PREFACE.

58 ROMFORD ROAD,

STRATFORD,

March 25th, 1903.

A MEETING of the Institute of Marine Engineers was held on Monday evening, March 23rd, at the Institute premises, 58 Romford Road, Stratford, E., when Mr. A. E. MILLS read a Paper on "Water-tube Boilers," and a discussion thereon followed. The Paper had been read at Cardiff before the Bristol Channel Centre on February 25th.

Mr. J. R. RUTHVEN (Member of Council) occupied the chair.

The CHAIRMAN, in opening the meeting, said the Paper had already been read and partly discussed at Cardiff, but the subject was of such importance that it would stand being read again, and also discussed from different points of view.

Mr. MILLS then read his Paper.

Before the discussion was proceeded with a number of diagrams were shown on the screen, illustrating the theory of the water-tube boiler, and the construction of several well-known types of water-tube boilers. The discussion was adjourned.

JAS. ADAMSON,

Hon. Secretary.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1903-1904.

President Elect—SIR JOHN GUNN.

Local President Elect (B. C. Centre)—
LORD TREDEGAR.

ONE HUNDRED AND TENTH PAPER
(OF TRANSACTIONS).

WATER-TUBE BOILERS.

BY

MR. A. E. MILLS (MEMBER).

READ AT
3 PARK PLACE, CARDIFF,
ON
WEDNESDAY, FEBRUARY 25th, 1903.

CHAIRMAN:
MR. W. SIMPSON (MEMBER).

AND AT
58 ROMFORD ROAD, STRATFORD,
ON
MONDAY, MARCH 23rd, 1903.

CHAIRMAN:
MR. J. R. RUTHVEN (MEMBER OF COUNCIL).

WITHIN the last few years great prominence has been given to the question of water-tube boilers, principally, no doubt, on account of the trouble arising from the use of the Belleville boiler in the

Navy. Before discussing the merits and demerits of this type of boiler, it might, however, be of advantage to refer to those of the cylindrical marine type, and to note those fractures in the latter which have rendered necessary in some instances the adoption of the water-tube type of boiler.

In the cylindrical boiler a large mass of water has to be heated, and, on account of the bad circulation, a long period has to be allowed to raise steam in order that the expansion of the different parts may be as gradual as possible, and that the consequent stresses set up may not result in strains to any part.

The circulation of the water, as generally agreed, is downward at the wings and upward at the centre over the furnaces, but is more or less confused, according to whether the boiler is forced or not, or whether the fire in one furnace is brighter than the others, etc., which must necessarily tend to priming, when unequal expansion will inevitably result, on account of the circulation in some parts being at times almost nil, and of great velocity in the others.

The repairs to these boilers have to be effected by skilled workmen, and are frequently of a very costly nature and occupy a considerable time.

The water in these boilers cannot be changed, the inside examined, and steam again raised in a comparatively short time, without unduly straining them.

The weight of the boiler and the large amount of water carried detracts from the earning powers of the vessel, and as at the present day the tendency is to increase the pressure in order to bring down the consumption, the extra thickness of plates required in the boilers not only adds to the weight, but also severely tries the capabilities of the manufacturer to turn out a good and lasting job.

In addition to the above disadvantages, it may also be mentioned that when it is required to renew the boilers, the deck and surroundings have to be removed, and heavy expenses have to be incurred, besides laying the vessel up for a considerable time.

Before going into the question as to how far these disadvantages are, or are not, overcome in the Water Tube Boiler, it would be well to review the fundamental principles which governed the pioneers in designing the Water Tube Boiler, in order that we may the better understand the various claims to efficiency of the different types, both as regards durability and also the transmission of heat. To begin with, we note that when a kettle of water begins to boil, the water rises above the normal level in a turbulent state around the edges, falls over towards the centre, and then descends. If, however, we urge our fire and so increase the heat of transmission, we upset the direction of the circulation by causing upward currents at the centre, so much so that the water is more or less lifted by the generation of steam and boils over ; so that in a boiler where the circulation is allowed to assert itself as described we must on no account urge the fire to any great extent, otherwise priming will take place, and so produce steam heavily charged with water.

If, however, we place in this kettle an inner vessel of smaller dimensions, with an aperture at the bottom, and keep it at a moderate distance from the sides and bottom of the kettle, and so separate the upward and downward currents, we find that the fire can be urged considerably without causing the water to boil over. From this we gather some idea as to how efficient circulation can be attained, and while forcing the fire, at the same time having definite and continuous currents of water in the boiler, we have a good circulation with less priming and consequently drier steam, together with greater durability, all the parts of the boiler being kept at the same temperature and also (which is a great advantage) less scale deposited on the heating surfaces owing to the more rapid circulation. We also have the important fact before us, that owing to this rapid circulation more steam can be generated in a given time, and consequently less space and weight of material are required.

If the currents of water are kept from interfering with one another, as in the arrangement of the kettle with the inner vessel, by taking a U tube with the top of each leg connected to a drum common to both and applying heat to one of the legs, circulation is set up, the water circulating more rapidly the greater the heat applied, and if heat is applied to the other leg circulation will still continue in the same direction, but with much greater force, so that in this arrangement we have a simple type of water tube boiler. If now the bottom part of the U be elongated and other tubes added parallel to it, we have one element of a well-known water tube boiler which has of recent years been largely used for marine purposes and which appears to have stood the test of time.

The Babcock and Wilcox marine boiler differs somewhat from the design of the one used for land purposes on account of such considerations as the motion of the ship, convenience of working the different valves and levers, in that the steam drum is placed across the front of the boiler at the top instead of lengthways. The front and back of the boiler consists of several mild steel boxes or headers of about 6 inches square and about 5 or 6 feet long, arranged alongside of each other and inclining forward, at an angle of about 15 degrees with the vertical. The front and back rows of headers are connected by 4 in. solid drawn straight tubes fixed at the above angle, which form the bulk of the heating surface, suitable holes being bored in each header, in which the tubes are fitted and expanded. Opposite the end of each tube other holes are bored in the headers for sighting cleaning and renewing purposes, these being fitted with forged steel covers, the surfaces being truly milled in order that the joint may be made by metallic contact. Each of the headers, which are of forged open hearth steel, is made sinuous or "staggered," so that the tubes immediately above and below one another may not be in the same vertical line, thereby tending to make the heating surfaces of the tubes more effective when acted upon by the gases which pass up between them.

The tops of the front headers, which form the downtakes, are connected to the bottom of the steam drum by short lengths of pipe, which are simply expanded into suitable bored holes and bell-mouthed, whilst at the bottom of each header similar short tubes connect each to a square forged steel box, which acts as a mud drum.

The tops of the back headers, which constitute the uptakes, are connected to the side of the steam drum by horizontal solid drawn tubes, discharging the mixture of steam and water at about the water level, and against a baffle plate, which runs the length of the drum, being open at the ends in order that the steam may be the better freed from the aqueous particles. This steam and water drum, besides being fitted with priming pipe, stop valve, safety valve, gauge glasses, and provision for feed delivery is also fitted with wash plates to prevent the sudden rush of water from one end to the other when the vessel is rolling.

Immediately beneath the nest of tubes there is a furnace chamber of large capacity for the admixture of air with the gases, which therefore promotes a more efficient combustion. The gases from this chamber are guided by means of flat tiles and baffles of fire brick to pass amongst the back half of the tubes first, then deflected downward amongst the tubes towards the front, and finally rise up at the front part of the nest to the space formed immediately beneath the horizontal row of tubes from the uptake headers to the steam and water drum, and thence to the funnel. It will be noticed that the flue gases impinge upon the tubes tangentially, and do not glide along the tubes, consequently, on account of the better breaking up of the gases the greatest amount of available heat is extracted by the heating surface.

The sides of the furnace are formed either of ordinary fire bricks or fire tiles bolted to the side plates, and the whole is encased in plating fitted with non-conducting material, which keeps the outside casing quite cool. This boiler is also made with $1\frac{3}{4}$ in. tubes in the place of the 4 in., when, of course, more heating surface may be obtained than would be the case with the larger tubes.

In the next type of boiler—the "Yarrow"—we still have the same principle of the U tube, but instead of extending and multiplying the bottom part, as in the previous boiler, the sides are extended and multiplied, and the lower part suitably increased in area, the circulation being caused and maintained by the difference in temperature of the gases surrounding the inner and outer layers of tubes, the hotter tubes, which are also the first heated, being the uptakes. As is well known, this boiler consists of a large steam and water drum at the top connected to two smaller water drums at the bottom, one on each side, by nests of straight tubes, slanting outwards at their lower ends. The diameter of the tubes is about $1\frac{1}{4}$ in. for the larger boilers and about 1 in. for the smaller.

This boiler has been extensively used for torpedo-boat destroyers on account of its very light weight and simplicity of construction. In the smaller boilers all three drums are each made in two parts with externally flanged and bolted joints, thereby giving easy access for cleaning the tubes and also for expanding the tube ends if found necessary at any time.

Between the two water drums the furnace grate is laid, the whole being cased in, in the usual style, the gases from the furnace passing between the tubes and thence to the funnel.

In the later type, for large installations, the tubes next the furnace are made $1\frac{3}{8}$ diameter and $\frac{1}{8}$ thick, and are curved outwards, the outer tubes are $1\frac{1}{8}$ diameter and one-tenth thick, being kept straight.

All the tubes are bell-mouthed at the ends, and so assist the circulation and give a more substantial grip in the tube plates. There are gaps left in the nests of tubes next the furnace in order to ensure a better passage of the gases, and a few of the tubes at each corner of the nests are kept as downcasts, the furnace gases being kept clear of them.

We now come to that much heard of boiler—the Belleville—wherein the circulation is limited, and here, instead of having the sides or the bottom parts of our U tube multiplied as in the previous cases, we have the uptake leg consisting of a double row of $4\frac{1}{2}$ in. straight tubes seven or eight deep, inclined 2° or 3° from the horizontal; the two rows are inclined in opposite directions with the side by side tube ends connected by being screwed into sockets formed on cast steel horizontal junction boxes, and jambed by back nuts screwed up against the ends of the sockets, the threads on the end of the pipe and in the socket being slightly different; and thus each double row of tubes forms a continuous spiral passage from the bottom to the top of each section. The top junction box of the section is fitted with a short length of pipe with a conical end, which simply fits into a similarly coned hole at the bottom of the transverse steam drum. At one end of this drum a downtake pipe about $4\frac{1}{2}$ in. diameter is fitted, at the bottom of which is a settling chamber or mud drum, of about 10 in. diameter by 39 in. deep, where any solids are deposited, the feed water passing off by a short connection at the top of the chamber into the distribution pipe, which is about $4\frac{1}{2}$ in. square, and connected to the bottom junction box of each section by short lengths of pipes of about $\frac{3}{4}$-bore only, which are screwed into the top of the distribution pipe and fixed by coned ends into the junction boxes.

The working level of the water is about half way up the nest of tubes, and the steam that is formed in each section, together with the entrained water, is delivered into an annular space formed within the steam drum by a circular partition, and so passes around the drum, giving a centrifugal action, thereby tending to separate the water from the steam.

Above the nest of generating tubes and steam drum an economiser is now fitted with tubes of about $2\frac{3}{4}$ diameter, which, of course, greatly adds to the economical working of the boiler, the hot feed water from which enters at the end of the drum in the form of a finely divided spray.

There is the usual provision for the feed delivery on the drum and the priming pipe inside, through which the steam passes on its way to the reducing valve with which all these boilers are fitted.

The furnace grate is composed of the usual arrangement of bars, and the hot gases ascend vertically amongst the nest of tubes, the total distance travelled by the gases being lengthened by the use of horizontal baffle plates laid between the tubes.

The boiler casing is made of double plates, the space between being filled with non-conducting material.

Similarly arranged to the Yarrow boiler, but with bent tubes, is the Thornycroft boiler; but instead of the tubes entering the steam drum at the bottom, and being drowned, they enter the top of the drum and deliver into the steam space, the tubes being curved to a radius struck from about the centre of the fire grate, afterwards being curved back with a small radius, and finally curved around to the top of the steam drum.

