INSTITUTE OF MARINE ENGINEERS

INCORPORATED

SESSION 1913-1914

President: THOMAS L. DEVITT, ESQ.

PAPER OF TRANSACTIONS NO. CCI

Recent Experiences of Babcock & Wilcox Boilers for Marine Purposes.

BY MR. JAMES H. ROSENTHAL (MEMBER).

READ

Monday, March 3, 1913.

CHAIRMAN: MR. J. T. MILTON (CHAIRMAN OF COUNCIL).

As the title of this paper denotes, the writer does not propose to deal at any length with the earlier history of the application of the water-tube boiler to marine purposes.

Apart from these very early installations, the introduction of the water-tube boiler for vessels of any size originated in France, where the Belleville boiler was installed about 1889 in certain ocean-going vessels of the Messageries Maritime Co. running between Marseilles and Australia, and also between Marseilles and Algiers. This boiler had already been tentatively adopted in the French Navy for a few cruisers, and the British Admiralty, after a thorough investigation of it in the French Merchant Service, eventually decided to instal it on a relatively large scale about 1893. Other water-tube boilers were coming into use about this period, among them the Babcock & Wilcox type, which, although previously widely adopted for land purposes, was then being adopted on small cargo vessels and tramp steamers. It is proposed to deal in this paper with the development of this type of boiler.

In the early installations of the Babcock and Wilcox boiler, troubles were encountered, but much valuable experience regarding design and operation was gained from them, and this materially assisted in eradicating defects and leading to the present-day successful use of the boiler in the mercantile marine.

The troubles referred to were only to a small extent due to questions of construction, and practically the only real defect in design was the lack of combustion space in the furnace. The troubles mainly arose from salt water leaking into the feed water, through the condensers on some of the ships being unsatisfactory, from the steam production for which the boilers were designed being assumed to be less than was really required, and from lack of suitable attention.

Constant improvements in material, especially in the quality of tubes obtainable, and design of details, coupled with improved proportions of furnace and in the heating surface for the work to be done, together with the increased knowledge, resulting in a large measure from the earlier experiences, have been the elements upon which the present-day success has been based. It should here be stated that the researches of the Admiralty have been of inestimable value as contributory to this result.

Some trouble was experienced with the Belleville boiler in the ships of the Navy, and this led, in 1900, to the appointment of a Special Boiler Committee, composed of members of the Admiralty and several of the leading marine engineers of the country, to investigate the various types of water-tube boilers which were then brought forward. The public records of this Committee bear evidence of the minute care and methodical thoroughness with which their investigations were pursued, to say nothing of the personal sacrifices in time and convenience which the members of the Committee devoted to the subject.

The result of the Committee's Report was that the notion which prevailed in certain quarters at the time, to the effect that only the Scotch boiler was reliable for arduous service, was shown to be entirely without foundation, and the conclusion, stated briefly, was that a modified Yarrow boiler with large tubes and the Babcock & Wilcox boiler were pronounced to be quite suitable for use in the future on large vessels of the Royal Navy.

The first vessel fitted in the Navy with Babcock & Wilcox boilers was H.M.S. *Sheldrake*, which, after extensive trials, was used as an instruction ship for stokers. This vessel has been since broken up.

The next vessel fitted with Babcock & Wilcox boilers for trial was H.M.S. *Hermes*, in which the orginal Belleville boilers were replaced by Babcock & Wilcox boilers, and on this vessel, trials, interesting from the mercantile marine point of view as well as from the Naval point of view, were carried out by the Boiler Committee in comparison with the R.M.S. *Saxonia* of the Cunard Company, a vessel fitted with cylindrical boilers of ample size and with Howden's forced draught. These trials were probably the most complete comparative trials of the kind that were ever carried out, and, although published in the records of the Boiler Committee, it will perhaps be considered of interest to have a summary of the results embodied in this paper.

In the following table are given the comparative evaporative efficiences.

	Saxonia.	*Hermes.*
Transmission of heat units per sq. ft. of heating surface	5,416	6,985
Lb. of coal per sq. ft. of grate	20·6	20
Temperature of feed water	178°	88°
Pressure of steam	199	227
Percentage of moisture in steam	Not taken	·09
Actual evaporation per lb. of coal	11·3	10·25
Equivalent evaporation per lb. of coal from and at 212°	12·33	12·17
Thermal efficiency	82·3	81
Actual evaporation per sq. ft. of heating surface	5·14	6·2
Equivalent evaporation per sq. ft. of heating surface from and at 212° F.	5·6	7·3
Temperature of funnel gases	396°	481°

When allowance is made for the fact that Howden's Heated Air System was used in the *Saxonia*, that her trial only extended for thirteen hours against the thirty hours of H.M.S. *Hermes*, involving, of course, in the latter case more loss through cleaning of fires, and that exhaust steam feed heaters were also fitted in the *Saxonia* but not in the *Hermes*, it will be judged that the boilers of the *Hermes* were really the more efficient.

Since that time the Babcock & Wilcox boiler has been very extensively adopted for large Naval vessels. In the Royal Navy alone it is installed to the extent of over a million horse power, this figure including the boilers of H.M.S. *Tiger*, which are in the aggregate of the largest power ever put into any vessel. In the United States, where the Babcock boiler is virtually the standard boiler for all large ships, it is also employed to about the same amount. The Italian Navy has adopted it in three battleships, and it is also fitted in the large super-Dreadnoughts built and building for Argentina, Austria, Brazil and Turkey. Such a development is in itself an assurance that the boiler has given ample proofs of reliability and efficiency.

The extent of the use of this boiler in the mercantile marine, up to June, 1912, is shown in the following summary :—

TABLE I.

	Ships.	No. of Boilers.	I.H.P.
Ocean cargo and passenger service	82	209	183,879
Canadian Lakes cargo service	43	86	80,000
Ocean and river dredgers	34	79	41,186
Harbour and river passenger service	62	116	78,781
Steam tugs	29	43	23,928
Yachts	8	9	3,705
Totals	258	542	411,479

Of the above, some of the principal vessels deserve mention as reflecting more especially the various advantages obtainable from the use of Babcock & Wilcox boilers. For the fast Cross-Channel Steamers, where the power is high, and consequently the weight of cylindrical boilers very considerable in relation to the displacement, the large saving in weight and other advantages that accrue from the adoption of Babcock & Wilcox boilers have resulted in a majority of the recent high-speed boats of this type being fitted with these boilers.

In this class, there are the South Eastern & Chatham Railway Co.'s Mail Steamers *Riviera* and *Engadine* of 10,000 H.P.

each, built by Messrs. Denny, of Dumbarton ; The London & North-Western Railway's *Greenore* of 7,500 H.P., and the Stranraer and Larne Cross-Channel Steamer *Princess Victoria* of 7,000 H.P. (in Fig.1 is shown the arrangement of boilers in this vessel) ; and two mail steamers of 11,000 H.P. each, being built by Société Anonyme John Cockerill for the Belgian State Railways ; a vessel of 3,300 H.P. belonging to the United Steamship Co. of Copenhagen, for the Harwich-Esbjerg passenger service, the boilers being fitted with superheaters.

The saving in fuel for raising steam and the rapidity with which it can be done are also qualities highly prized in these services.

Among the notable mail and passenger steamers are the *Wahine* of the Union S.S. Co. of New Zealand of 10,000 H.P., now being completed by Messrs. Denny, the s.s *Creole* of the Southern Pacific Co. of 7,500 H.P., and three vessels of the Adelaide Steamship Co. of 6,500 H.P. each. These latter bring the number of Babcock boilered vessels in this Company up to eight, the first having been in service since 1905. These vessels use inferior Australian coal, for which the large grate and combustion chamber of Babcock boilers is found to be of great advantage. The *Warilda* and *Wandilla* both made non-stop voyages to Australia last year, the former from Glasgow to Adelaide and the latter from Plymouth to Fremantle ; the sister ship *Willochra* is now on the voyage out.

The other vessels given in the foregoing list include several types of ship—from Thames tug boats to Japanese dredgers ; from large steam yachts to American Lake ore steamers, from Egyptian river steamers to ocean-going cargo and passenger vessels.

