiler heating surface of 17,536 sq. ft. and a superheater surface of 4,500 sq. ft., with a boiler pressure of 220 lbs. and a final temperature at the superheater outlet of 540° F. The boilers are oil-fired with the Wallsend-Howden system of oil-fuel burning.

The above boiler installation represents a modern installation without air-heaters and a boiler efficiency on service of practically 80% was realised. The actual results of a test while on service at sea of which we have knowledge are recorded later in the paper.

Plate V illustrates the boilers installed in the cargo boats, *Beaverhill* and *Beaverbrae* of the Canadian Pacific Steamships Ltd., and to which reference has been made in Mr. Johnson's paper before the Institution of Naval Architects in the spring of 1929.

In each ship there are four water-tube boilers, having a total boiler heating surface of 12,680 sq. ft., and a superheater surface of 2,760 sq. ft. for a boiler pressure of 265 lbs., and a final temperature at the superheater outlet of 676° F. These boilers use hand-fired coal as fuel and realised a boiler efficiency of 75%. They are still on service with hand-firing, and although the original design arrangement made the necessary provision for the substitution of mechanical stokers at a future date if required, this alteration has not yet been made, although we understand from the information given us in Mr. Johnson's paper that there is an increased boiler efficiency to be obtained by the use of mechanical stokers as compared with hand-firing.

Plate VI indicates the boilers which were installed in the three new steamers recently put on service by the L.M.S. Railway Co. for their Cross-Channel steamship service between Belfast and Heysham, the *Duke of Lancaster, Duke of Rothesay* and *Duke of Argyll.*

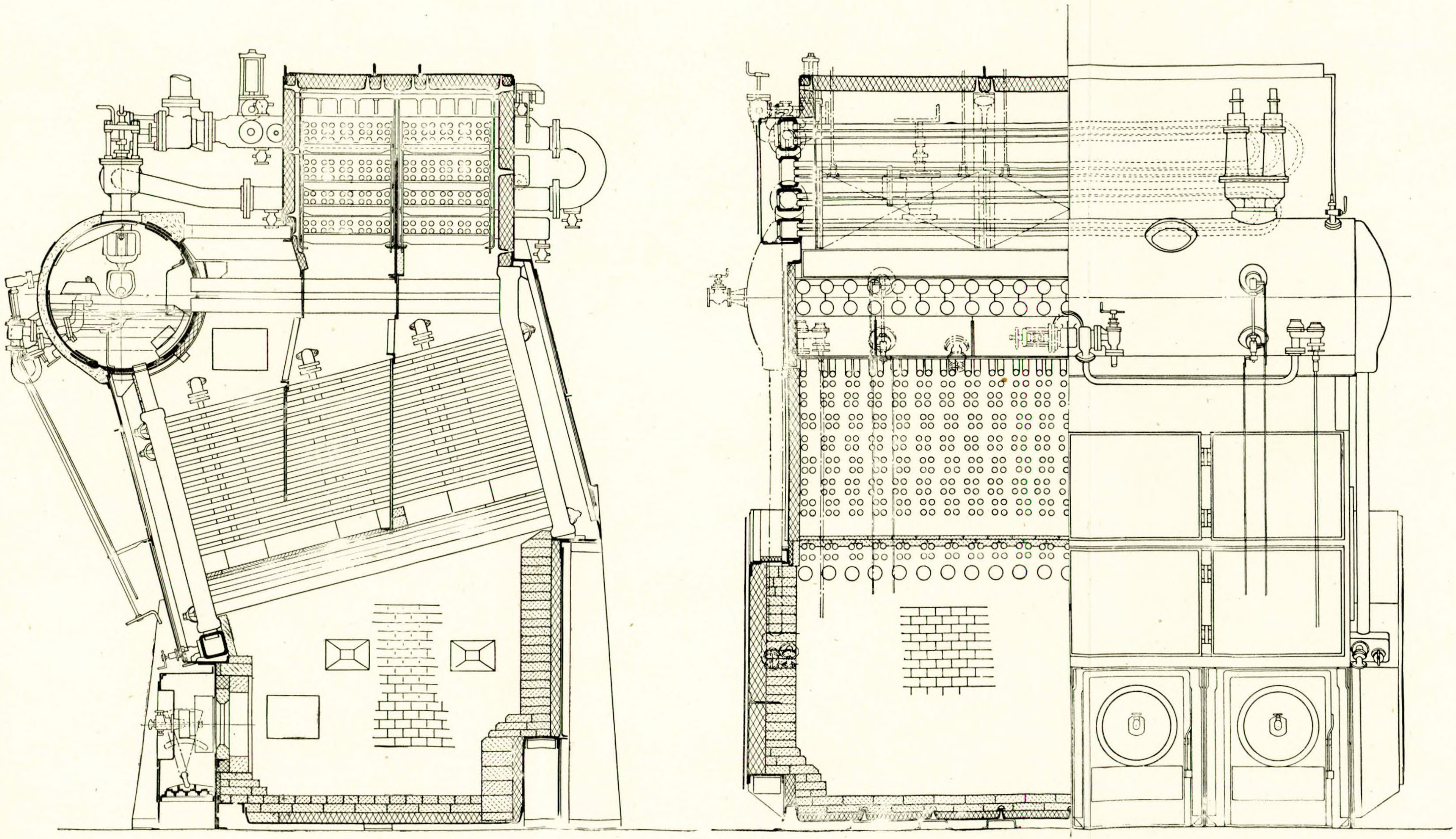


PLATE IV.

Each vessel has six boilers with a total boiler heating surface of 19,770 sq. ft. They work at a pressure of 225 lbs. and without superheat. The requirements for passenger accommodation in these Cross-Channel steamers leaves very little headroom and space for the boiler installation, and it has generally been accepted that where the amount of steaming is only for a few hours per day, and the total fuel required for steaming is not a large amount per day, that considerations of first cost, weight and space have out-weighed the conditions which might accrue in fuel economy by the provision of even a small amount of superheat.

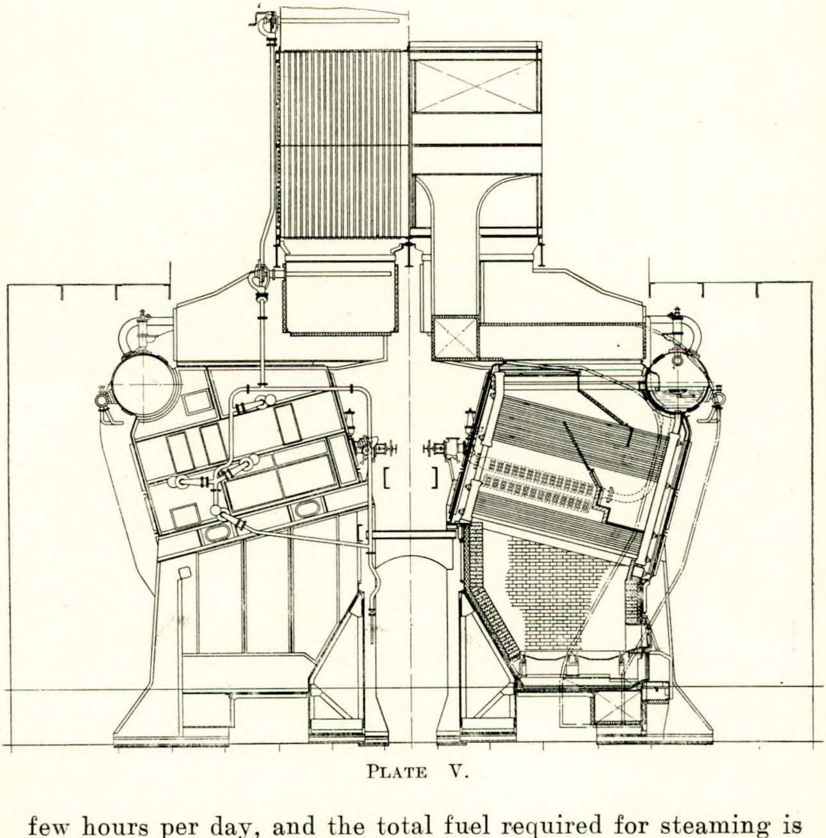


PLATE V.

During the year 1927, typical examples showing the increase in boiler pressure are the boiler installations in the oil tankers, *Scottish Chief* and *Scottish Heather*, the passenger steamers *Nieuw Holland* and *Nieuw Zeeland* and the *Statendam*, which latter installation has been described above.

Plate VII illustrates the boilers which have been installed in the oil tankers *Scottish Chief* and *Scottish Heather*. Each vessel has four boilers with a total boiler heating surface of 11,588 sq. ft. and superheater surface of 2,440 sq. ft., and an airheater surface of 4,000 sq. ft. The working pressure is 250 lbs. and final temperature at the superheater outlet of 506° F.

Plate VIII illustrates the boilers installed in the *Nieuw Holland* and *Nieuw Zeeland*, except that the airheaters are not shown. Each of these vessels has four boilers with a total heating surface of 13,932 sq. ft., a superheater surface of 6,400 sq. ft. and a total airheater surface of 15,320 sq. ft. The boilers are oil-fired with the Babcock and Wilcox system of oil burners and electrically driven oil-fuel pumps. They have a closed air supply system from airheaters to burners and they realised on trials and subsequently on service a boiler efficiency of 84%.

Detailed results of boiler performance are given in Table I. The boiler working pressure is 290 lbs. and the final temperature at the superheater outlet 670° F.

The boiler installation in the Holland-America liner *Statendam*, also commenced in the year 1927, has been fully described above.

In 1928 representative boiler installations are those which were commenced for the steamship *Canterbury* for the Cross-Channel service of the Southern Railway between Dover and Calais; for two new steamers for the Belgian State Railway, the *Prince Leopold* and *Princess Astrid* for the Dover-Ostend service and for the Clyde turbine passenger steamer *King George V*.

Plate IX shows the boiler installation in the Cross-Channel steamer *Canterbury*, which has four boilers having a total heating surface of 17,072 sq. ft. and without superheaters. The working pressure is 225 lbs. and the boilers are oil-fired with Babcock and Wilcox oil-fuel burners and the closed stokehold system of draught.

The same remarks, in regard to the boiler installation in this vessel as have been made for the Cross-Channel steamers for the *Duke of Lancaster* class, apply here.

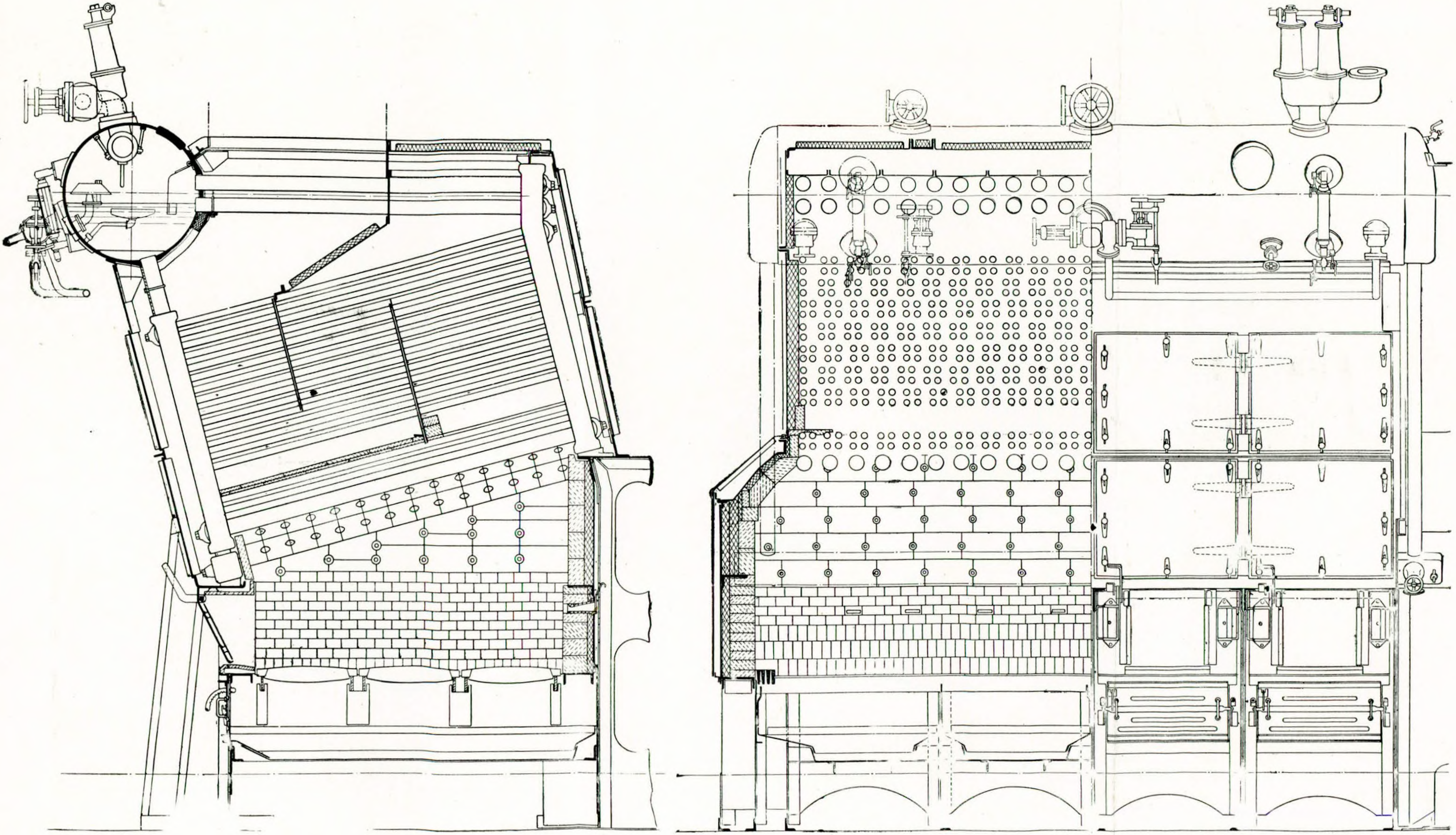


Plate VI.

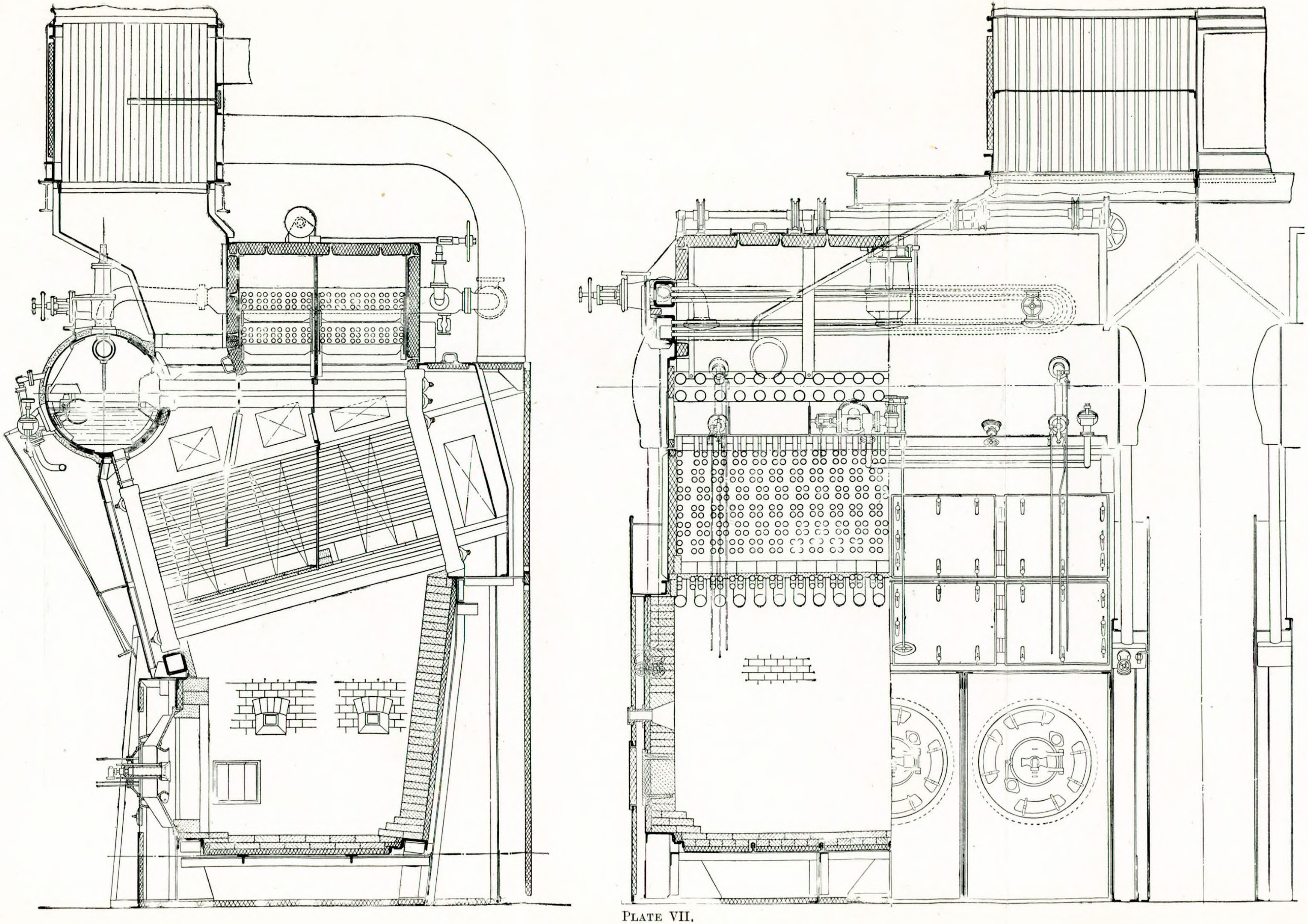
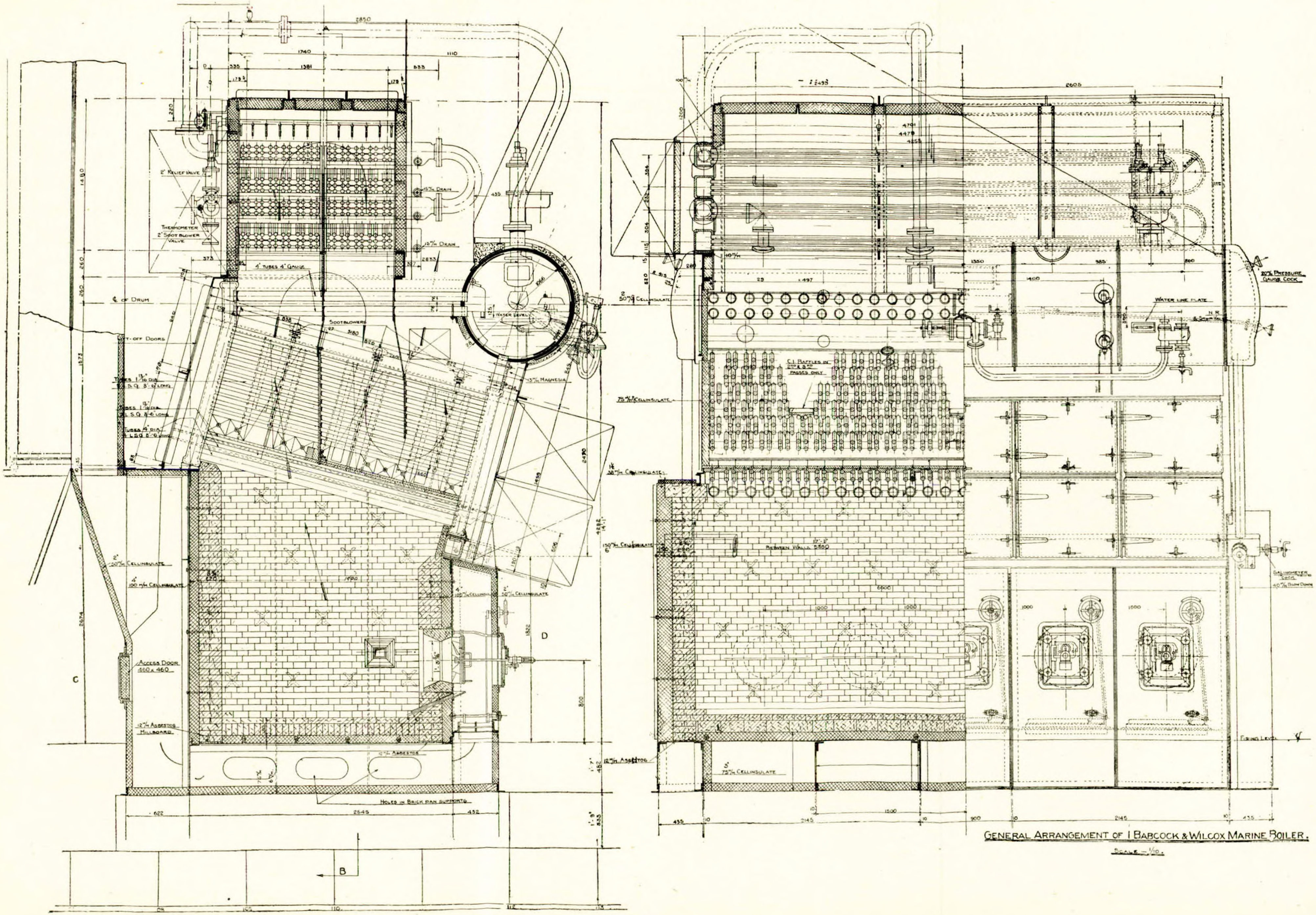


PLATE VII.

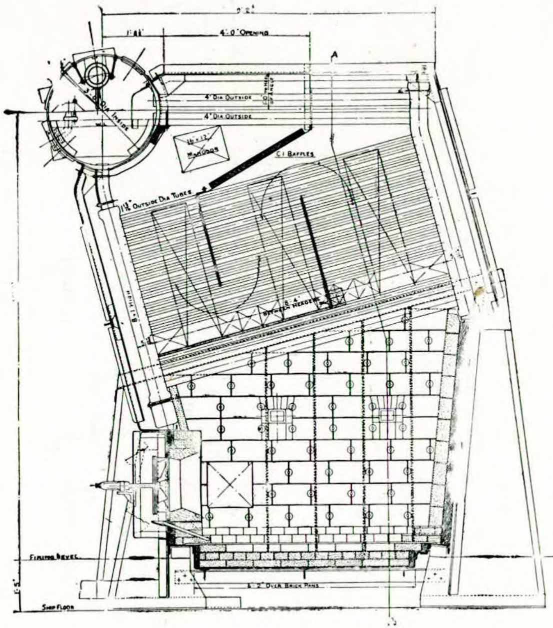
To Air Heater.



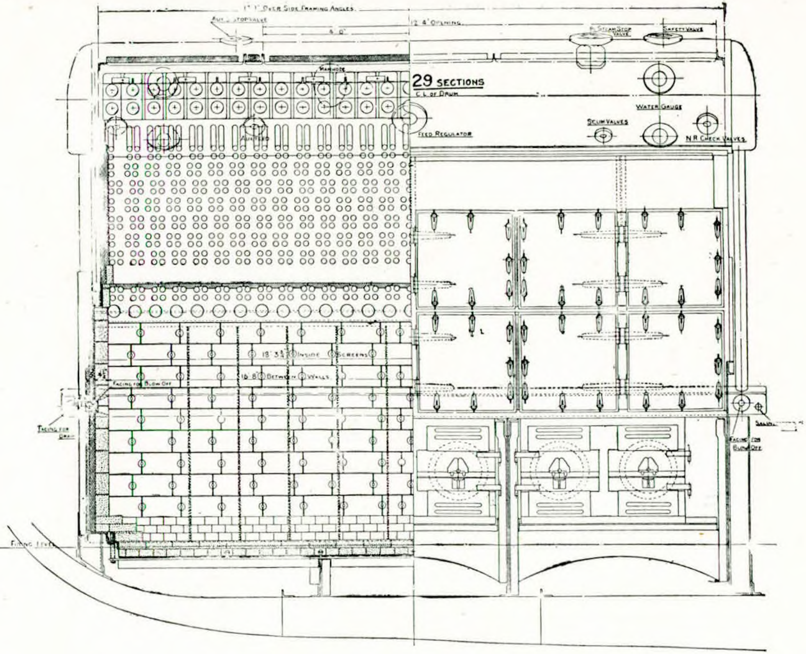
GENERAL ARRANGEMENT OF 1 BABCOCK & WILCOX MARINE BOILER.

SCALE – 1/10.

PLATE VIII.



Sectional Elevation.



Half Section at "A A"

Half Front Elevation.

PLATE IX.

The trip from Dover to Calais is made in about 1¼ hours, and the *Canterbury* does two trips, one each way, daily. The requirements for passenger accommodation permit only very limited headroom and space for the boiler installation, and the installation chosen without superheaters and any method of air heating is probably the most satisfactory for this class of ship.

Plate X shows the boiler installation which is being installed in the new steamers for the Belgian State Railway for the Dover-Ostend service.

There are six boilers in each ship, with a total boiler heating surface of 21,300 sq. ft. and a temperature of 620° F. The total superheater surface is 5,940 sq. ft. These boilers are being built for hand-fired coal as fuel, but arrangements are made and provision is made so that they can quickly be turned over for oil-fuel burning if desired at any time.

Plate XI gives front and side views of the boilers which have recently been installed in the turbine steamer *King George V.* They are designed to work with a safety valve load of 550 lbs. and to give a steam temperature at the superheater outlet of over 700° F.

It was considered of primary importance that the boilers should be robust and durable and to provide steam at the required pressure and temperature under the most efficient conditions possible consistent with the imposed limitations as regards weight and space.

The design finally adopted is as indicated in the accompanying Plate XI and photograph of the boiler in the shop.

The boilers are of the usual Babcock and Wilcox construction, each boiler being 18 sections wide and tubes 9 ft. 3 ins. long overall. Each boiler has a tube heating surface of 2,280 sq. ft., a superheater tube surface of 780 sq. ft. and an airheater tube surface of 800 sq. ft. The grate area of each boiler is 75·5 sq. ft.