In this boiler, however, there are large external downtake pipes, and the circulation is said to be such as to keep the uptake tubes full of a mixture of steam and water. Tube walls are formed on the inside and outside of each nest of tubes, there being left long triangular spaces at the bottom of the internal tubes and also at the top of the external tubes for the passage of the gases, which pass along the tubes, and not across, as in the previous boilers.

In grouping this type of boiler, the above arrangement is somewhat modified, in that two drums only are used, one above the other, the steam drum being, of course, the larger. The nests of tubes are straight for the greater part of their length from the bottom drum, and slant outwards as they rise, and then are curved around to the top of the steam drum, the downtake pipes being placed in the space between the nests, and are distributed throughout its length.

The four furnaces are placed on each side of the water drum, and extend for half the length of the boiler, the outer sides of the furnaces being formed by a tube wall; the bottom ends of the tubes are connected to a horizontal tube or small water chamber.

These boilers have a large heating surface and are used more for torpedo boats and small craft, but the same company manufacture the Thornycroft-Marshall boiler, which has recently been brought forward by the Boiler Committee, and which consists of headers arranged vertically in front, each pair forming an element with its horizontal layers of curved V shaped generating tubes and junction boxes, one leg of which is connected to each of the headers. At the top of each header a connection is made to the steam space of a drum, about 3 ft. diameter, and at the bottom of each header a connection is made to the feed distributing box, which is similar in arrangement to the Belleville, whilst downtake pipes are fitted between the steam drum and the feed distributing box. The tubes are $3\frac{1}{4}$ diameter, and can be inspected and cleaned from each end, where doors are fitted, the door in the junction box being common to the two tubes, and as the curve of the tube is slight, half of the tube can be seen from each end.

This boiler is also made with a stayed water-chamber in place of the headers.

We pass now to double tube boilers, or the Niclausse type, which consists of vertical headers, each header containing two rows of tubes placed zigzag, the tubes being slightly inclined and plugged at the back ends. Inside each of these tubes, placed concentrically, is an inner tube, similar to the tubes in a Field boiler. The headers are divided into a front and back part by a thin partition, the inner tubes forming the downtake receiving the water from the front of the headers, whilst the outer tubes deliver the water in the space formed at the back.

The bottoms of the downtake divisions are connected by a short length of pipe to a common collector which forms the blow-off pipe.

The tops of the headers are connected to the steam and water drum, which contains the usual baffle plates, and into which the feed water is admitted.

The inside and outside tubes are so connected with one another that both can be withdrawn at the same time.

The only difference between this boiler and the Durr is that the latter is not divided into sections but has a large flat water space with a partition to which all the generating tubes are connected.

Having now described most of the leading types of Water Tube Boilers as used for marine purposes, we glance back and take a general view of the changes which have been made in order to overcome the defects appertaining to the cylindrical type, and first we note that although the area of the surface of the water in some of these boilers is large, as it should be, the amount of water actually carried is considerably reduced, and that the quantity now required is divided up into small masses and surrounded by the hot products of combustion of the fuel, an arrangement conducive to the extraction of the maximum quantity of heat from the gases, and thereby raising the temperature of the water, which is such a bad conductor, as rapidly as possible. There is, however, one point to notice, namely, that with the high pressures the temperature of the water in the boiler must be high, and therefore the rate of conductivity is less than when lower pressures are used, and lesser still when steam instead of water is present in the elements, as in some types of boiler.

The velocity of the water through the tubes is much greater than in Cylindrical Boilers, as in water-tube boilers there is always a certain amount of "head" caused by the uptake tubes being partly filled with steam in addition to the small amount due to the slight difference of temperature of the water in the uptakes and downtakes. If, for instance, we take the Babcock and Wilcox boiler, where the vertical distance from the water level to the centre of the lowermost end of the lower tube is, say, 6 ft. 9 in., and allow that the boiler is working under proper conditions, namely, when the amount of steam evaporated is about equal to the amount of water discharged through the uptake tubes, or, what is the same thing, when the quantity of water discharged through the uptake tubes is a maximum, that is, when the uptake tubes are half full of water, then we have a "head" of 3 ft. $4\frac{1}{2}$ in., which gives a velocity of 14·7 ft. per second; but this of course is much reduced on account of friction. The velocity of water in the Belleville is, however, much less than this, owing to the constricted and tortuous passage through which it has to pass, and this, together with heavy and sudden changes of working, causes a doubt as to the actual level of the water in the boiler.

A great deal has been said about the bad effects caused by salt water getting into boilers of this description, and no doubt it is most desirable not to have any, especially in those boilers having the water level in the tubes instead of in the drum above them, but where the circulation is good, the tubes large and straight, or only slightly curved from the straight, salt water does but slight harm if the density is not allowed to increase too much, and, in fact, long voyages have been made with the use of salt water, after the first few days, and no damage has resulted.

The pitting of the tubes in the upper elements of the Belleville may be due to superheated steam being decomposed, the oxygen, combining with the iron, forming oxide of iron, and the hydrogen being left free, and not so much to the magnesium chloride splitting up and combining to form hydrochloric acid.

The steam from some boilers, notably the Belleville, passes through a reducing valve, being reduced, say, from 300 lb. to 200 lb. before passing to the engines, causing thereby a more even pressure to be maintained, together with drier steam, or steam slightly superheated, and therefore to some extent makes up for small steam space in the boiler, for when the space is small there is greater probability of obtaining wet steam than would be the case if the space were larger.

The steam, if perfectly dry on being reduced in pressure, would be slightly superheated, or if there was a certain percentage of water present the amount of heat liberated would evaporate the water in suspension. It is not, however, quite clear why a small steam drum should be employed, and for which it is necessary to add a reducing valve, as the extra pressure carried means that less heat is extracted from the gases on account of the less difference of temperature between the heating surfaces and the gases, and consequently more heat passes up the funnel than is necessary to maintain a sufficient draught to cause the required amount of air necessary for the combustion of the fuel to gain access to the furnaces.

The tubes in these boilers have the water circulating through them, and the gases passing around on the outside, so that any soot and grit deposited only covers a very small part instead of partially filling the tubes, as in the cylindrical type, and can be quickly cleared by means of a steam hose or with compressed air when such is obtainable. The scale on the inside may be easily removed by means of a tool formed with three spindles attached to a small turbine, the three spindles each carrying three or four chilled cutter wheels, the whole being fixed to a length of iron tubing which is connected to a pump by means of a hose. On pushing the machine through a tube and starting the pump the cutters open out and press against the sides of the tube, and the machine revolving cuts away the scale, which is washed away by the water.

As the tubes form the bulk of the heating surface, the only repairs likely to be necessary are the renewal of a few tubes, which can be readily obtained and fitted in a very short time; and unlike the cylindrical boiler, where sometimes half a row have to be removed in order to renew one, it is only necessary in most boilers to renew the one damaged. Tubes, however, last a considerable time, and the only repairs likely to be required are in the nature of a few fire-bricks and fire-tiles, although quite a different state of things exists with the Belleville, with its tubes fixed with screwed joints and its short nipple-pieces connecting the feed distributor to the headers and the headers to the drum, where leakage appears to take place so frequently.

All these boilers require regular and even firing, on account of the large grate areas, so as to prevent an excess of cold air from passing through the grates and unduly cooling the gases, and also that the tubes may be as equally heated as possible. There is also the additional advantage where there are two or more boilers that the feed supply does not require so much attention as would be the case if the furnaces were fired promiscuously and unevenly; in fact, in some installations the charges and the intervals between them have been carefully calculated for different rates of working, and good results have been obtained.

Steam may be raised from cold water in about half an hour without setting up any permanent defects, there being no riveted seams to leak or stays to fracture in contact with the flame or gases, and as regards efficiency in coal consumption the published results of steam trials which have taken place with the different types from time to time appear to show that the water-tube boiler can hold its own with the cylindrical type, and it seems very probable that in the near future this type of boiler will displace the cylindrical, not only in naval and passenger steamers, but also in the mercantile marine.

DISCUSSION

AT

3 PARK PLACE, CARDIFF,

ON

WEDNESDAY, FEBRUARY 25th, 1903.

CHAIRMAN:

MR. W. SIMPSON (MEMBER).

Mr. E. NICHOLL said Mr. Mills deserved their best thanks and the thanks of all the manufacturers of water-tube boilers, for his paper was full of interest, and especially after the paper recently read on the multitubular boiler, which had in some sense prepared their minds for what they had just heard. Mr. Mills is a bold and daring man, especially after the recent demonstrations.

1. In the first place Mr. Mills mentions the stresses set up in cylindrical boilers by bad circulation when getting up steam. Put in proper circulating arrangements, such as using the donkey pump for pumping the water from the bottom of the boiler through the blow down cocks and putting back through the feed cheeks, and all difficulty disappears. Of course this requires a donkey boiler, but nearly all vessels have one.

2. Then he mentions that the water in a cylindrical boiler cannot be changed quickly and the inside examined. Does he think that a cylindrical boiler is like the water-tube, unable to run a week without stopping for repairs such as renewing tubes? I should have to look through the log books of some steamers under my charge for years (I never remember a case) to find an instance of the boilers having been blown down at sea for repairs, and that on runs of twenty and thirty days.

3. I am glad to see that Mr. Mills agrees with me that thick plates increase the difficulty of making a good job.

4. Mr. Mills mentions that owing to the rapid circulation in water-tube boilers less scale forms. Now, as far as my information goes, this is not borne out by experience. Even in boilers like the Yarrow, where the circulation is admitted to be good and rapid, scale forms. I think it is an established fact that the more rapid the circulation the more steam will there be generated.

5. He gives some figures of the theoretical rate of circulation in a Babcock boiler, and if this were true in practice I have no doubt there would be far less trouble with tubes giving out, but unfortunately it is not so.

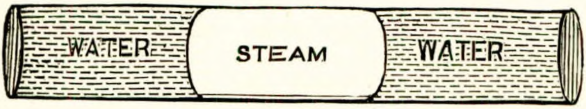
Now, if the water circulated equally through all the tubes, how can he account for numbers of tubes failing, many of which appear to have given out due to overheating. If I may judge by the frequency with which water-tube boilers appear in the reports issued under the Boiler Explosion Acts, and which may be obtained by anyone for a few pence, tubes giving out seems to be very common.

I call to mind the case of one of Messrs. Wilson's ships some few years ago, which was the subject of a report, and a more deplorable case I never read. (She was fitted with Babcock boilers). The vessel appears to have been knocking about the North Sea for days, and was eventually towed in short of coals. The trouble was all with the tubes in that case.

As I say, anyone interested in the subject of water tube boilers would do well to look up the reports I have mentioned, in which he will find some most interesting information.

Some of you will remember a previous paper read before this Institute on Water Tube Boilers, and Mr. Macfarlane Gray, during the discussion, pointed out that he had drawn attention to the defective circulation in water tube boilers some thirty years ago. With a number of tubes connected to one header, as in the case of the Babcock boiler, circulation might be one way in some tubes and the water stationary in others.

It has appeared to me that the cause of the burning of the tubes may be due and probably is due to this cause. Let us suppose that we have a tube exposed to intense heat, and circulation to be defective; the result would probably be that a cavity would be formed in the centre of the tube in which there would be nothing but steam, with the result that the tube gets overheated until too weak to withstand the pressure, and an explosion results.



This condition is, of course, more liable to take place in boilers with tubes nearly horizontal than with those vertical or nearly so.

In the case of an explosion from a tube on board H.M.S. *Terrible*, it was mentioned that the tube was salted up. Now this at first appears strange, seeing that the boiler density had not been above about 2/32, if I remember rightly; but if we take my assumption that a cavity was formed in the tube, I think we have an explanation of the salting, as follows: the tube would be red hot up to the water, and the salt would gather on the heated surface at the end of the steam bubble much in the same manner as we have salt formed on the outside of a boiler at a leak, due to the water being evaporated, and leaving the salt behind.

Then he says there is a doubt as to the level of the water sometimes in the Belleville. I think there is no doubt about it. I was told by a gentleman who had some experience with this boiler that the level of the water was not to be relied upon in any two parts, and it depended largely on the condition of the fires.

6. That pitting in the tubes may be due to the

causes mentioned is very probable, but is it not more probable that it may be due to free air going in with the feed water? I am well aware that by using feed-heaters and slow working independent feed pumps, the air is largely got rid of, but there still must be a considerable quantity yet in the boiler.