Experience has shown that the essentials requiring consideration to ensure the successful use of water-tube boilers in the merchant service are, in addition to reasonably good management,

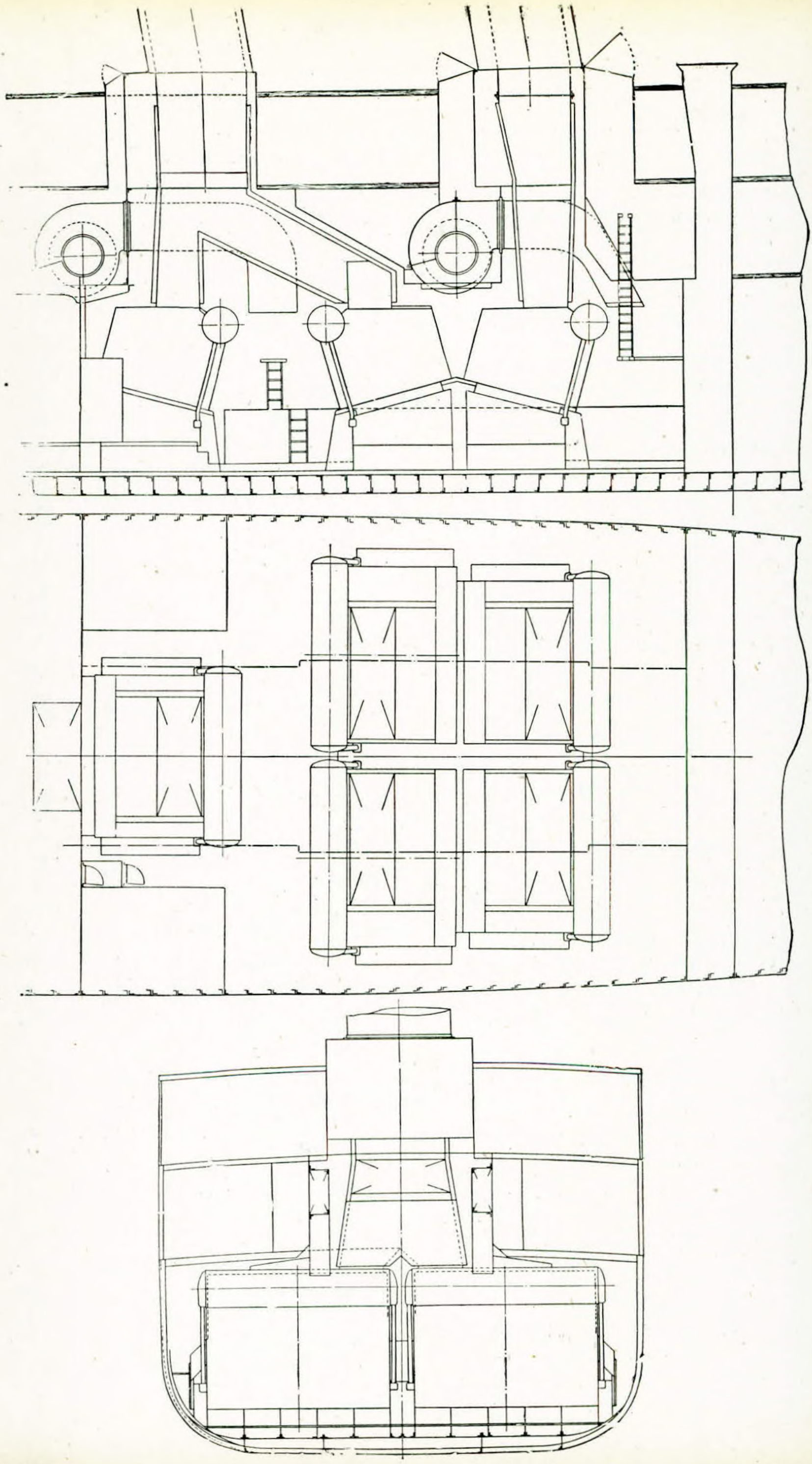
(1.) Well constructed and tight condensers.

(2.) The use of as little oil as possible in the engine cylinders and proper means of filtering the feed water.

(3.) Evaporators of adequate size, or other means of ensuring fresh water for feeding the boilers.

(4.) Regular examination of the water in the boilers, preferably by means of the chemical testing apparatus exhibited ; and

(5.) A careful and interested engineer.



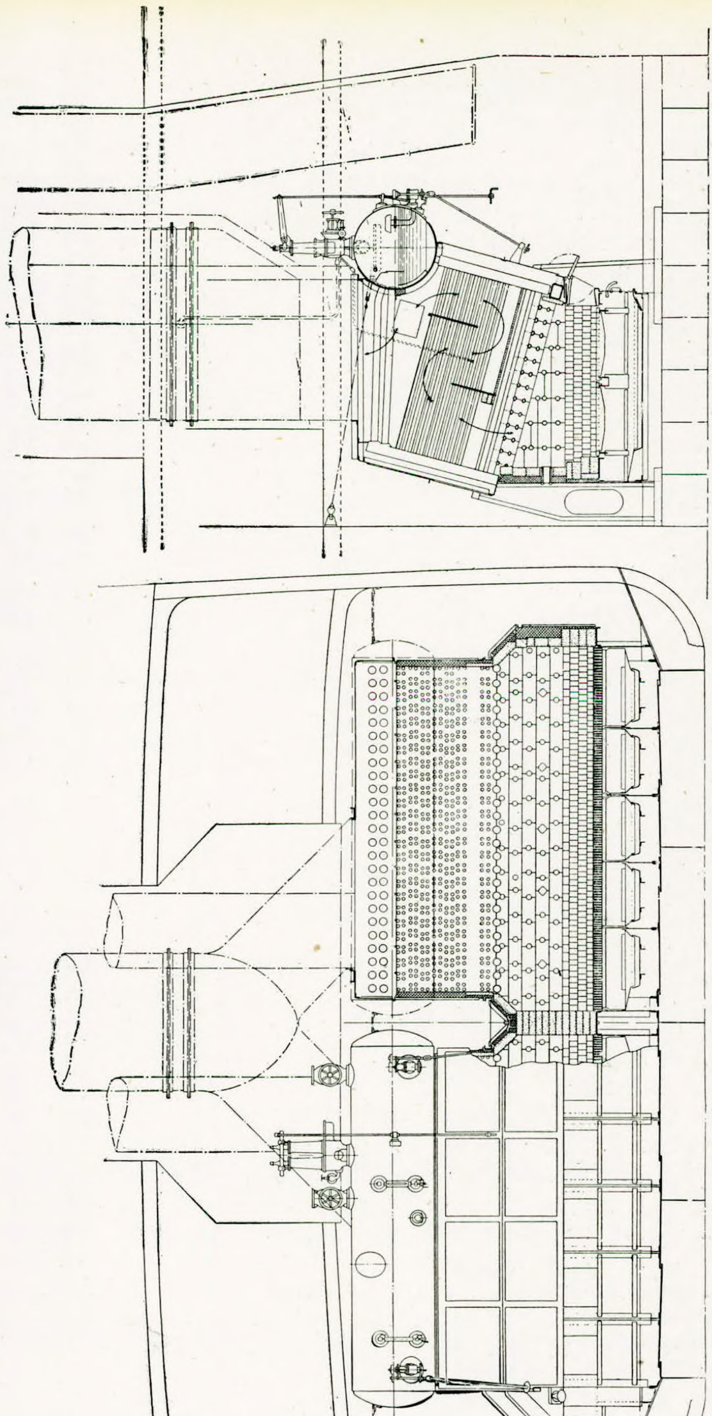


FIG. 2.

These conditions are regularly attained at the present time in all well engineered vessels, and in those cases in which they are not, it is safe to say that considerable improvement would be effected if they were observed.

Figure 2 illustrates the standard type of boiler as now used in the Navy and in the mercantile marine. As will be observed, the boiler consists of the steam and water drum, the sections of tubes, and the muddrum, which are all inter-connected by expanded tubes. Opposite each large tube in the bottom row, at both ends, and opposite each end of each group of four smaller tubes an internal handhole fitting, or door, is provided; these fittings have milled joints and a thin asbestos wire-woven gasket is used. There are no screwed joints in the boiler, tubes and headers are seamless, and all parts are of forged steel of the best quality. The sectionalization of the tube nest provides for ample elasticity, so that strains of expansion and contraction resulting from quick lighting up or forcing are not detrimental.