A good deal of consideration was given in the early stages of the design as to the position to be selected for the superheater. We had to bear in mind the recent Board of Trade rule that tubes which contained only steam should be situated in a position shielded from " direct radiant heat and where only hot gases and not flame can impinge upon them." An interdeck superheater could have been fitted, that is, a superheater fitted in a space between the generating tubes, as now very generally

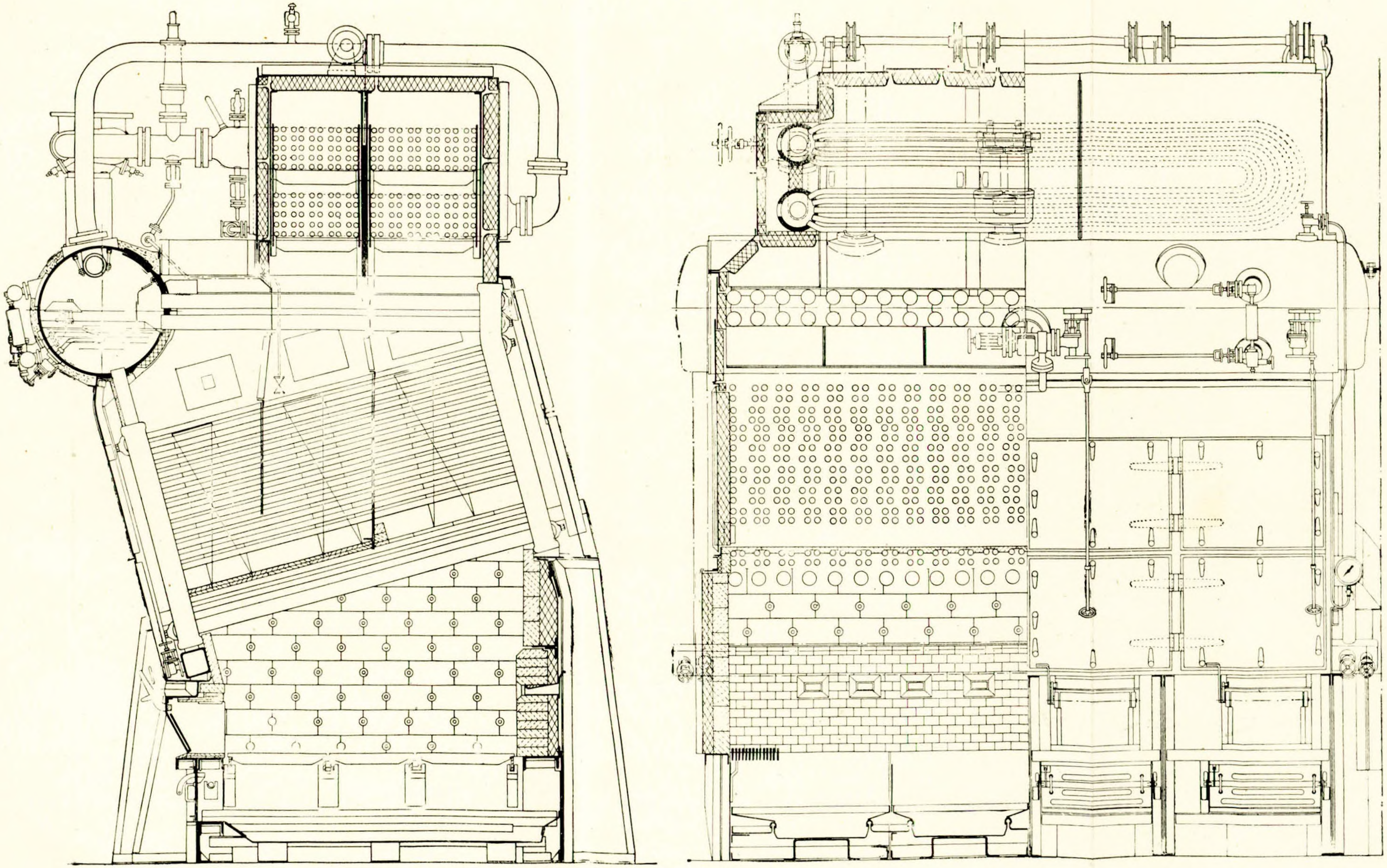


PLATE X.

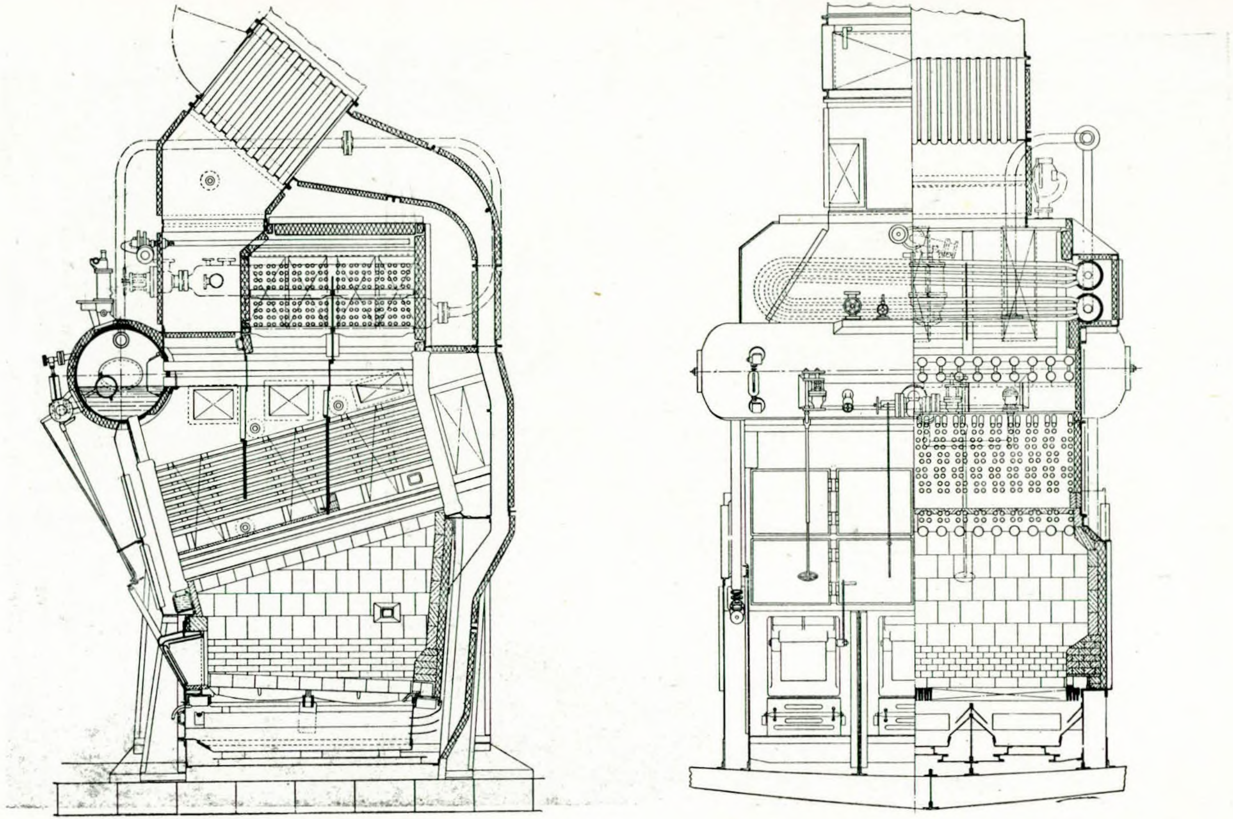


PLATE XI.

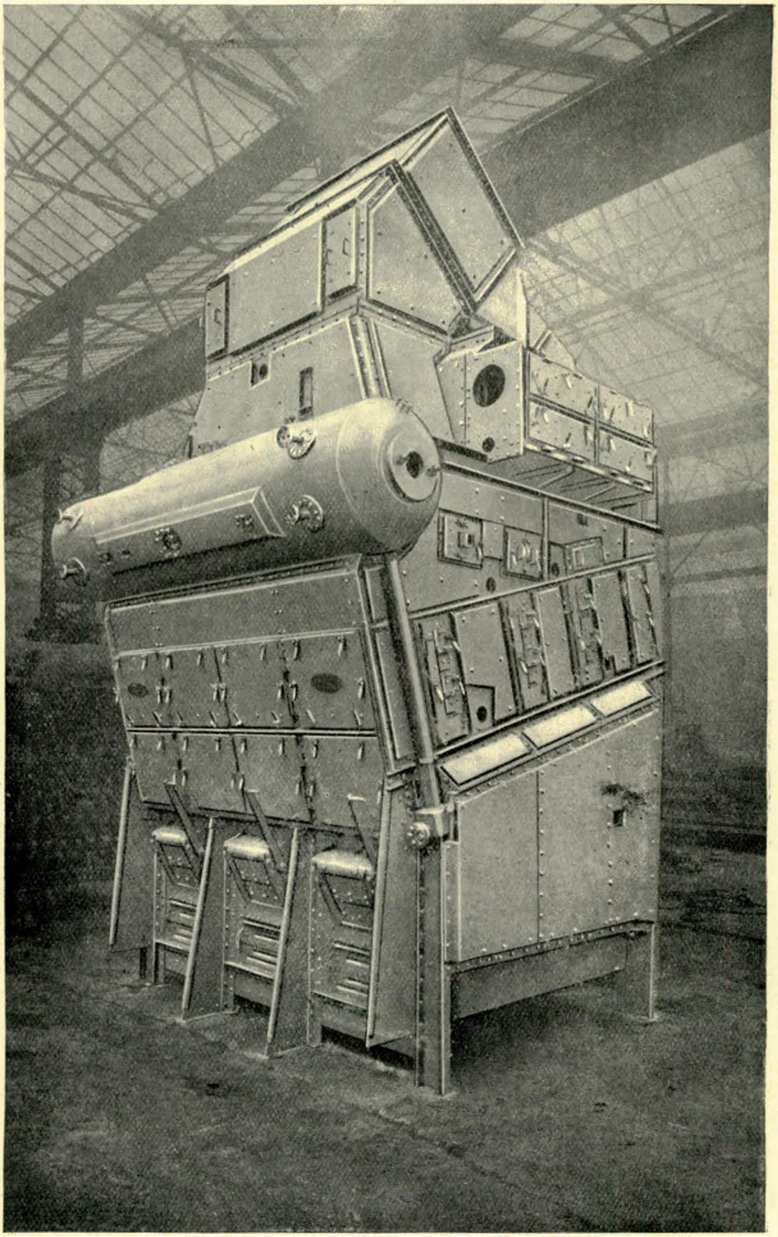


PLATE XIA.

used, but bearing in mind the Board of Trade attitude it was eventually agreed to use the super-posed position for the superheater as indicated on the drawing.

The boilers use coal as fuel and are hand-fired.

The boilers are worked under the closed stokehold system of draught; there is one fan situated at the level of the firing platform providing the air supply for both boilers to the boiler room. The air for combustion is taken from the top of the boiler rooms into and through the airheaters down the trunking at the backs of the boilers and guided by direction plates into the ashpit under the furnace bars. A system of cast iron air grids has been provided at the bottom of the side and back walls.

The boilers follow the usual construction of this well-known type.

We have now had the experience of a season's service in this luxurious Clyde passenger steamer, and it is considered to be true to state that the reliability and durability of the boiler has been well established. It is true that there was in the middle of the season an unfortunate accident in one boiler due to shortness of water. Even, however, under these circumstances the superheater was undamaged.

Examinations of the boilers at the end of the season's service show them to be in very good condition and with only such wear and slight distortion of some baffles, tube supports and a few casing plates as might have been expected. The furnace condition at the end of the season was in every respect good, the fire bars being practically in their original condition. The brickwork was good and the cast iron grids were also in good condition, except that the grids in the back wall begin to show signs of erosion at the top of the air supply inlets. Slight alterations have been made to still further improve the durability of those parts showing signs of wear and distortion ready for the next season's service.

The steaming of the boilers on service has been easy and normal and it is claimed without fear of contradiction that the boilers have established their reliability and good durability at the designed pressure and temperature of 550 lbs. and over 700° F.

We look forward with considerable interest to the further service in this Clyde passenger steamer.

The final illustration of boiler installations, Plate XII, shows the boiler which is being built for installation in the United

Fruit Company's steamer *La Marea*. The working pressure is 400 lbs. and final temperature at the superheater outlet of 710° F.

The particulars of some of the boiler installations described have been summarised in Table 2, and the results realised under

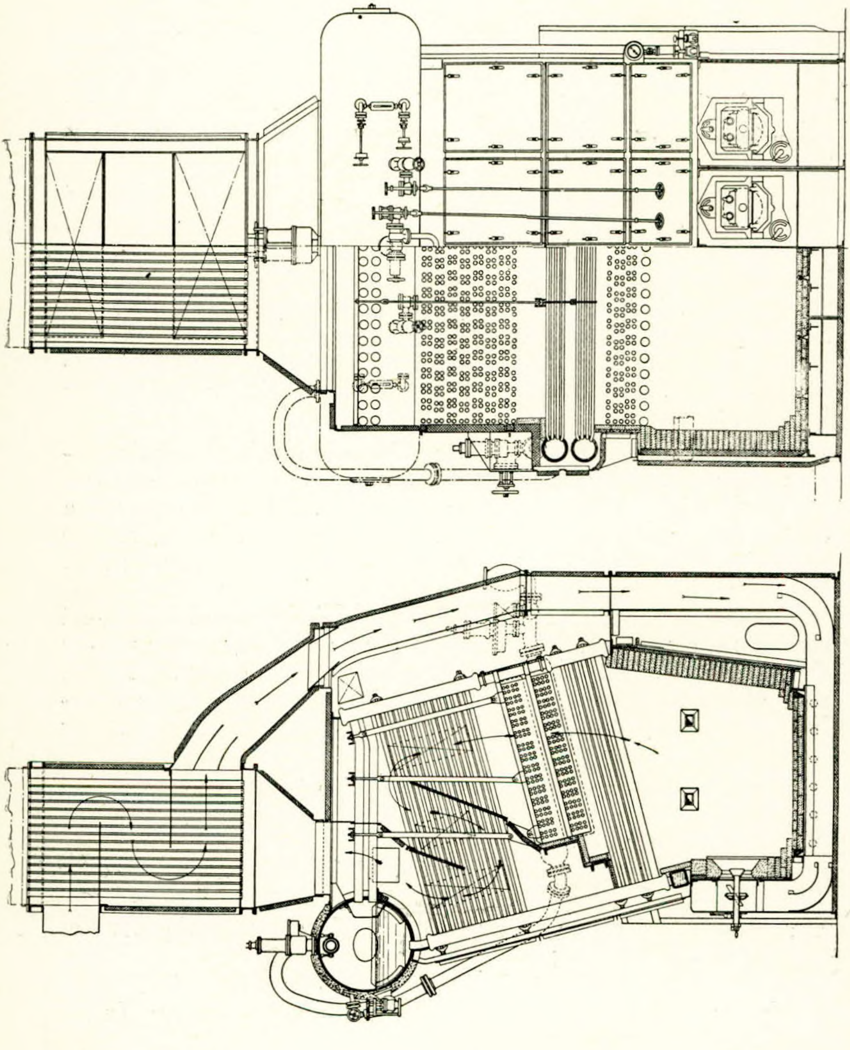


PLATE XII.

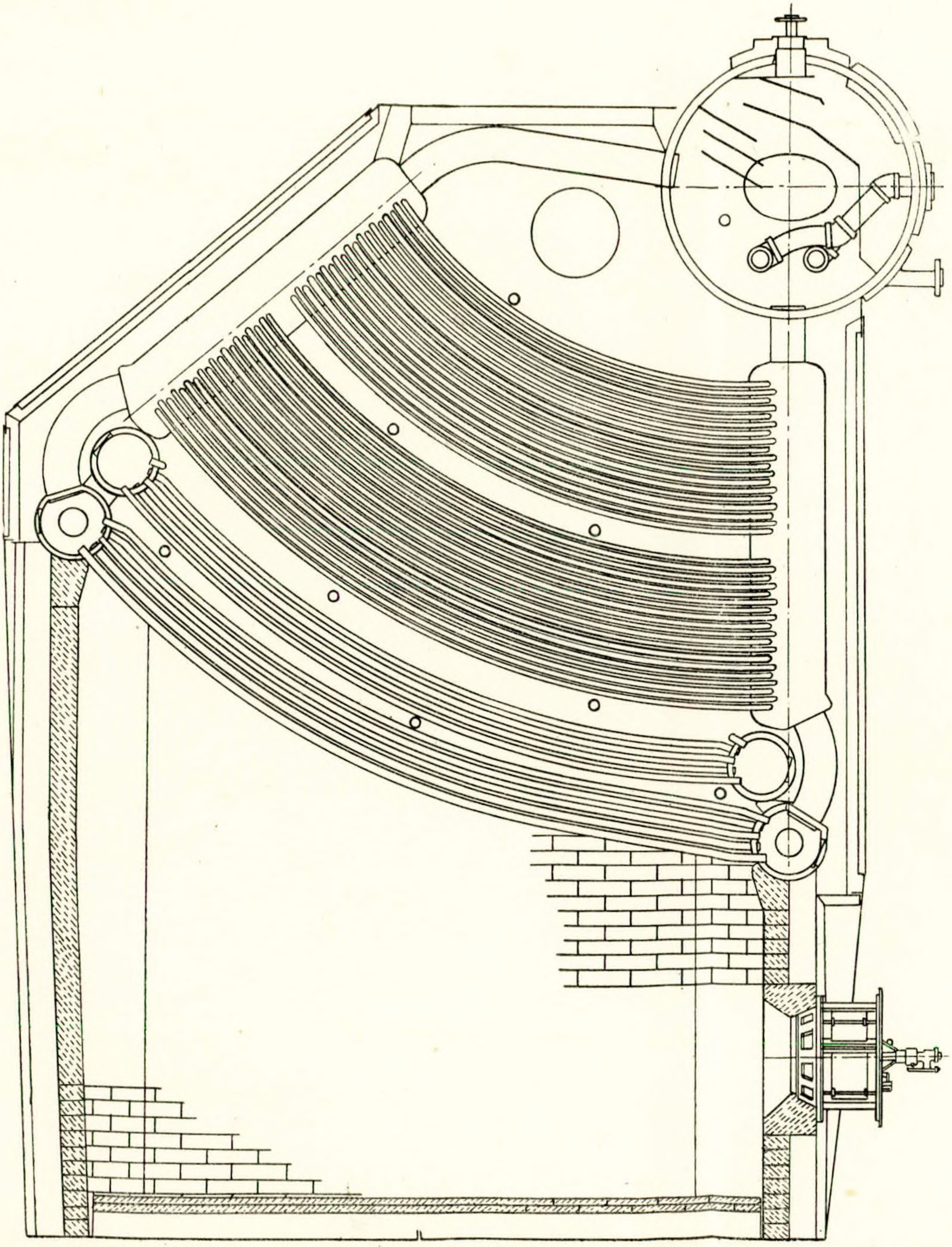


PLATE XIII.

trial conditions and on service have been included to illustrate actual experience obtained during the five years under review.

TABLE II.

SHIP.	DUKE OF LANCASTER.	BEAVERBRAE.	OP TEN NOORT.	NIEUW HOLLAND.		STATENDAM.
STEAMING CONDITIONS.	5 HOURS TRIAL.	8 HOURS TRIAL.	SERVICE	6 HOURS TRIAL.	SERVICE.	CONTRACTOR'S TRIAL.
Boiler or Superheater outlet pressure lbs./sq. in.	201	212	206	279	260	405
Saturated steam temperature °F.	388	392	390	414	410	449
Boiler or Superheater steam temperature °F.	388	661	500	580	594	675
Degrees of Superheat	—	269	110	166	184	226
Feed temperature °F.	194	172	158	171	241	270
Number of Boilers	5	4	4	3	4	6
Total Evaporation lbs.	87420	59600	74974	68530	67980	192500
Evaporation per boiler lbs.	17484	14900	18743	22843	16995	32083
Type of fuel	Coal	Coal	Oil	Oil	Oil	Oil
Fuel Value, gross B.T.U.'s	13100	13730	18600	19000	18500	18500
Fuel per boiler per hour lbs.	1873	1756	1438	1702	1263	2292
Steam per lb. of fuel lbs.	9·3	8·5	13·03	13·7	13·4	14
Steam per sq. ft. Boiler Heating Surface lbs.	5·3	4·35	5·54	6·67	4·86	4·48
Overall Boiler Efficiency on gross fuel value %	73·6	75	80	82·5	84·2	84·5
Description of Installation	Boiler	Boiler interdeck Superheater and Airheater	Boiler & superposed Superheater	Boiler, Superposed Superheater and Airheater		Boiler, interdeck Superheater & Airheater
Heating Surfaces in sq. ft. Boiler	3295	3170	3387	3483		7160
Heating Surfaces in sq. ft. Superheaters ...	—	690	925	1600		1680
Heating Surfaces in sq. ft. Airheaters ...	—	3600	—	3830		7160
Gas Temperature out of Boiler °F. ...	—	484	—	605	550	535
,, ,, ,, Airheater °F. ...	—	335	—	423	406	360
Description of Fuel	Coal.	Coal	Oil	Oil	Oil	Oil

The first two examples are with hand-fired coal as fuel and two representative boiler installations. The first is a boiler supplying saturated steam only and no other means, such as airheater or economiser, added to increase the overall boiler efficiency. The second example is of a boiler fitted with superheater and airheater, but the increase in efficiency is not as much as anticipated with good average firing. It can only be assumed that the firing conditions with a hot air supply to furnace adversely affects the quality of the stoking. Better results might have been obtained with a closed stokehold system of draught instead of the closed ash pit supply from airheaters as fitted.

The remaining examples are of oil-fired boiler installations and do not call for much comment, except to point out that from such information as is obtained from owners from time to time the boiler efficiency obtained on service is generally better than the results obtained on the makers' trials. This has been very noticeable in the case of the *Statendam*.

Unfortunately, complete performance results for propelling and auxiliary machinery and other steam plant and boilers are seldom published in sufficient detail to enable comparisons to be made.

Dr. Meijer, the Chief Superintendent of the Holland-America Line has, however, recently read a paper in Holland at the Hague on the results realised in S.S. *Statendam*. The figures quoted are ·619 lb. of oil fuel per S.H.P. per hour for all purposes, which represents an overall efficiency of 21·6 per cent., the fuel oil value being 19,000 B.T.U's per lb.

The results achieved, therefore, in vessels on service do seem to indicate that the conclusion advanced in 1926 that a high pressure steam installation could be made to compete with the marine oil-engine installation in operating costs has been practically established.

The subject of marine water-tube boilers has so far been treated only from the aspect of the description of different installations and the operating fuel costs.

The success of an installation is not determined, however, from this point of view only, and in choosing the type of propelling machinery to be adopted for any vessel for any particular service, the owner has to take into account many well-known factors.

In all cases the choice has to be made with a view to profitable business. The owner has to take into account the first cost, the weight and space occupied, the material and labour operating costs, the maintenance costs and the safety, durability and reliability of the propelling machinery equipment. These factors are interdependent.

If first cost is not an important matter then generally the remaining conditions can be well satisfied, and if it were possible to obtain a comparative analysis of fairly similar installations it would be expected that the cheapest installation would probably entail the highest maintenance and operating costs.

This is an aspect of the question that is probably fully considered by most Superintendent Engineers, but is one upon which the writer lacks knowledge.

It is, however, desired to discuss at not too great a length, the very vexed and important question of the weight and space occupied.

In Table 3, figures of weight and space for the boiler installations which have been described have been collected and compared. The figures may be considered as fairly representative of modern steamship water-tube boiler-room installations. It is probably axiomatic to say that both the naval architect and the marine engineer desire to limit the weight and space to minimum requirements consistent with obtaining satisfactory, if not low, material, labour, operating costs and maintenance charges and the necessary safety, durability and reliability of the steam generating plant.

In a long experience as an engineer officer of H.M. Navy, it has been realised that a gradual reduction in the amount of weight and space allowed per lb. of steam generated is expected. This tendency to require increasing power output from boilers per unit of weight and space in H.M. Navy has led to the abolition of the cylindrical boiler and the adoption of the water-tube boiler, and in later years to the adoption of the small tube type water-tube boiler in all classes of ships.

I have not been surprised to find that there has been the same request from the naval architect for all classes of ships in the Mercantile Marine to ask for the boiler equipment to be reduced in weight and to be limited in space.

In a recent paper given by General de Vito at the meeting of the Institution of Naval Architects in Rome in September, 1929, the author advocated the adoption of small tube oil-burning boilers with seamless receivers for the new projected Atlantic liners, and it was suggested at that conference that some consideration should be given to the desirability of choosing a large tube water-tube boiler so as to obtain the greater durability and reliability which are such essential features for a large passenger liner in order to maintain the regularity of service which is expected.

TABLE III.

WEIGHT AND SPACE OF MARINE WATER-TUBE BOILER INSTALLATIONS.

	Ship.	Steam Generating Plant.	Evaporation. Lbs. per hr.	Boiler H.S. sq. ft.	Boiler Rm. Floor Area sq. ft.	$\frac{\text{Evaporation.}}{\text{Floor Are}}$	Total Wt. with Water Tons.	$\frac{\text{Evaporation.}}{\text{Weight.}}$
1.	DUKE OF LANCASTER ...	B	120,000	19770	2126	56·5	253	475
2.	CANTERBURY	B	118,500	17072	1680	70	220	538
3.	PRINCE LEOPOLD ...	B.S.	152,460	21300	2202	69·3	318	480
4.	OP TEN NOORT... ...	B.S.	72,000	17536	2079	34·6	375	192
5.	SCOTTISH CHIEF ...	B.S.A.	55,000	11588	1424	38·5	243	226
6.	BEAVERHILL	B.S.A.	64,000	12680	1665	38·4	264	243
7.	NIEUW HOLLAND ...	B.S.A.	88,000	13932	2120	41·5	336	262
8.	LA MAREA	B.S.A.	45,000	8660	840	53·5	173	260
9.	STATENDAM	B.S.A.	210,000	42960	4278	49	744	282
10.	KING GEORGE V. ...	B.S A.	36,000	4560	612	60	90	400
11.	VICEROY OF INDIA ...	B.S.A.	160,000	32500	3950	40·5	505	316

B—Boiler. S—Superheater. A—Airheater.

It will probably be conceded that in two boiler installations of the same evaporative capacity, but one of which has been allowed greater weight and space in the ship design, this will prove to give better service. Better maintenance and lower upkeep cost will undoubtedly be the result of the plant with the better accessibility, and there is little doubt that those boiler installations which are more easily inspected, owing to the better accessibility of the working parts where the space conditions have not been too limited, get the better attention from the boiler room staff. Restriction in space and cramped conditions for personnel in cleaning operations undoubtedly implements a gradual falling off in efficiency.

It is the writer's impression that in many cases the boiler room installations have been too cramped for space for proper supervision.

If owners desire to repeat continuously on service the trial results there must be provision of reasonable accessibility to all boiler working parts.

In order to appreciate the effect on weight and space of a boiler installation by the use of higher pressures, the comparative figures selected from Table 3 have been the basis of the next diagram, No. 2.

The three curves, A, B, and C show the rise in boiler pressure and the increase in evaporation per sq. ft. of boiler floor space and the increase in evaporation per ton of boiler weight with the increase in pressure.

It should be noted that the information given in this paper is from completed vessels of which the writer has first-hand knowledge of the boiler installations, and undoubtedly it would have been of greater interest to the Institute if similar data from other well-known vessels giving excellent results on service could have been included. So far as is known, however, such figures have not been published, and in the absence of these figures the analysis of results is incomplete.

The figures, however, being from actual experience will doubtless be of some interest to members of this Institute and probably of use for future comparison.

Just at the time this paper was being completed, Mr. Mellor read his paper on the boilers of the P. and O. steamship *Viceroy of India* before the Institution of Engineers and Shipbuilders of Scotland and the figures given for the *Viceroy of India* in

Table 3 have been abstracted from that paper and the particulars of boiler-room floor space estimated from the drawings which have appeared in the public press.

The comparison between the boiler arrangement of S.S. *Statendam* and S.S. *Viceroy of India* is particularly interesting since the specified evaporation per square foot of boiler heating surface is the same in the two cases. It will be seen that the horizontal and larger tube boiler, although heavier than the vertical and smaller tube boiler, is not greatly so, and appears to have some advantage in floor space.

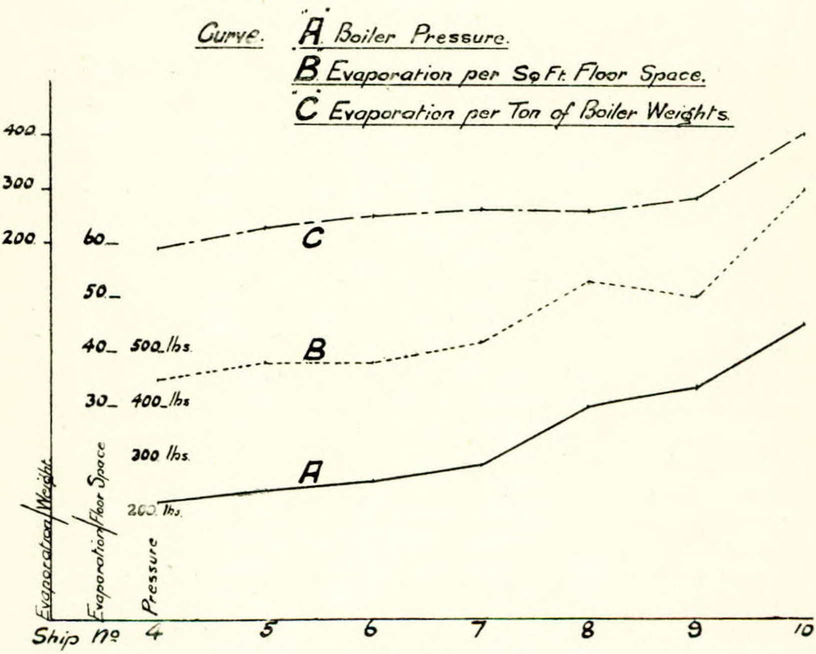


DIAGRAM II.