To obviate this difficulty, Belleville, in his original design before the economiser was introduced, put his feed into the steam space at a much higher pressure than the boiler was worked at—there was about 700 lb. in the pump against 300 in the boiler; this was done by restricting the feed opening into the boiler, about ½″ hole, I believe. By this means the air passed away with the steam and did not get into the tubes.

In the cylindrical boiler we have not so much chance of locking up any air, as it mostly rises to the surface and attacks the under side of stays, etc. Some of it gets into parts where the circulation is defective, such as beneath the combustion chambers at the back end of the boiler.

Mr. Mills states that the soot, etc., gathering on the surface of the tubes can be easily removed. Well, I have taken a little interest in water-tube boilers in case I should have the misfortune to have to do with them. I did not go to interested parties for my information, but to those who had experience with them at sea, and not in one instance did I get anything like a favourable reply.

This question of cleaning the soot off the tubes was one point. From what I could understand it was practically impossible to do it at sea and especially when the steam blower was used for blowing off the soot, for the moisture merely caked the soot. The efficiency of the boiler seemed to be fairly good for a few days, but when the tubes got dirty up went the consumption, and that, I believe, has been the experience in the Navy.

On trials of a few hours' duration the water-tube may hold its own against the Scotch boiler, but it has never yet done so in working for any time.

That the water-tube will displace the Scotch I do not believe for a moment, neither in passenger vessels nor in the mercantile marine. If it ever does it will be something very different from the present type.

Does Mr. Mills think that if the water-tube were even a moderate success the Cunard Company would stipulate for cylindrical boilers in the two fast ships contemplated? Surely Mr. Bain, their Superintendent, should have some knowledge of the water-tube after his experiences on the Boiler Committee.

The following, taken from the *South Wales Daily News*, is also very interesting:

"The return of casualties in connection with steam boilers in the British mercantile marine during the five years ending December 31st, 1902, has just been issued, and is, to say the least, of a startling character.

"According to the report there are 22,000 Scotch boilers in use in the mercantile marine, and 58 modern water-tube boilers, of which latter 11 have been removed and Scotch boilers fitted to replace them, which means that practically there are only 47 boilers of the water-tube type in the whole mercantile marine.

"Now comes the most vital part of the return. The numbers of casualties, persons killed, and persons injured per 1,000 boilers in use of the Scotch type were 4·32, 1·36 and 1·5 respectively. Coming now to the water-tube boilers, we find the following amazing statistics. There were 120·6 casualties, 86·2 persons killed, and 103·4 persons injured per 1,000 boilers in use. Not only does this return show the scarcity of the modern water-tube boiler in the mercantile marine, but it also shows in the most forcible manner the dangers incurred by its use. Such being the case, how can it be said with any sincerity that these boilers are suitable or safe for use in the Navy, where in time of war they would be subjected to a test which it is never necessary to apply on passenger or merchant ships?"

The water-tube boiler as at present constituted has not come to stay. The Navy begins already to discard it, the mercantile marine will never have it, and it is a lasting disgrace that so many millions should have been spent by putting in the Navy these boilers without a more thorough trial.

Mr. I. T. SHELTON (Member) said, while he did not lay claim to practical experience of the water-tube boiler, he believed that it had not been found that, with its use, there was any decrease in coal consumption, and that the principle feature of commendation was the capability of raising steam quickly. He agreed with Mr. Nicholl that the water-tube boiler had not come to stay in its present design, and that as yet it was an expensive tool and gave a great deal more trouble than the cylindrical boiler when well fitted.

Mr. D. ROBERTS (Member) advised a suspension of judgment with regard to the water-tube boiler, and asked them to remember how many years it had taken to bring the Scotch boiler to its present stage of development. He should like to ask Mr. Mills if he had any information regarding the steamers of Messrs. Wilson to which Mr. Nicholl had referred. He had some recollection of a statement being made in Parliament by Mr. Wilson which seemed to justify the water-tube boiler, though not the Belleville type. A great objection urged against the water-tube boiler was on the score of upkeep, but he believed Mr. Wilson's speech went to show that in this respect the water-tube boiler compared very favourably with the Scotch boiler. The question of the amount of water for steaming purposes in the boiler depended more upon its distribution than upon the actual quantity. In the Scotch boiler it was absolutely necessary to carry a large quantity of water to maintain a comparatively small quantity above the highest point of heated surface—in other words, the top of the combustion chamber might only have a few inches, while there would be 6 ft. or 8 ft. of water in the boiler. In the improved type of water-tube boiler the tubes were drowned, and connected with the steam drum below the water level. He believed the principle of the Belleville was a mistake, inasmuch as the tubes were too near the horizontal to permit of anything like a rapid circulation. With regard to Mr. Nicholl's remarks about the air, he believed that the question of superheated steam should not be overlooked in connection with the fitting of tubes. Altogether, he thought the experiments made by the British and German naval authorities tended to show that the large types of water-tube were more economical in up-keep and steaming power. There were accidents, of course, one reason for which was that the makers had not quite realised the kind of tube that was required. They had had the same trouble with the cylindrical boiler.

Mr. R. DAVIDSON (Member) said there was no doubt that the present unsatisfactory reputation of the water-tube boiler in the British Navy was largely due to the type chosen for the first installation. With regard to weight and water-space, the water-tube boiler showed to decided advantage. With regard to pressures, the water-tube had a very wide margin, in comparison with the Scotch boiler, having started where the limitation of the cylindrical had been reached. He did not see any solid advantage in the ability to raise steam in, say, half-an-hour, so far as the merchant service was concerned. Any slight saving of coal which might be obtained in getting up steam was lost through banking. He should like to ask if Mr. Mills knew of cases in which auxiliary boilers had been of the water-tube type—say, the donkey boiler to supply steam to winches in a large cargo boat, working intermittently. As to weights, given a certain heating surface, 14 ft. 6 in., what would be the comparative weights of a Scotch and, say, a Babcock & Wilcox water-tube boiler?

Mr. HENRY recalled the time—about two years ago—when the water-tube boiler was known in the Navy as the "Hell Fire" boiler, because of the liability of tubes to give out. The correspondence which Mr. Mills had read as to the celerity with which defects could be remedied, seemed to indicate that this liability still continued.

Mr. MILLS said the instances quoted had reference to intentional tests, and not to accidents.

Mr. E. W. SYDENHAM (Member) said as an officer in the Navy he was not permitted to express opinions upon specific types of boilers, but he might say he had had experience of water-tube boilers continuously running for twenty days out of the month, and had never known them choked with soot. The undoubted strategic advantages of the water-tube over the cylindrical boiler for the Navy made him hope that the present drawbacks to the former might be speedily overcome. With regard to casualties to water-tube boilers, and the figures which had been quoted from a newspaper, there were various matters to be considered. The five years referred to were years in which were conducted many and continuous experiments, and he was quite certain the percentage would be very greatly reduced in the future. He ventured to think that if they compared the water-tube boiler casualties with those of the Scotch boiler in its infancy, the comparison would not be unfavourable to the former.

Mr. SCOTT said, in compliance with a request made at the last meeting, he had brought for inspection the model of a boiler he had patented, for which he claimed reduced weight and also a complete circulation, which made the bottom of the boiler equally as hot as the top, from the commencement of the fires, enabling steam to be raised in the quickest possible manner.

Mr. ROBERTS: Mr. Scott's boiler is a modified water-tube boiler.

Mr. SCOTT: It is really half-way between the two.

Mr. GEORGE SLOGGETT (Hon. Local Secretary) said he agreed with Mr. Sydenham and other speakers that the water-tube boiler ought to be more thoroughly investigated and developed. For certain purposes its advantages were undoubted. He related some of his experiences with water-tube boilers on torpedo-boat destroyer speed trials.

The CHAIRMAN said it was in the matter of boilers they had to look for future economies rather than in engines, and they, as an Institute of Marine Engineers, could not discuss the question too fully. He considered the water-tube boiler was the boiler of the future, although its present design must undergo many modifications.

On the proposition of Mr. ROBERTS, seconded by Mr. SCOTT, it was resolved to adjourn the discussion, and the meeting closed with a vote of thanks to the Chairman.

DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, MARCH 23rd, 1903.

CHAIRMAN:

MR. J. R. RUTHVEN (MEMBER OF COUNCIL).

The CHAIRMAN said he hoped there would be a good discussion, as Mr. Mills was present, and would answer questions on any points that he had not made clear to them. Mr. Mills had gone over all the well-known types, but he considered they could not know too much about the water-tube boiler, especially as it was being fitted so very largely in the Navy.

Mr. JAMES ADAMSON, the Honorary Secretary, then read a communication on the subject from Mr. D. DONALDSON (Member), in which that gentleman said: Mr. Mills has given us an interesting, but on the whole, I would say, rather one-sided paper, in favour of the water-tube boiler, as he has omitted to state its many disadvantages, which undoubtedly are numerous, otherwise we would see more of them in use on board steamers at the present day. Dealing with the first part of the paper, I am sorry he has omitted to mention the "Stirling" boiler among his list of the best boilers on the market. There is no need for me to give a description of that boiler, as I have no doubt but that it is known to most of the members present; but I may say that I think it is one of the most suitable, and will stand the severe tests put upon boilers in the Navy, although, as far as I know, it has not had the opportunity of standing that trial as yet. Further on, Mr. Mills makes mention of pitting in the "upper elements" of the Belleville boilers being due to oxide of iron formed from the decomposition of superheated steam. I cannot say I have heard of much complaint of pitting in the "upper elements" of the Belleville boiler, but certainly there was a lot of trouble in the Navy with the economisers of these boilers, due to pitting, yet I think I am safe in saying that that is a thing of the past, at least in vessels where the chief engineer is really anxious for the welfare of the Belleville boiler. This defect was remedied by fitting lime tanks in all vessels fitted with Belleville boilers, which proves that the pitting was due to the presence of chlorine, thrown off from the magnesium chloride, combining with hydrogen and forming hydrochloric acid, the excess of lime introduced combining with the chlorine and forming calcium chloride. I doubt very much if Mr. Mills is correct in his statement that the velocity of the water due to circulation is better in the Babcock than in the Belleville boiler. The water in the Babcock boiler has to pass and try to force its way through a column of water quite equal in height to that in a cylindrical boiler, for it cannot be said that it has an equal velocity of flow through all the tubes, and the water in the bottom rows of tubes close to the furnace is partly converted into steam which cannot get away fast enough, and I have found that whereas the Babcock is an excellent boiler, giving very little trouble under natural draught conditions, with forced draught and heavy fires the bottom tubes do not, as a rule, last very long. This defect is not apparent in the Belleville boiler, although one cannot correctly speak of a circulation of *water* in that boiler at all, as under forced draught, say four inches of water pressure in the stokehold, which is common in the Navy, and which I question if the Babcock will stand at all efficiently, the circulation in the Belleville is so rapid that it is a mixture of steam and water rushing through the tubes, which gains heat as it rises, instead of losing it, as is the case in the Babcock, as it has no column of water colder than itself to force its way through. As regards repairs, Mr. Mills states that in the case of the renewals of a tube being necessary, in most water-tube boilers it is only necessary to renew the defective one, and that this is a merit over the cylindrical boiler. For my own part, I would undertake to put a permanent stopper in a tube of a cylindrical boiler and get under way again as quickly as replace a tube in any water-tube boiler. There are only two or three water-tube boilers, so far as I know, where the replacement can be efficiently or expeditiously carried out, should the defective tube be anywhere but in the first or second outer rows, without disturbing any of the others. These are the Belleville, where the element has to be drawn out before the tube can be replaced; the Stirling, where there are only four rows abreast and the tubes are so spaced as to overcome this difficulty; and the Niclausse, where any tube can be drawn and replaced, irrespective of its position. I know that in practice those in charge of the Babcock boiler do not hesitate to cut out the lower or upper tubes in line with the defective one, and there is more skill required to carry out the work of replacement quickly and efficiently than in the case of a cylindrical boiler tube.

In conclusion, I do not hesitate to say that it will take a very good man, with very good coal as well as good draught, to raise steam up to working pressure from cold water, in any water-tube boiler of size compared with the average cylindrical in use, as regards steaming power, in the short time of half an hour, with the exception of the Belleville boiler.