The furnace arrangement, providing ample space, is well adapted for any fuel, notably also for oil firing alone or in conjunction with coal. A large number of Naval vessels are fitted for the use of coal and oil simultaneously and in some of them the furnaces are fitted for oil only.

A design with furnace suitable for coal fuel on the outward voyage, capable of being rapidly converted into a furnace suitable for burning oil on the return voyage, has also been arranged for the special needs of large oil-tank steamers.

All boilers are encased by a sectionalized steel casing lined with a non-conducting and fire refractory material, in respect of which it may be said that years of experience have proved its excellent qualities and durability.

The furnace is lined with ordinary firebrick, or where the necessity exists for saving weight to the utmost extent, an arrangement of bolted-up fire tiles is provided.

The boiler has the usual fittings, and where a number of boilers are used on a vessel the Automatic Feed Regulator shown on Fig. 3; this has proved during ten years of experience a most efficient regulator; there are over 1,000 of them in use, and any failure in the apparatus performing the function for which it is intended, has yet to be recorded.

By the kindness of the South Eastern & Chatham Railway

Co., a comparison of the economy of the Cross-Channel Steamers *Riviera* and *Engadine* fitted with Babcock & Wilcox boilers and the *Victoria* fitted with cylindrical boilers is given. The *Riviera* and *Engadine* are slightly larger than *Victoria*, but the vessels are otherwise sister ships. The following table shows that, taking all points into consideration, the *Riviera* and *Engadine* attain a higher economy than the *Victoria*.

	No. of Double Trips.	Speed.	Coal per Trip.
Victoria, cylindrical boilers . . .	79	21·272	24·59 tons
Riviera, Babcock & Wilcox boilers .	111	21·868	24·58 ,,
Engadine, Babcock & Wilcox boilers	94	22·367	24·77 ,,

It is also found that on the Stranraer and Larne Service there is considerable economy in fuel in favour of the *Princess Victoria* over the *Princess Maud*, a sister ship of the same power, but fitted with cylindrical boilers.

Another notable instance of the superior economy of the water-tube boiler is found in the case of the s.s. *Creole*, of the Southern Pacific Railway Co. fitted with Babcock & Wilcox boilers, as compared with her sister vessels, the *Momus* and *Antilles*, fitted with cylindrical boilers. These vessels are engaged on the passenger service between New York and New Orleans, a run of about five days, and the average consumption over a recent series of voyages was as follows :—

	Creole.	*Momus.*	*Antilles.*
Tons per round voyage . . .	1,149 . .	1,412 . .	1,336

The vessels are 407 feet long by 53 feet beam, and are of about 8,000 tons displacement.

It will be noted that these results do not refer to the often quoted measurement of "Coal per I.H.P." Experience shows that this figure is often misleading, due largely to its being based on a totally inaccurate idea of what the average horse power at sea really is. Figures as low as 1·1 or 1·2 lb. of coal per I.H.P. are sometimes quoted as being obtained in daily service on long distance runs. That such results are hardly possible, or, if so, only in most exceptional cases, can easily be proved. In Fig. 4 is shown the number of pounds of water that a pound of coal of given calorific value will evaporate

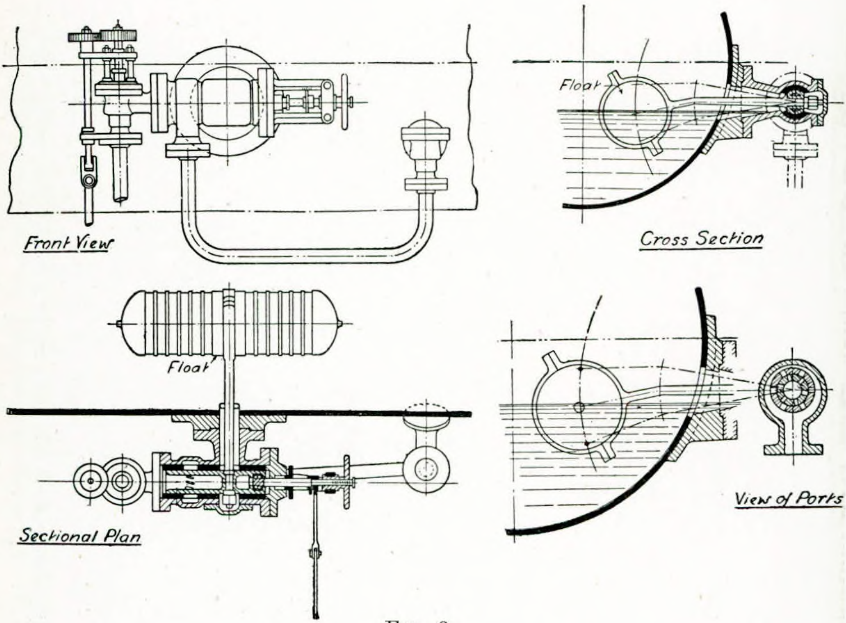


FIG. 3.

BABCOCK & WILCOX AUTOMATIC FEED-WATER REGULATOR.

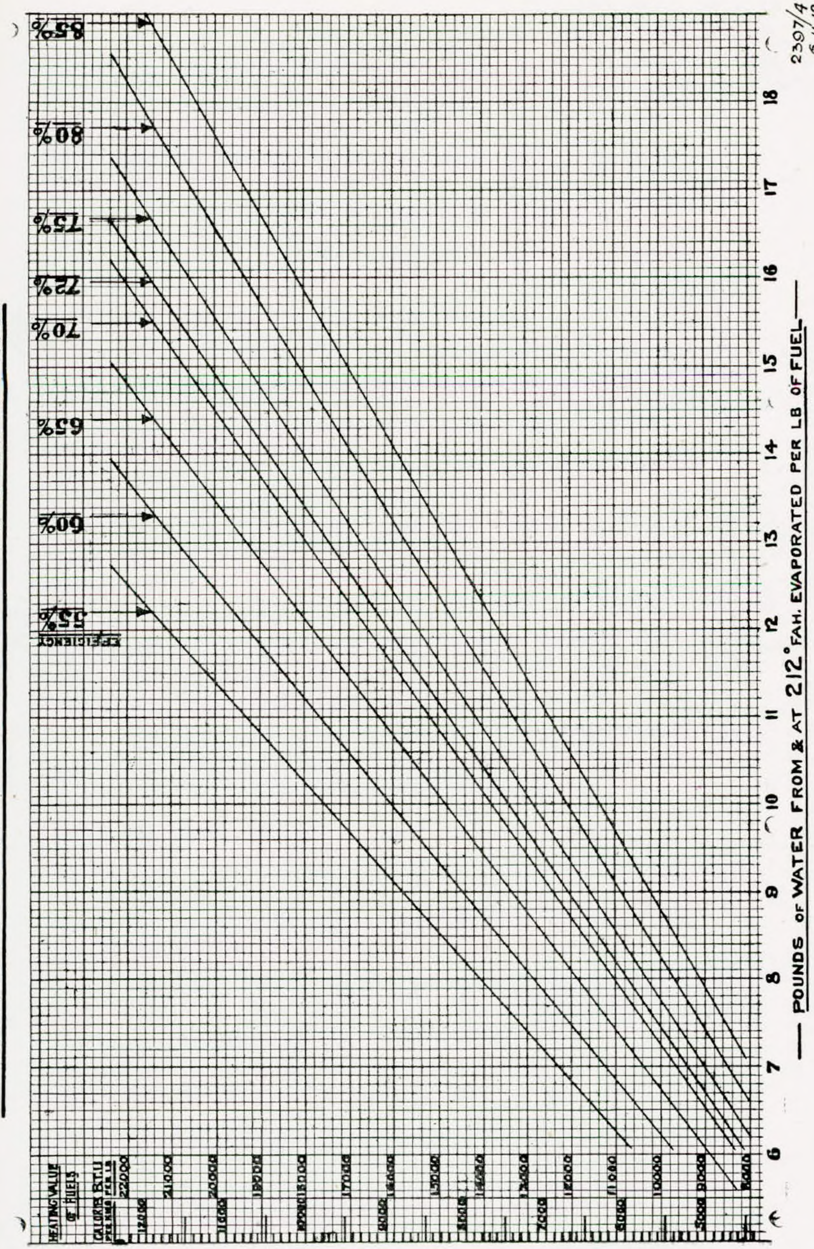

HEATING VALUE OF FUELS
CALORIES PER KILO
B.T.U PER LB
EFFICIENCY
55%
60%
65%
70%
72%
75%
80%
85%
POUNDS OF WATER FROM & AT 212° FAH. EVAPORATED PER LB OF FUEL

FIG. 4.

from and at 212° with a given boiler efficiency. Even taking coal of as high a value as 14,500 British thermal units and a boiler efficiency of 80 per cent., it is only possible to obtain 12 lb. of water per pound of such fuel from and at 212° Fahr., or 11·2 lb. at the actual working conditions of 200 lb. steam pressure and 200° feed. The figure of 1·1 lb. of coal per I.H.P. corresponds to a water consumption of 12·3 lb. per I.H.P, which very few, if any, triple expansion engines can attain, even in association with low pressure turbines and very high vacua. The average quadruple engine requires about 13·5 to 14·0 lb. actual per I.H.P. thus requiring an average of about 1·23 lb. of coal per I.H.P. for the main engines only.