On the subject of weight and space required for marine boilers it will be of interest to give the particulars of a new type of small tube light weight boiler which has been built and tried in America.

A paper which was recently read by Mr. J. H. King before the Society of Naval Architects and Marine Engineers in New York in November, 1929, on the subject of "Increased

Economy in Marine Steam Machinery with particular reference to Marine Boilers " gives some very interesting particulars of a new boiler which has been designed and built in America to provide a boiler which will give an evaporative output for less weight and space than has hitherto been obtained by the small tube type express boiler.

By the courtesy of the above-mentioned Society and Mr. J. H. King, I have been allowed to give the following quotation from his paper:—

" The limitations of weight and space that have prohibited the use of higher pressures in naval work have led to a very careful study of the problem of designing a boiler that would be very light in weight, compact and give a very high boiler efficiency with a low stack temperature, thus making it unnecessary to use an airheater for a high overall efficiency. A boiler that seems to meet all these requirements was designed by the Babcock and Wilcox Company. This boiler, which it is believed will be of great interest to the marine world, is shown in Plates XIII and XIV.

" Its construction provides no untried mechanical elements. In its use of sectional headers, nipples, etc., it follows the design of the usual Babcock and Wilcox marine boiler which has been thoroughly proven in many years' service. The headers, however, are cylindrical, thus permitting of grouping a large number of tubes that are accessible for expanding, inspection and cleaning from a single handhole plate. In the design in the particular boiler shown in Plate XIII, sixty-six tubes are made accessible by the removal of one handhole plate. The arrangement of the cylindrical headers, with a decreasing area of gas passage through the boiler, results in a uniformly high rate of heat transfer. A superheater, which is of the interdeck type, is located above the lower bank of generating tubes. These tubes are frequently referred to as a water screen, as they screen the superheater from the radiant heat from the furnace.

" The first two, or fire, rows of tubes are 1½ inches in diameter and the next three rows are 1¼ inches in diameter. All the tubes above the superheater bank are 1 inch in diameter.

" The drum is of riveted construction, 42 inches in diameter and built for a working pressure of 600 pounds. A boiler of this design and size of drum can be built for 750 pounds working pressure without any change, except a slight increase in the thickness of the drum shell. At very high pressures, an airheater or economiser can be added if desired."

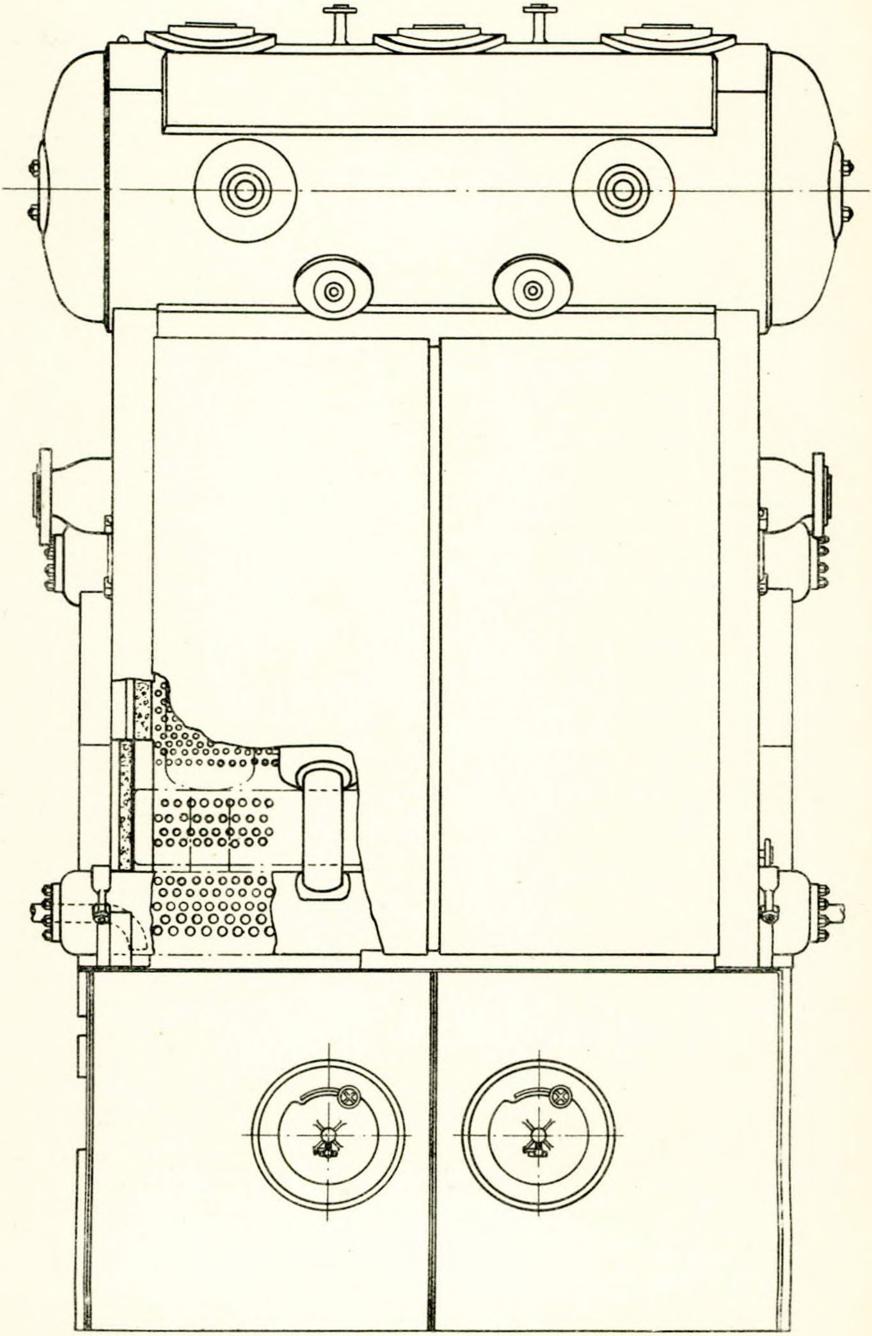


PLATE XIV.

This boiler has been constructed and tried on shore and efficiencies of over 80% have been obtained with the boiler and superheater only without airheater. The trials are being continued.

It may be of interest to readers of this paper to call particular attention to a feature in the design of this boiler mentioned by Mr. J. H. King, namely, that a large number of tubes can be examined by the removal of any one of the handhole doors in the cylindrical headers.

Although the number of tubes which can be dealt with from one door is perhaps regarded as an advantage, yet it is a matter for judgment whether the real advantage does not lie with the sectional boiler with straight tubes and arranged with a small door at each end of a large tube or at each end of a group of four tubes, so that individual inspection of any part of the boiler can be carried out expeditiously and satisfactorily.

The real advantage of the sectional type boiler over other types is that by the removal of a few small handhole fittings an exact appreciation of the internal condition of the boiler tubes can be ascertained without any discomfort or exertion and without even waiting for the boiler to cool down.

A boiler which offers unique facilities for the examination and cleaning of its internal surfaces, section by section, from the stokehold platform has advantages over a boiler which has to be opened right up and allowed to cool completely before any one can even ascertain what work, if any, is required to put it into condition for service again.

Drum Construction.—With the introduction of the high steam pressures for marine purposes, the seamless drum has been adopted, either with closed in ends or with the drum ends riveted into a seamless shell.

It is quite a practical proposition to use a riveted drum up to a pressure of 650 lbs. and this type provides a less costly steam drum, although the manufacture of seamless drums in increasing numbers may tend to bring down the cost of these drums. The weight of the riveted drum will not be very different from that of the seamless drum if the extra cost for machining unnecessary metal from the seamless drum can be permitted.

With modern methods of riveted construction the possibility of trouble with the riveted seams by the commencement of steam leakage through the seams from inside is very remote and there should be no hesitation in using this method of drum construction if desired.

An illustration is attached of a typical seamless boiler drum such as has been used in recent vessels. Plate XV.

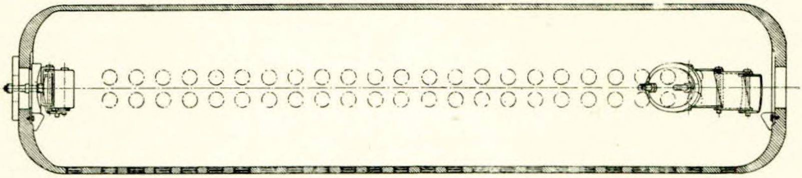


PLATE XV.

Water Gauge Mountings.—The water gauge mounting for the higher pressures has not caused any difficulty—the plate glass type or window water gauge being that most favoured and forged steel valves are used when the pressure exceeds 300 lbs. in lieu of the more general water gauge cock which is used for pressures below 300.

Superheat.—It is desired to refer briefly to one other point in connection with marine boiler installations and that is in connection with the now almost universal use of superheat to a greater or less extent.

Generally in order to safeguard the superheater tubes which have a steam content only under all the different furnace conditions to which the boiler and superheater may be subjected, it is of the first importance that a flow of steam through the superheater tubes should be taking place under all conceivable conditions. In other words, this implies that all the steam taken from the boilers should be taken from the superheater stop valve to ensure that all the steam generated passes through the superheater tubes.

It is probable that in nearly every vessel a supply of some saturated steam is required, and it is considered the saturated steam required can be best supplied by means of a de-superheater.

A very good form of de-superheater is that which has been employed in the *Statendam* and is illustrated in Plate No. XVI. Its purpose is to provide saturated steam to the heaters and other services which are normally operated by steam bled from the main turbines. Whilst manœuvring this source of supply

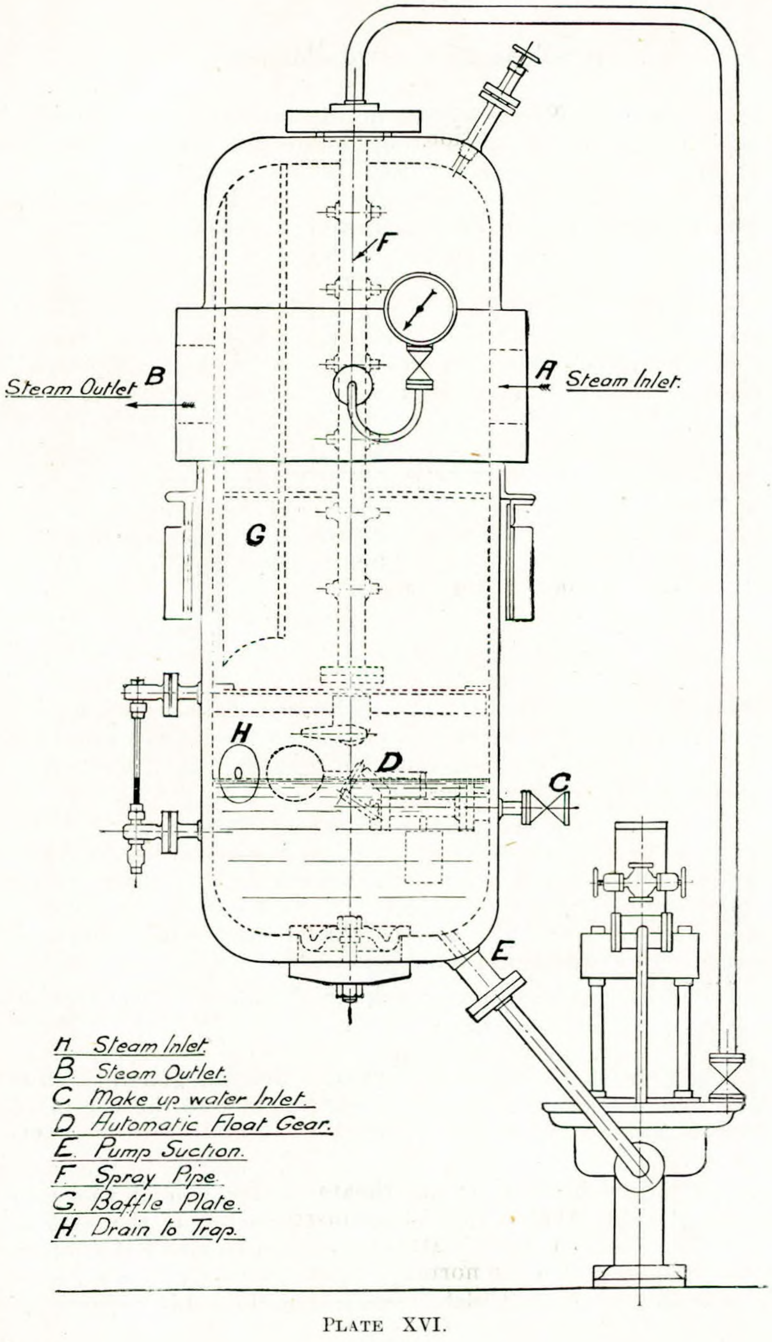

F
Steam Outlet B
A Steam Inlet.
G
H
D
C
E
A Steam Inlet.
B Steam Outlet.
C Make up water Inlet.
D Automatic Float Gear.
E Pump Suction.
F Spray Pipe.
G Baffle Plate.
H Drain to Trap.

PLATE XVI.

from the intermediate stages of the turbines is not available and the de-superheater is brought into use. The temperature of the outgoing steam can be maintained constant by means of a thermostat arranged to actuate the regulating valve on the steam supply to the de-superheater circulating pump. The level of the circulating water in the vessel is maintained constant by an automatic float valve. The water inside the de-superheater cannot rise above a predetermined level because the overflow pipe just above the high water mark is connected to a steam trap which ensures excess water being rapidly discharged from the vessel. Provided the de-superheater is well lagged there is no loss of heat involved and this method of providing any saturated steam supply required from boilers with superheaters is much to be recommended.

Feed Water.—This paper would not be complete without brief reference to the subject of the condensing plant and treatment of feed water in marine propelling machinery installations.

Only a short time ago in Mr. Eskil Berg's paper on Electric Propulsion we were told that condenser troubles are practically eliminated on electric ships. This statement was made presumably on the benefit that might accrue in relieving any strains on the condenser tubes caused by sudden changes in the flow of steam, both in amount and quality which may be due to the use of astern turbines.

This opinion seems to be an unduly optimistic one, but there is little doubt that both design of and material used with the modern condenser has rendered it almost completely immune from leakage due to accidents such as were very frequent in past history, and has rendered the modern condensing plant much more durable and reliable.

Immunity from salt water leakage, due to condenser troubles, has now reached a stage which makes the use of water-tube boilers for marine purposes quite a reasonable and practicable proposition from this point of view, which has generally in the past been considered the principal objection to the use of this type of boiler.

There is still remaining, however, the question of the supply of make-up feed water, and in this respect also it was noted that Mr. Eskil Berg, in his paper, stated that the make-up water on the electric ships is less than one quarter that on any other type of similar steamer. This certainly is an item of some advantage, and it is conceivable that this reduction in water loss which Mr. Eskil Berg leads us to assume has been obtained in recent ships may also be obtained in new ships irrespective of the type of power transmission used.

With the adoption of higher boiler pressures, which may reasonably be put at pressures exceeding 300 lbs. per sq. in., experience has shown the necessity or at any rate the very great desirability of using distilled water for make-up feed, and the ideal conditions seem to be to use distilled water for first filling the boilers and for make-up feed and only such slight treatment of this water as is necessary to render it sufficiently alkaline in order to prevent corrosion of the internal surfaces of the boilers and steam pipes which might be caused by gases in solution or by the distilled water itself.

It is considered correct to say that the feed water treatment generally in use has been with the use of lime, with or without the addition of soda, whether in the form of soda ash or caustic soda.

With pressures exceeding, say, 300 lbs. per sq. in. experience is being obtained that the use of lime is not entirely satisfactory although with a boiler pressure up to 430 lbs. in which distilled water is being used as the make-up feed water the careful use of lime and soda without serious concentration of the boiler water is giving good results on service. It is with the higher pressures essential to adhere to a standard of the use of distilled water only.

A satisfactory method which can be recommended, therefore, is to use pure water which contains no extraneous salts and to eliminate all treatment by chemicals or re-agents to the minimum consistent with giving the water a definite alkalinity. This is most easily carried out by caustic soda added to the boiler water on first filling. In the absence of any soluble or insoluble salts, such as would be the case if pure feed water is used, the only other possible cause of trouble there may be is with any occluded gases present in the feed water. If treatment is necessary on this account to prevent corrosion, the use of small quantities of tri-sodium-phosphate appears the best which can be recommended.

It is necessary with any treatment to ensure that there is not any accumulation or concentration of extraneous salts in the boiler water, and the following limitations are recommended:—

If no other treatment is necessary than the use of a small quantity of caustic soda to render the boiler water alkaline—

(*a*) A maximum for the boiler water of 30 grains per gallon of caustic alkalinity.

If feed water treatment is necessary, due to the presence of any gases,

(*b*) a definite alkalinity of the feed water,

(*c*) a maximum alkalinity of the boiler water of 30 grains per gallon of caustic alkalinity and a maximum of 10 grains per gallon of phosphate.

If any soluble or insoluble salts are present in the feed water—

(*d*) the amount of extraneous salts in the feed water should not exceed 2/10ths of a grain per gallon, the hardness ascertained by the soap test should be nil, and there should not be more than a trace of chlorides, tri-sodium-phosphate being added to the feed water as necessary to keep the phosphate content in boiler between 5 and 10 grains per gallon.

(*e*) the concentration in the boiler water should not exceed 100 grains per gallon, that is, 30 grains per gallon of caustic alkalinity, 10 grains for the phosphate and 60 grains per gallon for the extraneous salts (which would indicate leakage).

The foregoing recommendations have been compiled on the understanding that the distilled water being used as make-up feed requires little or no treatment, and that the necessary alkalinity condition of the boiler water is obtained in the direct and easy manner by the use of caustic soda only added to the boiler water.

If continuous treatment of feed water is necessary, then it would be recommended that the tri-sodium-phosphate should be put in the boiler water when first filling to the extent of 10 grains per gallon, and the feed water treated with caustic soda (one-tenth grain per gallon) and if necessary tri-sodium-phosphate to work within the above-mentioned limits.

Supply of Air for Combustion of the Fuel.—There are several alternative methods in use and each system has advocates, but it is desired in the paper to stress the importance of a well-designed fuel air supply.

As a naval engineer officer, my main experience has been with the closed stokehold system of draught for either coal or oil-fuel necessarily adopted in order to burn maximum quantities of coal on a given grate area or oil-fuel in a given combustion space.

It is a system that can be easily controlled and offers the best immunity against injury by furnace flame entering the boiler-room.

It entails somewhat more careful ship construction of boiler room bulkheads and decks to render the compartment air tight, but the system does benefit by the fact that any boiler casing leakage is from boiler room into furnace.

Four examples of coal-fired boilers have been given, the *Beaverhill*, which has a naturally ventilated boiler room and a forced draught confined duct air supply from fan through airheaters to furnaces and induced draught fans fitted for assisting funnel draught as and when required.

The boilers are hand-fired and under usual or normal conditions with little or no pressure + or – in the furnace and open stokehold there is great heat from the furnace doors when firing, which is a source of some discomfort to firemen.

The *Duke of Lancaster* and *Prince Leopold* have the closed stokehold system with hand-fired furnaces.

The *King George V.* has a closed stokehold air supply. Air for combustion of fuel is taken from this closed stokehold through the airheater and confined duct to furnace with funnel draught only from the furnace. The result has been a cool and calm condition in the stokehold and ease of hand-firing as compared with the opened stokehold and closed duct supply from fan to airheater to furnace. This system is undoubtedly one that would be favoured by boiler room personnel.

It is understood that a similar system has been adopted in the *Bremen*, and it is the writer's opinion that this method will be increasingly favoured.

In the five examples of oil-fired boilers described, one has the closed stokehold system and the other four a forced draught confined duct system from fan through airheater to furnace. In two cases induced draught fans are also fitted to assist the usual funnel draught.

For both types of fuel for facility of control and better habitability of boiler rooms and comfort of personnel the closed stokehold system of draught is preferred and wherever possible the addition of airheaters of moderate dimensions with air supply trunks to furnace.

It is important to arrange the air supply trunking to the fan and from fan to airheater and the gas passages from boiler to airheater and airheater to funnel with the minimum obstruction to passage of air and gas and changes in direction of flow should be as easy as possible and suitable guides provided. A smooth and regular air supply is necessary for efficient combustion and requires less fan power.

Conclusion.—In conclusion it is desired to say that endeavour has been made to write a paper that will prove of interest, without too much recapitulation of matter that has been already published at other institutions and in the press.

The task of avoiding repetition has not been easy, and your indulgence is claimed for such lapses as do occur, and also for what may appear to be exploitation of one type of water tube boiler, although it must be conceded that, as the paper has been written to acquaint members of actual experience, some partisanship may have occurred in places. In any case it has been endeavoured to avoid any statements not based on the results of experience.

It has been endeavoured to review from the information available to the writer the trend of events as shown from actual water-tube boiler installations and experience with the same.

As experience is gained with installations working at higher pressures and temperatures, reliability and low cost of maintenance on service is being proved.

Under these circumstances, and with a low actual fuel cost, the modern steam plant for marine propulsion should have a favourable outlook in the choice of propelling machinery equipments in the future.

It has the added advantage that any kind of fuel can be used.

It is hoped, therefore, that the contribution of this paper to the Institute will serve to bring to the front the continued use of the steam plant and the better outlook for the use of coal as fuel. The writer has not embodied in this paper any remarks on the subject of the mechanical methods of burning coal as fuel, principally because much has already been written recently on this subject. It is, however, sufficient to say here that the outlook for either mechanical stokers or pulverised fuel with water-tube boilers using high pressure and temperature is promising.

DISCUSSION.

The CHAIRMAN: Admiral Whayman has given us much food for thought and for discussion. As the title states, the subject is water-tube boilers, not any particular boiler, and I think Admiral Whayman has been very fair in giving us the general view of the question. We might open the subject by setting up a few more idols, and before we begin our iconoclasm perhaps another old Royal Naval Engineer, our old friend Mr. Arthur Spyer, might give us a few words on the subject.

Mr. A. SPYER: I must ask your indulgence, because in spite of my intimate acquaintance with Admiral Whayman, I had not an opportunity of reading his paper until just now. The first thing that strikes me is that the impression on my mind and I think on your minds is that at last, in spite of the opposition to the water-tube boiler which has been felt for so many years by marine engineers, it has made its way at last. It has come, and it will come to the front. We certainly ought to thank Admiral Whayman for the very valuable information he has given us which must have taken a great deal of time and trouble to prepare. The inevitable conclusion on reading his paper is that another important consideration is coming rapidly to the front and is rapidly proving itself, i.e., the considerable increase in the boiler pressure and in the temperature of the steam. As regards pressure, there is no serious difficulty, but when we come to the question of temperature it is a different matter. The fact is that we have not within commercial possibilities suitable materials for use in superheaters, valves, or pipes which will enable us to use temperatures above 700/800° F. without increasing costs to an extent which will render them uncommercial. As a matter of fact the pressure gives no cause for worry; we are building for our own works a boiler giving 10/12 tons of steam per hour at a safety-valve load of 1575 lb. and a temperature of 800° F. Of course that is not a toy, and will show what can be done. Probably it will be some time before we get up to those conditions in marine practice. Admiral Whayman has given us some very pertinent remarks as to the necessity for the use of pure water in such boilers in connection with high pressure. If you are going to use (as you certainly are) high pressure boilers at sea, you must have good feed water, otherwise you are going to have trouble. Admiral Whayman tells us that in the *Statendam* the overall efficiency is 21·6 per cent. That is less than the thermal efficiency which is obtained in the Diesel engine, but if you take into consideration the cost of fuel the dollar efficiency is in fact very satisfactory. In connection with this achievement we have to thank the Board of Trade representatives for the valuable help they have given us and for the attitude they have taken. Instead of adhering to hard and fast rules not intended for water-tube boilers they have given us every assistance, and I should like to thank them through Mr. Vose for the help they have given us. (Applause.)

Mr. J. R. DOUGLAS: I would like to thank the author for his most interesting paper, and although I am not a water-tube boiler advocate at present, I am interested in this type of boiler from the point of view of the use of powdered fuel. I consider that it is in this connection that the water-tube boiler will prove most satisfactory. We have had experience of powdered fuel applied to a Scotch boiler which has involved a certain amount of trouble. If we had had a water-tube boiler I think we should probably have had very little trouble.

On page 1 (of the proof copy) reference is made to a steam installation showing the relative results obtainable with various types of auxiliaries, as follows:—

1. With steam driven auxiliaries ·667 lb. of oil per s.h.p./hr. for all purposes.

2. With motor driven auxiliaries ·648 lb. ditto.

3. With motor driven auxiliaries and Diesel generators ·62 lb. ditto.

I think you will agree that a very good average performance of a Scotch boiler installation with steam auxiliaries and no "fancy" gear is ·72 lb. of oil per s.h.p./hr. This is a very satisfactory result considering that you are not paying anything for extra electric generators and motors, which naturally reduce the steam consumption but increase the initial cost where motor auxiliary plant is used. My experience is that the crux of the question is the feed water. On the North Atlantic the feed water difficulty has been got over by the use of Scotch boilers for supplying the make-up feed, thus if the Scotch boiler is not used for main steam supply it should be used in the form of an evaporator. The Company with which I am connected own a large fleet of vessels, of ages between two and thirty years, and we have not a single one in which we do not have condenser trouble. If the trouble is not with the tubes it is with the packing, and if not with the tubes or the packing it is with the tube plates. That is one of the first objections I have at present to the water-tube boiler with its higher working pressure. If one contemplates a tramp steamer with water-tube boilers in which one had to carry out all the conditions mentioned on pages 29-30, it seems to me that it would be necessary to carry a chemist in addition to the ordinary engineroom personnel! We have not at present engineers with the necessary qualifications to carry out those conditions.

Nevertheless, as Admiral Whayman says, water-tube boilers are bound to come, and no doubt by that time engineers of the Merchant Navy will be better educated to deal with them.

Mr. W. HAMILTON MARTIN: The author referred to drum construction and endeavoured to assure us that it is quite a practical proposition to use riveted drums up to a pressure of 650 lb.

I put the following question lately to a well-known boiler expert in Holland: "What thickness of drum plate should one take as a maximum for riveting?" His reply was: "The maximum allowable plate thickness for 'drums' in which riveting can still be applied would seem to depend on the relation between plate thickness and internal diameter of the drum, without losing sight of a minimum plate thickness. For a plate thickness of more than 1¼ inches and with a drum diameter of less than 20 to 25 times the plate thickness, it would already merit consideration to omit the riveting, and most certainly so if the makers in question are not in possession of an installation to anneal the drum after it has been rolled."

The rivets, he considered, then also become too thick to guarantee proper riveting (plus minus 1⅜in.) and transmit too much heat to the plate. One can share his opinion, and the author's comment on it would be appreciated.