But, with its many defects, I feel certain that the water-tube boiler will become more general in the mercantile marine, as there are none of these of a very serious nature, and they are generally looked upon as far worse than they really are; while the gain effected by less displacement for equal boiler power will in course of time be realised by shipowners.

The CHAIRMAN remarked that at a previous meeting, when a Paper on cylindrical boilers was read, one gentleman (Mr. Sinclair) raised a question about the water-tube boiler. Mr. Sinclair had said that so far as his experience went he was assured it was heavier, occupied more space, and cost a great deal more money. He apparently had no doubt about its economy as a steam producer, although that was a point that would be worth going into. He would be very pleased to hear some more questions raised; they ought to make it as full a discussion as possible.

Mr. W. LAWRIE said he thought it would have materially assisted the discussion if Mr. Mills had brought his Paper more up-to-date, in regard to the experience that had been gained by the use of the water-tube boiler during the last two or three years, instead of giving a description of the boilers and getting into the old groove where they were before. In the opening sentences the author had said: "Within the last few years great prominence has been given to the question of water-tube boilers, principally, no doubt, on account of the trouble arising from the use of the Belleville boiler in the Navy." They heard more of the Belleville boilers later on in the Paper, but as to its actual work he gave them no guidance. He thought that everyone who had followed the course of experiments that had been made in the Royal Navy must have learned some lessons from what had occurred and what they had accomplished. He rather thought that the net results of the working of the Belleville boiler in the Navy had justified the action of those members who had opposed its introduction into H.M. ships. The Admiralty commenced their experiments in 1893, and now in 1903 they were still experimenting, and about the only thing they had done so far with the water-tube boiler was to squander a vast amount of money, and in that operation they had crippled some of the finest vessels in the British Navy. Whoever was responsible for such a state of affairs ought to be brought to book. It was rather a serious matter for the nation. He considered those responsible should be severely dealt with, for they had not acted without being very much warned. When the Naval Estimates were brought before the House of Commons in 1894, such men as Sir A. B. Forwood, Mr. E. G. Harland, and Mr. Penn opposed the introduction of those boilers into the Navy, and some consideration ought to have been given to their views. They ought not to have rushed madly and blindly into the matter, as had been done, whereby they had crippled fifty or sixty of the finest ships, all for the want of a little common sense. He did not want to say too much about the Belleville boilers—they seemed to him to be something in the nature of "automatic fire-sprinklers," and what good purpose they served he did not know. How was this to be stopped? The member for West Ham had said that members of Parliament were very busy men, and they must not approach them until they had everything boiled down to a kernel. They would find that technical experts were not agreed, and until they could agree upon a particular boiler it was no use going to the House of Commons. It was a very poor state of affairs when a member of Parliament talked like that. He thought the engineer ought to speak a little louder and make himself more heard. There were certain paragraphs in the early part of Mr. Mills's paper wherein he dealt with the demerits of the cylindrical boiler. According to Mr. Mills the cylindrical boiler had no merits at all. The author said that "in the cylindrical boiler a large mass of water has to be heated." The cylindrical boiler required more water than the water-tube boiler, and if it could be proved that they could produce and maintain steam as economically with the smaller body of water required by the water-tube boiler as with the larger amount used with the cylindrical boiler, then by all means he would say, use the smaller quantity. But they could not consider the boiler apart from the fuel it consumed. Regarding the question of economy, he did not think it could be put forward that the Belleville was a very economical boiler. He was of opinion that the author did not consider that particular boiler to be economical, because he had shunted the question entirely. In the last paragraph of his paper Mr. Mills said "as regards efficiency in coal consumption the published results of steam trials which have taken place with the different types from time to time appear to show that the water-tube boiler can hold its own with the cylindrical type." He (Mr. Lawrie) thought that was rather a weak assertion. He considered the author should let them know where to look for those published results. What they were he did not know. If he referred to a two or three-hours' trial with a new boiler, using picked coal, and with the contractor's men on board—well, they all knew the value of such a trial. Take the case of the *Hyacinth* and *Minerva* trials. On the outward passage there was no result, but on the run home from Gibraltar to St. Catherine's Point the Belleville boiler had the start, owing to getting up steam quickly, but they did not get to St. Catherine's first. The *Minerva*, fitted with cylindrical boilers, arrived off St. Catherine's Point one hour twenty minutes ahead of the *Hyacinth*. In that run home the water-tube boilers burnt 550 tons of coal, against 451 tons burnt by the cylindrical boilers. He had heard of tests to show that those water-tube boilers burnt no more coal, evaporated more water, and were better boilers, but when they came to put them on a station they told a different tale. He thought the report of the Boiler Committee would also bear out the fact that the water-tube boilers were not the most economical. On page 15 of that report it was stated that "from the evidence before the Committee it appears that no type of water-tube boiler at present in use is, on general service, as economical as the cylindrical boiler." Those were about the only published statements that he knew of. There was one little complaint he ought to make. He had already said that the Paper was not up-to-date in some results. At Cardiff Mr. Mills had given some figures, and he thought they ought to have those figures that night. In the same paragraph in which the author had said that with cylindrical boilers a large mass of water had to be heated, he also stated "that a long period has to be allowed to raise steam." He (Mr. Lawrie) had seen steam got up very efficiently and without trouble in a cylindrical boiler in three hours, the machinery being between 7,000 and 8,000 h.p.; they were ready for steam by the time the engines were warmed up. Even supposing they could get steam up quicker, what was the advantage? In what vessel of the mercantile marine would they leave the getting up of steam to the last hour? The gain was hardly worth talking about. Mr. Mills also complained that with the cylindrical boiler the circulation was bad; he said it "is more or less confused, according to whether the boiler is forced or not, or whether the fire in one furnace is brighter than the others, etc., which must necessarily tend to priming." He (Mr. Lawrie) did not understand that they could not drive a cylindrical boiler without priming. In his experience he had seen cylindrical boilers driven for all they were worth, and as a rule the engines would take more steam than the boilers could give them. When crossing the Atlantic they never spared a minute, and on the voyage home they had to distil water for 600 head of cattle, but they took it out of the feed-water of the boiler; that showed how clean it was. He took out the boilers he had just referred to, and they were twenty years old. He thought when they came to have boilers that could stand a test like that, it was about time for them to be shown whether the water-tube boilers were going to be more useful or not. Then, with regard to repairs, Mr. Mills had said: "The repairs to these cylindrical boilers have to be effected by skilled workmen, and are frequently of a very costly nature, and occupy a considerable time." They must think of the work they had to do; they had a certain amount of fuel, and from that fuel they had to extract a very fierce heat. That heat played on the iron or steel plate, and they could not put a fierce heat on the plate without punishment, and they were obliged to renew it and make it good again. He would not go into the expense connected with the Belleville and cylindrical boilers, although he thought it would be as well if members only looked up the cost of some of the Belleville boilers in the Navy. He would only take four examples out of the lot, and they were neither the best nor the worst. The *Hyacinth*, of 10,000 I.H.P., had been running one year nine months, that was twenty-one months in actual commission, and the total cost of her boiler repairs was £6,393, or £304 8s. 7d. per month. Some of those repairs were put down to alterations, but they all knew what that meant. The second-class cruiser *Highflyer*, of 10,000 I.H.P., had been two years six months, or thirty months, in actual commission, the total cost of repairs to boilers in that ship amounting to £1,705, or £56 16s. 8d. per month.

Both those vessels were fitted with water-tube boilers. With regard to warships fitted with cylindrical boilers, the second-class battleship *Minerva*, of 9,600 I.H.P., had been three years two months, or thirty-eight months, in actual commission, and the total cost of repairs to her boilers amounted to £1,228, or £32 6s. 4d. per month. It must not be forgotten also that the *Minerva* was a much older vessel than the *Hyacinth*. The first-class battleship *Majestic*, also fitted with cylindrical boilers of 12,000 I.H.P., had been six years five months, or seventy-seven months, in actual commission, and during that period her boiler repairs amounted to £3,707, or £48 2s. 10d. per month. If they considered the difference in the cost of maintenance of those boilers they would see that so far as the water-tube boiler was concerned—and so far as they had information on the subject—it was all in favour of the cylindrical boiler. He would just mention the *Hermes*, which was in commission one year two months, and cost £40,863. That sum included an amount of £32,400 for new boilers for the vessel. The only vessel he noticed in the return that showed a record for low cost with the water-tube boilers was the *Cressy*, which was in commission for one year, the cost for repairs, etc., to boilers in that ship only amounting to £149. Those tables showed that the cylindrical boiler was very much cheaper than the other in the matter of repairs. In another paragraph the author said: "The water in these (cylindrical) boilers cannot be changed, the inside examined, and steam again raised in a comparatively short time, without unduly straining them." He (Mr. Lawrie) thought the author ought to make his meaning clearer. Did he mean to infer that they had not time in port to clean their boilers? If so, he could not agree with him. The cylindrical boilers, as a rule, did their work in a proper, business-like manner; they went from port to port and did not require to be blown down. He thought the cylindrical boiler could be cleaned when necessary. In the next paragraph Mr. Mills stated that "the weight of the (cylindrical) boiler and the large amount of water carried detracts from the earning powers of the vessel." That had been a moot point for a long time; it was one of the points that had been raised by the chairman at the beginning of the meeting. At the time when the Naval Estimates were before the House of Commons, Sir A. B. Forwood gave them the comparative weight of water-tube and cylindrical boilers. In the matter of weight he considered that the cylindrical were just about as good as the water-tube boilers. He would like to make another quotation from the Boiler Committee's report. On page 8 it was stated that "the additional evaporating plant required with Belleville boilers and their greater coal consumption on ordinary service, as compared with the cylindrical boiler, has hitherto nullified to a great extent the saving of weight effected by their adoption, and, in considering the radius of action of ships fitted with them, no real advantage has been gained by their use. The Committee cannot say, however, whether this may not apply to other types of water-tube boilers; this can only be determined by extended experience." He had seen that the water-tube boiler had never been considered as much of a saving in weight, and he was of opinion that they covered more floor space than the cylindrical. It was a remarkable commentary that engineers should use a boiler possessing no good points! When Mr. Mills came to sum up the faults of the water-tube boiler, they appeared very trifling. He said it was most desirable not to use salt water, but he went on to say that it did but slight harm if its density were not allowed to increase too much. He (Mr. Lawrie) did not quite follow that reasoning. There were other good qualities put forward for these water-tube boilers. They were told how economical they were, and also that they did not get very dirty on the tubes, like the tubes of the cylindrical boiler. He was a little astonished to hear any engineer talking in that way. A great point had been made of the fact that they did not require a great deal of water with the water-tube boiler, that the water was divided into small quantities, and that the circulation was well maintained. That was one of the troubles with the water-tube boiler, and he was afraid they were trying to get too much power out of too little water. If the boiler were to work satisfactorily they must arrange that the feed and evaporation balanced and synchronised each other. If they happened to get more feed water than the evaporation was taking away they would get priming; or if, on the other hand, they got too little feed water into the tubes they would get the tubes hot. Thus they would see that the water-tube boilers had their drawbacks. He made some inquiries of the manufacturers of water-tube boilers some two or three years ago, but they did not furnish him with much information. The disadvantages of the Belleville boiler compared with the cylindrical boiler, as summed up in the report of the Boiler Committee, were: (*a*) the circulation of water was defective and uncertain, and the water gauges did not indicate the amount of water in the boiler (those causes had led to serious accidents); (*b*) an automatic feeding apparatus of a delicate and complicated kind was necessary in order to make the safe working of the boiler possible; (*c*) a great excess of pressure over that in the boiler was required in the feed pipes and pumps; (*d*) a considerable excess of boiler pressure over the working pressure at the engines was necessary; (*e*) the quantity of water in the boiler varied at different rates of combustion, although the same level might be shown on the water gauges; (*f*) separators with automatic blow-out valves on the main steampipes were required in order to provide for water thrown out of the boilers when the rate of combustion or the speed of the engines was suddenly increased; (*g*) a constant and excessive loss of feed water; (*h*) the upper generator tubes were liable to fail by pitting or corrosion, and, in economiser boilers, the economiser tubes were still more liable to fail from the same cause. The trouble from that cause had diminished recently, but the liability of those parts to corrosion still existed, and must be regarded as a serious disadvantage; and (*i*) the upkeep of Belleville boilers had proved to be exceedingly costly, whereas that of cylindrical boilers was trifling, and that disproportion was likely to increase materially with the age of the boilers. On account of the necessity for more repairs, ships with Belleville boilers would be laid up more frequently and for much longer periods than similar ships with cylindrical boilers. They had heard a great deal of the small quantity of water used in the water-tube boilers, and what a saving it was. In that room they had been told of a case where the tubes had even run dry before anyone discovered it. Also, they had heard of the necessity sometimes for those on deck to let the engineer know that there was a blow in the boiler; in that case they were absolutely ignorant of the trouble below. He would like to read the Board of Trade return of the casualties of water-tube boilers in the mercantile marine. Safety was the great point. There were 22,000 Scotch boilers in the mercantile marine, and fifty-eight water-tube boilers, and the casualties, per thousand in use, of the Scotch were 4·32, whereas the proportion of casualties in the water-tube would work out at 120·6 per thousand in use. The number of men killed per thousand in use with the Scotch was 1·36, but with the water-tube it was 86·2. The number injured per thousand in use with the Scotch was 1·5, whereas with the water-tube it amounted to 103·4. He considered that up to the present those who had advocated the water-tube boilers had not proved their case; if they proved their case he would be willing to have it. He did not think there was one engineer in a thousand who would stand in the way of improvement, although they had been told that prejudice was against the adoption of water-tube boilers. He thought the figures he had given them would prove that the Board of Trade was right, and he was sure it was the wish of the Institute of Marine Engineers that the best boiler should carry the day, and that it would do, whatever their individual opinions might be.