The steam used for Auxiliary machinery in a ship like the *Lusitania* amounts to about 15 per cent. of that used in the main engines, and even in a tramp steamer to over 5 per cent; a fair average of 10 per cent. brings the total steam for all purposes per I.H.P. of main engines to 15·1 lb. or equal to about 1·35 lb. of coal per I.H.P. per hour as a minimum, even with abnormally high thermal efficiencies for both engines and boilers, with 200 lb. steam pressure, and feed water heated to 200°. It should be realized that an average boiler of 70 per cent. efficiency fired with ordinary coal of say 13,400 B.T.U.'s per pound will only evaporate 9·7 lb. from and at 212°. The feed temperature may only be 150°, bringing the actual evaporation at 200 lb. pressure per pound of coal to 8·66 lb. of water. It is a good triple expansion installation that requires less than 15·5 lb. per I.H.P. for all purposes, and under these circumstances this entails a consumption of 1·79 lb. of coal per I.H.P. It has been thought necessary to emphasize this, as boiler efficiency in terms of coal per I.H.P. is often quoted without definition of the engine efficiency. A very low figure for pounds of coal per I.H.P. frequently means that the I.H.P. has been exaggerated, and this can generally be deduced from the diagram Fig. 4.

As far as recent experience is concerned, evaporative trials are rarely carried out on board ship in the mercantile marine, but in the British Navy on the official steam trials the water consumption per I.H.P. or per shaft horse-power is ascertained in a large number of cases, and the results show that the thermal efficiency of the boilers is about 75 to 80 per cent. In the case of H.M.S. *Dreadnought* the results of the trials were published, and the main figures are given in Table II.

The efficiencies as determined by the Boiler Committee after some very careful and thorough experiments show comparisons between the thermal efficiencies of the Babcock & Wilcox and cylindrical boilers then tested, and are given in Table III.

TABLE II.

TRIALS H.M.S. "DREADNOUGHT."

Trial	15 hours $\frac{1}{5}$ full power	30 hours $\frac{7}{10}$ full power	8 hours full power
Steam pressure, lb.	220	232	241
Air pressure	·5″	0·9″	1·2″
Shaft horse power	5,087	16,930	24,712
Coal per S.H.P.	2·42	1·7	1·51
Water actually evaporated per lb. of coal	10·28	10·01	10·3
Water per horse power per hour— Main engines / Auxiliary engines	25·1	17·01	14·41 / 1·15 — 15·56

TABLE III.

Vessel.	Boiler.	Lb. of Coal per sq. ft. of Grate. 14.	18.	20.	27.	29.
H.M.S. *Hermes*	B. & W.	—	—	81	77·8	—
H.M.S. *Minerva*	Cylindrical	69·7	—	—	—	68·4
R.M.S. *Saxonia*	Cylindrical	—	—	82·3	—	—

In view of the fact that oil burning is at the present time so much to the front, a synopsis of evaporative tests carried out by a Board of United States Naval Officers on one of the Babcock & Wilcox boilers of the U.S. battleship *Wyoming* will be of interest. This boiler has a heating surface of 2,571 square feet with a combustion chamber of 217 cubic feet. It was fitted with eleven burners of the Babcock & Wilcox type, the principle of which is to atomize the oil by centrifugal action. Six tests in all were carried out with results as follows :—

TABLE IV.

Number of test	1	2	3	4	5	6
Duration, hours	4	3	3	3	3	2
Kind of oil used			Texas	Crude	Oil	
Number of burners used	3	4	8	8	8	11
Steam pressure, lb.	212	210·7	210·4	214·8	214·8	209·9
Oil pressure, lb.	131·3	175·6	188·8	153·2	171·8	191·1
Air pressure in inches	·72	1·64	2·1	2·58	2·79	4·83
Temperature of oil, ° F.	210·1	184·0	183·4	199·0	195·7	175·3
Temperature of feed water ° F.	211·2	201·0	160·9	185·6	182·8	168·6
Temperature of funnel gases, ° F.	447	533	666	702	630	771
Oil used per hour, lb.	666	1,202	1,704	1,922	1,947	2,972
Water evaporated per hour from and at 212°, lb.	10,569	18,895	24,494	27,149	30,064	40,712
Equivalent evaporation per sq. ft. H.S. from and at 212°, lb.	4·11	7·35	9·53	10·56	11·69	15·83
Equivalent evaporation per lb. of oil from and at 212°, lb.	15·86	15·72	14·37	14·12	15·44	13·70

In conclusion, the question will be asked what are the advantages obtainable with the Babcock & Wilcox boiler over the well-tried cylindrical type, and why is it not more rapidly displacing the latter?

The advantages may be summarised as follows:—

(1) It is somewhat more efficient in fuel, and much less fuel is required for lighting up.

(2) Steam can be raised quickly.

(3) It is not subject to detrimental strains due to forcing or to being rapidly lighted up.

(4) It is safe from any devastating explosion.

(5) Any repairs which might be required could be rapidly carried out by the ship's staff.

(6) It is more suitable for the higher pressures and more readily adaptable to oil firing and superheating.

(7) In the same ship's space much more grate surface can be obtained, avoiding the necessity for high forced draught.

(8) It effects a large saving in weight, and

(9) In large installations considerable space is saved.

The Babcock & Wilcox boiler is rectangular in shape, and as the spaces between the bulkheads available for boilers are usually rectangular, it is obvious that this shape more efficiently covers the floor space available for grate area, whilst the shape lends itself to the installation of considerably more heating surface than is possible in the same overall dimensions with a cylindrical boiler.

The table on pages 206 and 207 gives approximately the relative heating and grate surfaces for both types of boilers for several classes of ship, and indicates the gain in weight and space occupied that would be due to the use of Babcock boilers :—

It is not necessary, before an audience of marine engineers, to elaborate the advantages to the ship as a whole, that are derived from these gains. Now that the Board of Trade grants the Babcock boiler the same certificate as it does to the cylindrical boiler, one of the leading objections to its adoption, i.e. that of inability to comply with the same survey conditions, no longer holds good.

On the other hand, the conditions under which the boiler can be successfully adopted were never so favourable as they are at the present time. In the first place, the introduction of the steam turbine for many classes of vessel has eliminated the risk of oil finding its way into the boiler water *via* the engine cylinders. Great improvements in the design of auxiliary machinery and feed-water filters have taken place. The introduction of improved designs of condenser has materially lessened the troubles due to salt-water leakage, while modern evaporators of high capacity and low weight are now more readily obtainable. The immense improvement in tube making during the last few years has resulted in greatly increased reliability. Besides all these mechanical reasons, more accurate estimates of boiler power required and the consequent dimensions necessary are now made.

All these contributory causes are tending to facilitate the wider adoption of the water-tube boiler.

Even if the marine engineer is not very conservative, the shipowners are, and the natural self-interest of the shipbuilder to utilize his expensive plant for making cylindrical boilers has been a retarding influence. It may be stated, however, that there are signs that these deterrents are yielding to the progressive spirit of some of our leading shipbuilders.