We were also told that the 600 lb. pressure boiler which he showed on Plate XIII. can be built for 750 lb. working pressure without any change other than thickening up the shell of the riveted drum. Where the drum in this example is comparatively small, its thickness is probably nothing unusual. The general opinion, however, as to the advisability of riveting such parts for high pressures, especially when thick plates have to be used and double butt-straps become necessary, differs widely from this view. I need only quote the remarks made by Mr. Harold Yarrow on Mr. Spyer's paper at the last Spring Meeting of the Institution of Naval Architects when he referred to the use of forged and welded drums and to the objections of longitudinal joints in drums for high pressure boilers, thereby indicating the importance of avoiding riveted and bolted joints wherever possible when preparing a design for such service.

Mr. Rosencrantz of International Combustion Ltd. likewise in his paper on "Developments in High Pressure Steam Generators" lately said, "No one will seriously contend at the moment that drums constructed of plates having thicknesses of 2½ inches can be successfully riveted. There are those who are disposed to question the advisability of accepting riveted seams with 2½ inch plates or even 2 inch plates, and certainly riveted drums of plates approaching these thicknesses have not been universally free from trouble. By no stretch of imagination can it be argued that a riveted seam improves a boiler drum.

Forged drums cost two to three times as much as riveted ones, in which lies the greatest argument against their adoption. In Germany the gap between drums having a plate thickness for which riveted seams are universally acknowledged to be satisfactory and the thickness above which forgings from a solid ingot is the only accepted means of production has been filled with drums made with lapwelded seams. Although their cost is somewhat in excess of riveted seams, they enable a drum to be produced at very much less cost than from a solid ingot."

When discussing this matter with Dr. Ing. Munzinger of the A.E.G., Berlin, this well known boiler expert informed me that on the Continent riveting is not considered any longer for drum seams which have to withstand more than 200 lb. Welded shells with riveted-in ends are, however, still used for pressures up to 300 to 350 lb., over which pressure the use of a welded drum with hemispherically-closed ends is becoming the rule. Only when the higher pressures from 700 to 750 lb. and upwards are required does the forged drum become competitive. According to him in Germany and elsewhere on the Continent *welding has been developed as a necessity arising out of the repeated cases of damage with riveted constructions with thick plates.*

Mr. W. H. Patchell, well known to us all, has also expressed a strong opinion that lapwelding is bound to come into wide use here for boiler drums and seemed to doubt whether the Insurance Companies would definitely refuse to insure if an actual installation were offered. He also realises the shortcomings of riveting for high-pressure work. Mr. Arthur Spyer, the General Manager of Messrs. Babcock and Wilcox, the author's firm, told us in his reply to my remarks on his paper before the last Spring Meetings of the Institution of Naval Architects on "Modern Developments of Marine Water-tube Boilers" that his firm had used several of these welded drums on Continental installations which had all behaved very well indeed, proving entirely satisfactory and safe in service, facts, he added, which obviously must lead to people over here considering the position. He knew Messrs. Thyssen were very particular themselves as to the manufacture of these drums, and have their own special methods of testing to ensure reliability.

The reason why the author did not mention the welded drum construction may possibly have been because these have as yet not been fitted to Mercantile Marine boilers, and their application has as yet not obtained the approval of the British registration authorities, although they are approved in more than a dozen other Countries and acknowledged to be a vast improvement on riveting. The decision lately adopted by the Board of Trade and Lloyd's Register to accept carbon arc-welded main steam pipe flanges in ships, a type of weld which, after all is said and done, offers a greater element of doubt than a fire-lapwelded one, while being moreover applied to parts subjected to greatly varying strains and stresses, is considered by many to be a fact which augurs well for the early approval by the Registration Societies of water-gas lapwelding on boilers in Great Britain. As such welded drums are at present under consideration for installation on Mercantile Marine boilers of various sizes by well-known shipowners for large liner tonnage, it would seem opportune to refer to this method of construction for this new field in this discussion, and the comments of the author or others would be appreciated.

I have one or two photos with me showing such welded constructions and a section of an actual water-gas roller-lapweld of a drum of $3\frac{1}{2}$ inch wall thickness. For those who are interested in this method of lapwelding of drums, and the meticulous care, inspection, testing, annealing, etc., comprised in their special manufacture, I would refer to a description I gave in the May, 1929, issue of our Transactions, entitled "Thyssen Water-gas Lapwelded Boiler Drums." It is worth pointing out here that in such welded constructions, the margin of doubt as to the soundness of the material is reduced to the barest possible minimum as compared with such parts when forged down from the solid ingot.

For various reasons it will not always be possible to ensure the continuous use of distilled water only in a vessel's boiler, just as it is seldom possible to keep all oil out of the boilers or feed circuit. This is at least as important as the precautions mentioned by the author which are necessary to eliminate the bad effects of salts.

Our President, Admiral Sir Robert Dixon, when discussing Professors Mellanby and Kerr's paper on "Use and Economy of High Pressure Steam Plants" at the Institution of Mechanical Engineers two years ago, pointed out very rightly that "*oil was a much more dangerous ingredient in feedwater than salt*, but unfortunately no means existed for detecting the presence of small quantities in boilers. In highly stressed boilers such as high pressure boilers must be, the presence of the slightest oil film in the tubes would most certainly lead to overheating of the tubes, and this fact possibly became more important with increase of steam pressure." I had occasion to contribute some remarks on the detection of oil in boilers during the discussion of Messrs. Lewis and Irving's paper, "Corrosion of Iron and Steel" before this Institute (see Transactions 1928/9), in which I described a special gauge which detects the minutest amount of oil entering the boilers, and by its periodic use the operating staff is enabled to check the "oiliness" and take timely precautions to keep it within prescribed limits while also checking the oil removing efficiency of filters or separators. Apart from the danger to tubes from overheating, a thin film of oil present on the water surface of a boiler or drum, which act as efficient oil-catchers, will materially increase the surface tension, adversely affecting the generating capacity of the boiler and thus lowering its efficiency. Although with all electric and turbo-driven auxiliaries the entry of oil can be almost entirely eliminated, yet it may still occur, and in many installations where high pressure boilers would be fitted in the Mercantile Marine, the installation may be such that oil is more likely to find its way into the feed water if not carefully guarded against. I am mentioning it therefore, seeing that the author omitted to do so, and would be glad if he would give his views on this point, and whether there is any indication that this danger from oil is on the decrease.

I would add my appreciation to the author for his most valuable paper, which will be a welcome acquisition to our Transactions.

Mr. S. F. DOREY, M.Sc.: Admiral Whayman's paper is a valuable addition to the Transactions of this Institute and deals thoroughly with the latest developments of the water-tube boiler in the Mercantile Marine and the care necessary for its successful working.

At the present time I think it will be agreed that so far as the Merchant Service is concerned the water-tube boiler has only been adopted for use in vessels on special service where circumstances arise which, as in the case of Naval vessels, make it a necessity.

It is true that some few ordinary cargo vessels have been fitted with water-tube boilers, but the ordinary cylindrical boiler is, and I think for a considerable time yet, will be generally adopted for the ordinary type of cargo vessel.

Consideration of high thermal efficiencies which entail higher steam pressures has, however, shown that there is a limit to the usefulness of the Scotch boiler and consequently more attention has been focussed on the water-tube boiler. The paper is therefore of interest in indicating how this type of boiler is extending greatly in the Mercantile Marine and giving satisfactory results.

It appears to me, however, that the results given in the paper show little additional experience to that already obtained with the water-tube boiler in Naval vessels, since the employment of high pressures at sea is in its infancy. On looking up particulars of the machinery of the vessels mentioned in the paper, I find that only three are fitted with reciprocating engines, viz., *Scottish Chief*, *Scottish Heather* and *Op ten Noort*, the latter having Lentz engines. In dealing with merchant ships we cannot fail to think of reciprocating engines, and as one who would like to see the water-tube boiler more generally adopted for use in cargo vessels, I think Admiral Whayman might give some more detailed facts relating to the suitability of water-tube boilers with these engines. So far as the ordinary type of vessel is concerned, we have no definite facts to prove that the water-tube boiler is more suitable than the Scotch boiler, and I think there are many reasons why it is not suitable, but which with a little more general knowledge might easily be overcome.

It will be noticed that in the ships mentioned above, the steam pressure is only moderate, of such a degree that Scotch boilers could be used probably in preference to the water-tube boiler by most superintendents.

It is with the higher steam pressures that the water-tube boiler definitely takes the lead though this entails an alteration in the type of machinery since experience has shown that both triple and quadruple expansion engines are unsuitable chiefly on account of lubrication difficulties.

Coming now to the question of fuel, I find that only four of the vessels quoted are coal burning. Undoubtedly water-tube boilers are more suitable for oil and pulverised coal burning, particularly where prolonged steaming is necessary, though from experience I have had with water-tube boilers, the Babcock and Wilcox boiler has the advantage over the small tube type of boiler as with ordinary coal, hand-fired, there is not the " nesting " on the fire row tubes.

Referring to the boilers in the *King George V*, the author states "We have now had the experience of a season's service in this steamer, and it is considered to be true to state that the reliability and durability of the boiler has been well established." Now for those who are familiar with the Clyde season, I think three months' service is hardly sufficient proof of reliability taking into account the one accident which occurred. It is appreciated that the boilers are working under abnormal conditions on the service in which the vessel is employed, but I am sure that if the same satisfactory results are obtained after at least three seasons, it will be an extremely good advertisement for the Babcock and Wilcox high pressure marine boiler.

Admiral Whayman, however, continues by saying that different parts have been examined and have given satisfaction, but the following sentence seems open to question: "Slight alterations have been made to improve still further the durability of those parts showing signs of wear and distortion for the next season's service." Now we do not know what these parts are, and I notice the author makes no reference to tubes. After all, it is the tubes which determine the life of the boiler, which up to the present is very young. It is easy to renew the tubes though this means closing down the boiler, and unless a spare or additional boiler is fitted, it is necessary to stop the vessel when a tube gives out. Very often it is possible to steam for a considerable period with a perforated tube. It is, however, extremely doubtful whether a ship would be fitted with only one water-tube boiler.

In the case of the *King George V*, the author makes reference to the position of the superheater and to the requirements of the Board of Trade, and incidentally the classification societies which make it necessary to remove these tubes away from the radiant heat of the furnace. In the case of the coal fired boiler the radiant heat, with a heavy fire, will be greater than with oil burning. If the position of the superheater for the *King George V* is compared with that of some of the other arrangements illustrated, it will be observed that with the latter the superheaters are nearer the fire, and the author's explanation of this would be of interest. Would Admiral Whayman give us some further information as to the reliability of the superheated tubes? Everything depends on the rate of flow of steam through the tubes. That is why I am particularly interested in the *King George V*. The vessel arrives at a pier with a heavy fire, and with the engines stopped the flow of steam through the superheater is practically nil, and the tubes become overheated. In this vessel they are well screened, but in the case of the Yarrow type of boiler I have seen the tubes a dull red shortly after stopping. In this respect, therefore, it will be interesting to see how the express type of Babcock and Wilcox boiler, illustrated in plate XIII of the paper, behaves, though from the tests available at present I gather the boiler has not been operated with coal. I should, however, be glad to know whether Admiral Whayman considers the position of the superheater tubes in this type of small tube light weight boiler suitable for coal firing, with rapid changes of temperature in manœuvring and a variable demand in output.

The author has quite rightly emphasised the importance of purity of feed water, and this applies to all water-tube boilers irrespective of the working pressure. In the case of high pressure boilers, it would appear that there is less risk of priming than with low pressures.

Brief mention has been made of the use of pulverised fuel and also mechanical stokers, and in my opinion the successful development of these will hasten the more general use of the water-tube boiler in the mercantile marine.

In conclusion, I would much appreciate any information Admiral Whayman can give regarding velocity of flow in the lower bank of tubes, and also in the superheater tubes, velocity and temperature of hot gases between these tubes and the pounds of steam generated per hour per square foot of tube heating surface in lower and upper banks of tubes for the ordinary marine type of Babcock and Wilcox and for the small type express boiler.

MR. C. V. A. ELEY: I have had an advantage over some of the previous speakers in having looked through this paper on my way from Birmingham to London. I would like to add my appreciation of the very instructive paper by the author, because it gives records of actual results achieved. Such results have been far too slow in coming for this country to stand supreme in steam engineering at present. The 550 lb. pressure of the *King George V* appears to be the highest recorded pressure of any completed steamship in this country. Why? There was a steamer running on the Thames from London Bridge to Southend in 1886-7 with a boiler pressure of 500 lb. That was, I believe, a Perkins water-tube boiler. We have had materials which would stand hydraulic pressures up to twenty times 500 lb. for the last forty years. We have had

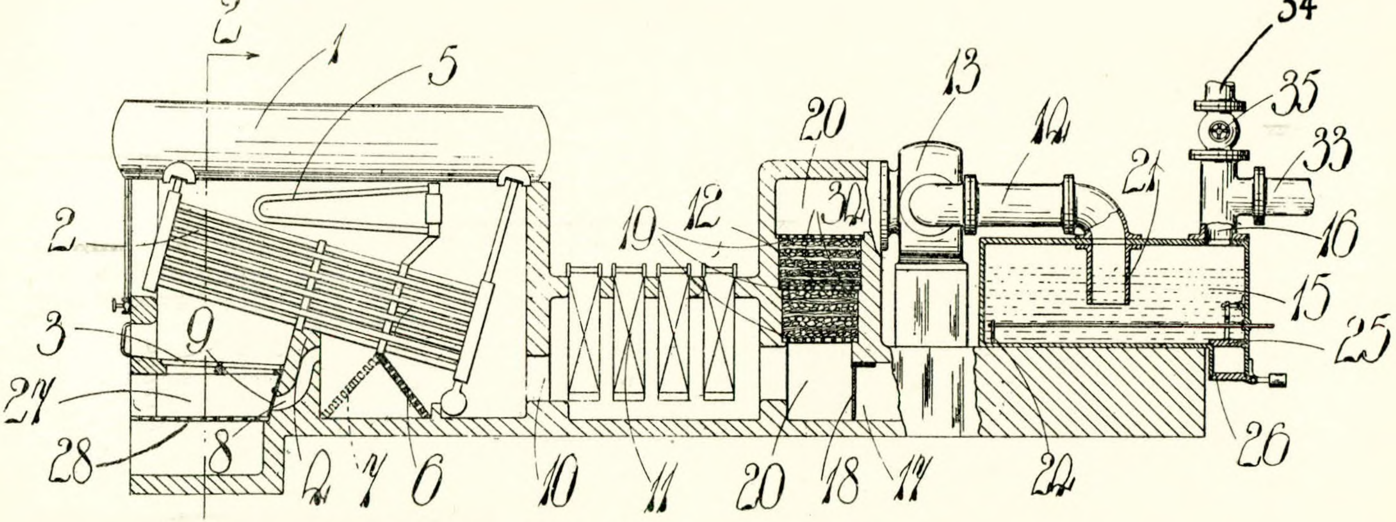


FIG. A.—Proposed method of dealing with Flue Gases other than by Chimney.

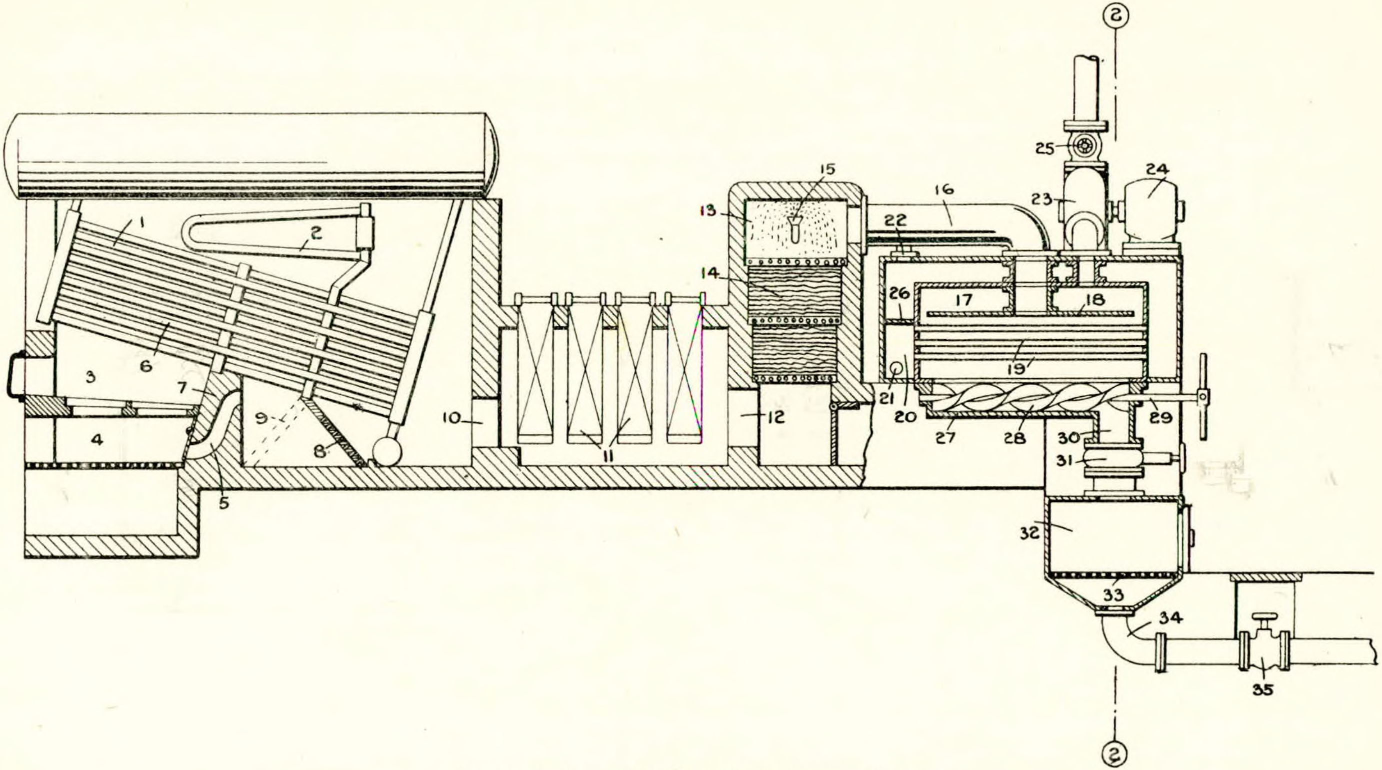


FIG. B.—Another method, alternative to that shown in Fig. A.

superheated steam up to 700° F. and have used superheaters for the last thirty years. Steam at critical pressure is only 700° F. (or to be correct, 703° F.). Then why have we waited thirty years to use these means for using very high pressure steam in the Merchant Navy. The steam engine should have been still with us using either coal or oil, or both. In the present state of the iron, coal and steel trades of this country the Merchant Service would do well if it endeavoured to support these industries. The position of such industries cannot be sound while there are only 150 blast furnaces at work out of 400. Just consider the loss of employment equivalent to the conveyance of coal, coke and ore to the 250 blast furnaces not working, and pig iron from them to all parts of the World! Then add to it the loss of transport of coal for ships of the Merchant Navy. In the case of the steam driven ship it is true that huge spaces are occupied between decks for uptakes. If you look at Plates I, II and III you will notice this; it has always been so, but why should it continue? The uptakes of the vessel shown in those illustrations occupy a space of 60 ft. x 20 ft. x 30 ft. at each funnel, of which there are three, totalling 108,000 cu. ft. which cannot be used for passenger or cargo space. This is so important that I would like to suggest to those present the recovery of those spaces by using other means for dealing with waste gases instead of uptakes and funnels. I believe it can be done. I have two illustrations of my proposal here. The gases on leaving the boiler, instead of being carried through the uptake might be carried to a tank at the boiler room level, taken through by means of an induced draught fan, or, if preferred, by a pump in this manner. By means of the induced draught fan the gases would be either put under 6 ins. to 8 ins. of water, or otherwise, from the top of the tank the gases could be drawn through the water and then not only would you clean the gases of dust, grit, etc., usually flying about the decks, but you would be able to pass them overboard with the water which might be the circulating water from the condenser or some other source. This would put the steam driven vessel on a basis which would more equal that of the oil engine driven vessel in respect to machinery space occupied, by recovering all such spaces for passenger and cargo accommodation, whilst passengers would not be subject to the dust flying about the decks.

With regard to boiler pressures I would like especially to refer to a diagram which I put before other institutions at a previous date, in 1923, which I think has so far only been pub-

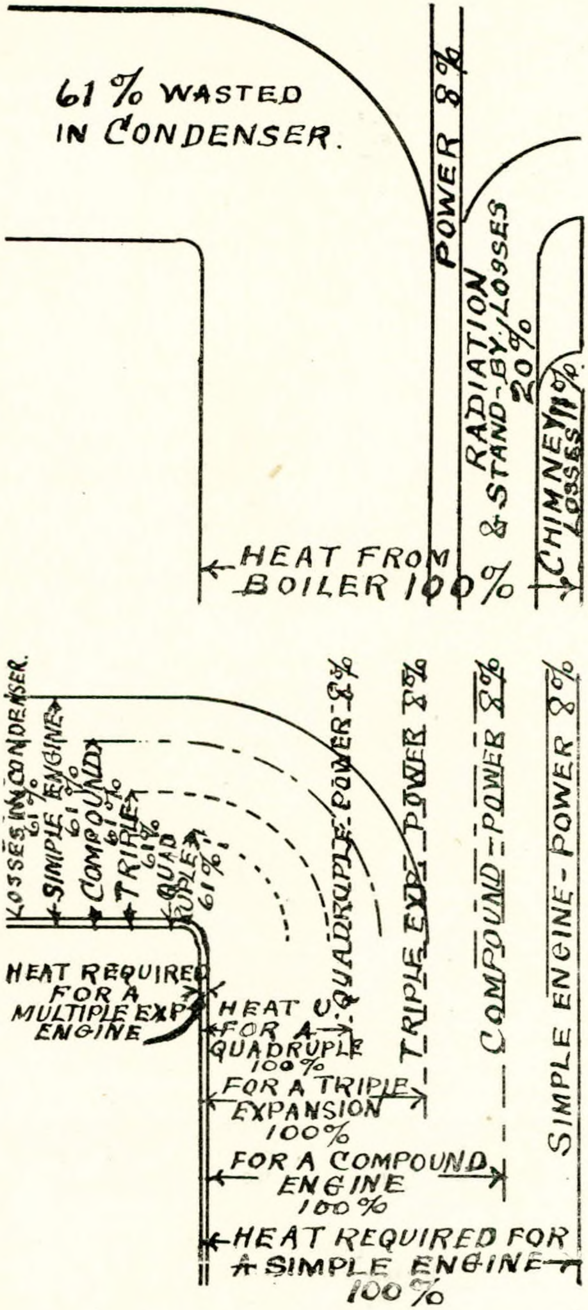


FIG. C.—Heat requirements and losses with Steam Engines.

lished in the Midlands. If a vessel were designed in which the pressure was 1,200 lb. and even the old type of reciprocating engine was used, I think it would be possible to carry out useful work at a very low rate of steam and fuel consumption, much lower than has yet been known. I can go back to the time when I left London and left the sea for land service. One of the first things I did in the Birmingham area was to put in a

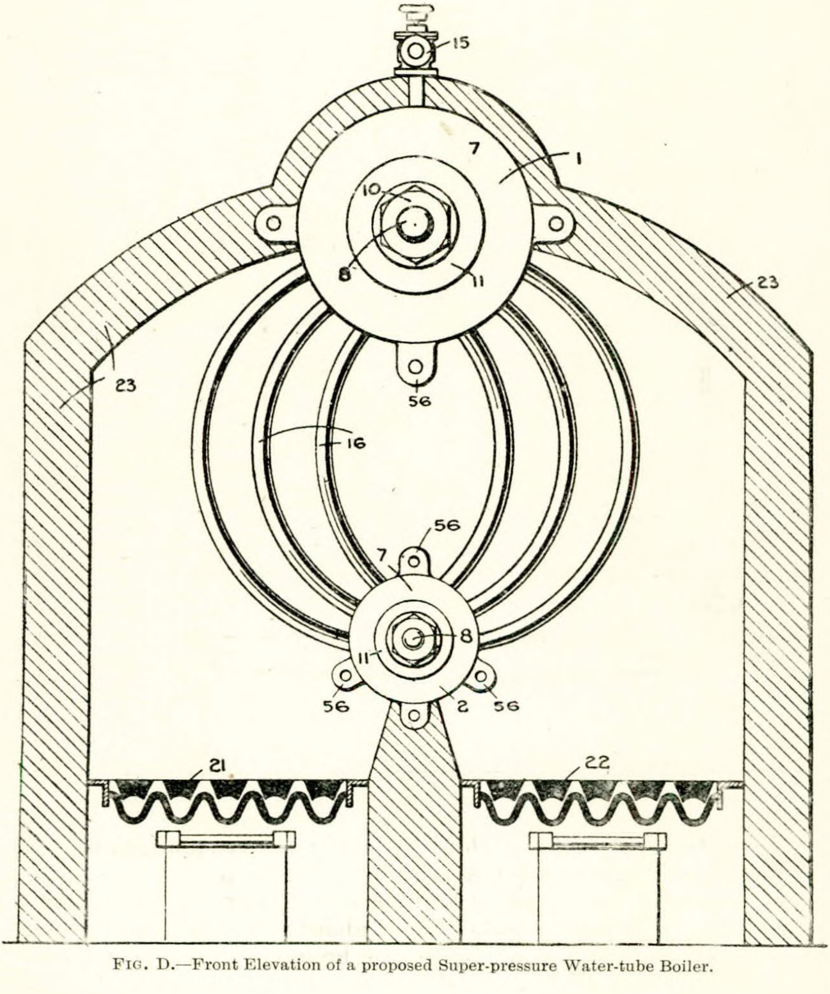


FIG. D.—Front Elevation of a proposed Super-pressure Water-tube Boiler.

quadruple expansion engine at 200 lb. pressure which pressure was too high for works engineers at that time. That engine and water-tube boiler have gone on working for over 32 years, half of the time night and day, and has done its work exceedingly well, using only 10 lbs. of saturated steam per I.H.P. per hour. Therefore, I must disagree with Mr. Dorey who said that water-tube boilers are not suitable for sea service as the above boiler gave no trouble. What I suggested might be done with that engine about five years ago was to make another engine with four smaller cylinders and couple on to the first engine. The first cylinder then, about 2 ins. diameter, would take steam from a new water-tube boiler at 1,200 lb. pressure.