Mr. S. C. SAGE said his experience had been entirely with the cylindrical boiler. He might be said to be an advocate of that type of boiler. There was one point they had yet to learn, and that was the durability of the water-tube boiler, as to which he was afraid he would never live to see what he had seen that day, and that was a cylindrical boiler, exactly twenty-five years old, still working in a collier vessel. A collier steamer was supposed to get about as severe work as any of their merchant steamers. The twenty-five year old boiler to which he had referred was now working at its original pressure under Lloyd's classification. During those twenty-five years it had had one of its furnaces renewed. It was now going through its special survey No. 3, and he was confident that it would continue working at its original pressure for another four years. He doubted whether twenty-five years hence any water-tube boilers that were now being installed would be in existence, or even any part or particle of them, let alone working at original pressure. In the mercantile marine the question of weight and space occupied was important in a pecuniary sense, but it was much more important in warships, on account of the armament and other parts. He thought it had not been demonstrated that there was any advantage with water-tube boilers in the matter of weight. In the mercantile marine they were not so particular as regards space occupied; there was plenty of room about the boiler. It was the weight they should save, and he thought that was a very important consideration in a warship. The question of cost was also an important consideration, and while they, as engineers of the mercantile marine, should give every attention possible to the war vessels of the

Empire, they were more concerned with the vessels of the mercantile marine. He thought that the figures quoted by Mr. Lawrie showed very distinctly that their merchant ships had not taken kindly to water-tube boilers of any type. He thought that the sooner those responsible for the machinery in their war vessels again followed the fashion set them by the mercantile marine the better it would be for them as a nation. The Navy was many years behind the mercantile marine in abandoning the horizontal type of engine; in fact, there were still engines of that type in use in the Navy. Without wishing to take too much credit to themselves as engineers of the mercantile marine, he was of opinion that the sooner the engines and machinery of their warships were constructed, managed, and engineered generally on the same lines as those of their merchant ships the better it would be for the country.

Mr. C. W. MURRAY said he thought the author of the paper deserved the thanks of all progressive engineers, and, as one speaker had already observed in the discussion at Cardiff (although perhaps the remark was sarcastic), the thanks of all water-tube boiler manufacturers. The latter welcomed papers of that kind, especially when so admirably prepared and with opinions so clearly and temperately set forth as in the present case. Discussions on the water-tube boiler question could not be too thorough. With the concluding remarks of Mr. Mills' paper he entirely agreed. The water-tube boiler could, and did —at least one type—hold its own with the cylindrical, and more than that, possessed many advantages which the cylindrical could not claim. To that conclusion he had been driven by the logic of facts, and although his association with a well-known firm of water-tube boiler manufacturers might be held by some to discount any expression of opinion he might advance, he must be allowed to say that in the experience which had led up to his present belief had been included the design, construction, and maintenance of the cylindrical as well as other types of water-tube boilers. His remarks that evening would be confined to only one of the water-tube types which Mr. Mills had described—the Babcock and Wilcox. The demerits of the cylindrical type, as enumerated by the author of the Paper, might be briefly summarised as follows: (1) Bad circulation; (2) inability to raise steam rapidly without causing excessive strains; (3) costly nature of repairs; (4) great weight in proportion to steam produced; and, (5) liability on occasions to prime. To these might be added: (1) Want of facilities for thorough cleaning; (2) difficulty of transport; and (3) necessity for expensive opening up of shipwork when boilers had to be renewed. How did the shell boiler compare with the Babcock and Wilcox as regards circulation? In shell boilers no one could define what the circulation was—many experiments had been made, and he thought he was right in saying that with every variation of the firing, currents were set up in the boiler which impeded each other's progress—that meant they had a condition of things which tended to produce priming. In the Babcock and Wilcox boiler it was found that immediately the fire was lit the circulation began in a perfectly natural direction, and as the heat increased the circulation was simply quickened, running in the same direction. The more they forced the boiler the drier the steam became, because the circulation was in one direction. He had never known an instance of priming. Exhaustive tests had shown that under normal conditions the steam in Babcock and Wilcox boilers contained less than 1 per cent. of moisture—he did not think that in the cylindrical type they could, under normal conditions, ever get steam with a percentage of moisture of less than 1 per cent. With regard to the time required for raising steam in big cylindrical boilers—such as at one time he had under his charge—he thought it would be admitted that even when hydrokineters were fitted or feed pumps used to produce a circulation, six hours was not too long a time to allow for raising steam from cold water, and that, of course, pre-supposed that there were other boilers or a boiler at work in the ship to produce the steam for working the hydrokineters or driving the feed pumps. In the Navy, although perhaps not so much in the mercantile marine, raising steam rapidly was often of great importance, and under certain circumstances —especially in the case of ships on active service—it might be of vital importance. Two or three hours' delay in a squadron, or even a single ship, might make all the difference between success and failure. In that connection it might be well to quote Admiral Melville, the engineer-in-chief of the United States Navy. Admiral Melville had said: "The fact that water-tube boilers raise steam quickly is of the greatest importance. I have stated elsewhere that I consider the battle of Santiago to have developed the necessity of the use of water-tube boilers, whether it taught us anything else or not. It would have been of the greatest advantage to have had, during the blockade of Santiago, boilers capable of raising steam in less than half-an-hour. Coal need not have been used to keep the boilers under steam all the time; the *Massachusetts* might have shared in the glories of the fight if she had been fitted with water-tube boilers; the *Indiana* would have kept up with the *Oregon*, the *New York* would have developed at least three knots more speed, and the Navy would have been spared a controversy. I think the *Colon* would not have got so far away as she did. But we did not have water-tube boilers." In the merchant service one might recollect occasions where delay had been productive of serious inconvenience, and he thought that in claiming facility for raising steam rapidly as an important quality, most progressive engineers would admit that the validity of the claim was established. How long did they take to raise steam in a water-tube boiler? That, of course, depended somewhat upon the construction of the boiler and the amount of water it contained. The Babcock and Wilcox

Company had made several tests to determine this, and the data relating to one of these tests might be of interest. The boiler was of the marine type, and had a heating surface of 2,640 square feet, and a grate surface of 63·25 square feet. The temperature of the water in the boiler was 72°, and the height of the water in the gauge glass one inch. From the time the match was applied, exactly five minutes elapsed before steam was formed; 125 lb. of steam was showing in the gauge at eleven minutes from the start, and the full working pressure of 215 lb. in twelve minutes 40 seconds from the start. An examination of the boiler after the test showed no injury or change in its condition in any respect. It might be observed that as it would take much longer to warm up the machinery in the engine-room, such rapidity in raising steam was not of much real advantage, but it was quite obvious that the quicker they could obtain steam the quicker they could start warming up the engines. Besides having the ability to raise steam rapidly, the Babcock and Wilcox boiler could be cooled with equal rapidity, and quickly examined and repaired, if repairs were necessary. That could not be done in the case of the Scotch boiler without causing leaky seams and tube ends. As most of the engineers present that evening were practical men they must know that the Scotch boiler was not the paragon of perfection that it had been claimed to be during the last few months, especially at discussions as to its merits in comparison with the water-tube boiler. In giving them examples of the durability of the water-tube boiler, he would supply the names of the vessels, so that they could verify his statements for themselves. From these examples they would see that the water-tube boiler did not deserve all that had been said against it that evening. The steamer *Zenith City*, equipped with Babcock and Wilcox boilers in the spring of 1895, had, at the completion of the season of 1900, travelled a total of 300,000 miles. The total cost for repairs to each boiler at the end of the fourth year amounted to

35 dollars, which sum was expended as much on repairs to boiler fittings as to the boiler proper. At the end of the fifth and sixth years no repairs were needed. The steamer *Charles Nelson* was fitted with these boilers, and the owner stated that the steamship "has been in constant and active service at sea upwards of 34 months, and the boilers have given good satisfaction." There had been no expense whatever for repairs, and the boilers were in good condition. They had shown an excellent economy and furnished plenty of steam, using the various Pacific coast coals. The *Nelson* had made good passages to and from Manilla, on two occasions equalling the average time made by the United States army transports. Concerning the steamer *Dirigo*, boilered at the same time as the *Nelson*, her owners said she had been on active service for the same number of months, and the results obtained warranted their installing two similar boilers in the steamer *John S. Kimball*, one in the steamer *Archer*, and ordering another for a steamer under construction. At the expiration of a 12,000 mile voyage from Boston to Cavite, the boilers of the United States gunboat *Marietta* needed only a few grate bars. That run was in addition to the war service of the little vessel, and the memorable trip around the "Horn" in company with the battleship *Oregon*. After spending the winter and spring of 1899 on the Atlantic coast, the cruiser *Chicago* made a trip around Africa, returning to New York *viâ* South America, and stopping at Rio Janeiro. The total distance travelled was 35,000 miles, and on arrival she was able to proceed at once to Buenos Ayres, as there was nothing to do to her boilers. The gunboat *Annapolis* had steamed 62,000 miles, and no repairs had been made. The steamer *Queen City* completed at the end of the season of 1900 a total of 250,600 miles, and no repairs had been made on her boilers. The steamers *Alex McDougall* and *Presque Isle* had each carried about 430,000 tons of iron ore, steaming a distance of