That Babcock & Wilcox boilers can be made in any well equipped boiler shop is indicated by the fact that they are

TABLE

SHOWING COMPARATIVE SIZES, WEIGHTS AND

Type of Ship.	Intermediate Passenger Steamer.		Large Cargo Liner.		Large Combined Passenger and Cargo Liner.	
Estimated steam production per hour from feed at 150° F. 200 lb.	75,000		112,500		140,000	
Estimated steam per I.H.P. per hour for all purposes	15		15		14·0	
Equivalent horse-power	5,000		7,500		10,000	
Type of boiler	Cylindrical	Babcock	Cylindrical	Babcock	Cylindrical	Babcock
Heating surface, sq. ft.	13,300	16,370	21,750	25,850	26,500	32,515
Grate area, sq. ft.	335	450	530	650	700	900
Approx. weight of boilers and water, and all mountings and fittings, but no funnels or uptakes, or stokehold accessories, tons	420	195	535	282	780	380
Draught	Howden	Assisted	Assisted	Assisted	Howden	Assisted
Floor space occupied by boiler-rooms, sq. ft.	1,850	1,585	3,420	2,280	3,835	3,068
Fore and aft length of boiler-rooms and transverse bunkers	56′ 0″	44′ 0″	72′ 0″	51′ 0″	77′ 0″	71′ 0″
Increase of H.S., per cent.	—	23·0	—	19·0	—	22·5
Increase of G.S., per cent.	—	34·3	—	22·5	—	28·5
Saving in weight, tons	—	225	—	303	—	400
Saving in floor space, per cent.	—	14·33	—	Entire forward stokehold	—	20 per cent. and longitudinal bulkheads now fitted 6′ 6″ from sides
Saving in fore and aft length	—	12′ 0″	—	Abt. 27′ 0″	—	6′ 0″

V.

SPACES OF CYLINDRICAL AND B. & W. BOILERS.

Large Intermediate Atlantic Liner.			Large Fast Atlantic Liner.			Large Fast Atlantic Liner.	
	240,000			750,000			1,000,000
	15			15			14·3
	16,000			50,000			70,000
Cylindrical	Babcock	Babcock alternative	Cylindrical	Babcock	Babcock alternative	Cylindrical	Babcock
52,150 1,260	57,810 1,600	66,200 1,800	146,000 4,000	188,510 5,170	164,650 4,480	158,350 4,050	221,544 5,474
1,320 Natural	672 Natural	825 Natural	4,200 Assisted	2,360 Assisted	2,035 Assisted	4,750 Howden	2,615 Assisted
7,275	5,700	5,920	20,268	20,268	13,460	18,235	16,115
127′ 0″	106′ 0″	117′ 0″	321′ 0″	321′ 0″	252′ 0″	—	—
—	10·81	26·9	—	29·0	12·8	—	39·9
— —	27·0 648	42·8 495	— —	29·15 1,840	12·0 2,165	— —	35·3 2,135
—	Entire forward stokehold	10′ 0″ saving in length and longitudinal bulkheads 7′ 0″ in from side adopted	—	Existing spaces used to instal much larger boilers	Longitudinal bulkheads installed	—	11·63
—	21′ 0″	—	—	—	69′ 0″	—	53′ 0″

currently under construction in the works of Messrs. Beardmore, John Brown & Co., Cammell, Laird & Co., Denny & Co., The Fairfield Shipbuilding Co., Harland & Wolff, Scott & Co., and Vickers. The heavy plant for making cylindrical boilers is not necessary,—but can be used.

The cost of Babcock & Wilcox boilers is perhaps slightly more than that of cylindrical boilers of equal power, but the difference is insignificant in comparison with the value of the ship and the greater earning capacity, owing to the saving in weight and space occupied.

The writer trusts that this paper will not induce a charge of exploitation, but the fact is that in presenting to this Institution a short survey of the introduction of the only water-tube boiler that is extensively adopted in the mercantile marine, it is impossible to avoid references to facts and reasons which, while perhaps exceeding the limits of purely mechanical or scientific research, are, nevertheless, accepted features of a most important development in the history of marine engineering.

CHAIRMAN : I am glad to see a very good meeting to-night. This is the last paper of the session and I am sure you will agree that it is not by any means the least important. Mr. Rosenthal, who has come at some personal inconvenience, is, as I suppose you all know, the head of the great firm of Babcock & Wilcox, and I think we are highly honoured in having him here to give us this paper. The paper is a very valuable one, and I think we can all say that Mr. Rosenthal's last paragraph is fully justified and that no one can make any charge of unduly commending the Babcock & Wilcox boiler. In giving information about any of the water-tube boilers, it is impossible, of course, to avoid mentioning names, and as the Babcock boiler is practically the only water-tube boiler used in the merchant service, and one of the two types used in the Royal Navy, Mr. Rosenthal can, naturally, hardly help pointing out that the Babcock boiler is a good one. Perhaps, before the discussion takes place, I might point out that the figures given on pages 206 and 207 refer to designs only, and are not particulars from actual ships. Of course one knows perfectly well that no large fast Atlantic liner of 70,000 h.p. has got Babcock boilers—

that has to be left to what might be in the future. I should be very glad if some one would now open the discussion.

Mr. D. Donaldson: I should like to take the opportunity of asking if trouble is still experienced from the lower tubes of the boiler sagging. It is some time since I have examined a Babcock boiler, but I have examined a fair number in land service and that was the only fault that came to my notice—the lower row of tubes sagging, owing to the very high temperature to which they were exposed—but nowadays it appears that in the marine boilers at least, there is a much greater space allowed between the firebars and the first or bottom row of tubes, than formerly.

Mr. Wm. Walker: Following on the remarks of the last speaker, I presume he refers to trouble with "hogging" and not "sagging." My own experience is that the tubes do not sag, they hog, and I remember that a long time ago, whilst attending one of the Universities, a Professor there put forward a theory in explanation of this. I do not know whether it is recognized by Messrs. Babcock & Wilcox, but the theory was that the tube, under working conditions, occasionally gets short of water, and the underside, becoming hotter than the upper side, has a tendency to elongate. It is prevented from doing this by reason of the headers, consequently the metal is compressed and when the tube cools down the underside is shorter than the upperside and naturally the tube will rise or hog over the fire. But there is a more serious trouble, in my experience, with these tubes, and that is local bulging. Many theories are put forward to account for this. Some put it down to oil, others to deposit, or a combination of both. In some cases there is a very small percentage of oil, scarcely traceable and very little deposit, and yet there is trouble with local bulging. I do not know if Mr. Rosenthal has any theory as to how this can be eliminated, but the trouble certainly exists, not only with Babcock boilers, but I believe with all types of water tube boilers.

Mr. Wm. McLaren: Mr. Rosenthal is to be congratulated on bringing this paper before us in the interests of the Babcock boiler, and from the great improvements which have been made in this boiler, it is evident that it has benefited by the criticisms passed upon it at this Institute some years ago and by the experience which has been gained since then. On page 195 we get the gist of the matter, the essentials required for successful working, and not the least important of these is the last one mentioned, "a careful and interested engineer." If they get all they desire there is no doubt success will always attend the Babcock boiler. Although our Chairman has pointed out that the figures given refer to designs only, it is something which may be attained to in the future. Of course the Scotch boiler is still very efficient in many respects, but from the figures that have been given to us to-night, taking space for space and weight for weight, there seems no doubt of the advantages of the Babcock boiler.

Mr. F. M. Timpson: I would like to join with the previous speakers in thanking Mr. Rosenthal for the very illustrative paper he has given, and for the opportunity of finding out some points in connection with this subject which are not generally known. Mr. McLaren referred to the difficulties with this type of boiler experienced some years ago. I think the *Buenos Ayrean* was one vessel in which there was considerable trouble, but I have never heard the circumstances satisfactorily explained. Perhaps the author would give us some idea of how the difficulties were met in that instance. There is one feature in connection with the Babcock boiler which is rather interesting and that is that in a great many shore installations the marine type of boiler is adopted, which goes to show that this must be the preferable type. To my mind there are certainly some great advantages in the water tube boiler, and particularly so in vessels on short services, where there is a good deal of raising and lowering of steam, with consequent leakages in the cylindrical boiler. I do not think the Babcock boiler is adopted to the extent it might be, and one point in relation to this was remarked upon by a previous speaker, an interested engineer is of importance. It appears, however, that there is a growing demand, and in the future there will be a greater number of water tube boilers in use as they offer advantages which are readily appreciated by marine engineers, in the saving of weight and space, quick raising of steam and other items.