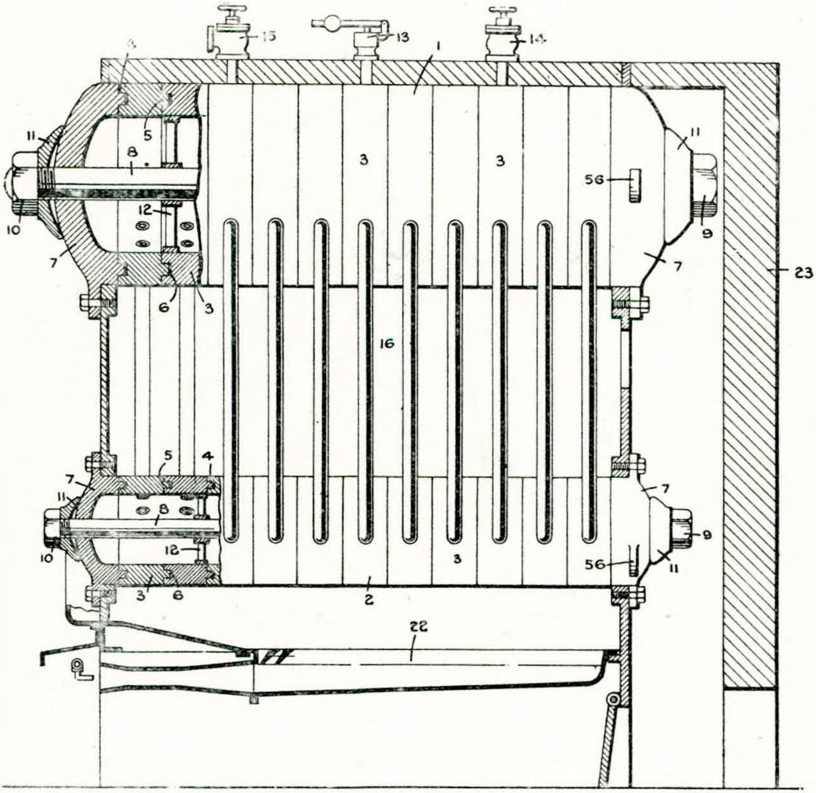


FIG. E.—Side Elevation of proposed Super-pressure Water-tube Boiler

The same application could be made to a larger engine, starting, say, with a 3 in. cylinder and going to 4½ ins., then 6 ins., then 9 ins. before coming into the first cylinder of the main quadruple expansion engine. That would give double the power with a much smaller weight than if you had the 200 lb. job alone. Also you would have such a small quantity of steam being used; the consumption would be about 2 to 2½ lb. of steam per I.H.P. That would reduce the size of boilers so much that it would make up for the additional weight required for the additional pressure.

The boiler which I proposed to use at 1,200 lbs. pressure was as illustrated below, and would have made a very serviceable job, I believe. It is of similar design to the one which worked in Birmingham for 32 years, but made sectional instead of a riveted job.

MR. W. MCLAREN: We have had in this Institute the battle of the boilers years ago, the water-tube boiler having been championed by both Mr. Murray and Sir James Kemnal of the author's firm, but we do not seem to get any further forward. The makers have to their credit the boiler installation in the *Viceroy of India*. It is up to the engine builders now to come into line with the water-tube boiler. If they find no insuperable difficulty in producing satisfactory high pressure Diesel engines, surely they can produce a steam engine capable of taking superheated steam.

Referring to Plate III, is it correct that the steam drum is athwart the ship? It might not be dangerous, but it seems that it might be bad for the circulation. As regards forced draught with a closed stokehold, I am decidedly in favour of the closed stokehold if you keep within limits. My own experience is that ¾ in. to 1 in. of water is satisfactory. We have worked at higher pressure, but when we shut down, the tube plates were always found to be leaking. We have never had a furnace in either a Scotch or Lancashire boiler which has been able to use powdered fuel, and that is what has converted me to the water-tube boiler, because the furnace can be quite satisfactorily arranged for either powdered fuel or oil fuel.

MR. F. O. BECKETT: With high pressures it seems to me that all installations should have a de-gasser or de-ærator plant fitted so as to nullify the action which takes place, causing corrosion. Admiral Whayman has shown us a boiler (see the last illustration, Plate XIII) with bent tubes. My experience has been that bent tubes suffer fatigue at the junction of rolling, due to stresses and elongation from one side to the other. In the Babcock and Wilcox boiler spoken of to-night, there is one point about which I am rather at a loss, i.e., the nipple which carries the header to the steam drum. These nipples may be as short as you can make them, but the sinuous headers take anything from 6 to 10 or 15 tubes per section, and the whole of that tube area has to pass through that nipple into the drum. I am at a loss to know how circulation takes place amongst the tubes. Is there any speed known of water circulating over the tubes near the fire compared with tubes in the top of the section? Superheaters have been mentioned, and although it may seem unkind for a layman like myself to say so, I consider it very essential that they should always be kept out of the flame. The author spoke about a handhole cover being take out for inspection. He did not state what diameter hole that was. Could a man get his body through it? because if not, how could he put in a new tube? In conclusion, I wish to add my testimony to the excellence of this paper.

Mr. G. R. HUTCHINSON: I have much pleasure in complying with the Chairman's request to propose a vote of thanks to Admiral Whayman. We all recognise that he is an authority on water-tube boilers, and I think it is hardly necessary for him to apologise in the paper for any bias he may have displayed. A firm declaration of one's views is a good thing to have in any paper, and it certainly stimulates discussion. I propose that we accord a very hearty vote of thanks to Admiral Whayman for his interesting and valuable paper. (Carried with enthusiasm.)

Sir ARCHIBALD ROSS, K.B.E. (by correspondence): I regret very much that I am unable to be present to hear Admiral Whayman read his paper on the 14th. I feel sure he will receive the congratulations and thanks of the Institute for such a careful and complete review of the position to-day of ships' boiler installations. In connection with the *Viceroy of India* the comparison of weights for steam generated as stated on page 20 is 317 lbs. per ton for this vessel with Yarrow boilers and 282 lbs. for the *Statendam* with Babcock and Wilcox,and in a more recent proposal the corresponding weight for a 28,000 S.H.P. installation is 950 tons for 275,000 lbs., or 290 lbs. per ton weight. In both cases the installation is as Admiral Whayman describes it—boiler, superheater and air-heater.

On page 18 it is stated that the results indicate that the conclusion advanced in 1926 regarding high pressure steam installations competing in operating costs with the marine oil engine has been practically established. This is always a debatable point depending on two essential features, one being the relative price of boiler or so-called Diesel oil over which shipowners, let alone marine engineers have very little, if any, control, and the other whether in the resultant costs of running and upkeep, the latter figure has been accurately rendered.

But if we omit this particular item—often a more expensive one in internal combustion engines the figures given as a basis for the *Statendam*, viz.: ·619 lbs. oil for all purposes in order to compete with the best performances for internal combustion engines on consumption for all purposes, which we may safely take as ·5 on large powered vessels, implies that the relative costs of the two fuels must be in the same proportion, in other words boiler oil at, say 50/-, and Diesel oil at 61·9/-. At present the quoted prices do not show such a difference and with Diesel oil at 70/- and boiler oil at 60/- the steam installation would have to come down to below ·6 lbs. oil per S.H.P. (to be exact ·584).

This is perhaps a somewhat paltry difference to which to draw attention, in view of the great importance in the history of marine engineering that so near an approach has been attained.

In comparing vessels fitted with oil-fired boilers and steam turbines with large Diesel generating plants there is the additional complication of allotting the cost of the two kinds of fuel oil.

One is aware of the even higher pressures to which the Admiral's firm is working on land installations, and one would like to have heard whether the question of jointing for boiler mountings, not to mention pipes, has caused any difficulties, not only from the point of view of keeping the actual joints tight under water and steam tests, but with regard to the life of the joints and deterioration of bolts subjected to high temperaures.

May I add that in making these few comments I hold no brief for internal combustion engines over steam, nor for any one boiler indicated in the paper over another.

Mr. R. B. ARMSTRONG (by correspondence): Admiral Whayman's paper is an admirable one and is well timed in view of the increase in pressures we are now being asked for in order to meet the competition of the Diesel engine, and we are under a debt of gratitude to the latter in bringing this about.

As an apostle of the water-tube boiler for merchant ships for many years, I welcome this opportunity of saying a few words on the subject, from the point of view of another type of water-tube boiler, which the firm with whom I am associated are now manufacturing, namely, the Hawthorn Armstrong boiler. An example of this boiler has recently been tested under rather unique conditions, which I think may be interesting to the members of the Institute of Marine Engineers.

The conditions under which this boiler was ordered were as follows: To be able to do the work of an ordinary cylindrical boiler under the same conditions of working, i.e., personnel to be the same as that found in a whaler and to be capable of being fed with a salt water solution at full power without priming, as the engines which the boilers were to serve were of the reciprocating type. The choice of the water-tube boiler was made with a view to saving the weight entailed by the use of the cylindrical boiler, which in this case amounted to 60 tons. This saving, of course, resulted in increased speed of the vessel.

In order to prove the conditions required, shop trials were carried out, and with a 13% salt feed solution, a dryness fraction of 97½% was obtained at full power and at half-power with 33% of salt feed the same dryness fraction was obtained. During the course of these trials, the accumulated salt pumped into the boiler was about 4 cwts., but when the boiler was opened up for examination, no trace of salt deposit was found, and the interiors of the boiler and tubes were perfectly clean. The boiler is now installed in the Whaler *Narona*, and giving good service in the South Seas.

We are glad to hear what has been achieved by the makers of the Babcock and Wilcox boiler, and we thank Admiral Whayman for his paper.

WRITTEN REPLY BY THE AUTHOR.

As there was insufficient time at the end of the meeting at the Institute on Tuesday evening, the 14th of January, to reply as was desirable to all the points raised by the various members during the discussion, it is proposed to embody the replies in the following written contribution.

With regard to Mr. Douglas's remarks that he is interested in the water-tube type of boiler from the point of view of the use of powdered fuel, this is a very welcome statement to hear, and it is hoped that the experiments which my firm contemplate at their works at Renfrew with a pulverised fuel plant in association with a water-tube boiler working with a safety valve load of 550 lbs. and a final steam temperature of 750° F. will shortly be re-started.

The figure quoted by Mr. Douglas of ·72 lb. of oil per s.h.p., which it is presumed represents the fuel consumption for all purposes obtained with a Scotch boiler installation, is the best figure the author has heard reported up to the present. It emphasizes the importance of keeping continually in mind the advantages of higher pressure and temperature steam machinery, since working on the assumption that the boiler installations with a Scotch or water-tube boiler will give high efficiency figures, it is only in the direction of the use of higher pressures and temperatures we could look for greater economy in fuel.

With regard to the question of feed water, it was endeavoured to point out in my paper that the amount of make-up feed water with modern installations should become a falling quantity and such as could be easily supplied with a modern small size evaporating plant. It seems to the author that under these conditions, it is not right to use the weight and space which must be provided for cylindrical boilers to provide distilled water as make-up feed in the quantities which should be necessary with an up-to-date installation.

The trouble which Mr. Douglas has experienced in the fleet of vessels in his Company with condensers will, it is hoped, be eliminated in modern plants with condenser tubes and packings of the latest design and material. Apparently the conditions mentioned in the last part of my paper in regard to the testing of boiler and feed water in a vessel have been to some extent misunderstood by Mr. Douglas. The means of determining the alkalinity and even the phosphate content of the boiler water, if this chemical is used, are very simple, and apparatus supplied for this purpose is very compact and easily understood and used.

It is an advantage to use pure feed water with all boiler installations and is not one that should be confined to water-tube boilers, as the use of a pure feed water is undoubtedly one of the greatest means of ensuring durability, reliability and long life of a boiler.

Mr. Hamilton Martin has made a few remarks upon the importance of keeping oil out of the boiler and feed water being equally important to the continuous use of distilled water. This is undoubtedly true, but the subject was not touched upon by the author in his paper as it was not desired to make the subject matter for discussion too crowded. That the elimination of oil from feed water is a most important point to be attended to in any propelling machinery installations is realised by all sea-going engineers, and the first ready means of detecting the presence of any oil in the boilers is given by the usual alkalinity test.

It is not desired to write more fully on this subject, except to say that modern propelling machinery installations include the usual well known precautions to ensure that oil shall not enter the feed water, and as the demands for fuel economy are tending to strengthen the choice of rotary auxiliary machinery, either turbine or electrically driven, the necessity for the use of oil for internal lubrication is decreasing in the more modern steamship installations and the danger of oil mixing with the feed water is becoming less.

With regard to Mr. Hamilton Martin's remarks in regard to welded boiler drums, it is acknowledged to be desirable to retain a minimum wall thickness compatible with safety in a pressure vessel exposed to the effect of temperature. The solid forged drum has, in the majority of cases, been manufactured to a thickness determined by the plate efficiency through the tube holes, and except where saving of weight is important the drum wall in the steam space and the water space is of the same thickness. The riveted drum, on the other hand, can be arranged so that the plate in the steam space is only of the thickness necessary from the point of view of the riveted joint, whilst the tube plate is based on the thickness determined by the efficiency of the plate through the tube holes. It may be noted particularly that in no case in high pressure work at the present day is the thickness of a riveted water tube boiler drum ruled by the riveting itself, and in consequence, the suggestion that thicker plates are required if a riveted drum is used is incorrect. With a suitable arrangement of tube holes, plates of approximately 2in. in thickness may be used for riveted drums suitable for pressures as high as 650 lb. per sq. inch, and the experience with the riveted drums installed at Langerbrugge for a period of four years shows that riveted drums can be, and are satisfactory for pressures as high as 800 lb. per sq. inch. Admittedly, if joints can be replaced with solid material this is an advantage, but it would seem a better condition to have a riveted structure, the strength of which can be determined by methods proved by years of experience, rather than a drum, the joints of which have been made by a process which cannot be checked as regards regularity and solidity, and where there is no means of knowing exactly the extent to which the joint is sound. In the writer's view, until welded drums can be manufactured by a machine process which entirely eliminates the human element, there can be no guarantee that they are satisfactory, unless a means is invented for ascertaining with absolute certainty that the weld is homogeneous throughout. An hydraulic test such as is provided by the manufacturers of welded drums does not create in the metal those stresses which we know are set up in the walls of such a vessel under the effect of even normal saturated steam temperatures.

It is mentioned that welding has developed as a necessity arising out of the repeated cases of damage with the riveted constructions having thick plates. This statement is really exaggeration, because when it is considered that riveted constructions used as pressure vessels throughout the world since boiler making began are almost innumerable, and that the failures could certainly be counted with comparative ease, it will be obvious that the welded drum did not arise as a means of overcoming riveted drum failures. My firm has constructed between 35,000 and 40,000 riveted drums of various descriptions and the total number of drum failures would not reach half of 1% of the number of drums supplied.

I have been very interested to read Mr. Dorey's considerations that, so far as the Merchant Service is concerned, the water-tube boiler has only been adopted for use in vessels on special service and he appears to express the opinion that the water-tube boiler has not been generally adopted with reciprocating machinery. I find that at least 500 ships which have been fitted with Babcock and Wilcox boilers have reciprocating propelling machinery.

Mr. Dorey states that so far as the ordinary type of vessel is concerned we have no definite facts to prove that the water-tube boiler is suitable, but surely if the required quantity and quality of steam for the reciprocating engine can be more economically produced by the water-tube boiler and the water-tube boiler requires less weight and space than the cylindrical boiler for its installation, this is an undoubted advantage.

With regard to the water-tube boilers in *King George V*, which work at a safety valve load of 560 lbs., Mr. Dorey's consideration is that three months service is hardly sufficient proof of reliability. It can only be stated in reply that this was the considered opinion after the 1929 service of the vessel, and the results of the vessel's services in 1930, and subsequent years will doubtless confirm the reliability.

With reference to Mr. Dorey's request to know the parts that had shown ordinary wear and tear, reference to my paper will show that these have been mentioned. What was referred to was the slight distortion of some baffles, tube supports and a few casing plates such as might have been expected due to ordinary wear and tear on any service. There has been no sign of any damaged tubes except in the one case of damage to generating tubes through shortness of water, which has been fully dealt with in the Board of Trade enquiry. With regard to the position of the superheater in the boiler, this must generally be determined by the amount of superheat required. Experience up to the present with superheater tubes fitted in the various positions in the boilers indicated in my paper has been satisfactory.

With reference to Mr. Dorey's concluding request for information with regard to the velocity of flow in the lower bank of tubes and in the superheater tubes, I must ask to be allowed to omit this in my reply on this paper as such a subject cannot be replied to in a few words, and more rightly forms the subject of a separate paper and discussion.

I have to thank Mr. Eley for his remarks, especially those in which he advocates the use of the steam engine in order to increase the amount of coal which can be used as fuel. This is a most important point and the main object of the author's paper was to show that the improvements in steam machinery which are now being realised enable us to provide a propelling machinery installation which can use coal as fuel and show an economic advantage as compared with the use of oil as fuel with the internal combustion engine.

With regard to Mr. Eley's remarks on the disposal of exhaust gases, it may be of interest to observe that a good deal of saving in uptake space is being achieved in modern marine boiler installations, and the reduction of these spaces to the minimum appears preferable to the contemplation of a method such as is suggested by Mr. Eley.

Mr. Eley's remarks upon the possibility of increasing the boiler pressure up to 1,200 lbs. are undoubtedly of interest because it is in this direction that advance will be made in order to make use of the additional heat available in the steam which can be obtained with a small proportionate increase in fuel expenditure.

With regard to Mr. McLaren's remarks asking with reference to Plate 3, if the steam drum is placed athwart the ship, this is correct and this arrangement seems preferable to maintain good boiler circulation at all times. Inspection of the boiler drawing will show that the steam and water circulation is separate in each individual section, and is liable to less disturbance due to the pitching of the ship than by rolling. It is for this reason that it is generally preferred for an ocean-going ship to have the steam and water drum placed athwartship. The writer is in full agreement with Mr. McLaren's desire to maintain the air pressure in a closed stokehold within moderate limits, and our experience is of the same order as the figures quoted by Mr. McLaren, namely, $\frac{3}{4}$in. to 1in.

Mr. Beckett in his remarks also asks about the circulation in the sections of the Babcock and Wilcox boiler, pointing out that the whole of the water supply to one section is through the nipple connecting the downtake header to the steam and water drum. Even at extreme rates of evaporation such as for instance 10-15 lbs. of steam per sq. ft. of the total boiler generating tube surface, the velocity of the water supply through the downcomer nipples is so low that there is ample area for the supply of water through these nipples at all rates of evaporation.

With regard to the speed of flow of steam and water in the tubes, I will refrain from speaking on this question for the reasons which I have stated earlier in my reply to Mr. Dorey. It may be sufficient to say that the speed is, of course, greatest in the fire row boiler tubes and gets less and less towards the top tubes. At the ordinarily accepted boiler ratings the speed of flow in the bottom rows is low and extremely small in the top rows.

With regard to Mr. Beckett's question as to the size of the handhole cover, this is only a small door in front of the headers opposite each tube and all tubes can be easily withdrawn and replaced through these handhole doors.

I have been very pleased to receive a copy of the written contribution from Sir Archibald Ross, and most pleased to read that he generally agrees with me that the fuel oil operating costs of the modern steam installation and Diesel engine are now practically comparable. Undoubtedly we hope soon, now, to achieve steam marine propelling machinery installations with a total consumption of oil fuel per s.h.p. hour for all purposes of just under ·6 lbs. With regard to Sir Archibald's question as to the efficiency of jointing at the higher pressures, experience has been up to the present, quite satisfactory both from the point of view of joint tightness and with regard to the life of bolts.

I desire also to thank Mr. R. B. Armstrong for his written contribution, and have been very interested to read the results obtained with water-tube boilers fed with a certain percentage of salt water.

The CHAIRMAN: I remember a little more than ten years ago when I first went to sea I was in a ship with boilers working at 60 lb. pressure, and we had a lot of trouble due to corrosion of plates, and priming, and had a difficult job to get steam; later on when we got a boiler working at 180 lb. we had much less trouble. The water-tube boiler to-day is starting where the Scotch boiler left off. You have your Scotch boiler up to the top pitch of perfection of material, etc., and the water-tube boiler is beginning at that point. I have no doubt that our sons will go on with the water-tube boilers and later on they will be able to give their experience with the mercury boiler or some other type from that day. Recently there was a report published of a boiler explosion and that happened to be a water-tube boiler. One only of the original engineers came back with the ship—a cargo ship of the tramp type—which went a fair cruise to the Mediterranean and America before she returned. They had an explosion on the way, but all the boilers came back! That was not a bad experience for the boilers in face of these difficulties. To-day we hear a lot about our own feeding and the importance of taking certain proportions of vitamins A, B and C, but we go on without bothering much about what we eat and still persist. And if we go on with the water-tube boilers, even although the engineers may not be qualified chemists, we shall, I have no doubt, get on quite well with their feeding arrangements.

ABSTRACTS.

FLOATING DOCK FOR FALKLAND ISLANDS. "Engineering," 15th November, 1929.

Built to the order of The Falkland Islands Company, Limited, a floating dock has just been despatched from the Wallsend shipyard of Messrs. Swan, Hunter, and Wigham Richardson, Limited. The dock is of the sectional pontoon type; it was completely erected at Wallsend, but was not riveted. After being dismantled, the material was loaded on board a ship for export to Port Stanley in East Falkland Island, some 8,000 miles distant from England, where it will be erected and put into commission. The overall length of the dock is 180 ft., the inside width, 45 ft., and the lifting capacity, 600 tons, accommodating ships of a maximum draught of 9 ft. The main pumping machinery consists of two similar sets of centrifugal pumps, each driven by a semi-Diesel engine through bevel gear and shafting. The pumps are each connected with a common drain, and together they can lift a ship within an hour. In each wall of the dock is a pair of mechanical side shores, and, at each end of the walls are fitted roller fenders.

A NEW UNION-CASTLE LINER. "The Engineer," 29th November, 1929.

On Sunday afternoon last, November 24th, there arrived in the Thames the new motor passenger liner *Llangibby Castle*, which has been built and engined by Harland and Wolff, Ltd., for the East African service of the Union-Castle Mail Steamship Company. The new liner completed successful trials last week and left the Clyde at the week-end with a large number of guests on board. Heavy weather was encountered in the Irish Channel and when rounding Land's End, and although the vessel was in ballast, she showed herself to be a very steady ship. The principal dimensions of the new liner are as follows: Length, 485 ft., beam 66 ft., depth 33 ft. 6 in., with a measurement of about 12,000 gross tons. With her two low funnels she presents a pleasing appearance. Accommodation is provided for 250 first-class and 200 third-class passengers, and the latest navigation and safety equipment is fitted. The main propelling machinery comprises a twin-screw arrangement of eight-cylinder Harland-B. and W. four-stroke, double-acting oil engines, each equipped with a supercharger and an exhaust gas boiler. The pressure chargers are of the Büchi type, and consist of a blower driven by an exhaust gas turbine. The heat from the exhaust gases is recovered in a Clarkson thimble-tube boiler, which is fitted with the Clyde low-pressure system of burners for port use. The main engines have a cylinder bore of 740 mm., with a stroke of 1500 mm., and at 108 r.p.m. they have a designed output of 8500 S.H.P. The service speed of the ship is about 14½ knots. There are three 250-kW oil engine driven generator sets, also a small emergency generator set. The refrigerating equipment is by J. and E. Hall, Ltd., of Dartford, the holds being steel lined. The *Llangibby Castle* is scheduled to sail from London on December 5th for Africa, where she will join her sister ships of the Union-Castle Line.

THE INVENTION OF THE SCREW PROPELLER.

In the Australian " Western Mail " of August 8th, 1929, under the heading " Science and Engineering," the question of the screw propeller and who invented it, is reviewed. Blackie's Popular Encyclopædia is quoted and the work of T. P. Smith is cited as having led to the screw propeller being adopted for service in 1834. Meantime Robert Wilson of Dunbar was also devoting time and attention to it and subsequently had his design fitted on vessels. Edward Shorter of Wapping Wall was also at work in the same direction and his design was fitted on the Transport *Doncaster*, and the following is a copy of the letter sent to him, certifying the success of his design, " We the undersigned captains of the ships *Dragon* and *Superb* have seen the *Doncaster* moved in a calm a distance of two miles in Gibraltar Bay with sufficient velocity to give her steerage way by the sole use of your propeller." Signed by Captain S. Aylmer, *Dragon*, and Captain R. Keats, *Superb*.

There is also a letter dated Malta, September 4th, 1802, from Captain John Short, of the *Doncaster*, stating how useful the propeller had been to the ship and how interesting it had been to onlookers to watch the movements during a calm.

According to Lindsay's History of Merchant Shipping, Vol. IV., Edward Shorter took out a Patent in 1800 for " a perpetual sculling machine," having the action of a two-bladed propeller and this was the type fitted. The history of John Ericsson and his venture in having a boat made and fitted with his design of propeller in 1836 are interesting; this craft attained a speed of 10 miles per hour, a schooner of 140 tons was towed at seven miles per hour on the Thames and the American packet ship *Toronto* subsequently was towed astern at fully five miles per hour. Experiments were afterwards shown to the Lords of the Admiralty, but they failed to favour the screw propeller.

T. P. Smith was finding favour in July, 1839. The Steam Ship Co. was formed to carry the patent into service. The first vessel fitted successfully was the *Archimedes*, 237 tons, with 9 ft. 4 ins. draught; the driving power was an engine with cylinder 37 ins. diameter by 3 ft. stroke; the propeller consisted of two half-threads of 8 ft. pitch, 5 ft. 9 ins. diam., each 4 ft. long, placed diametrically opposite each other at an angle of 45° on the propeller shaft. Tests were carried out between the *Archimedes* and the fastest paddle boat *Widgeon* on the Dover to Calais route. The best run of the *Archimedes* was from Dover to Calais in 2 hours 1 minute and on the return in 1 hour 53½ minutes, in 1839.

As time went on experiments proceeded and it is interesting to read the accounts showing the progressive advancements to the present day.

THE CARRIER-RING FLEXIBLE COUPLING. "Engineering," 1st November, 1929.*

The older methods of erection allowed, generally unconsciously, for the compensating effect of loosely fitted bolts and so forth, in cases in which want of alignment between the units of shafting occurred. Such methods, while comparatively harmless with the lower speeds of the shafts and the smaller loads transmitted, have long been recognised as inadmissible under present-day conditions, and consequently many attempts have been made to devise suitable flexible couplings. Illustrations of one of the latest designs of flexible coupling are shown in Figs. 1 to 7, annexed. This is known as the Carrier-Ring flexible coupling, and is manufactured by Messrs. The Power Plant Company, Limited, West Drayton, Middlesex. The coupling consists of five main parts. These are shown in Fig. 1, and comprise two coupling discs, or bodies, two halves of a protective cover, and a carrier ring. The latter is illustrated separately in Fig. 2, in order to show its construction more clearly. It consists simply of a steel ring with a notched periphery, into which notches are driven flat-steel springs of such a length as to project on each side of the ring, and of the cross section shown in Fig. 4.

The shaft couplings, which consist of flanged discs keyed on to the respective shafts, have notches on their peripheries corre-

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* We are indebted to "Engineering" for the loan of the seven blocks illustrating this article.

sponding with the springs and giving them the appearance of pinions. The resemblance is very partial, however, as the sides of the notches are straight and parallel in a plane at right angles to the shaft axis. Looking at the edges of the flanges towards the axis, as in Fig. 5, however, it will be seen that the

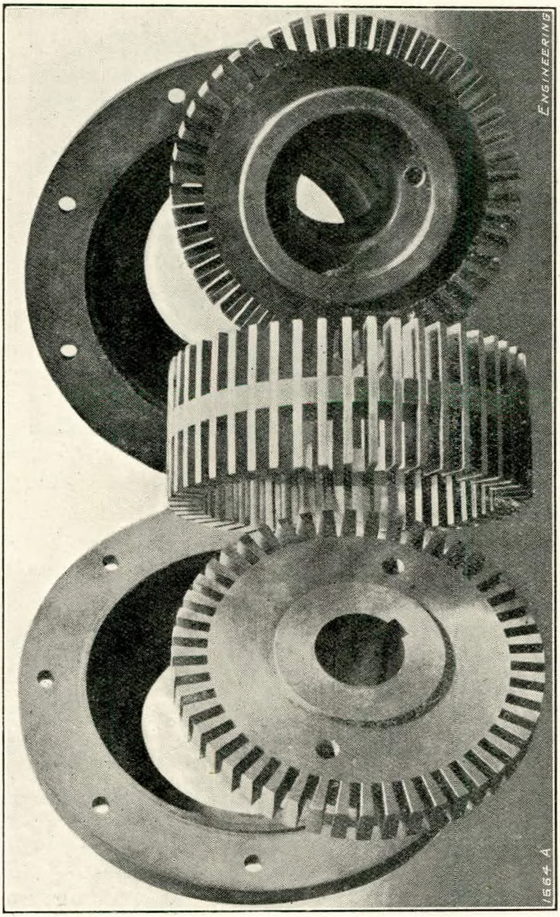


Fig. 1.—Elements of Complete Coupling.

edges of the notches are rounded off on the sides adjacent to the carrier ring. The curvature at these points is parabolic, so that the springs shall lie in contact with the sides as they become deflected under load. This deflection is shown in the

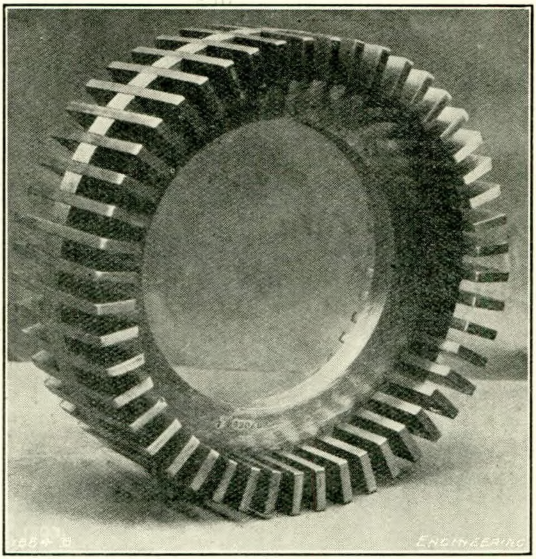


Fig. 2.—Carrier Ring.