130,000 miles. One tube, due to an original imperfection, had been renewed in the boilers of the *Alex McDougall*; the *Presque Isle* had needed nothing. It was a significant fact that vessels equipped with Babcock and Wilcox marine boilers rarely find it necessary to call in the services of a shop boiler-maker. After the recent war with Spain it was found necessary to renew the furnaces of the battleship *Indiana*, requiring the services of not only the New York yard, with its gang of boiler-makers, but the furnaces had to be corrugated in a particular shop. All this detained the ship at the yard for four months. Had the *Indiana* been equipped with, say, ten water-tube boilers of the straight tube type, the tubes being expanded into place with ends accessible, the first three rows over the fire might have been removed and replaced, where blistering or burning had taken place through oil or salt in the feed, or from any other cause, and repairs made entirely by the ship's engine-room staff in not more than three weeks' time. One of the largest firms shipping ore from Lake Superior, equipped, a few years ago, a new 6,000 ton freighter with water-tube boilers, and when asked what they considered one of the greatest advantages attained by the use of these boilers, replied, "We can load our vessels at the rate of a thousand tons an hour and unload them almost as quickly. This means that our stay in port is only a little over six hours. In that time we can blow a boiler down, make a joint on boiler steam piping, grind in a leaky safety valve or renew a tube ; can refill and have full steam and be ready to sail for destination as soon as the ship is loaded, and yet have no fear of straining the boilers from unequal expansion in getting steam quickly. With our old cylindrical boilers we would just about have them cooled off ready to work upon by the time the ship was loaded, and the rest of the time occupied upon the repairs, refilling, and slowly raising steam, meant detention of the ship and loss to us." On the great lakes of North America the water-tube boiler was used to a great and constantly growing extent. There freight was carried cheaper than on any body of water in the world, and the commercial success in the adoption of the Babcock type was an assured fact, and one of the strongest points in the claims for its advantages. Something had been said that evening about weight, and he took it that no one would controvert the fact that excess weight reduced carrying power. The saving in weight with water-tube boilers was indisputable. It was often pointed out that the weight saved by the introduction of water-tube boilers was annulled by the extra amount of coal which had to be carried owing to the economy in consumption of coal being less than in the Scotch type. He would point out, however, without referring to the question of economy for the moment, that there was a far greater saving than the mere difference in the weight of the two types of boilers. M. Normand demonstrated, at a meeting of the Naval Architects some years ago, that in vessels where the constant weight to be carried, as imposed by the conditions of the case, such as cargo in high speed steamers, was small in relation to displacement, any saving in weight conduced to a decrease of displacement more than four times greater, the speed and time of steaming remaining the same. For instance, if through the adoption of water-tube boilers instead of cylindrical a saving of 250 tons was effected in the weight of the actual boilers, it meant that the displacement of the vessel might be about 1,000 tons less, thus saving a great deal of money in first cost and in maintenance and allowance for depreciation. As to the saving in weight by the adoption of the Babcock boiler, it was a difficult matter to make any precise statement. If a superintendent engineer sent out an inquiry for a cylindrical boiler, simply stating the H.P. required, and left it to the makers to submit their proposals and specifications, he would find that they varied to a large extent; that was a difficulty most water-tube boiler makers had to cope with. It was not unusual for a water-tube boiler maker to be asked to forward specifications, plans and price for the supply of a boiler of a certain h.p., no other information being vouchsafed; they had to assume that the engines were triple expansion, and that probably the power was required for sea-going speed, and make their tender accordingly. But what he wanted to bring before them was that if they were informed of the definite particulars of the service of the ship, the type of engines, the coal that was to be used, and the length of the voyage, it was very probable that the Babcock boiler when fitted would show a saving of between twenty and forty per cent. of weight as compared with the Scotch boiler. He thought that superintending engineers and naval architects were not likely to undervalue its advantages in such respect. Mr. Lawrie had told them of some difficulty he had had in obtaining the price of water-tube boilers; he might say that his firm —Babcock and Wilcox, Ltd.—would give courteous attention to any enquiries they received. He supposed that the evaporative efficiency of boilers was a question of the greatest importance to engineers at the present day. In the American Navy there were six gunboats, sister-ships in every respect, save that two of them were fitted with water-tube boilers and four with cylindrical. The figures he would give in reference to those six vessels were by Admiral Melville. The *Annapolis*, fitted with water-tube boilers, went 26·38 knots per ton of coal at most economical speed, and the *Marietta* 22·27. The *Vicksburg*, the best of the boats fitted with cylindrical boilers, 21·25 knots per ton of coal at most economical speed. Of the other boats fitted with cylindrical boilers, the *Newport* only went 18, the *Princetown* 19·6, and the *Wheeling* 16·6 knots. He maintained that as a comparison of efficiency these figures were valuable; they spoke for themselves. Those vessels were sister-ships, and it might be taken for granted that the boilers, both water-tube and cylindrical, were the best the respective makers could design. About two years ago a large firm of

English manufacturers resolved to experiment with the Babcock and Wilcox boiler as against the cylindrical boiler. They ordered a marine type water-tube boiler from Babcock and Wilcox, Limited, to develop a certain power, and it was erected in their works at the side of one of the best types of cylindrical boiler. A number of exhaustive tests were made and the results briefly were as follows: The first tests were made burning 25 lb. of Nixon's navigation coal per square foot of grate per hour, when the Babcock boiler had an efficiency of 82·7 per cent. while the cylindrical boiler had an efficiency of 80 per cent. In the next tests, Yorkshire coal in the form of nuts was burnt—35 lb. per square foot of grate surface per hour—when the Babcock boiler showed an efficiency of 72·7 per cent. and the cylindrical an efficiency of 61·9 per cent. Both these boilers were erected for about 500 I.H.P. regular working. Another instance. A few months ago they were called upon to supply four marine type boilers for an important electric light installation and guarantee a certain high efficiency. After the boilers had been erected and running in full working order for some months the official tests were carried out. Welsh coal (unscreened) was used, and an efficiency of 78·3 per cent. obtained. In that case the boiler was hand-fired. At the second test of a companion boiler fitted with a chain grate stoker, and using West Hallam screened nuts, the result obtained gave an efficiency of 80·3 per cent. He ventured to think that any Scotch type of boiler would have some difficulty in equalling, to say nothing of surpassing, these figures under similar conditions. Speaking of durability, the Babcock marine type boiler had not been in existence more than about ten years, but he could assure them that the first boiler built in this country (of 375 H.P.) was working at sea at the present time and at its original pressure, and, so far as they had opportunities of judging, was likely to last a great many years more. As loss of feed water on trial trips with

Belleville boilers had been spoken of, he would like to refer to a test which had been carried out at their Renfrew Works in order to determine what amount (if any) the Babcock boiler would lose through leakage of joints or other causes. A boiler of about 1,000 H.P. was kept up to full working pressure of 270 lb. per square inch for about thirty hours, all holes being stopped by blank flanges before steam was raised, and it was thought by some of their critics that the boiler would show a considerable loss of water through superheated steam escaping through the expanded joints; but at the end of the thirty hours' test there was no apparent difference of water level in the gauge glass. So much for the tightness of the Babcock boiler, which was simplicity itself. There were no screwed joints or ferrules, and it had every facility for examination and repairs. He would point out that the only repairs which were ever required in the Babcock boiler were the renewal of tubes. These tubes cost little in comparison with corrugated furnaces, or even plain furnaces. The only thing that could happen to the boiler was that a tube might be burnt through, due probably to an accumulation of scale caused by bad management, or by the entry of oil into the feed-water. That tube could be cut or drawn out and a new one inserted in a very short space of time, and the boiler would then be as good as ever; it would not mean a reduction of working pressure, and they would supply a part just as good as the original boiler.

Mr. W. McLaren (Member) said that he thought the discussion of Mr. Mills's paper might be continued on the following Monday. Mr. Mills ought to consider himself a little bit flattered that the discussion had taken the turn it had. During the 1898-9 season they had a paper on the subject, and one of the authors spoke for all he was worth on the water-tube boiler, but it might be information for Mr. Mills to know that one of those authors had turned right round in his opinion, and a few months ago, in one of the influential engineering journals, he had condemned water-tube boilers. When a professed expert changed his views so entirely, he did not think it said much for the water-tube boiler in the mercantile marine. He would continue his discussion at their next meeting, when he trusted Mr. Murray would be present to give them some further information. In conclusion, he moved that a vote of thanks be accorded to Mr. Mills for his paper and for the admirable slides they had been shown on their new lantern.

Mr. J. THOM seconded the motion. He said he did not think the subject was exhausted by any means, and he considered they ought not to be too conservative in their views. They must give Mr. Mills all due thanks for his excellent paper.

The motion was carried unanimously.

Mr. MILLS briefly responded, and said he hoped to have the pleasure of continuing the discussion on the following Monday.

Mr. W. E. FARENDEN proposed a vote of thanks to the chairman, and Mr. J. B. JOHNSTON having seconded, the vote of thanks was cordially agreed to.

Mr. MILLS then formally moved that the discussion should be adjourned until the following Monday.

Mr. D. HULME seconded the motion. He said he had had some ten years' experience with a Babcock boiler, and they had obtained very correct tests of the evaporative power, and the quantity of steam taken from them.

The motion was carried, and this concluded the business of the evening.

PREFACE.

3 Park Place,

Cardiff,

March 25th, 1903.

A meeting of the Bristol Channel Centre of the Institute of Marine Engineers was held here this evening, Mr. M. W. Aisbitt (Vice-President) in the chair.

The discussion was resumed on the Paper by Mr. A. E. Mills (Member) on "Water-Tube Boilers," read at the previous meeting. At the outset Mr. E. Nicholl, R.N.R., read some comments which had been contributed by Mr. Henry, who was unable to be present.

J. G. Walliker,

Hon. Local Secretary.

DISCUSSION

AT

3 PARK PLACE, CARDIFF,

ON

WEDNESDAY, MARCH 25th, 1903.

CHAIRMAN:

MR. M. W. AISBITT (VICE-PRESIDENT).

MR. E. NICHOLL (Member): The following is from Mr. N. P. Henry, South Shields, who is unable to be present:

"The minute description of the different types, and the full details of design of the water-tube boilers given by Mr. Mills made almost unnecessary, and discounted the carefully prepared illustrations which were shown. Whereas this all must have given Mr. Mills much thought and composition, it is in the generalities, and explanations at conclusion of his Paper, that give opportunity for interesting and expert discussion. Whereas many are not so much interested in the different types and designs, all are so and desire further education respecting actual results. Mr. Mills objected to the recently published statistics of the Board of Trade, and complained that the figures therein gave a wrong impression and exaggerated the actual facts. I cannot understand his contention, as the figures are given in percentage. The statement he particularly objected to was that which gave 86·2 per cent. of deaths due to the water-tube boiler. He suggested that this only represented, say, five deaths. This, he thought, put matters in a different light. Let me give more light. The returns prove, that had the whole of the vessels in the mercantile marine been fitted with water-tubes, instead of five deaths there would have been roughly