Mr. D. Hulme: My experience of the Babcock boiler is not very extensive and is confined principally to shore work. I have never been in charge of one at sea, although many of these boilers have been under my observation on trial trips and I was naturally curious to see the results. I have had under my charge for twenty years a Babcock boiler on which an accident occurred some time ago. I believe the Board of Trade report upon it has been issued although I have not yet seen a copy. One of the tubes, which had been in the boiler for twenty-one years, gave way. It was exceptionally thin and the tube itself hogged. We find the lower tubes do not hog—this one was in the second row from the bottom. My own opinion on the matter is that the tube did not burst, but broke. We had 190 lbs. of steam on the boiler at the time. I was standing in front of the boiler. It was just after the dinner-hour and they were starting to raise steam again. The man opened the fire door, put in the rake and started the draught and I attribute the break to this sudden rush of air. There was no great trouble with it. There was a slight thud, then an immense amount of dust came out. I immediately called out to the stoker and when he came up it appeared he had burnt his arm just below the elbow, due to starting back with the sudden shock, but otherwise there was no accident whatever. In no other type of boiler would there have been so little harm done with a broken tube. The tube itself was not $\frac{1}{32}$ in. thick all round. We had a new boiler put in some few years ago, and on it there is every facility for measuring every pound of steam and water evaporated by the boiler, which is usually 3,000 lbs. per hour. With the forced draught we have been able to get out 5,600 lbs. instead of 3,000, but I came to the conclusion that owing to the elevation of the tubes it might not be efficient to give any more than the latter amount. Up to that point we are very careful to see that there is a fairly uniform heat all over the tubes. I have had some experience of having one boiler with cast-iron headers and another with steel headers. Of course, in the land boilers the joint is on the outside. With the cast iron we can always keep them tight, but we cannot with the steel; I think that is due to the unequal expansion. It appears to me that the sides strain, with the result that there is a leakage at top and bottom. Of course it would not do to put too much strain on this; we could not expect it to carry a pressure of 5,000 to 6,000 lbs. per square inch. We have never yet had an accident with them; but we are very particular to see that the man understands them, and the bad results that would occur if he put too much strain on them both. I did not know until a very short time ago that the paper was to be read this evening or I should have prepared myself with more data as to the results we have got out of the boilers; but if the discussion is adjourned I may be able to provide some more information in this respect at the next meeting. I have had some experience of pitting taking place in the drums. This has been in the form of dishing of about 1 in. or $1\frac{1}{2}$ in. diameter, but it is due entirely to the water we use. I quite understand that it is our own fault, but it is quite unavoidable as it is the only water available. The method I adopt is to drill a hole through the bottom of the "pit" and put a stud in. On the other side I put a zinc plate so as to ensure that there is a metallic contact.

Mr. J. G. HAWTHORN: After that very lucid description from Mr. Hulme, one cannot but be struck with the great immunity from danger which is one of the advantages of using the Babcock & Wilcox boiler, and, if for no other reason, that in itself should commend the boiler to the marine engineer. Then, again, there is the great saving in weight and the consequent greater earning capacity of the vessel. In Table V, for a vessel of 5,000 horse power Mr. Rosenthal gives the weight of 420 tons for the cylindrical boiler and 195 tons for the Babcock boiler. For 10,000 horse power we get the weights of 780 tons and 380 tons respectively, so that the Babcock boiler is estimated to weigh less than half of the cylindrical boiler. Could Mr. Rosenthal say what percentage of that 380 tons in the Babcock boiler is water, so that we can compare our own statistics with regard to the cylindrical boilers. In the high-powered vessels, for example the 70,000 horse-power vessel, the saving in weight, although still remarkable, is not so great relatively. Another point in connection with these figures that struck me was with respect to the ratio of grate surface to heating surface. Roughly, it works out at 36 sq. ft. to the sq. foot for the Babcock boilers and 40 to the sq. foot for cylindrical boilers. That amount of heating surface seemed to me to be rather high for the Babcock boiler and it occurred to me whether so large a ratio was necessary. Should we have a greater ratio under the same conditions as in the ordinary cylindrical boiler; that is to say, can we dispose the heating surface in the Babcock boiler to greater advantage than we do in the cylindrical boiler ? On the whole the paper is one which has a great educational value, if we fully digest the figures given. As has already been mentioned one great factor in the successful adoption of this boiler is the necessity for a "careful and interested engineer." Many a good thing which has been put into a ship's engine-room has received its deathblow through the lack of interest of the engineer in charge. If the sympathies of the sea-going engineer can be enlisted, I have no doubt that the Babcock boiler will in time largely displace the ordinary cylindrical boiler.

Mr. A. H. MATHER : We are very much indebted to Mr. Rosenthal for bringing this paper before the Institute. I do not think we have had a paper on water-tube boilers read at the Institute for quite a long time, and since we last discussed the subject a great many changes have taken place, not only in the water-tube boiler, but in other types of boilers also. With regard to the five points Mr. Rosenthal has given for the successful working of the Babcock & Wilcox boiler, generally speaking they are applicable not only to the water-tube boiler. I think the same points are now just as essential with any type of installation and they are probably attended to very much more closely than they used to be. There appears to be no doubt that with the Scotch boiler, dealing with larger quantities and having larger reserves of steam, the same detailed attention to firing to give regular results, is not so necessary as it is with the water-tube boiler ; but if the same amount of attention is given to boilers generally as is recommended here, good results will certainly follow. Mr. Rosenthal refers to the necessity for well constructed and tight condensers. I think Mr. Hulme will bear me out when I say that the number of condensers found to be absolutely tight, up to comparatively recently, was a very small one. Mr. Rosenthal also refers to evaporators of adequate size being essential, which brings up the question of what amount of feed make-up is found to be necessary due to the boilers themselves. How does the proportion of make-up water compare with that of a good cylindrical boiler installation ? I have had very little opportunity of seeing the Babcock boiler in service at sea. I have only been on one short run with this boiler on a trial trip, but I had a good many trips with Belleville boilers, and one point that used to cause a great deal of trouble in those days was the question of the fusible plugs. In the Babcock boiler there is a large number of small doors. Of course with the joints inside there is a much better chance of making them tight than if they were outside, but it would be of interest to know what kind of experience is gained with these joints in actual continuous service and whether there is an appreciable amount of leakage specially due to this.

Mr. John McLaren: One point Mr. Rosenthal mentions is in connection with the construction of the tubes. The manufacture of tubes has improved considerably during the last ten or fifteen years, and this is one of the features which has brought the water-tube boiler to its present state of perfection. Some time ago I had a talk with our Chairman on this subject of tubes in boilers, and he told me of some tubes which had been overheated—they had been red-hot—and instead of collapsing they were cut in two. There is one point Mr. Rosenthal has not touched upon and that is the question of priming, and I am given to understand that this is one of the great difficulties with water-tube boilers at sea. I should like some information on that point. I think the time has come when the claims of the water tube boiler should be thoroughly studied, and with this is involved to some extent the question of lubrication. With all the methods of filtration, oil still gets into the boiler, and I take it that the great point with the water-tube boiler is cleanliness, freedom from oil and other impurities. I was very pleased to hear this paper after the number of papers we have heard on the internal combustion engine, and I think if we have an efficient boiler there is no doubt the steam engine will be required for many years to come.

Mr. Timpson: Mr. McLaren has brought up the question of priming, and I should like to ask a question in this respect. In the United States Navy they used reducing valves in connection with the main engines and I should like to ask if there is any advantage, with higher pressures in the boiler. in using reducing valves to do away with priming. With regard to explosions, I had an experience, not with a Babcock & Wilcox boiler, but with a water-tube boiler, where a tube gave out. My experience is not the same as Mr. Hulme's, as there was a drop in pressure and then a rise—which lifted the safety valve with an alarming roar and then collapsed. The boiler was running at about 250 lb. pressure when the tube collapsed, and the gauge went up to 300 and then went down. Another point is in connection with the water in the gauge glass. In running with the water-tube boiler the water would show all right when running at full speed, but when the vessel stopped the water would perhaps run out of sight in the gauge glass. This is rather alarming to those used with ordinary boilers when the drop of water in the glass is less and not so rapid.