Fig. 3.

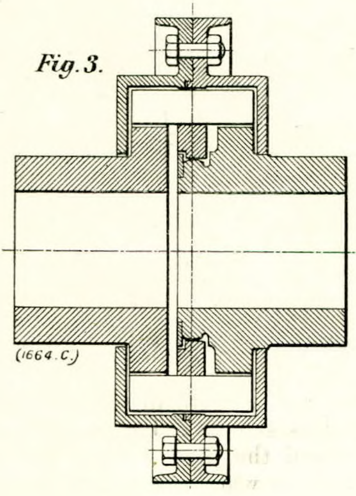


Fig. 4.

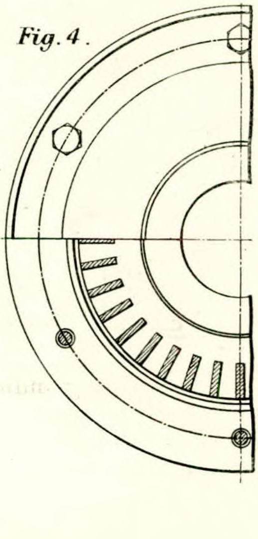
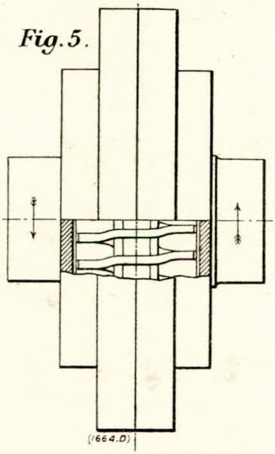


figure and demonstrates how the spring cantilevers are shortened by the curvature of the sides of the slots as the load increases. It is understood, of course, that the arrows on the couplings in Fig. 5 do not denote direction of rotation of the two shafts, but merely indicate that a state of torque exists when the springs are seen curved as shown. The carrier ring provides angular flexibility between the driven and driving shafts and remains in a vertical plane when the two shafts are

Fig. 5.



"ENGINEERING"

Fig. 6.

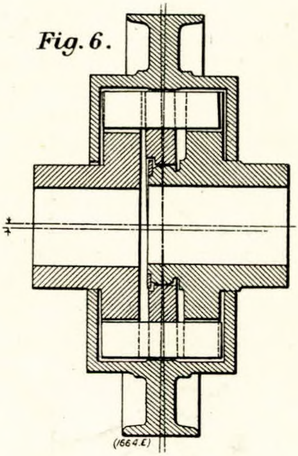
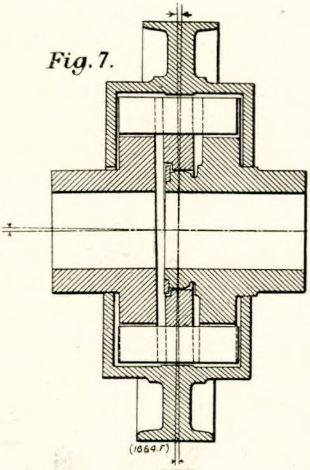


Fig. 7.



in line. A completely assembled coupling in this condition is shown in Fig. 3. It will be noticed that the ends of the springs are well clear of the sides of the cover, in order to allow for longitudinal movement.

The two parts of the cover are bolted together with a spigoted joint, which is oil tight. The cover retains the grease in which the springs are immersed while rotating, the grease naturally being directed by centrifugal force to the area occupied by the springs. One half of the cover is attached to one of the couplings; the other half is clear of the other coupling to allow for any want of alignment. The effects of parallel non-alignment, or off-set, and those of inclined shafting, are shown in Figs. 6 and 7 respectively, and a constructional feature not hitherto referred to can conveniently be mentioned here. This feature is the turning of a projection on one of the couplings with a spherical surface on which the carrier ring runs, and the fitting of a washer-like plate to retain the ring in place. The spherical seating permits the carrier ring to incline in any direction that the misalignment of the shafts may impose, and as the springs can move radially in the slots of the coupling flanges, any eccentric motion of the parts caused by the same misalignment is taken up. The wear due to the displacement of the engaging surfaces one over the other is very small owing to number of surfaces provided for taking the load, all of which surfaces are highly finished. The whole coupling is metallic, and the simplicity and uniformity of the elastic elements permits of easy repair.

ASSIST THE COAL INDUSTRY.

"I have been particularly interested in powdered coal. The Admiralty will watch with interest the experiments undertaken in that direction. I hope shipowners will give the widest possible facilities for experiments, having regard not only to economy, though that is important, but to the probable effect upon a great basic industry."—Mr. A. V. Alexander, First Lord of the Admiralty, quoted in "The Shipping World," 18th September, 1929.

THE ECONOMIC STANDPOINT.

"The task of reorganising the economic life of the people and putting it on a sounder basis is of vital interest to all, whether the position is examined from the point of view of shipbuilding, iron and steel, coal mining, agriculture, or fishing—which are our staple industries. Whether the reorganisation means changes in methods of production, of marketing produce, in transport, or changes in international business relations, we cannot stop short of making these changes in the economic life of the people." Mr. William Adamson, Secretary of State for Scotland, quoted in "The Shipping World," 18th September, 1929.

110,000-Kw. Turbine for the Ford Works at Fordson.

"Engineering," 6th December, 1929.

A steam turbine of a somewhat remarkable type is being constructed by the General Electric Co. for the power station of the River Rouge plant of the Ford Motor Co. The most striking feature of the unit is the reversion to the use of vertical shafts which, originally introduced by Curtis, were subsequently abandoned for the horizontal pattern which is more accessible and simplifies the problem of cooling the generator. In the present case, the floor space available was very restricted, and by the vertical arrangement it has been found possible to install the whole set on a floor space measuring 57 ft. 6 in. in length by 23 ft. in extreme breadth. The overall height above floor level will be under 21 ft., and the output more than 4 kw. per cubic foot of space occupied. The total weight of the machine will be some 900 tons. The above figures are those sent to us by the makers but, in the absence of details, seem difficult to reconcile with further data also given, according to which the high-pressure turbine and generator will be mounted directly on top of the low-pressure turbine and generator. Possibly, however, the floor level referred to above may be many feet above the base of the machine. The initial steam pressure is to be 1,200 lb. per square inch, with a total temperature of 725 deg. F. On leaving the high-pressure section, the steam will be withdrawn from the turbine and reheated to 550 deg. F. The designed vacuum is 29 in. The speed will be 1,800 r.p.m., and the generators will deliver 60-cycle current at 13,800 volts. The air coolers will, it is stated, be integral with the generators, the heat losses in which will be utilised for feed heating. To provide the condensing water required, a tunnel 3½ miles long and 15 ft. in diameter is to be constructed between the River Rouge and the Detroit River. This will deliver some 600,000,000 U.S. gallons per 24 hours.

THE THAMES FERRY STEAMER "WILL CROOKS." "Engineering," 6th December, 1929.

The paddle ferry steamer *Will Crooks*, the first of two Thames ferry steamers being built for the London County Council, was launched on November 20th, by Messrs. J. Samuel White and Company, Limited, East Cowes, Isle of Wight. The vessel, which is to convey passengers and vehicles across the Thames at Woolwich, is of the flush-deck type and has a large deckhouse amidships for passengers. The top of the deckhouse forms the deck for carrying vehicles, the maximum weight allowed being 100 tons. Passengers, to the number of 1,000, can be accommodated. The vessel has a length, between perpendiculars, of 171 ft. 7 in., a breadth, moulded, of 44 ft., and a depth, moulded, of 7 ft. 6 in. The deck machinery comprises one capstan fitted forward for working cables, and one capstan aft for warping. The propelling machinery consists of two independent sets of simple condensing engines, driving the port and starboard wheels respectively. Each engine has two opposed and inclined cylinders, 33 in. in diameter and having a piston stroke of 36 in., operating a single crank. Steam is supplied by two boilers of the gunboat type operating at a pressure of 50 lb. per square inch, and fitted with superheaters. The boilers are 9 ft. 7 in. in diameter and 17 ft. 6 in. long, and each is fitted with two furnaces. The auxiliary machinery includes an electric generator, three feed pumps, two feed heaters and filters, one general-service pump, and two combined circulating and air pumps.

FLOATING DOCK ON THE RIVER GANGES. "Engineering," 3rd January, 1930.

Messrs. Swan, Hunter and Wigham Richardson, Limited, Wallsend-on-Tyne, have constructed a floating dock which, after erection at Wallsend Shipyard, was dismantled, and has just been shipped in parts to India. The dock is of the sectional pontoon type, and is self-docking. The two walls are each a separate and complete structure, resting on four pontoons, and each of the latter is divided into watertight compartments. The dock will be re-erected by native labour, under European supervision, on the right bank of the River Ganges, at Mokameh Ghat, about 50 miles below Patna, in the United Provinces. With the rise of the river during the rainy season, the dock will be floated into the stream. The overall length of the dock is 210 ft., the width between the walls being 56 ft., and the overall width about 66 ft. The lifting capacity of the dock will be 500 tons, and the depth of water over the keel blocks will be 4½ ft. In a house on one of the walls is placed the controlling gear to operate the valves for filling and draining the dock. On the top of one wall is a vertical multitubular Cochran boiler, supplying steam to an engine which operates the pumping machinery through a vertical shaft. The dock will be employed in repairing shallow-draught paddle steamers, barges, and landing stages, there being a ferry service between Mokameh Ghat and Semaria Ghat, on the left bank of the river.

SIXTY YEARS AGO. "The Engineer," 6th December, 1929.

Although the Suez Canal was opened on November 17th, 1869, it was not until December 3rd that we were able to give our readers an account of the ceremony from the pen of a special correspondent whom we had dispatched to represent us at it. He was in passing the only representative of a British scientific journal present on the occasion. He witnessed the ceremony from the deck of the steamer *Fayoum*, an ex-P. and O. paddle steamer of about 2000 tons, which had been acquired by the Khedive. In this vessel, lightened of all ballast to reduce her draught for the passage of the canal, he sailed from Alexandria on the 14th, and after an exceptionally rough trip arrived next day at Port Said. The inhabitants of Alexandria, he noted, expressed nothing but hostility to the canal, for they viewed very unfavourably the rise of a new port so close to their own. At Port Said he found the entrance harbour to be a fine sheet of water enclosed by two moles running for about 2000 yards out from the shore. He was doubtful, however, about the future of the moles and harbour. The moles had been constructed of huge blocks formed from the local sand mixed with Marseilles lime. They had been tumbled anyhow into position in the hope that in time the drift of the sand would close the interstices. It had not done so at the time of his inspection, and he feared that the harbour would silt up unless constant dredging were resorted to. He sounded the entrance harbour after his arrival and found about 24 ft. of water at most places. Ships of all nations except British crowded the harbour, dressed with flags by day and illuminated by night. Bands, broadsides and bombshells rent the air, and in the midst of the excitement two men-of-war ran aground when endeavouring to enter the harbour. Then came rumours that a vessel, the *Latif*, had gone aground anything from 7 to 20 miles up the canal, and that the passage way had been blocked. Under the superintendence of the Khedive himself, however, and with resort to a strenuous night of work, the vessel was refloated in time for the formal opening next day. At 2 p.m. on the 17th the *Fayoum*, with our correspondent on board, entered the canal at Port Said, the thirty-second of the line of ships forming the procession. Six of the vessels ahead ran aground, and at 7 p.m. the *Fayoum* herself struck the bank and threatened to swing across the canal. Eventually Ismailia was reached, and from there our correspondent sent off his dispatch. Sounding the canal so far as he had gone, he found frequently depths of 24 ft. or more instead of the 18 ft. which rumour had prognosticated. The banks gave him cause for anxiety. They were, he said, much too steeply sloped, and the wash from the *Fayoum*, even although her speed was only from 4 to 7 knots, visibly brought down a trail of sand and pebbles into the water.

SALVAGE OPERATIONS AT SCAPA FLOW. "The Engineer," 6th December, 1929.

On Friday, November 27th, the upturned hull of the 4000-ton ex-German light cruiser *Bremse* was safely brought alongside the Lyness Pier depôt of Cox and Danks, Ltd. The ship was towed a distance of 10 miles from the site at which she was raised, which is one of the most exposed positions in the Flow. Actually, the vessel was floated upside-down on practically an even keel some months ago, but during a storm the buoyancy was lost and the ship heeled over on her side, necessitating the provision of new air locks and a recommencement of the salvage operations by means of compressed air. These operations have been continually interrupted by heavy weather, and it was only on Wednesday, November 25th, that the hull was refloated with a small list of 7 deg. to 8 deg. The *Bremse* is the first of the light cruisers to be raised, and she is the twenty-ninth ship to be salved by Cox and Danks, Ltd. Preparatory work is now to be begun on the *Hindenburg* and the *Von Der Tann*, which will form the main programme of next year's operations. Meanwhile, several of the gun turrets which have been cut away from the cruisers already raised are being recovered. It is with great regret that we record the death of one of the salvage engineers of Cox and Danks, Ltd., Mr. M. Carmichael, who was in charge of the salvage operations on the White Star liner *Celtic* at Queenstown. Mr. Carmichael succumbed to gas when going to the rescue of two workmen in one of the holds.

A DEARTH OF MARINE ENGINEERS. "The Engineer," 13th December, 1929.

A report which has been drawn up by the Society of Consulting Marine Engineers and Ship Surveyors, dealing with the present shortage of marine engineers and suggesting some remedial measures, has recently been submitted to the Board of Trade, the Shipping Federation and the Chamber of Shipping. Figures are given to show that, while a larger number of ships is now being built and more complicated main and auxiliary propelling machinery is being installed, the number of certificated engineers available to operate them has diminished. The Society in its report considers that the present eighteen months' qualifying period before the examination is taken is too long, and that a period of twelve months should be reverted to. It is also suggested that the present distinction between the experience gained in coastal ships and that gained in deep-sea vessels is too arbitrary and should be abolished. A further suggestion is that the Board of Trade examination should be improved and that National Certificates and engineering college certificates should be accepted up to the stage certified, in lieu of the present Board of Trade examinations in mathematics and drawing. A proposal is also put forward that an additional third-class certificate might be introduced, which would enable its holders to take charge of vessels with machinery up to 100 nominal horse-power. If this were done then the holders of second-class certificates might be allowed to take charge, as chief engineers, of vessels engined with machinery up to 300 nominal horse-power. The present shortage of engineers is stated to exist more with regard to cargo steamers than large liners. The Society expresses the desire that its members should co-operate with other recognised bodies, whose aim is to increase the number of competent and certificated sea-going engineers.

DEARTH OF MARINE ENGINEERS. "The Engineer," 27th December, 1929.

Sir,—Having been an engineer on cargo ships for six years, I was interested in your article on the "Future of Marine Engineering," December 13th.

I do not think there is a dearth of marine engineers. One has only to look at the Board of Trade returns each week to see that there are plenty of certificated engineers passing out.

But these men, having for their own convenience put up with bad food, bad accommodation, excessive overtime (unpaid), and forced into doing their own greasing on watch, have made up their minds to return to these conditions only as a last resort, with the result that the better-class companies—unfortunately in a small minority—have plenty of applicants, or the men have taken up shore jobs at a reasonable wage.

A case in point.

The Synthetic Ammonia and Nitrates, Ltd., (I.C.I.), Billingham, Yorks., have recently built a power station. There are fourteen fitter-drivers on the running staff, twelve being certified marine engineers. The charge hand, three leading hands, and four fitters on the maintenance staff are the same. With the exception of four, all these engineers have left ships within the last ten months.

The only thing to be said in favour of the majority of cargo vessels is that one can get one's time in quicker for the examination, and that promotion to chief engineer at the handsome wage of £24 per month occurs sooner than in the better-class companies.

The owners have the remedy in their own hands.

Treat their engineers as officers and not glorified firemen, and they will get the men without interfering with the present regulations governing the B.O.T. examinations.

SINBAD.

Middlesbrough, December 14th.

NEW SUPER LINERS FOR ITALY. "The Engineer," 13th December, 1929.

According to an official announcement of the Lloyd Sabaudo Company, a contract has now been signed with the Stabilimento Tecnico Triestino of Trieste, for the construction of a new passenger liner of about 45,000 gross tons, which will be employed in the company's service between Italy and North America. After careful consideration of the various systems of ship propulsion, it has been decided to propel the ship by high-pressure geared turbine machinery of the latest type. The design of the boilers has been entrusted to Yarrow and Co., Ltd., of Glasgow, by whom the full working designs will be supplied. A service speed of 26 to 27 knots is mentioned, which will enable the voyage from Naples to New York to be accomplished in about seven days. The proposal was originally made that the new liner should be named the *Conte Azzurro*, but it has since been pointed out that as she will initiate a new class of ship with a greater speed than the liners of the *Conte* class, an entirely new name is to be preferred. The second super-liner for the service of the Navigazione Generale Italiana, has now been placed with the Ansaldo Company, of Genoa. She will be generally similar to the Lloyd Sabaudo liner in her dimensions and designed speed.

THE CANADIAN PACIFIC LINER "EMPRESS OF JAPAN." "The Engineer," 20th December, 1929.

One of the most important launches of the year took place at the yard of the Fairfield Shipbuilding and Engineering Co., Ltd., at Govan, on Tuesday last, December 17th, when the new 26,000 ton twin-screw express liner *Empress of Japan*, which is being built for the Trans-Pacific service of the Canadian Pacific Railway, safely took the water.

The new liner has been specially designed for the Canadian Pacific fleet, and when completed she will be the largest and fastest steamship in that service. Her propelling machinery will comprise twin-screw, single-reduction, geared turbine machinery, with high-pressure Yarrow boilers, combined with Scotch auxiliary boilers, the general machinery installation being similar to that so successfully designed by Mr. J. Johnson, the Company's Chief Superintendent Engineer, for the *Duchess* class liners. A slightly higher steam pressure and steam temperature has been chosen, and, with one or two minor exceptions, electrically-driven auxiliary machinery will be employed throughout. The principal dimensions of the new liner are as follows:—

Hull Particulars.

Overall length: 666ft.
Breadth, extreme: 87ft.
Depth to "A" deck: 56ft.
Service speed: 21 knots.
Gross tonnage: 26,000.

Passenger Accommodation.

First-class passengers: 400.
Second-class passengers: 164.
Third-class passengers: 100.
Asiatic passengers: 548.

Propelling Machinery.

Type: Twin-screw, single-reduction, geared Parsons type, three-stage turbines.
Total output: 30,000 S.H.P.

Boiler Installation.

Number of H.P. Yarrow water-tube boilers: Six.
Working pressure: 425 lb./sq. in.
Superheat temperature: 725° Fah.
Number of L.P. Scotch auxiliary boilers: Two.
Working pressure: 200 lb./sq. in.

Auxiliary Machinery.

Number of turbo-generators: Two at 600 kW.
Number of oil engine driven generators: Four at 300 kW.

As indicated in the above table, the propelling machinery will be of the latest Parsons type, comprising twin-screw units, each consisting of a high-pressure, intermediate, and low-pressure turbine in series, designed to use steam at a pressure of 375 lb. per square inch, and a total superheated temperature of 700° Fah. The Weir type of regenerative condenser will be fitted, and other engine-room auxiliaries have also been chosen for their high economy and reliable working. As above stated, both steam turbine-driven and oil engine-driven generator sets are to be installed, giving a flexible and economical supply of power. The boilers, both of the Yarrow high-pressure and of the Scotch auxiliary types, are designed for oil burning only, and it is of interest to know that the fuel bunkers, when filled, will amply suffice for the whole of the Pacific voyage, a distance of 13,000 miles.

In proposing the toast of the builders, Captain James Gillies, the General Manager of Canadian Pacific Steamships, Ltd., made some interesting references to certain technical aspects of ship propulsion. The recent spell of tempestuous weather had, he said, served to remind all of us of the difficulties which attend the propulsion of large high-speed liners operating in Atlantic service. It was becoming apparent, he thought, that a four-day Atlantic crossing—the limit for surface ships, for both physical and commercial reasons—was being approached. The problem of driving such ships at a speed such as that of the *Bremen* was an engineering one. It was necessary to accommodate a very large horse-power in the smallest possible compass, with the minimum of weight compatible with reliability and durability, and with such an efficiency that the requisite bunkers could be carried. Further important considerations were those of damage or depreciation through the vessel being hard driven throughout the year, the motion of the ship in a seaway, and its safe navigation. With regard to the *Empress of Japan*, although she would have a service speed of 21 knots, it was expected that an additional speed of at least one knot would in favourable weather be registered. The passage between Vancouver and Yokohama, a distance of 4,200 miles, would be made in eight days, or a day less than with the earlier liners. The new liner *Empress of Britain*, which was being built by John Brown and Co., Ltd., at Clydebank, and will be commissioned early in 1931, was designed to make the passage from Southampton to Quebec in five days, thus shortening the Atlantic part of the journey. With regard to advances in propelling machinery, it was of interest to reflect that in the *Empress of Canada*, built by the Fairfield Company in 1922, the machinery weight was 3,400 tons, with permanent bunkers of 6,100 tons, for a speed of 19 knots and 20,000 S.H.P., whereas with the *Empress of Japan* the machinery would weigh only 3,200 tons, with permanent bunkers of 6,100 tons, for a speed of 21 knots, and 30,000 S.H.P. The progress which had been made by Sir Charles Parsons and Mr. J. Johnson with high-pressure geared turbine machinery had resulted in new records being established, first by the *Empress of Australia*, and later by the *Duchess* class of liners, and in the case of the *Empress of Japan* a new record was looked forward to. He did not think, however, that the last word had been said with regard to the high-pressure turbine system of propulsion, and important developments in boiler design were foreshadowed which would increase the commercial efficiency of the propelling machinery and enlarge the radius of action of large passenger liners, intermediate liners, and fast cargo steamers. The new liner would be the first of her type in the North Pacific Ocean to be propelled by high-pressure steam machinery, and he felt that she would be a worthy illustration of her builders' all-round shipbuilding and marine engineering capacity.

A NEW BLUE FUNNEL MOTOR LINER. "The Engineer," 27th December, 1929.

The new Blue Funnel motor liner *Menestheus*, which has been built and has had her machinery fitted at the yards of the Caledon Shipbuilding and Engineering Co., Ltd., of

Dundee, recently ran successful trials in the North Sea. She has now left Dundee for Falmouth, where she will be dry docked before proceeding East. She is a standard Holt liner of about 8,000 gross tons, and is propelled by twin-screw, four-stroke, single-acting oil engines, working on the airless injection principle, and pressure-charged by the Rateau system, which employs an exhaust gas turbine-driven blower. The total output of the engines is 8,600 S.H.P. at 110 r.p.m., when pressure charged, and 6,600 S.H.P. at 105 r.p.m. when not charged. The engines, which have been designed and built by Burmeister and Wain, Ltd., of Copenhagen, have " Perlit " castings for the principal parts, and a new system of water cooling is applied which allows the amount of water passing from the main cylinder heads and jackets to the suction of the cooling water pump to be varied, enabling the engine to be run warmer in cold weather without diminishing the flow through the jacket spaces. The propeller shafts are carried in tunnel bearings of the latest Michell type, and a new system of Hastie steering gear of the electric-hydraulic type is fitted, in which one of the Hele-Shaw pumps is motor driven and the others coupled direct to a Brotherhood three-cylinder air engine. If the supply of electricity to the motor fails, a solenoid immediately opens the compressed air supply valves and starts up the air engine driven pump. Like all the recent Blue Funnel Line ships, the *Menestheus* is built of high elastic limit steel.

A UNIFLOW MARINE ENGINE. "Shipbuilding and Shipping Record," 30th January, 1930.

The advantages of the uniflow principle as applied to the reciprocating steam engine are well known, and in the efforts which are being made to improve the efficiency of the marine reciprocating steam engine the use of this principle has frequently been urged. An interesting form of engine embodying the uniflow principle has recently been made and tested by a well-known Dutch firm of marine engineers, and the results obtained are sufficiently encouraging to warrant the building of units of larger power. The engine in question is of the three-cylinder compound type, three cylinders being employed in order to obtain a more uniform turning moment on the shaft—the high-pressure cylinder, which is of conventional design, exhausting to two similar low-pressure cylinders in which the uniflow principle is employed. The distribution of the steam is carried out by means of piston valves operated by the familiar Stephenson valve gear, and in order to reduce the cost of construction, all three piston valves are of the same size. The engine is designed to receive steam at a pressure of 225 lb. per sq. in. superheated to 572° F., and the cut-off in the high-pressure cylinder at 35 to 40% is so arranged that the steam is still slightly superheated when it reaches the low-pressure cylinders at a pressure of about 45 lb. per sq. in. and where a cut-off of 20 to 25% is employed. During the course of the tests in the makers' works the engine developed 366 I.H.P. at a speed of 117 r.p.m., and it was found that the engine had a steam rate of 10·18 lb. per I.H.P. per hour, while the overall indicated efficiency ratio was 69%. It is claimed that these figures represent an economy of 10% as compared with the ordinary triple-expansion engine working under similar conditions.

A CENTURY OF NAVAL ENGINEERING. "The Engineer," 10th January, 1930.

The decision recently reached by the Engineer-in-Chief of the Fleet, Engineer Vice-Admiral R. W. Skelton, and his Department, to place on record in the third Thomas Lowe Gray Lecture an account of the progress made in naval engineering during the last century is to be welcomed by all engineers. Those who attended listened with evident appreciation to a review of marine engineering progress, which was valuable, both on account of its human and technical interest. In the comparatively short time at Admiral Skelton's disposal, he touched upon the long series of changes, in the gradual evolution of new and improved types of propelling and auxiliary machinery put into service since 1829, when the first steam fighting ship, H.M.S. *Dee*, was laid down at Woolwich. The earlier events which are less widely known than those of more recent date were dwelt upon by the lecturer in some detail. It was thus possible to follow the steps in the development of successive engine types from the beam and side lever engine to the modern geared steam turbine unit of high power or the development from the flue tube and cylindrical boiler to the oil-fired, high-duty, water-tube boiler of present-day design. The outstanding feature of the review is the interplay of naval and mercantile practice, and the constant help of marine engine designers and allied industries in the solution of naval problems. On the other side, the careful observation of engineer officers and the experience gained in service often prepared the way for a further step in advance.