1,900, against the actual, about, 29, due to the Scotch boilers. These figures, in my opinion, deserve the title of 'startling,' which Mr. Mills thought was objectionable. I have previously stated, on good authority for my assertion, that the water-tube boiler is known to the stokers in the navy as the 'hell-fire boiler.' I think the foregoing figures justify its *nom de plume* from the stoker. While it is amusing to hear so often in defence and extenuation that the water-tube is in its infancy, there is small doubt that, had the great and genuine opposition to it as a menace to our navy not been raised and sustained, there would have been many more fitted. As it is, we have now, in some of what the country hope will be our best fighting ships, that which, to say the least, is looked upon with, to put it mildly, distrust by many eminent engineers, and I believe by the majority of mercantile engineers. This feeling, unless allayed, will stand the country in poor stead in the event of, say, an early naval war, for the following reason: It is admitted that the numerical *personnel* in engine-room department of the navy is not all that can be desired, and credit is due to the Admiralty for recent efforts to remedy this. Meanwhile, in the event as above forecasted, the immediate demand would be imperative, 'More engineers and stokers.' Perhaps this cry for volunteers will be even more necessary and urgent than it was during the late war for the army. What happens? The volunteer must necessarily be drawn from the mercantile marine, and this is where even more trouble with the water-tube boiler will commence. The most enthusiastic supporter of the type must, and does, admit that they require special treatment. The Belleville, particularly, requires regular and even firing. All need a constant and momentary feed, which if it fails instantly places the boiler *hors de combat*. Yet these complications will be in the care and supervision of men who have never yet been on war service and cannot imagine what actual warfare is. As a mercantile engineer I would not discount the courage and ability of our class, but we must not forget how our soldiers were surprised, and educated, by first acquaintance with the effects of modern weapons and tactics. I daresay our naval experts will be even more so when the time comes. Thankful the commander who, in stress of actual warfare, has not the cry from below that the reason why the efficiency of the department is affected is because it cannot maintain what, as has been said, could be so quickly obtained, viz., the all-powerful and necessary steam. The inquiry, of course, will decide that it was not so much the design or defect of the boilers, as that they had been 'mismanaged.' I may say, respecting this boasted superiority in quickly obtaining steam, I have, in my own experience, obtained a working pressure of steam upon an old 'Scotch' boiler in three hours without detrimental effect. This, of course, was in great emergency. We have yet to be thoroughly convinced that the other great argument in favour of water-tube boilers is substantiated, viz., the saving in weight. Is not this chimerical, and against the knowledge of extra consumption, and that at least in some instances of the mercantile marine they demanded a special ballast tank to carry its demand for fresh water? Mr. Sloggett, in his impromptu remarks in discussion, doubted from his personal experience the alarmist opinions and experiences of opponents to water-tubes. I suggest from his description of all the loveliness of the torpedo-boat destroyer's stokehole that he was at an exhibition or builder's private view. I do know that an important official of the respected firm whose name he mentioned personally described to me how in their attempts to obtain the guaranteed speed pandemonium reigned, and their lives were in their hands owing to the vagaries and shortcomings of the particular boiler he named. Admitting that water-tube are superior to and outclass the Scotch boiler upon the question of increased pressure, at which the latter is supposed to have reached its maximum, does this even balance the fact that whereas there is no question of reliability or confidence in the one, it assists the other to its own destruction? Is the rapacity of the water-tube maker not assisting towards its own undoing? What other troubles or tragedies are suggested by the Board of Trade statistics? They affirm that during a period of five years 20 per cent. of the water-tubes in use were replaced by Scotch boilers. We have grave reasons for supposing that such an enormous percentage could only be necessary by very serious defects or failures. Mr. Mills, amongst other objections to the Scotch type, reminds us that to replace them necessarily heavy expense is incurred removing decks, etc. I suggest that the owners of the above 20 per cent. considered it preferable to go to that expense, if not as an outlet for water-tubes, as an inlet for the Scotch type. Another objection he mentions is that of priming. I suggest that in the Scotch type, even if it is inefficiently designed and shows such a tendency, means can be adopted to minimise its ill effects. That the water-tube is not guileless in this particular propensity is instanced by Mr. Mills explaining the position, and, we presume, necessity, for the priming pipe in its design. I have in my possession a statement by an engineer of very considerable experience in the Royal Naval Reserve, whose identity, for obvious reasons, I do not disclose. I quote from what was voluntarily sent to me. 'On speed trials of H.M.S. —— found all boilers satisfactory under easy steam. As soon as full speed trials began our troubles commenced with the water-tube boilers. We had to draw fires in two boilers through shortness of water. This was attributed to the irregularity of automatic feed (a so-called good point). It was impossible to get correct water level. The tubes were hot and buckled. Result—trials abandoned and ship missed her place at station. The severe experience entirely changes nature of steel in tubes. I have examined tubes cut sectionally from different battleships after six months' use. Many pitted very badly, several pitted through. Tubes that were galvanised no better or more reliable than those not galvanised. In one vessel nine of twelve trials were failures owing to water-tubes, and in every case there was great risk of life.' Wherever we turn the testimony is inefficiency and unreliability. *Vide* Press: 'The *Russell* has water-tube boilers, and has the usual condenser troubles associated with this type of steam generator.' Again *vide* Press: 'The Cardiff Lighting Works do not want any more water-tube boilers.' If the future results were not shaping to be tragical it would read like comedy that, simultaneously with the announcement that the Admiralty have decided to fit future vessels with four-fifths water-tubes, it is published that H.M.S. *Essex* could not perform a short eight hours' trial because of failure of her boilers, which are of that type. The evidence is overwhelming that the type is inefficient and generally unsatisfactory for purposes where there is necessity for complete and regular performances."

Mr. NICHOLL pointed out that a return had just been published by the Government giving the cost incurred for repairs to engines and boilers in navy ships since their first commission. From this return it appeared that warships fitted with Scotch boilers cost, on the average, about £500 a year for repairs to the boilers, the smallest expenditure being £513 to the *Tribune's* boilers in three years eight months, and the highest £5,652 to the *Edgar's* boilers in five years ten months. On vessels fitted with water-tubes the expenditure on the boilers ranged from £470 in two years three months on the *Ocean* to £24,563 in one year on the *Europa*. On the boilers on the first-class cruiser *Powerful* £17,905 was spent in three years, and on those of the *Terrible* £10,084 in four years three months; so that repairs were altogether disastrous as compared with the Scotch boiler.

Mr. T. A. REED said he did not know where Mr. Henry had found pandemonium on board with the water-tube boiler. He (the speaker) made it a point of witnessing as many trials on board torpedo-boat destroyers as possible, and he must say his experience was totally different from that described by Mr. Henry. The case cited at the last meeting by Mr. Geo. Sloggett he presumed was that of a full-power trial of a 30-knot torpedo-boat destroyer off Portsmouth, when they were both on board, and he confirmed Mr. Sloggett as to the splendid results and the comfortable working conditions. He had intimate knowledge of these boilers, built by Palmer's, and of the many thousands of tubes put in he doubted whether one in a thousand had given out. It was the small tube type of boiler that was adopted on board torpedo-boat destroyers, and there could be no question that the smaller water-tube boiler was an unqualified success. Steam could not be raised anything like so quickly in a cylindrical boiler because of the enormous strains that would be set up. He had known torpedo-boat destroyers steaming down the Tyne within twenty minutes of the fires being lighted. They must have a type of boiler in the navy that was capable of quickly raising steam in case of emergency, especially in the case of the *Scout* class, but it might be that the modern cylindrical would meet all requirements in the large battleship, where the importance of quickly raising steam was not so great. The coal consumption of the cylindrical boiler was much more economical in the end than the water-tube boiler.

Mr. T. ALLAN JOHNSON said the water-tube boiler occupied a position to which the Scotch boiler could never attain. But it had one drawback, and that was the difficulty of the circulation of the water. They could not tell the position of the water in a water-tube boiler by the gauge-glass; it seemed as if every tube needed a gauge-glass of its own. This difficulty, however, was one which should be overcome by some automatic arrangement, as in the case of the time-stoker and the time-feeder.

With regard to the leakage of water-tube boilers, there was no doubt a considerable "breathing" movement going on, and this, again, should be capable of being neutralised. What should be done was to decide upon the suitable size of tube to ensure the best working. Then there was the question of material and manufacture. There seemed to be no uniformity of quality, strength and thickness. Failures that had occurred were due to defects which no mortal eye could possibly have detected. The use of the microphone would reject a large percentage of the tubes that were ever made. Since lime water had been introduced defects from corrosion in the water-tube boiler had become rare. He was an advocate of fresh water and lime water, but he drew the line at sea water. He believed the only drawback to the use of lime water was the occasional plugging of the gauge-glass. The water-tube boiler with lime water could be adopted for the marine type with advantage. The lime water would knock out the zinc slab altogether. Of course, it neutralised all the acids inside the boiler, whether arising from oil or feed-water or other causes. The main lines along which they had to work were: 1, the use of lime water to prevent corrosion; 2, keep to within 10 lb. or 12 lb. under the full pressure so as not to strain the safety valve; 3, time-stoking, uniform firing and uniform steam, for sake of economy; 4, more satisfactory method of packing joints, etc. These were all engineering improvements, which must come with experience. Then, much good would result from the keeping of history sheets of boilers and tabulating the results. Although they might hold diverse views upon the subject of water-tube boilers, they must all feel grateful to Mr. Mills for having given them facts and figures over which they could ponder with advantage.

Mr. W. SIMPSON agreed that they were indebted to the author of the Paper, who had advocated no particular water-tube boiler but had dealt with principles. In the speaker's opinion the water-tube boiler was the boiler of the future.

Mr. SAGE said while the water-tube boiler was lighter and raised steam quickly, there was a larger consumption of fuel—a serious matter in long voyages—and a larger store of water was necessary. As to the quick-raising of steam on board warships, he did not see that it was necessary. It was far better to have the steam handy—to have the ships lying under banked fires for any emergency. It was all very well to speak of trial results, but they were continually reading of battleships breaking down and of costly boiler repairs being necessary. It might be that by getting the tubes made of uniform density throughout and of good quality many of these breakdowns would be obviated.

The CHAIRMAN pointed out that the water-tube boiler had displaced the cylindrical on board torpedo boats because no torpedo boat could be run with cylindrical boilers on her displacement; while in the case of large battleships, with their armoured decks, the water-tube boiler was fitted and refitted at less cost. The authorities were faced by certain conditions, and it was these conditions which dominated them and not the alleged inefficiency of the cylindrical boiler. High pressures had necessitated circular boilers in order to stand the strain. A man named Jordan built, in about 1872, the first water-tube boiler, with tubes about ten inches in diameter. Unfortunately they were condemned, Jordan being some twenty or thirty years ahead of his time. Why should they put in circular forms if the same arrangement of tubes gave the same pressure, without the loss of stokehold space, which they got in the circular? He believed a great mistake had been made in making the water-tube boiler so light. He did not see the necessity or the desirability of quickly raising and reducing steam. The boiler must pay for the sudden strain, and to this might be attributed the frequent leakages they heard so much of. A member had hinted that the tubes were bad, but they had good tubes in the Scotch boiler, and why should they not be good in the water-tube boiler? They must have a water-tube boiler designed and made to last equally as long as the cylindrical boiler, and a good step in this direction would be to double the capacity at the back-end, double the area of the tubes, with about 50 per cent. more water in it.

In proposing a vote of thanks to the author of the Paper, Mr. T. A. REED said the automatic feed regulator was part and parcel of the water-tube boiler, and while some types were failures, others were very nearly perfect. He instanced a case where on board a torpedo-boat destroyer the automatic feed regulator practically did all the feeding from the Tyne to the Thames, on account of the extremely rough passage.

Mr. W. SCOTT seconded the vote, which was heartily accorded.

A similar compliment to the Chairman, and the proceedings terminated.

Mr. A. E. MILLS, in replying on the discussion, writes: Before proceeding to reply to the different criticisms brought forward in the discussion of the Paper, I wish to express my thanks for the kind way in which my efforts have been received. I should, however, have been glad to have heard some opinions expressed on the details of design of the different types, and also of their suitability for the mercantile marine, as all have their own particular advantages. In what has been said I notice that several mention the downfall of the Belleville, the faults of which have been in some cases levelled against all types. I do not propose, however, to go into the troubles experienced with the Belleville, as they are all very generally known, and I fail to see that much would be gained by doing so. There is one thing, however, we must not overlook, and that is that the thermal efficiency of the *Hyacinth's* boilers throughout the trials was higher than that of the boilers in the *Minerva*, the difference being considerable at 2,000 I.H.P., small at 5,000 I.H.P., and very great at 8,000 I.H.P. This naturally leads to the experts examining the conditions of the cylindrical boilers in order to find out in what way they could possibly improve the heating surface, when it was decided to try the effect of fitting retarders, which increased the efficiency from 61·4 to 68·4 per cent., or a gain of 7 per cent., thereby making the heating surface as effective in the one case as in the other. A great deal has been said by Mr. Nicholl upon the circulation in water-tube boilers, in which he maintains that the circulation is bad, and that in consequence scale is formed in the tubes, and that tubes gave out frequently through overheating, and that the bad circulation was proved thirty years ago in this type of boiler, by which, I believe, Mr. Nicholl refers to the Jordan boilers which were fitted in the Guion liner *Montana*. Now these boilers consisted of horizontal rows of 15 in. tubes, $\frac{3}{16}$ in. thick and 15 ft. long, connected by 12 in. vertical pipes near the ends. The first three or four rows over the dead plate were intended to be for heating the feed-water, and it was thought that no steam, or only a very little, would be generated in them, consequently the top ends of the 12 in. tubes were only fitted with a $\frac{7}{8}$ in. pipe leading to the steam drum. It so happened, however, that steam was generated so fast that the small pipe was not large enough to carry it away, the consequence being that the water was depressed and left the tubes bare. Then, again, it was considered that the tubes fractured after the boiler had been emptied through the contraction of the tubes in cooling, but whatever the cause was, I do not think we can compare this case with the present-day designs.

Mr. Nicholl brings forward the results of experiments on a Babcock and Wilcox type of boiler by M. Brüll, Past President of the French Institution Civil Engineers, namely, that the circulation in the lower tubes may take place as mentioned in the Paper, but not in the upper tubes, the water there being said to be almost stagnant or a circulation taking place even in the opposite direction. Now these results were said to be obtained when the experimental boiler was evaporating 2·3 lb. of water per square foot of heating surface—an amount which could be obtained with the fires very low, or nearly out, consequently there would be very little "head," and therefore, as far as the upper tubes are concerned, the circulation cannot be said to have as yet properly asserted itself. This is all the more reasonable when we take into consideration that 22 per cent. of the total evaporation takes place in the lowest row of tubes and only about 4 per cent. in the topmost row. Therefore I think it must be conceded that when a boiler is working at or above the rate for which it was designed, that the circulation does take place as pointed out by theory, and which has been verified by the makers by means of glass models.