CHAIRMAN: I should like to say a few words on the point raised by Mr. McLaren and Mr. Timpson as to water-tube boilers priming. On page 193 you will observe the figures given in connection with the trial of the H.M.S. *Hermes*. That was with the Babcock boiler, and you will notice that the amount of water in the steam was only ·09 per cent. I was one of those on the Special Boiler Committee referred to by Mr. Rosenthal, and I can assure you that all the figures in that Committee's report are absolutely accurate. Every figure was verified in every possible way. In all the Boiler Committee's tests they had special apparatus for testing the dryness or wetness of the steam, and as the wetness in the steam in this instance is only ·09 per cent. you may take it that the boilers of the *Hermes* did not prime. Another point raised was in connection with the water-gauge glasses. In any boiler you may have the water-gauge glass to show a different level of water to that in the boiler, and in some of the boilers tried by the Boiler Committee the gauge glasses had to be modified entirely. I do not specially remember anything of the gauge glasses of the *Hermes*, so I presume they gave a true record. Mr. Rosenthal gives a list of five requirements for the best working of the Babcock boiler. Please note that these conditions should be regularly attained in all vessels, not specially for Babcock boilers but for all boilers. One feature he has left out—an important one with the water-tube boiler—and that is the question of firing. The results of the trials in the *Sheldrake* showed very conclusively that with irregular firing such good results were not obtained as ought to have been obtained, and the main feature in most modern design is the exceedingly large combustion chamber spaces as compared with those provided in the *Sheldrake* boilers. If there is one thing in which the Scotch boiler excels, it is that it is not so sensitive to bad firing as the water-tube boiler. That arises from the nature of the design. In all boilers a very short space of time elapses from when the products of combustion leave the fire-grate till they are into or between the tubes. In considerably less than a second the air passes from the firebar and enters the chimney; but in that short space of time all the wonderful chemical combination of the oxygen and the fuel has had to take place and the evolved heat has to be absorbed into the water in the boiler.

In the water-tube boiler the products of combustion do their work still more quickly than in the Scotch boiler, so that the Scotch boiler can be worse used than the other without such serious effects; but with skilful firing, as we had in the case of the *Hermes*, a remarkable efficiency is obtained. I say advisedly a "remarkable efficiency," as in this case it amounted to 81 per cent. I must say that this efficiency astonished us and we checked the figures very carefully. In the case of all the Boiler Committee's trials the coals were carefully weighed, sampled and analysed, the whole of the water that went into the boiler was carefully measured, and the wetness of the steam determined. Of course we fully realized that all the water in the feed is not necessarily evaporated, and it is on this account that the wetness of the steam must be determined, otherwise a priming boiler would appear to be an efficient one. These figures in the case of the *Hermes* and the *Saxonia* show the actual thermal efficiency—82 per cent. in the *Saxonia* and 81 per cent in the *Hermes*. They are absolutely reliable figures and I believe they are the highest ever obtained.

Mr. D. Hulme: In reference to priming, we use our boilers for testing purposes and very frequently use them to the utmost capacity, but I have never seen, on any occasion, water suspended in the glass above ½ in. Priming is an unknown quantity. We have had 210 lbs. of steam on our boilers and in less than five minutes have brought the pressure down to 180 lbs. and have never seen anything in the way of priming. In testing our own machines we have to test the quantity of water that we take from the boiler and the quantity of steam generated from that, and in no case has it varied above a decimal point, that is if we have been evaporating. Our consumption of boiler steam has been at the rate of 1·16 or 1·17, and it has never gone above 1·19. I have been out on trials with water-tube boilers where I have seen as much as 8 in. suspension of water in the glass. I think this suspended water is due to the high ebullition.

Chairman : There are two things which must be attended to in connection with the water gauges on a boiler. These are, to get the right positions for the steam, and the water ends. To see that they are in places where there is no motion either of the water or of the steam. If there is any motion of the water due to circulation or of the steam through proximity to the stop valve, there will always be a false indication. In water tank boilers there ought to be very much less difficulty in getting a true indication than in others.

Mr. W. Walker : Is it not due to the fact that under working conditions the main tubes of the boiler are not full of water ?

Chairman : I am not speaking of the difference of level in the water gauge, I am referring to the accuracy of the gauge in giving a true indication of what is taking place in the boiler. If there is a big motion of steam in close proximity to the steam end of the gauge, the water will be drawn up, or if the water is in motion at the bottom end it will show lower in the glass. These conditions must be avoided if the water gauge is to give an indication of the level of water on the inside of the boiler at any particular time.

Mr. Timpson : In two cases I know of the water was 1 in. in the glass when the vessel started, and at full power it went to $\frac{3}{4}$ glass. When the engines stopped the water dropped out of sight. It is rather alarming when one is not used to it.

Mr. Donaldson : I should like to ask where the superheater is usually fitted in the marine type of boiler and if it is in the same position as in the land type, i.e. between the inlet and return tubes of the headers and below the steam drum.