In the earlier years marine engineering advances were held back by the desire to retain the sailing qualities of ships and the need for lifting the propeller. With the introduction of the iron ship and the provision of more accommodation below the water line, higher engine speeds and new designs were adopted, and later it was possible to make use in the Navy of Kirk's excellent work on triple-expansion engines. Boiler troubles seem to have been experienced at recurring intervals, but they, and the difficulties with the surface condenser, were surmounted when the necessity of a clean feed free from air was fully appreciated, and when suitable metals for tubes and shells became available. It is interesting to read that the commercial production of seamless tubes was brought about by a boom in bicycles, but this is only one of many instances of the many-sided needs of naval engineering. The Admiralty committees on boiler pressures seemed to have no doubt of the economies which would be brought about by the use of higher pressures, but the danger of too quick a movement in this direction in pre-war years was illustrated by the troublous experience with the Belleville boiler, which having given good results in the French mercantile marine, caused a good deal of anxiety to naval engineers. It is a great credit to the engineering *personnel* that difficulties in operation were surmounted and satisfactory operation was later achieved. Admiral Skelton's statement that the successful outcome of the late war—which turned ultimately on the endurance of the British Navy—was in a great measure due to the perfection of the engineering machinery of the Fleet, which was developed and operated by the *personnel*, who were intensively trained and tried, both in design and operation, in the troubled times of the Belleville boiler, is a striking instance of the possible value to engineers of difficult experience, if it be met in the right way. In the introduction of the steam turbine, the geared turbine, and oil fuel, progress was unretarded, and the Navy kept step with the mercantile marine. When some years ago difficulties were encountered with double-reduction gearing in mercantile ships, the good experience of the Navy with single-reduction gearing was often referred to. It is a tribute to both workmanship and materials that out of some 720 sets of gear fitted in naval ships, transmitting powers ranging up to 36,000 I.H.P., only five cases of failure on service, which entailed renewal, are on record. With regard to the oil engine, it appears that the lack of a suitable heavy-oil engine held back the application of that type of prime mover to submarine work for some years. The extensive research and development work which was done by Vickers Ltd., on the airless injection engine led to the utilisation of that type of engine in practically all submarines. The steam-propelled "K" class submarine formed, however, an interesting departure from that practice. With the founding of the Admiralty Engineering Laboratory in 1917 the oil engine problem was attacked under the leadership of Engineer-Commander C. J. Hawkes, and twin-screw 3,000 S.H.P. oil engines based on the designs of the Laboratory are now installed in the submarine "X 1." Their weight is apparently 51 lb. per horse-power. Admiral Skelton assesses the difference in economy between modern steam plant and oil engine propelling machinery at about 30 per cent., and while anxious to obtain that advantage, he is apprehensive of loss of reliability and increase of engine weight. In this respect the new German naval ships with oil engines for main propulsion and for cruising have aroused keen interest among marine engineers. The installation of geared twin-screw M.A.N. engines of 50,000 S.H.P. in the *Ersatz Preussen* and the use of a centre shaft cruising oil engine of 12,000 S.H.P. on the *Leipzig* promised important developments, especially as the engine weights have, by the use of alloy steels and special light metals, been reduced to something like 17·5 lb. per B.H.P. In referring to the contributions of the metallurgical industries to the advance of naval engineering, we cannot overlook the recent introduction of high elastic limit steels of the "D" quality and the "Martinel" steel, which is now being employed in Holt Line ships. In his paper on the battleships *Nelson* and *Rodney*, read before the Institution of Naval Architects in March last, Sir William Berry dealt with the great saving in weight made possible by the use of such new steels. Equally important has been the saving in weight introduced by the use of aluminium and other light alloys for internal fittings. In this respect the recent experience gained with stainless steel and light alloys in the construction of airships will prove most valuable to naval constructors and engineers. On the steam side, tribute must be paid to the work of Dr. Bengough and the Condenser Tube Corrosion Committee of the Institute of Metals, which has led to the more careful manufacture of condenser tubes and the increased use of cupro-nickel and monel metal tubes, which bid fair to banish trouble from this source. From the tables given by Admiral Skelton we note that the best fuel consumptions are those of the battle-ship *Nelson,* 0·789 lb. per h.p. hour, and the *Berwick* 0·89 lb. per h.p. hour. At the present time high-pressure Parsons turbines are to be installed in a new Thornycroft-built destroyer, and there seems no doubt that in the new ships an effort to reach Mr. Johnson's figure of 0·60 for the new *Empress* class ships will be made. Another promising factor for the reduction of weight is the increased use of welded instead of riveted structures, both for hulls and machinery scantlings, and great success has been achieved in these directions in recent continental warships.

In concluding his lecture, Admiral Skelton pointed to the re-action between commercial marine engine designs and naval engineering progress. The necessity to design high-powered and highly economical propelling and auxiliary machinery has always acted as an incentive to intensive design in many branches of engineering and applied science. The forthcoming International Conference on Naval Disarmament may alter classes and types of ships, but we do not think that the demands made upon the naval engineer will be lessened; indeed, they will almost certainly be increased by the new problems which are likely to be presented. At such a time, a review of a century's progress, such as was given in the Thomas Lowe Gray Lecture, spurs us on to meet future problems in that high spirit which was characteristic of the pioneer workers in this most important branch of engineering science.

A NEW FAST MOTOR SHIP FOR NORTH SEA SERVICE. "The Engineer," 10th January, 1930.

The new motor ship for the Bergenske Shipping Company's Bergen-Newcastle service, which is being built by the Elsinore Shipbuilding and Engineering Company and engined by Burmeister and Wain, Ltd., in Denmark, is to have a speed of 19½ knots when supercharged, and will be able to make the voyage from Bergen to Newcastle, quayside to quayside, in 21 hours. She will incorporate the latest safety equipment and her length will be 412ft. 10½in., with a beam of 54ft. Her displacement on a 20ft. draught will be about 6,950 tons, and her measurement about 5,600 gross tons. Modern cargo holds and refrigerated cargo spaces with the latest cargo-handling devices, are to be fitted. The propelling machinery will comprise a twin-screw arrangement of ten-cylinder, four-stroke, single-acting oil engines of the airless injection type, which will be designed to operate with Burmeister and Wain's latest type of supercharger driven direct from the main engines. The normal engine speed will be 155 r.p.m., at which about 11,000 I.H.P. is to be developed with the engines unsupercharged, and 12,400 I.H.P. with both superchargers in operation. When carrying 2,000 tons of cargo, the maximum power given above will correspond to a speed of about $19\frac{1}{2}$ knots. Besides the main engine-room a special auxiliary engine-room is to be provided, in which three 180kW generator sets, driven by three-cylinder Burmeister and Wain engines of 250 B.H.P. output, are to be installed.

THE LATE PROFESSOR H. L. CALLENDAR. "The Engineer," 24th January, 1930.

We greatly regret to have to record the death of Professor Hugh Longbourne Callendar, Professor of Physics at the Imperial College of Science, London. Dr. Callendar was born at Hatherop in 1863, and was the eldest son of the late Hugh Callendar, of Magdalene College, Cambridge. He was educated at Marlborough College and at Trinity College, Cambridge, of which he was appointed a Fellow in 1886, and from which he received the degree of M.A. in 1888. In 1894 he was elected a Fellow of the Royal Society and two years later he was elected a Fellow of the Royal Society of Canada. From 1893 to 1898 he was Professor of Physics at McGill University, Montreal, and from 1898 to 1902 he occupied a similar post at University College, London. Professor Callendar will always be remembered for his work on the properties of steam, a subject on which he acquired a world-wide reputation and into which, by the adoption of thermodynamic reasoning, he introduced a degree of rationalisation which had previously been lacking. His Thomas Hawksley lecture on certain aspects of this subject, which he gave on November 1st, 1929, before the Institution of Mechanical Engineers, was a memorable exposition of its most recent developments. It was distinguished on the personal side by a characteristic but almost embarrassing modesty on the part of the lecturer when referring to his own great contributions to our knowledge of the properties of steam and water.

THE NEW P. AND O. LINERS. "The Engineer," 24th January, 1930.

At the annual general meeting of the Peninsular and Oriental Steam Navigation Company, which was held last month, the Earl of Inchcape, the chairman of the company, referred to the early placing of an order for two electrically propelled passenger and cargo liners of about 20,000 gross tons for the company's Australian service. The order for these two ships has now been placed with Vickers-Armstrongs, Ltd., of Barrow-in-Furness, and the ships, which will take two years to complete, will be built at Barrow. The new liners will be slightly larger than the *Viceroy of India*, and the maximum speed will, it is understood, be about 20 knots. The propelling machinery will consist of twin-screw turbo-electric equipment, each turbo-alternator being designed to give the ship the desired normal service speed. The electric propelling machinery will be manufactured by the British Thomson-Houston Company, Ltd., at Rugby, which firm will act in collaboration with Vickers-Armstrongs, Ltd. The boilers are to be of the latest Yarrow high-pressure, oil-fired type, and the boilers for the first ship will be built by Yarrow and Co., Ltd., at Scotstoun, while those for the second vessel are to be constructed at Barrow to the design of Yarrow and Co., Ltd. The main propelling and auxiliary machinery of the new ships will be generally in accordance with the installation on the *Viceroy of India*, but it will include several new and interesting features, which have been adopted as a direct result of the very successful experience gained in the operation of the *Viceroy of India*, which on the occasion of her last voyage, made a record run. The order is an important one for Barrow-in-Furness, and it is understood that an average of about 2,500 men will be employed on the work.

FIRES IN BUNKER AND CARGO COAL. "The Engineer," 24th January, 1930.

An interesting memorandum on fires which have occurred during the last three years in ships carrying coal either as cargo or in the bunkers has recently been issued by the Fuel Research Section of the Department of Scientific and Industrial Research. Data have been collected concerning 336 fires, which occurred on 272 ships, and the conclusions reached as to their cause are given, together with recommendations as to the precautions which should be taken in order to prevent such fires. Most of the fires were traced to avoidable causes, and the number of fires attributed to spontaneous combustion alone only amounted to 14 per cent. of those investigated. The inquiry shows that most of the fires which occur in steamships originate in the bunkers, and that in over half the cases examined the heating of the coal to the critical temperature was assisted by direct heat from the boilers, steam pipes and other sources. The suggestions made, which, if carried out, would, it is stated, reduce materially the number of fires, include greater care in loading and stowing the coal, the prevention of the external heating of the bunker walls, the mixing of different coals, and the prevention of air paths through the coal. The ventilation of coal bunkers is dealt with, and some recommendations are made with regard to the handling and stowage of specially susceptible coals, such as highly bituminous coals, German brown coal, and Silesian coals.

THE ENGINES OF THE GERMAN CRUISER "ERSATZ PREUSSEN."

"The Shipbuilder," January, 1930.

Discussion of weight reduction in naval vessels by means of high-speed Diesel engines cannot be left without mention of the new German "cruiser annihilator" *Ersatz Preussen*. This vessel, as is generally known, will be propelled by Diesel engines aggregating 50,000 S.H.P. on four shafts. The engines are of the latest M.A.N. double-acting, two-stroke cycle, airless-injection type running at about 215 r.p.m. The power is transmitted to the shafts through single-reduction gearing having a reduction ratio of rather less than two to one. The weight per B.H.P. of these engines is as low as 17½ lb., a figure which is substantially less than that of any other double-acting, two-stroke cycle oil engine yet built, and actually lower than the specific weight of not a few quick-revolution, trunk-piston, four-stroke cycle engines! In fairness to the latter type, however, it should be mentioned that the weight per H.P. of the Beardmore super-charged engines of the *R*.101 is less than half the figure mentioned. How the figure of 17½ lb. per B.H.P. is achieved in the case of the *Ersatz Preussen's* machinery can only be the subject of conjecture at present, but it is patent that special materials have been freely used, since the weight of very similar M.A.N. double-acting engines of the land type is about 55 lb. per B.H.P.—in itself a wonderful figure judged by the standards set by normal single-acting marine oil engines of the slow-speed type. In this class of machinery, weights of the order of 250 to 350 lb. per B.H.P. are usual. The rating of the German naval Diesel engines will, of course, be high, as 50,000 S.H.P. will only be demanded on occasion and never for many hours at a time. It is not improbable that free use has been made of aluminium alloys in these remarkable engines, and it is to be hoped that we shall learn more concerning their design when the *Ersatz Preussen* goes into service. To achieve a superior power-weight ratio to that obtainable with geared turbines and water-tube boilers for this class of vessel is an accomplishment which must rank with the production of, say, the machinery of the *Turbinia*, the *Mauretania*, the *King George V.*, the *Bremen*, the *Selandia* and other epoch-making examples along the path of marine engineering progress. If the *Ersatz Preussen's* machinery demonstrates that it possesses reliability and durability in service, German engineers will have achieved another great triumph.

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BOILER EXPLOSION REPORT.

REPORT NO. 3031. T.S. *King George V.*
O.N. 148912.

Report No. 3031, deals with an explosion which occurred on the Turbine Steamer *King George V.* The investigation was conducted by Messrs. J. Graham and G. E. Jenkins.

The boiler from which this explosion took place was the forward one of two coal fired, high pressure, Babcock and Wilcox, marine type water tube boilers. It was constructed of steel throughout and consisted of eighteen sections of solid-drawn straight steel tubes which were expanded into forged steel sinuous headers at each end. The water tubes formed practically the whole of the heating surface of the boiler, and were inclined from the front or downtake headers, to the back or uptake headers. Extending across the boiler was the forged steel steam and water drum which was of 3ft. internal diameter and 13/16th inch minimum thickness and 1 11/16th inches thick in way of the mountings, return tubes, and downtake nipples. The length of the drum was 14ft. over the ends. Access to the drum was obtained through two manholes 15ins. by 11ins., one at each end. The upper ends of the front headers were connected directly to the steam and water drum by short nipples 4ins. external diameter by 2 L.S.G. in thickness, and the back headers were connected to the top end of the steam drum by two rows of straight return tubes 4ins. external diameter by 2 L.S.G. in thickness. Extending across the front of the boiler, below the front headers, was a mud drum which was a forged steel box of square section, 7½ins. by 7½ins. externally. This was connected to the lower ends of the front headers by short nipples, 4ins. outside diameter by 2 L.S.G. in thickness. The mud drum was also connected at each end to the steam and water drum by a downcomer tube 4ins. outside diameter by 2 L.S.G. in thickness. The uptake and downtake headers were of rectangular section, being 6¾ins. wide by 6⅛ inches deep externally. These headers and the mud drum were seamless, and made from weldless steel blanks. The lowest row of water tubes over the fire were 4ins. outside diameter by 1 L.S.G. thick, and adjacent to these were two rows of water tubes 1 13/16th inches outside diameter by 7 L.S.G. thick. A space was left above these tubes to accommodate a horizontal flame baffle, and immediately above this were ten rows of water tubes 1 13/16th. inches outside diameter by 8 L.S.G. in thickness. These small water tubes were arranged in groups of four tubes in all headers except the outer ones. In the latter they were arranged in groups of four and two, to clear the boiler casings. Hand holes were formed in the headers opposite the ends of the tubes for purposes of examination, and cleaning. Each hand hole was fitted with a door which was secured by a stud and forged steel dog. All the water tubes were made of hot-finished solid-drawn steel tubes which were secured in place by expanding and bell mouthing. The 1 13/16th inches water tubes were made by Messrs. Babcock and Wilcox, while the 4in. tubes were made by the Bromford Tube Company, Birmingham. A Babcock and Wilcox superheater was placed above the boiler in the path of the gases (see Plate). This consisted of solid-drawn steel tubes 1½ inches outside diameter by 8 W.G. thickness, which were bent into " U " shape and expanded into steel boxes.

The boilers were constructed in accordance with the regulations and requirements of the Board of Trade, all the material being tested by the Board's Surveyors. On completion both boilers were satisfactorily tested by hydraulic pressure to 875 lbs. per square inch. There were three firing doors which open inwards on to a fire grate which was common to the whole width of the boiler, the grate being 6ft. 10ins. long and 10ft. wide. Baffles were fitted as shown on the plate to direct the passage of the hot gases on their way to the uptake.

The usual mountings were fitted, the main and auxiliary self-closing stop valves being placed on the superheater. A single spring safety valve set to blow off at 545 lbs. per square inch was placed on the superheater, while the statutory double spring safety valves were placed on the saturated steam and water drum. The other fittings on the saturated steam and water drum were the automatic feed regulating valve, and the main and auxiliary hand-feed check valves, saturated steam auxiliary valve, pressure gauge and two water gauges. The water gauges were designed to suit the high pressure and temperature and consisted of a cast steel body suitably recessed on each side to take specially-prepared glass plates $\frac{5}{8}$in. thick through which the water was visible. Between each glass plate and the steam and water was interposed a thin sheet of mica which prevented the plates being dissolved by the water and steam. The glasses and mica sheets were secured by bronze coverplates. Suitable jointing was provided to ensure steam and water-tightness and the coverplates were secured to the shell by ten $\frac{5}{8}$in. steel bolts which passed through the shell and coverplates. The ends of the shell were connected to the steam and water valves by forged steel tubes which passed through stuffing boxes at the valve chests. The whole fitting was mounted on forged steel distance pieces which were attached to the steam and water drum. Safety devices were fitted in the steam and water ends between the shut-off valves and the gauge, consisting of a bronze spring automatic valve in the steam end and a bronze ball in the water end. In the event of a gauge glass breaking the spring automatic valve was closed by the rush of steam and the ball seated itself on a specially prepared seat in the water end. The shut-off valves could then be closed by hand. Each water gauge was illuminated by an electric lamp, the light being deflected diagonally upwards by means of a grid placed between the lamp and the water gauge. With this form of illumination the surface of the water in the glass showed as a brilliant light when viewed from the firing platform. The water gauges were placed a distance of 5ft. 2ins. on each side of the centre line of the boiler. The boiler room was closed and under air pressure, cold or outside air being delivered to the boiler room by means of a fan. The cold air became heated and rose to the upper part of the boiler room from where it passed into the preheater at the base of the funnel. After being heated there by the waste gases it passed down between the double casing at the back of the boiler, into the ash pit and through the fire bars. The products of combustion travelled around the water tubes in the path arranged by the baffles and thence through the air preheater to the funnel. Water drenchers were fitted so that the fires might be extinguished in emergency. The boiler was arranged to burn coal and was hand-fired.

There was a loud report in the boiler room when the explosion occurred. The sixth generating tube, counting from the starboard side of the furnace, in the row of 4in. tubes next the fire, ruptured longitudinally on the side next the fire, as shown on the Plate. Through the aperture the contents of the boiler were discharged on to the fire grate.

The explosion was caused by shortness of water in the boiler which led to overheating of the tubes to such a degree that one of them bulged, and finally ruptured under the stresses set up in the material by the internal pressure.

The boiler from which the explosion took place was one of two Babcock and Wilcox type, high pressure, marine boilers which were designed to supply steam at a working pressure of 550 lbs. per square inch to the main propelling and auxiliary machinery. Saturated steam was led from the upper steam and water drum to the superheater, whence it passed through the main and auxiliary self-closing stop valves to the machinery.

On the 19th July, 1929, the vessel was making a run from Greenock to Campbeltown. After leaving Greenock, on the outward passage, the vessel called at Gourock, Dunoon, Wemyss Bay, Fairlie and Loch Ranza, leaving the last-mentioned place at 11.30 a.m. for Pirnmill. At 11.35 a.m. the explosion occurred. At the time of the explosion a Third Engineer, Mr. James Grant, who holds a second-class ordinary certificate of competency, and the Chief Engineer, Mr. John Whyte, who holds a first-class ordinary certificate of competency, were on the firing platform in the boiler room together with Messrs. Adam Greig and Thomas Turner, firemen, and Mr. William O'Neill, coal trimmer. The self-closing main and auxiliary stop valves on the forward boiler instantly shut, thus isolating the forward boiler. Flames and smoke came out of the spaces between the doors and their frames. The men were hurled off their feet by the force of the explosion, Mr. Grant being temporarily blinded. As soon as Mr. Whyte realised what had happened he turned on the drenchers to stop the generation of steam. Mr. Grant, the firemen and trimmer got up through the emergency escape and the air locks into the alleyways.

A Third Engineer, Mr. John Nicholson, who holds a second-class ordinary certificate of competency, went down to the boiler room immediately after the explosion, and acting under instructions from Mr. Whyte he shut off the boiler by closing all the valves on it, with exception of the main feed check valve which was already shut. The firemen came down, and after this the vessel steamed on one boiler.

On deck the explosion was noticeable as a dull thud. The concussion blew off the manhole lids which gave access to the boiler room and bunkers in the starboard alleyway, and the alleyway was filled with dust for a short period, but no damage was done and no person on deck was injured.

When the noise of the explosion was heard the Second Engineer, Mr. John Sangster, who holds a second-class certificate of competency, was on the manœuvring platform in the engine room, and he immediately accelerated the feed pumps.

In view of the explosion the Master of the vessel decided to return to Greenock. The s.s. *Davaar* came alongside, the passengers for the remaining ports of call were transferred, and the *King George V* returned to Greenock steaming on one boiler. The vessel arrived at Greenock at 4.35 p.m. without further incident. Mr. Whyte and Mr. Grant remained on duty during most of the return journey.

I visited the vessel on the evening of the 19th July. On entering the furnace of the forward boiler the 6th tube from the starboard side in the row of tubes nearest the fire was seen to be ruptured. The opening was $7\frac{3}{8}$ins. long and 6 1/16th ins. maximum width, and the edges at the fracture were drawn out to a knife edge. The forward end of the rupture was 1ft. $8\frac{1}{8}$ins. from the forward header face and the tube was forced up $2\frac{3}{4}$ins. by the reaction of the escaping steam. The external appearance of the under side of this tube in the region of the rupture showed that it had been severely overheated and the remaining portions of the tube on the under side indicated that overheating had taken place over practically the whole length of the tube in a lesser degree. A sketch of this tube is given on the plate. All the remaining tubes in the fire row were hogged, the deflections upwards varying from 11/16th inch to $\frac{3}{4}$in. The position of maximum deflections was on a line parallel to the back brick wall of the furnace where the hot gases would impinge on the under side of the tubes as the gases swept past the horizontal baffle and up the first gas passage. Each of these tubes showed distinct signs of overheating externally over a length of from 3 to 5 feet. The surface was coated with heat scale and the ash from the grate was fused into the surface of the tube. The tubes on either side of the ruptured tube showed a slight increase in diameter, varying from 1/32nd to 1/16th inch. Looking upwards amongst the 1 13/16th inches water tubes the portion of the external surface upon which the flame could impinge showed distinct indications of having been overheated, the lower rows of tubes being bent in an upward and outward direction. The brick work of the horizontal baffle was also slightly disturbed.

Internally, the tube which ruptured was clean, which was to be expected as the contents of the boiler were discharged through it. The remaining tubes in the bottom row were free from any signs of oil or scale deposit, but a thin coating of black metallic heat scale which came out in sheets about 2ins. by 1½ins. was obtained from some of the tubes when in position in the boiler. The bottom row was subsequently cut out of the boiler, and each of the tubes was found to be covered internally on the lower surface with heat scale. This was loosened by hammering the tube externally and was removed in considerable quantities. The presence of this heat scale inside the tubes and on the outside is conclusive proof that at the time of the explosion there was very little water in the boiler. The remaining water tubes were clean.

In this vessel the main water supply consisted of Greenock town's water, which was passed through the evaporators and condensed before being used in the boilers. At the commencement of the season the boilers were filled with distilled water and were subsequently fed entirely with distilled water. The forward boiler had been emptied on two occasions since the vessel came on service in May, and on both occasions had been filled with Greenock town's water, the subsequent make-up feed being distilled water. The feed water passed from the condenser to a feed supply tank from where it was pumped through the feed heater into the boilers. Three pumps were used for this purpose, two being in the engine room, and one in the boiler room. The pumps in the engine room were kept moving at a uniform speed, while the pump in the boiler room was kept working at whatever speed was necessary to maintain the working level of water in the boilers. The boiler room pump was under the control of the engineer on watch in the boiler room, the two engine room pumps being controlled from the engine room only. Means of communication were provided between the two compartments by speaking tube and telegraph. The feed tank was provided with a sight glass which showed the height of water in the tank. This sight glass was visible to the engineer on duty on the bottom platform in the engine room, but was not visible to the engineer on the upper platform. An overflow pipe was provided which led back to the main feed supply tank in case the water reached too high a level.

On the morning of the 19th July, Mr. James Grant was in charge of the boiler room on the outward journey. He commenced duty at 6.30 a.m. and prepared the boilers for the day's work, opening all the boiler mountings himself. Before moving from the berth at Albert Harbour, the water in the starboard water gauge of the forward boiler stood at a height of three-quarters glass, *i.e.*, the total length of the visible gauge glass being $8\frac{5}{8}$ins., there would be about $6\frac{1}{2}$ins. of water in the glass. It was also stated by various witnesses that the steam end of this water gauge was leaking badly. With regard to the port water gauge, Mr. Grant states that no water was showing in it as the vessel had a list to starboard. The evidence of the ship's engineers and the master is to the effect that the vessel had always a list of three or four degrees to starboard, due to the bunker sizes and inequalities in the stowage of stores, etc. Such a list on the vessel would cause a difference in level in the port and starboard water gauges which would vary with the list. Again, on this service the passengers may move from one side of the deck to the other as the interest changes, and thus cause a rapid change in the position of the water level in the gauge glasses.