Mr. Rosenthal : The first question asked was in reference to the tubes sagging, or rather hogging. The first speaker, of course, meant hogging. This question of hogging is one which is a great deal talked about, but it is really talked about more than it is worth. The tubes will hog sometimes and it does not matter if they do. Certainly, as far as all our researches go, there is generally a reason for the hogging, this reason usually being that there is a film of oil in the tube, or some other foreign matter, which immediately becomes overheated. What we are quite certain of is that this hogging does not take place owing to accumulation of steam in the tube. That theory has been dispelled over and over again, because there are hundreds of instances where the boilers have been working for years and there has been no hogging, and if it were a question of accumulation of steam and not a question of foreign matter being on the heating surface, hogging would be a regular thing instead of being, as it is now, an occasional occurrence. As to the question of local bulging, I daresay most of you will know that that can be due to nothing else than local heating again. Unless the heat is prevented from getting to the water the tube cannot get hot. It may be there is a local bulging, and on looking inside one can find nothing. That simply means that whatever has been there has got dislodged again. You cannot always be sure that nothing has been there because the surface is perfectly clean. It may be a globule of oil which has caused it. You may look and find no trace of oil in the spot where the local bulging occurs, but you may find it somewhere else in the boiler. Local bulging ought not to occur, and if it does, something is wrong with the attention, or with the filtering arrangements, or too much oil is used, or something else has happened which should not have happened. Mr. W. McLaren raised the point as to the progress with the watertube boiler having been benefited by criticism. That is undoubtedly the case. We have learned through criticism and through failures more than through anything else. As to the question of the care of the engineer, that is undoubtedly a very important factor. I used to go out on the trials and the earlier voyages of the first ships fitted. I rarely go out now, but I know that the engineers to-day are very different. The men that we knew have got older and wiser and the young engineers of the present day know more than those in the past. They are better educated, possibly they have to work harder for their Certificates, they attend such Institutes as this and get interested in the progress of the science of engineering. These are all factors that have told, and I say without hesitation that the marine engineer is quite a different man from the men of twenty years ago or even ten years ago. He can therefore deal with an apparatus that requires more intelligence to attend to. One cannot put a water-tube boiler and a fine set of machinery and plant, working at 200 or 250 lbs. pressure, in the hands of a man who does not know his profession—of course that would mean certain disaster. One cannot put it in the hands of a man who has not the character to say that what another man can do he can do. Mr. Timpson referred to the *Buenos Ayrean*. The *Buenos Aryean* was one of those educational matters I have referred to. It was a ship in which the Scotch boilers did not give enough steam for the engines and so they thought it would be a good plan to make up the deficiency by putting a Babcock & Wilcox boiler in. So did we at the time and we afterwards found out that it was a very bad plan to put a Babcock & Wilcox boiler in a ship like that, because of the lack of suitable attention. They found that the water-tube boiler could be turned into a sort of "maid-of-all-work." Whenever there was a difficulty the water-tube boiler was called upon to do the work and they saw that it could be forced to any extent. The superintendent engineer was a man who believed in the good old Scotch boiler and nothing else, and he was not particular about looking well after the boiler, because of his prejudice. That is the reason why the boiler on the *Buenos Ayrean* was not such a success as it might have been. When the boiler was taken out it was quite good and only required a few tubes to be put in. This could have been done in the ship and the boiler might have done well with reasonable attention. That is one of the things we do not do now, excepting where we are sure of the boiler getting proper treatment. The next question was about the use on shore of the marine type boilers. There are several reasons for this. For one thing, experience has shown that our marine type boiler is the most efficient steam generator that there is. It will give a higher thermal efficiency and, for the quantity of steam produced, takes up less space. It will be found that, generally, the B. and W. marine type of boiler on shore is put into electrical stations. It is there a question of arranging the boiler plant in some kind of symmetry with the turbine plant to take up the smallest space, and the Babcock boiler of the marine type meets these conditions best. Another question raised by Mr. Timpson was with regard to priming. The absence of priming is a very remarkable feature. In the early days when we designed the marine boilers, we used to think that if the ship rolled about there would be a lot of priming, so we put in wash plates and found that these prevented the water rolling too much. If the water is kept at the proper level and reasonably clean there is no priming. I do not see any reason why there should be because it can only result from a frothy condition of the water, or too little water in the boiler as is the case in some other designs of water-tube boilers. None of these conditions ordinarily prevail in the B. and W. With regard to the reducing valve, that is a question of the quantity of water there is in the boiler and the rate at which it is evaporated. The reducing valve used to be a regular adjunct to the Belleville boiler because the Belleville boiler had an extraordinarily small amount of water in it and the water surface was not of any size. With that boiler it was customary to meet the defect by obtaining as high an accumulation of heat units as possible by carrying a much higher pressure than was required in the engines. We have never followed that rule and have never found it necessary to use a reducing valve. They have now discarded its use in the United States Navy. With regard to the question of improvements in tube making, there is absolutely no doubt of that, and nowadays no one thinks of using anything but seamless tubes in a water-tube boiler. I would not think of putting in a welded tube under any conditions. I do not say that welded tubes are necessarily bad, but there is always an element of weakness in a weld. A tube will stand very high pressures even if only welded on the skin, and that skin weld may at some time give out. Welded tubes have been brought to a very high state of perfection and it is remarkable that so many are satisfactory, but there is the possibility of the weld being partially made, in some instances, perhaps through some foreign matter getting in, and that is why the weldless tube gives a great advantage over the same in the water-tube boiler. The water-tube boiler would not have been so much used in the Navy for torpedo boats or in any other kind without the perfecting in the manufacture of seamless tubes having taken place. The instance Mr. Hulme gives of a land boiler evaporating double what it was intended to do is interesting, but we have a great many instances of that taking place. As to the question of limit of evaporation, there is no limit to evaporation, as far as the possibility of transmitting heat to water is concerned, as long as the circulation provides that the water touches the tube, and the tube, consequently, does not overheat. I do not know exactly what that limit is, but we have made experiments evaporating at the rate of 100 lbs. of water per sq. ft. and we did not burn the tube then. Of course the question of limit of evaporation brings in other factors, the factors of efficiency and all other practical points that occur in the generation of steam ; but, from a mechanical point of view of the possibility of evaporating water, there is no reasonable limit that I know of. As to the question of steel headers not keeping tight, I think I shall take an opportunity of sending someone to Mr. Hulme's place to make those headers tight. We are making about 1,500 of them per week and it is certainly not a general experience. With regard to pitting, as Mr. Hulme said, that is a question not of the boiler but of chemistry. Mr. Hawthorn made a very interesting reference to the effect of burst tubes in cylindrical boilers. It is particularly interesting to me because I frequently come across men who entertain me with the fact that the Scotch boiler has no faults. With regard to the question of weights on Table V. Of course this table is compiled from designs that we have and are constantly sending out to people who inquire, and the figures referring to cylindrical boilers are collected from data that one can easily obtain on this subject. The difference between the 720 tons and the 780 tons is explained by there being in the one case single-ended boilers and in the other case double-ended, which would mean a slight saving in weight. The Babcock boiler is a square thing—a Scotchman once called it a " kist o' whistles." These are all coal fired installations and not oil fired. In oil fired the comparison is very much more favourable to the water-tube boiler. That is why for 10,000 horse power the weight is practically double that for 5,000 horse power. It was remarked that the saving in weight is not very great, but it is generally found that even 100 tons saving in weight on a vessel of 5,000 h.p. is considered of some value. Of course the saving in space is also a very important feature, especially in passenger boats. The question continually crops up in the cross-Channel boats, in which a foot or two saved is of considerable importance. The question was also raised as to the relative heating surfaces and grate surfaces of the Babcock & Wilcox boilers and the other types. Of course we have to compare natural or assisted draught with the Babcock boiler, and the Howden forced draught with the cylindrical boiler, as that is the more regularly used arrangement to make the cylindrical boiler give as much as possible. We find that we can put in more grate surface and there is no doubt whatever that the balance of efficiency is always best with the lower rate at which the fuel is burnt, whatever theory may exist to the contrary. Mr. Mather referred to the feed make-up. As far as our experience goes, it is the same with the Babcock & Wilcox boiler in this respect as it is with a good cylindrical boiler; that is to say, there is no water lost at all by the boiler itself. The doors are jointed on the inside and are held on by the steam pressure. They do not leak. There are no fusible plugs in the boiler. The reason why they were used in the Belleville boiler is, of course, a well-known one and I need not enter into it, but they were very troublesome things indeed. I think the Belleville boiler would have been as well without as with them, but Belleville did not. Mr. McLaren referred to oil engines. That also is a subject to which I have given a great deal of attention. It has been my business to investigate the oil engine question a great deal, because when the oil engine for marine purposes was introduced with such a flourish of trumpets, it was thought there would be no more boilers used, so I concerned myself with the matter. The mechanical progress made with it has been remarkable; the best brains in the world have been given to its development, but for all that I do not think it will ever be used for a 70,000 h.p. ship. With regard to lubrication, the engineer generally likes to put on the oil, but it should get into the bearings and not into the cylinder, and everybody who wants to get good results out of any type of boiler will have to meet this difficulty. You all know that engines can be run perfectly satisfactorily with no appreciable quantity of oil in the cylinder. Generally speaking, with high pressures no oil is required in the cylinders. For five years I ran a yacht in which I had taken off the old cylinders and put in four new ones. I put in a B. and W. water-tube boiler and it ran for 15,000 miles without a drop of oil in the cylinders. There was not a tube burst or a leak in the boiler and we never had a tube hogging either up or down. Mr. Milton referred to the question of firemen. The firemen can undoubtedly shovel a lot of coal into the Scotch boiler and then take a rest, but they should not be allowed to do so with the Babcock boiler. For the first few hours the fireman does not like that, but he soon finds that the lack of rest in one way is compensated in another. He finds there is such an advantage in having the fire doors all at one level that he forgets the other matter and is perfectly satisfied. It has certainly been found that in a few hours a man can drop his firing habits of a lifetime and find himself at home with a Babcock boiler where there are level and even fires and he can fire all his doors at the one level. The variation in the water level is not in any way due to the tubes not being full of water. It is only due to the variation in the density of the mixture of steam and water. The superheater is fitted in the inclined space between the inclined tubes and the horizontal tubes. They are so fitted on thousands of stationary installations and in many instances on board ship. In the latest method on board ship it is carried above the top tubes. I have touched briefly upon all the points raised and I may say that I am very grateful to you for the kind way in which you have received the paper and the interest you have shown in it. It encourages me to keep in view a paper on further progress on Atlantic liners, which will no doubt be accomplished before long. If you would like a variation from the subject I would be prepared to give a paper on oil engines.

Mr. HULME : In justice to Messrs. Babcock & Wilcox I may say that we use three of their boilers, one with cast iron headers and two with steel. One of these is a standard size boiler, but the boiler I referred to was specially designed for a small space and the headers had to be specially designed.

Mr ROSENTHAL : Up to about a year or two ago we used to weld these headers. Then we succeeded in making them entirely from drawn steel, drawn from an ingot, and in this form it has all the tensile, bending, mechanical and chemical properties required to conform to the specification for the best Admiralty plate.

Mr. J. McLAREN : I am sure we are all indebted to Mr. Rosenthal for the very able paper he has given. It has been full of information and personally I intend to study it at leisure. It is always of value when specialists come here to give their experiences on the subject of which they know most. The Babcock boiler is a matter of which we all know a little, but our knowledge on this subject has been greatly added to to-night, and I think we will all look forward to hearing Mr. Rosenthal on the subject of oil engines. I have much pleasure in proposing a hearty vote of thanks to him for the paper he has give us.

Mr. F. M. Timpson seconded the resolution which was carried with applause.

The meeting concluded with a vote of thanks to the Chairman on the proposal of Mr. W. Walker.