Mr. Grant was relieved for breakfast by Mr. John Nicholson, who holds a second-class ordinary certificate of competency, and during this period the vessel was moved from Albert Harbour to Princes Pier. Everything worked satisfactorily, and when Mr. Grant returned in about twenty minutes time the water stood at about half glass in the starboard gauge, there being no water in the port gauge and the vessel still having a list to starboard. The water was kept at this level until leaving Princes Pier. The vessel left at 8.45 a.m. and after calling at Gourock and Dunoon, arrived at Wemyss Bay at 9.47 a.m. Up to this time everything was satisfactory. The feed pumps were kept working at piers in order to keep the water as high as possible in the drum preparatory to moving off, and at Wemyss Bay the starboard water gauge filled up until the water level was out of sight in the glass, there still being no water visible in the port water gauge. The water gauges on the after boiler were in about the same condition, viz., the starboard gauge with the water above the top of the glass, and the port gauge with the water occasionally showing above the bottom nut. The appearance of water in the port water gauge of the after boiler is explained by a difference in the water levels of the boilers. With the vessel upright the height of water in the water gauges of the forward boiler is equal, whereas in the after boiler the water in the port water gauge shows 1¼ins. higher than in the starboard glass. The vessel left Wemyss Bay at 9.50 a.m. and the foregoing conditions remained unaltered in the forward boiler. The vessel arrived at Fairlie at 10.20 a.m. and left at 10.24 a.m. for Loch Ranza. This distance is covered in about an hour's continuous steaming and there was therefore no variation in the conditions as regards the load on the boilers. Shortly after 10.30 a.m. Mr. Nicholson went into the boiler room for the purpose of relieving Mr. Grant for about ten minutes. Mr. Grant told Mr. Nicholson of his uneasiness regarding the excessive water which was in the forward boiler. The hand control feed check valve on this boiler was half shut at the time, this having been done by Mr. Grant. Both Mr. Grant and Mr. Nicholson stated that shortly after Mr. Nicholson's arrival in the boiler room the water in the starboard glass of the forward boiler came down to half an inch below the top of the glass and the port gauge showed no water, that is the water level may have been higher than the top of the glass or below the bottom. Mr. Grant then opened the check valve full open. Both then commenced to blow through the water gauges by opening the drain slightly off the face so as to allow the water level to come slowly down in the glass, and then closing the drain when the water would rise to its own level. The port and starboard water gauges on the forward boiler were blown through in this manner, and in the case of the starboard gauge, the water level was seen to come down in the glass, and on closing the drain to rise up until it went out of sight. When the port gauge was tried no water showed in the glass. Both engineers then tried the gauges by opening the drain and closing the steam and water ends alternately. The water ends of the gauges blew strongly, and when the steam end was opened with the water shut, there was first a strong blow which died slowly away. This dying away was due to the safety device which is placed in the steam arm of the gauge, and which closes the steam end in the event of a gauge glass bursting. About this time large bubbles commenced to rise up inside the starboard water gauge. The bubbles were the full width of the glass and from $1\frac{1}{2}$ to 2 inches long according to Mr. Grant's evidence, while Mr. Nicholson stated that they resembled soap bubbles. The water level in the starboard glass became very erratic as it would bubble for a short period, and then settle quietly at about three-quarters full of the glass. According to Mr. Grant's evidence, the water now rose until it went out of sight in the glass, and he was satisfied that there was too much water in the boiler, but in view of the list of the ship he thought that water could not show in the port glass. In the circumstances he shut the hand feed check valve on the forward boiler so that no water could now get in, and watched the starboard glass to see if the excess water would be evaporated and the water come into sight. Throughout the foregoing period there was no water showing in the port gauge. The feed check valve remained closed for two or three minutes and as water did not appear Mr. Grant opened the check valve full open and went to fetch Mr. Whyte, the Chief Engineer. As soon as the feed check valve was opened up, Mr. Grant states, the feed checks could be heard thumping hard as the water went into the boiler. This indicated that the water level in the boiler was low, that the feed regulator was working and admitting more than the normal quantity into the boiler. Mr. Whyte had been down in the boiler room on two occasions that morning, and the water level in the forward boiler, according to his evidence, showed almost full glass in the starboard gauge, and three inches in the port gauge. This differs from Mr. Grant's statement, inasmuch as he did not see water in the port water gauge throughout the morning. Mr. Whyte also states that he had on several occasions looked at the water gauges from the alleyways through special sight glasses fitted in the casing sides for observing the water gauges without it being necessary to enter the boiler room. Mr. Whyte stated that the heights as given by him above occasionally varied owing to variations of list due to the movement of passengers on the decks above. He, Mr. Whyte, arrived in the boiler room in a few minutes after being called, and Mr. Grant told him that there was too much water in the forward boiler, to which Mr. Whyte replied that it was a good fault. Mr. Whyte states that as the starboard water gauge was full up with water, *i.e.*, that it could not be seen and no water could be definitely seen in the port gauge, he went up to the platform in front of the water drum so as to see the port gauge more distinctly. From this viewpoint he saw water just showing in the bottom of the glass of the port gauge, and in the starboard gauge the water was out of sight. From this time on, the evidence of Messrs. Grant and Nicholson differs from Mr. Whyte except in one important matter, viz., that when the drain of the starboard water gauge was eased, water fell and again rose in the glass, and that the same result was obtained after blowing through the steam and water ends. All are in agreement on this point. Mr. Grant states that Mr. Whyte told him to shut the feed check and Mr. Nicholson states that Mr. Whyte told him to slow down the boiler room feed pump. These orders were carried out and Mr. Whyte then told Mr. Nicholson to go to the engine room to assist in manœuvring the vessel into Loch Ranza. Mr. Whyte's statement is that he ordered the check valve to be shut within a minute or so before the explosion took place. The statement by Messrs. Grant and Nicholson is therefore to the effect that the feed check valve on the forward boiler was shut and the pump eased before arriving at Loch Ranza, while according to Mr. Whyte's statement the check valve was not shut until after the vessel left Loch Ranza.

The evidence of Mr. John Sangster, the Second Engineer, who holds a second-class certificate of competency, states that prior to the explosion he had received an order from Mr. Grant to ease the engine room pumps as the boilers were carrying too much water. Mr. Grant states that Mr. Whyte and he were both in the boiler room throughout the time the vessel was in Loch Ranza, that during this time nothing was visible in either water gauge and that the feed check valve remained shut. The vessel arrived at Loch Ranza at 11.25 a.m. and left at 11.30 a.m. for Pirnmill. There had been some blowing through of the gauges with the drain, and the steam and water ends had been tested at intervals after Mr. Whyte came down. The port gauge was now being tried and it was while this was being done that the explosion took place, the time being 11.35 a.m. The subsequent events have been described in the first part of this report.

No record of the times of arriving and leaving the various piers is kept by the engine room staff, and these have been obtained from the Master of the vessel, Captain Angus Keith.

There seems to be no doubt that instead of having a water level above the top of the starboard glass, there was actually no water in it at all, and Messrs. Whyte, Grant and Nicholson knew definitely that there was no water in the port glass. From the evidence it appears that the vessel had a permanent list to starboard which changed with the movements of passengers. If the water was carried at a high level in the starboard glass and there was a movement of the passengers to the starboard side, the water would quickly go higher in the starboard side of the water drum and lower in the port side. This would be indicated in the water gauges. If the list was sufficient the conditions might have been such that the starboard glass was full of water and the port glass empty. Such a condition would occur with a list of about five degrees, but the evidence regarding the inclination of the vessel at the time is not conclusive.

It has previously been stated that the feed supply tank in the engine room was fitted with a water gauge. Any accumulation of water in this tank would indicate that water was not being supplied to the boilers in sufficient quantity to maintain the water in the boilers at its normal level and this accumulation would be shown on the tank water gauge. The evidence showed that very little use had been made of this gauge to indicate how the boilers were being fed, the engineers relying entirely on the boiler water gauges. This apparent neglect was explained by considerable variation in the range of the tank water levels under service conditions. The periods of steaming between the various points of call were short and as it was necessary to keep pressure of steam high for manœuvring, the demand for feed water was irregular. Mr. Nicholson—who was in charge of the auxiliary machinery in the engine room on the morning of the explosion—stated that he did not observe any abnormal fluctuations in the feed tank gauge during the morning. As he was in the boiler room for a considerable period that morning, the accumulation of feed water in the tank would not be observed, but that it did take place would appear to be beyond doubt.

Throughout the morning the engineers kept the water in the after boiler under close observation. Mr. Whyte stated that just before the explosion took place the water in the after boiler was just showing in the bottom of the port glass and was high in the starboard glass. Mr. Grant stated that before arriving at Fairlie the gauges in both boilers were showing almost the same water level, viz., water showing in the starboard glass and practically none in the port glass. He also stated that on arrival at piers, sufficient water was pumped into the boilers to fill the starboard water gauges above the top nuts and that in about three minutes after leaving a pier the water in these gauges would show below the top nuts. After leaving Loch Ranza the water in the starboard water gauge of the after boiler came into sight but it did not do so in the starboard gauge of the forward boiler and this caused him to become uneasy about what he thought an excess of water in the forward boiler. Mr. Grant also stated that both water gauges on the forward boiler were in good working order and that he never had cause to be other than satisfied with the water gauges on either boiler.

The water gauges were taken off the boiler in the presence of Garnet E. Jenkins, and although there was a little sediment and spongy jointing material in the stand pipe and the drain of one of the glasses, all the passages of both were clear and water passed freely through when poured in from one end. The safety devices in both water gauges were also in satisfactory working order. It is difficult to understand how water could be seen in the starboard gauge unless it was an illusion of men who were extremely anxious, and whose minds were obsessed with the idea of the damage which might be done by water passing through the superheaters and into the turbines. All thoughts were directed to excess and not to shortage of water.

Their evidence shows that the feed check was half shut for a considerable period between Fairlie and Loch Ranza, and that for three minutes it was completely shut. It was again shut off before arriving at Loch Ranza and remained closed until the accident, a period which from the times of arrival and departure exceeded ten minutes. The evidence also showed that the feed pumps were slowed down for a period, the duration of which cannot be definitely ascertained. We have calculated that at full load the water in the drum would be reduced from the top to the bottom of the glass in $4\frac{1}{2}$ minutes and that a further 3 minutes would evaporate the remainder of the water in the drum. If the water was below the bottom of the glass originally, it would appear that there was very little water in the boiler at the time the explosion took place. Any water there was would be in violent ebullition, and would be forced off the tube surface next the fire. The heat transfer through the tubes would then cease and the tube become rapidly overheated to such an extent that it would bulge locally and subsequently rupture.

All the tubes in the boiler with the exception of the top return tubes are being renewed.

Observations of Mr. A. E. Laslett, Engineer Surveyor-in-Chief.

In cases of boiler explosions due to shortness of water it is often difficult to obtain a satisfactory and reliable account of the circumstances which preceded the explosion. In this case it was stated by witnesses that the appearance of a water gauge indicated excess of water; but the boiler was practically empty, and as the gauge was connected directly to the steam drum, it was impossible that water could have shown in the glass, particularly after it had been blown through. A sustained and completely satisfactory test of the steam end of the water gauge mentioned in this case was prevented by the action of safety devices. Such fittings are best omitted from the steam ends of water gauges, but there is no reason to suppose that the gauge was in any way defective and not in perfect working order.

Those in charge were experienced certificated engineers, and while it is difficult to understand how, from their observation of the starboard gauge the error was persisted in that there was an excess of water, it is even more difficult to account for their disregard of the port gauge, which was on the high side of the ship owing to the list to starboard. In marine boilers it is required that water gauges should be so placed that water shows in the glass at its *lowest* safe level. When, therefore, to meet variations of list it is required that two water gauges shall be fitted on opposite sides of the larger marine boilers it is obviously intended that water shall be shown in both glasses, thereby ensuring sufficient water above the entire heating surface, with the ship listed to any angle.

Had proper and intelligent use been made of the water gauges, the absence of water in the port glass would have been accepted as an indication of low water level and the explosion would have been avoided.

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BOARD OF TRADE EXAMINATIONS.

List of Candidates who are reported as having passed examination for certificates of competency as Sea-going Engineers under the provisions of the Merchant Shipping Acts.

For week ended 4th January, 1930:—

NAME.	GRADE.	PORT OF EXAMINATION
Paton, Robert C.	1.C.E.	Glasgow
Hide, Thomas A.	2.C.	,,
Lamont, John	2.C.	,,
McAuslan, Peter S.	2.C.	,,
Mowatt, John W.	2.C.	,,
Williamson, Robert C.	2.C.	,,
Cowie, Ian H. H.	1.C.	London
Halliday, Albert E.	1.C.	,,
McCarthy, John	2.C.	,,
Davidson, Frederick F.	2.C.	Belfast
Lunt, Alfred N.	2.C.	,,
Godfrey, Leslie H.	1.C.M.E.	Liverpool
Clayton, Alfred L.	1.C.	,,
McCullagh, James H.	1.C.	,,
Quayle, William	1.C.	,,
Stephenson, Walter	1.C.	,,
Ewens, Ernest	1.C.	North Shields
Trewhitt, Robert	1.C.M.E.	,,
Horn, Edward G.	2.C.M.E.	,,

For week ended 11th January, 1930:—

Horsburgh, William S.	1.C.M.E.	Glasgow
Matheson, Kenneth A. M.	2.C.	,,
Cressey, Fred	1.C.	Hull
Munro, Thomas E.	1.C.	,,
Skelton, George A.	1.C.	,,
Witty, George	2.C.	,,
Heath, Frederick C. M.	1.C.M.E.	,,
Feather, Leslie E.	1.C.M.E.	London
Findlay, Robert A	1.C.M.E.	,,
Stevenson, Harry	1.C.M.E.	,,
Helm, Alistair I.	1.C.	,,
Pemberton, Arthur G.	2.C.	,,
Wallis, William R.	2.C.	,,
Griffiths, William	1.C.	Liverpool
MacClements, Andrew	1.C.	,,
Turner, Wilfred	1.C.	North Shields
Wilson, Edmund P.	1.C.	,,
Beckwith, John A.	2.C.	,,
Elliott, Henry H.	2.C.	,,
Mackintosh, George Y.	2.C.M.	,,
Minto, Bertie	1.C.M.E.	Sunderland
Sandilands, Charles W.	2.C.	,,

For week ended 18th January, 1930:—

Grieve, Aubrey N	1.C.M.E.	London
Gidley, William H.	2.C.	,,
Walker, Cecil H.	2.C.	,,

For week ended 18th January, 1930—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Campbell, Duncan	1.C.	Glasgow
Miller, John	1.C.	,,
Morton, Hugh	1.C.	,,
Thomson, Archibald	2.C	,,
Simpson, Anderson M.	1.C.M.	,,
Anderson, Robert	1.C.	Leith
Gilray, Thomas M.	1.C.	,,
Scott, Stewart W.	1.C.	,,
Stevenson, Oliver S.	2.C.	,,
Tennant, Douglas	2.C.	,,
Wade, Charles C.	2.C.	,,
Jefferies, Frank H.	1.C.	Cardiff
Margetts, Ronald S.	1.C.	,,
Evans, David T. P. L.	2.C.	,,
Paulsen, Harry P.	2.C.	,,
Cain, Arthur R.	1.C.	Liverpool
Hagedorn, Cecil C.	1.C.	,,
Smith, Sydney	1.C.	,,
Watson, Eric	1.C.	,,
Farries, William	2.C.	,,
Kenna, Cecil J.	2.C.	,,
Lewis, William H.	2.C.	,,
Pritchard, Joseph	2.C.	,,
Roberts, Edward E.	2.C.	,,
Roberts, George E.	2.C.	,,
Glendinning, Augustus S. M....	1.C.M.E.	,,
Cavell, Herbert D.	1.C.	Southampton
Oxborrow, Charles R.	1.C.	,,
Robbie, Andrew W.	1.C.	,,
Coleman, Cyril R. S.	2.C.	,,
Smith, Joseph L.	1.C.	North Shields
Stephens, John C.	2.C.	,,
Bormond, Joseph	2.C.M.	,,
Wardhaugh, William	1.C.M.E.	,,

For week ended 25th January, 1930:—

Jasper, Alfred	1.C.M.E.	London
Meader, Henry J.	1.C.M.E.	,,
Stewart, Francis	1.C.	,,
Mason, James	2.C.	,,
Murray, Brian P.	2.C.	,,
Logie, Alexander C. W.	1.C.	Glasgow
Caldwell, Andrew M.	2.C.	,,
Caldwell, Thomas	2.C.	,,
Horne, George	2.C.	
Watt, Robert	2.C.	,,
McConochie, Kenneth	1.C.M.	,,
Milne, Robert C.	1.C.M.	,,
Cleator, Albert I.	1.C.	Liverpool
Gee, Richard N.	1.C.	,,
Gibson, John L.	1.C.	,,
Hurst, Norman L.	1.C.	,,
Lomas, John	1.C.	,,
McLellan. Thomas H.	1.C.	,,
Owen, Robert	1.C.	,,
Smith, Frederick E.	1.C.	,,
Wild, Norman E.	2.C.	,,
Levens, Austin C.	1.C.M.E.	,,
McKinnell, Thomas	2.C.M.E.	,,

For week ended 25th January, 1930—*continued*.

NAME.	GRADE.	PORT OF EXAMINATION.
Blachford, John	1.C.M.E.	North Shields
Burton, Harry	1.C.M.E.	,,
Heslap, Philip	1.C.	,,
Hibbs, Joseph	1.C.	,,
Shilling, Stanley S.	1.C.	,,
Smith, James H.	1.C.	,,
Craney, Edward	2.C.	,,
Newlands, Victor R.	2.C.	,,
Bittlestone, John S.	1.C.	Sunderland
Ridley, Edward A.	1.C.	,,
Vallack, Henry W.	1.C.	,,
Brown, John J.	2.C.	,,
Evans, Edwin	2.C.	,,
Macdonald, William K.	2.C.	,,
Scott, Horace J.	2.C.	,,
Brydon, Harold	2.C.M.	,,

For week ended 1st February, 1930:—

McCullagh, John	1.C.M.E.	Belfast
McCammon, William J.	1.C.M.E	,,
Walker, Allan F.	1.C.	,,
Fairweather, Robert S.	2.C.	Glasgow
Johnstone, William T.	2.C.	,,
Bithell, Alfred	1.C.	Liverpool
Bolton, Thomas W.	1.C.	,,
Francis, John	1.C.	,,
Tooley, George F.	1.C.	,,
Jones, Cyril	2.C.	,,
Loader, Edward J.	2.C.	,,
Sutton, Sydney A.	2.C.	,,
Cooper, William F. B.	1.C.M.E.	,,
Lazarus, Thomas J.	1.C.M.E.	,,
Wynn, George W. C.	1.C.M.E.	,,
Gillespie, Alexander W.	1.C.M.E.	Southampton
Lockhart, William	1.C.M.E.	,,
MacDonald, David	1.C.M.E.	,,
McMath, James K.	1.C.M.E.	,,
Paul, Victor N.	2.C.	,,
Birss, Andrew L.	1.C.	Leith
Bremner, John F.	1.C.	,,
Duncan, William	1.C.	,,
Craib, Gilbert S.	2.C.	,,
Paterson, Peter M.	2.C.	,,
Stewart, John H.	2.C.	,,
Chalmers, James C.	2.C.M.	,,
Valentine, David W.	2.C.M.	,,
Rome, Robert	1.C.	North Shields
Miller, John G.	2.C.	,,
Williamson, Harold G.	2.C.	,,
Morris, Thomas H.	1.C.	Cardiff
Robins, Reginald G. C.	1.C.	,,
Black, John J.	2.C	,,
Carney, Leonard C.	2.C.	,,
Rogers, Richard E.	2.C.	,,
Whitefield, Arthur W.	2.C.	,,
Sincock, Leonard F.	1.C.M.	,,
Margetts, Ronald S.	1.C.M.E.	,,
Barr, John	1.C.M.E.	London
Crouch, Reginald C.	1.C.M.E.	,,

For week ended 1st February, 1930—*continued.*

NAME.	GRADE.	PORT OF EXAMINATION.
Verano, Frederick E.	1.C.M.E.	London
Boase, Eric J. J.	1.C.	,,
Harris, Henry C.	1.C.	,,
Nevill, John H.	1.C.	,,
Chenery, Frederick J.	2.C.	,,
Hayward, Albert D.	2.C.	,,
Yates, Alfred F.	2.C.	,,

For week ended 8th February, 1930 :—

Avenell, John P.	1.C.M.E.	London
Kerr, John	1.C.M.E.	,,
Moss, John A.	1.C.M.E.	,,
Fender, Edward	1.C.	,,
Tamblyn, Leslie R.	1.C.	,,
Combes, Rex W.	2.C.	,,
Miller, Frank W.	2.C.M.	,,
Petch, Kenneth C.	2.C.M.	,,
Bowman, James	1.C.M.E	Glasgow
McFarlane, William J. C. ...	1.C.M.E	,,
Richardson, Norman A. ...	1.C.M.E.	,,
Povey, William G.	1.C.	,,
Brown, James F.	1.C.	,,
Bruce, Alec D.	1.C.	,,
Low, David W.	1.C.	,,
Strang, James W.	1.C.	,,
Young, Robert H.	1.C.	,,
Griffiths, Edward C.	2.C.M.	,,
Helm, Francis	1.C.	Hull
Jackson, Henry E.	1.C.	,,
Cooper, David W.	2.C.	,,
Hill, Charles	2.C.	,,
Smith, Harold	2.C.	,,
Chrystie, John J.	1.C.	Liverpool
Clark, James W.	1.C.	,,
Plimmer, John J.	1.C.	,,
Barnes, Gilbert	2.C.	,,
Duffus, Stewart	2.C.	,,
Wannop, Edward	2.C.	,,
Fuller, Walter	1.C.M.	,,
Holdsworth, John R.	1.C.M.	,,
Downham, Albert	2.C.M.	,,
Evans, Arthur M.	1.C.M.E	,,
Moore, William H.	1.C.M.E	North Shields
Stoker, Oswald	1.C	,,
Williamson, Arnold	1.C.	,,
Cessford, Charles D.	2.C.	,,
Kinelato, Andrew T.	2.C.	,,
Ledward, John T.	2.C.	,,
Terry, Robert	2.C.	,,
Atkinson, William C.	2.C	Sunderland
Braunton, Harold	2.C.	,,
Ferdinands, Norman D. V. ...	2.C.	,,
Parker, John B.	2.C.	,,
Robinson, Walter N.	2.C.M.	,,
Ross, William	2.C.M.	,,
Askew, William H.	1.C.	,,
Rourke, Leslie B.	Ex.1.C.	Liverpool
Scarisbrick, Charles W.	Ex.1.C.	,,

INSTITUTE NOTES.

CORRESPONDENCE :—The latest "Bolnes" Engine.

54, NEW BROAD STREET,
LONDON, E.C.2.
24th January, 1930.

The Secretary,
The Institute of Marine Engineers,
85-88, Minories, London, E.C.3.

DEAR SIR,

Our attention has been drawn to a statement made in a paper read at your Institute and published in your booklet for January, 1930, that the latest "Bolnes" engines are totally enclosed.

We beg to advise you that this is not the case. The latest "Bolnes" engine is open-fronted, in the same manner as the well known "Bolnes" semi-Diesel.

Yours faithfully,

(Arthur R. Brown, Ltd.)

H. E. FLETCHER, Director.

JUNIOR SECTION.

Since the inauguration of the series of monthly meetings for the Junior Members, the following events have to be recorded. The Committee are grateful for the willing assistance which is being rendered by Members of Council and others in making these meetings really successful, and thereby infusing new interest and ambition amongst not only the present Student Graduates and Graduates, but many of their apprentice and student friends whom it is desired to attract to our Membership.

On Thursday, December 12th, 1929, an Informal Address was given by Mr. J. R. Douglas, Superintendent Engineer, Blue Star Line (Member) on "What is expected of a Junior Engineer on joining his first ship." Mr. S. N. Kent, Superintendent Engineer, Prince Line Ltd. (Member of Council), occupied the chair. This inaugural meeting was attended by over sixty junior members and friends, who accorded the Lecturer and the Chairman a hearty vote of thanks for the interesting and valuable information and advice which they imparted to the audience.

The next meeting on Thursday, January 9th, 1930, was devoted to a Film Display, featuring " The Birth of a Liner," by courtesy of Canadian Pacific Steamships, Ltd., followed by " Gear Cutting," by courtesy of the Gear Grinding Co., Ltd. Mr. E. F. Spanner, R.C.N.C. (ret.), M.I.N.A. (Member) presided as Chairman on this occasion, and the Lecture Hall was filled to its capacity by an appreciative audience, which included both Junior and Senior Members and their friends.

On Thursday, February 13th, an Informal Address was given by Mr. S. N. Kent, Superintendent Engineer, Prince Line Ltd. (Member of Council), on " Discipline as applied to the Engine Room, etc." Mr. J. R. Douglas, Superintendent Engineer, Blue Star Line (Member) was in the Chair. The attendance was considerably less on this occasion; nevertheless the audience evinced keen interest in and appreciation of the lecturer's homily and the Chairman's additional remarks. At the close the Chairman kindly offered two prizes of one guinea each for the best sketch and the best report respectively of a repair to a winch or other auxiliary engine, the competition to be open to junior members up to March 13th.

BOOKS ADDED TO THE LIBRARY.

Purchased:—

" Fires in Steamship Bunker and Cargo Coal." Special Report No. 5. Published by the Department of Scientific and Industrial Research, under the authority of H.M. Stationery Office. Price 2/- net.

" Testing of Lifeboats' Lifting Hooks." Instruction to Board of Trade Surveyors. Published by H.M. Stationery Office. Price 1d.

Presented by the Publishers:—

" Schools, 1929." Published by Truman and Knightly, Ltd., 61, Conduit Street, London, W.1. 7½in. x 5½in. x 1⅝in. 766 pp. and map.

This publication purports to be the most comprehensive guide obtainable to the scholastic facilities of Great Britain, and parents or guardians will find it a most useful aid in the choice of a school. A valuable feature is the section devoted exclusively to schools offering special facilities for vocational training, while an article on " Choosing a School " mentions the facilities offered by the Publishers for obtaining expert advice on this important subject.

Presented by the Publisher:—

" The Motor Ship Reference Book for 1930." London, Temple Press, Ltd., 5-15, Rosebery Avenue, E.C.1. 8½in. x 5½in. x 1in. 278 pp. Price 5s. net.

This excellent annual publication maintains its high standard in the 1930 edition. It is five years ago since " The Motor Ship Reference Book " was first published. At that date there was scarcely two million tons of motorship tonnage in service, but this figure has risen to over seven million gross tons at the present time. It will be appreciated, therefore, that there is ample justification for a volume such as the one under review.

After some elementary considerations relating to the cycle of operations in oil engines, etc., the book goes on to give brief descriptions of some of the best known types of marine Diesel engine. Perhaps the two most useful sections of the work are those which give the principal Diesel fuel bunkering stations throughout the World, and the list of motorships in service. The latter feature is distinctly comprehensive, giving all vessels of over 2,000 gross tons that have been completed since the end of 1924. Motorships on order at the time the book went to press are also tabulated. Some useful comments on motorship developments in 1929 are given towards the end of the book, which is undoubtedly excellent value for the modest price asked.

" On the Bottom," by Commander Edward Ellsberg, U.S.A. Pp. 306. 8in. x 6in. Profusely illustrated. Published by Constable and Co., Ltd., London. Price 10/- net.

At first sight one might think " On the Bottom " was romance or fiction—it is more than either. Commander Ellsberg's account of the salving of the *S* 51 is an epic. Unfortunately rammed by the *City of Rome*, the *S* 51 plunged to the bottom to a depth of 135ft., 100 miles from land in unprotected waters. He tells us how throughout the weary months of their struggles and disappointments in their heroic endeavours to make air-tight a vessel of many compartments, already a coffin for 18 unfortunate men and officers, of their daily contact with the dead and the eventual sudden lifting of the *S* 51 during the height of a gale and subsequent foundering.

One is enthralled in reading of Divers Smith, Kelly, Edie and Frazer tunnelling underneath the vessel through many feet of sand and clay. Commander Ellsberg has certainly given the reading public a splendid description of that wonderful class of men, the deep sea divers.

ELECTION OF MEMBERS.

List of those elected at Council meeting held on Monday, 3rd February, 1930:—

Members.

Edward Geoffrey Berry, 14, Shenfield Road, Woodford Green, Essex.
George William Brown, 24, Stockton Terrace, Grangetown, Sunderland.
William Edward Burns, 46, Hart Street, Ulverston, Lancs.
Alexander Duncan Edmund, Robert Gordon's College, Aberdeen.
Charles Hedley Haller, Selwood, Venn Grove, Plymouth, Devon.
John Hudson, 187, Eightieth Street, Brooklyn, N.Y., U.S.A.
Thomas Armstrong MacGregor, *c/o* Donachie, Drimhill, Broomberry Drive, Gourock.
Ronald Arthur Sandison, Denbank, Cults, Aberdeen.
Albert Wall, Penrhos, Holyhead, Anglesea.
George Herbert Williams, Cambria, 44, Southern Way, London Road, Romford, Essex.
James Winterbottom, 44, Southern Way, London Road, Romford.

Associate-Members.

Hedley Albert Amos, 31, Hamilton Road, Southville, Bristol.
George Robertson Gray, Old Prospect Road, Wentworthville, N.S.W.
John Livingstone Roxburgh, Wren Cottage, Manor Gardens, Brighton Road, Purley, Surrey.
George Copland Morris Simmons, Rutherford Manse, Onslow Drive, Dennistoun, Glasgow.

Graduates.

Spencer Oliver Grant, Broome Lodge, Staines, Middlesex.
Edwin Charles Plastow, 89, Convamore Road, Grimsby, Lincs.

Transferred from Associate Member to Member.

Frederick Arthur Rogers, 5, Watson Place, St. Jude's, Plymouth.

Transferred from Associate to Member.

Ian H. Cowie, 35, Ulundi Road, Blackheath, S.E.3.

Transferred from Graduate to Member.

William Redvers George, 10, Harbour Road, Barry, South Wales.
Cyril Walter Jones, 96, Peacock Street, Gravesend, Kent.