Now as regards the scale, I am unable to agree with Mr. Nicholl even on this point, excepting of course when the water which is being used is of too great a density. Messrs. Thornycroft say that after fifteen years' experience with hundreds of their boilers, that there has scarcely been any case in which it has been necessary to clean the insides of the tubes; that torpedo boats have frequently crossed the Atlantic using salt water, and it is a well-known fact that the United States torpedo boat *Ericsson*, fitted with their boilers, used salt water throughout the siege of Santiago without any ill effects. Messrs. Yarrow, two or three years since, exhibited before the members of the Institution of Civil Engineers some tubes which they had split up, and which had been in use for a long period, showing no scale, but only a light floury deposit. Of course, where the practice of pumping up the boilers when under banked fires is resorted to, that is, when the circulation is almost nil, then the water will deposit a scale, where it first comes into contact with the heating surface, probably for about two or three feet in the ends of the tubes leading out of the downtakes, but this can easily be removed either by hand or by means of the rotary cutter described.

In speaking of the tubes giving out, Mr. Nicholl makes out a very bad case, and if the troubles were as bad as depicted I do not think the water-tube boiler would have lasted as long as it has. He mentions a case of one of Wilson's steamers having to be towed in with fractured or defective tubes and short of coal, and states that the boat was fitted with Babcock & Wilcox boilers, but on inquiry I find she had Belleville boilers. Although trouble has been experienced with the tubes in the Belleville, owing no doubt partly to the construction, this trouble has not been the case with other manufacturers of boilers of the water-tube type, as very great attention is now given to the uniform quality of the tubes, and instead of fitting lapwelded, as was usual a short time since, a large number of boilers, if not all of the marine type, are now fitted with solid-drawn tubes of ample thickness; and I might mention in passing that Messrs. Yarrow have made a large number of experiments with tubes of nickel steel, with from 20 per cent. to 25 per cent. of nickel, which have proved themselves far superior to ordinary steel to withstand the temperatures to which they are exposed. The question of the formation of blisters on the tubes, and their giving out in consequence, may safely be put down to deposits of grease or scale, just in the same way that we sometimes hear of collapsed furnaces in the cylindrical boilers from the same cause. This defect, however, is not by any means of frequent occurrence, as the few following particulars will show. One steamer travelled 300,000 miles in four years, the repairs to each set of boiler mountings and boiler proper costing £7, and during the fifth and sixth years no repairs were required. In another steamer, during thirty-four months' working, the repairs were nil; whilst a gunboat travelled 12,000 miles and only needed a few firebars; a cruiser travelled 35,000 miles and required no repairs; a gunboat after travelling 60,000 miles needed no repairs; another steamer travelled 250,000 miles and needed nothing; and in the annual report of Admiral Melville, we find that the gunboat *Marietta* covered a distance of 130,000 miles at an average speed of 9·2 knots, having been under steam for nearly three months, and having been for more than a year in commission, that the boilers were in excellent condition and ready for any service, the only thing required being eight fire-bricks. I think I need say no more about blistered tubes, as the above excellent results are only a few out of a large number. Now, as regards the difficulty alleged in cleaning the soot off the tubes, I would refer Mr. Nicholl to the Boiler Committee's Report, wherein no difficulty whatever was mentioned. With the cylindrical, when fitted with retarders, there was, however, trouble at the back ends of the tubes.

In Mr. Nicholl's concluding remarks he gives the opinion that the water-tube boiler was not specified for the two large Cunard boats because Mr. Bain was too well aware of the defects, but I would remind Mr. Nicholl that the capitalists have something to say in the matter; and as regards the idea of the navy having begun to discard the water-tube boiler I am entirely unable to agree, for in 1900 sixteen boilers were ordered, in 1901 fifty-one, in 1902 seventy-six, and already for 1903 the number runs to forty, all by one firm, the total I.H.P. represented being 181,000; and when it is considered that this type alone has been placed in the different classes of vessels of the American navy to the extent of 354,000 I.H.P., and that the Yarrow, Thornycroft & Niclausse types are also very largely used in both navies, I think we can say that the water-tube boiler is proving itself to be more satisfactory than the cylindrical boiler it has displaced; and when we read Admiral Melville's report after the blockade of Santiago, wherein he says "that the use of water-tube boilers does not involve the use of anything but a tried, successful and reliable apparatus, that gives us positive and great advantages over the character of boilers heretofore generally used," "that we suffered severely in our short war with Spain from dropped furnaces in cylindrical boilers, and that I do not think these tubes more liable than furnaces to fail from a deposit of scale," I do not consider we are justified in blaming our naval officials for fitting the only type of water-tube boiler which at that time had had an extended use in large steamers.

Mr. Shelton speaks of the coal consumption being heavier for this type of boiler, and as I was misunderstood in the previous discussion of the Paper, I will again give the results of one of Wilson's boats, which during six summer voyages with cylindrical boilers used 1,072 tons of coal and averaged a speed of 11·45 knots, and in six summer voyages with water-tube boilers the consumption was 981 tons and average speed 12·05 knots, a reduction of 90 tons in coal burnt and a gain of 0·6 knot in speed, a result calculated to be equal to 130 tons of coal saved, the net gain being of course the saving in the cost of the coal, trimming, etc., and also in the carrying capacity of the vessel to the extent of the coal saved.

In reply to Mr. Roberts, Mr. Wilson, in 1900, in the House of Commons spoke as follows: "I find that the vessels of my own firm have made 800 voyages and run 700,000 knots, and practically we have not experienced all the dangers and difficulties that have been predicted. I do not say that the water-tube boilers are perfect. As we go on we get more knowledge, and we are getting, I hope, nearer perfection. In 1895 we had Belleville boilers put in the *Ohio*, but they were not satisfactory, and we took them out after runs of 111,000 knots to America and back. Personally, I feel convinced that the Admiralty will never go back again to the use of cylindrical boilers. I have heard it stated that there is no saving in the weight by the use of water-tube boilers, but there is an enormous saving. Take one of our smaller ships, where there is a saving of some 50 tons of weight in boiler and water, and if that ship makes 50 trips from Hull to the Continent and back, that is 100 in all per annum, they could by the use of the water-tube boiler carry 5,000 tons more cargo."

In answer to Mr. Davidson, the advantages of being able to get up steam in half an hour are that less coal is required to raise steam, and also that when a vessel is engaged in a trade that usually necessitates her laying under banked fires, that in the water-tube boilers the fires may be allowed to die out.

In regard to the use of the water-tube boiler as an auxiliary boiler, I do not consider it would be advisable unless the winches, etc., were connected to a condenser so that the condensed water can be returned to the boiler.

The weights of boilers ready for steaming in pounds per square foot of heating surface are about as follows: Cylindrical, 73; Babcock & Wilcox, 25·26; Niclausse, 28·3; Belleville, 38; Dürr, 26·5; Thornycroft, for *Monitor* class, including air heaters, 18; Yarrow, for battleships, 20; so that if we compare the 14 ft. 6 in. cylindrical with the water-tube, the heating surface being 1775, grate surface 59, I.H.P. 590, the Babcock and Wilcox type would equal 20 tons, and the cylindrical 57 tons.

Mr. Henry mentioned that the water-tube boiler was known in the navy about two years ago as the hell-fire boiler, and all I have to say is that, taking into consideration the good circulation, I do not consider any alteration in the name is necessary, although it is rather more than I claim in the Paper.

By the recent return of casualties to water-tube boilers in the mercantile marine, during a period of five years ending December 31st, 1901, it appears that five persons were killed and six injured, the actual number of boilers of this type in use being fifty-eight, of which eleven have been removed. This represents per 1,000 in use, 86·2 persons killed and 103·4 persons injured, which figures Mr. Henry has, accidentally, no doubt, called percentages.

Now, by the law of averages, the rate of casualties would gradually diminish as the number of boilers increased, so that when 1,000 were in use the percentage would be far below that quoted for, say, fifty. If, for instance, we take an indicator diagram and divide it into five equal parts, would the percentage of error when measured up be the same as when the card was divided into 100 parts? I think Mr. Henry will agree that in the first case we should obtain a result which was decidedly wrong, and in the second case the result would be very nearly correct, and as this is exactly a parallel case I maintain that the figures are entirely misleading. Then, again, if the statistics were further examined it would probably be found that the greater number of accidents occurred during the early period of the five years, at a time when this type of boiler was first being introduced into the merchant service at a high working pressure. The Admiralty experiments with the boilers of the torpedo gunboat *Sheldrake*, in 1898, entirely bear out Mr. Sloggett's remarks as to the capabilities of this type to rapid variations in working, for it was reported that when the engines were going at full speed, and suddenly stopped, the front tube doors and uptake doors being immediately opened and the ashpit doors closed, that the pressure did not rise more than 5 lb., neither did the safety valves lift. And, again, a report on a vessel fitted with Thornycroft boilers, says: The steam generating plant could be regulated nearly immediately to suit the steam consumption of the engines. At the end of the speed trials, for instance, the engines were forced up to 3,314 I.H.P. in a few moments. When going full speed the ship was often stopped immediately, and could be brought up to full speed again in a few minutes, it not being necessary to take any regard whatever to the boilers, these being able to withstand all sudden changes of temperature.

Mr. Henry, in his concluding remarks, mentioned that the Press had stated that the Cardiff Lighting Station officials had discarded the water-tube type. I have heard on very reliable authority, however, that this is another error, and that instead of "water-tube" it should have been "fire-tube," or dry back boilers.

Mr. Reed thinks that eventually cylindrical boilers will be used in battleships, but as this would entail a great reduction in the weight of the guns and armour, in order that the draught may not be increased, and consequently a slower speed for the same power, I am of opinion that the Admiralty will use the water-tube type for many years to come. With reference to the time taken in changing tubes, the makers of the Niclausse boiler say that on the *Téméraire*, the boiler being at full work, burning 80 lb. per square foot of coal, they drew the fire from the boiler, replaced all the tubes of one row in the bottom, filled up the boiler, and was at work again at the same rate of combustion in forty-two minutes. In the Russian battleship *Hcrabry* one tube was changed under like circumstances in thirty-two minutes. In the *Garibaldi*, in the presence of the Grand Duc d'Alexis of Russia, whilst the boiler was burning 72 lb. per square foot of coal, fires were drawn, boiler emptied, and one tube changed from the lower range, and started work again in twenty-eight minutes. On the *Seagull* two tubes were changed in fifty-eight minutes. It might be pointed out that where a number of boats are fitted with the Niclausse boiler, one spare set of tubes does for all. In the Paris river boats, for instance, over thirty of them are fitted with this type, and periodically the boiler tubes in one of them are withdrawn and replaced by clean ones.

I quite agree with Mr. Johnson's remarks about the Belleville; there are, as he says, a lot of good points about this type which are overlooked, the worst cases are brought into great prominence, and the good installations are quietly kept in the background. Dr. Elliott shows us that with a little careful handling the water level may be kept within bounds, even if the variation of working is extreme, and that when working from a light evaporation to a heavy one it is only necessary to somewhat anticipate results, and work with a rising gauge-glass, in order that the level may not vary more than about 12 in.

One of the worst features of the Belleville boiler is that the tubes are screwed into sockets, which are acted upon by the heat, and as Mr. Johnson says, the breathing movement, which must take place on account of expansion, sets up leakage at the ends. Another of the bad features is, of course, the long tortuous passage the steam and water have to travel before getting to the drum, and as an example of how these may be got over, I purposely described in the Paper the Thornycroft-Marshall boiler, which appears to have given very good results, and which was one of the types recommended by the Boiler Committee.

Mr. Sage mentions a case where 1,700 tubes have had to be renewed in one boiler, but I take it that this was one of those early types where lap-welded tubes had been fitted. There is no doubt, however, that in first introducing the water-tube type into the merchant steamer that some few failures did take place, but to judge by the results of recent years the makers soon profited by the experience.

Mr. Aisbitt is of the opinion that if greater surface and more weight of both water and boiler were allowed in the design better results would accrue, with which I must say I agree.

I note in Mr. Scott's boiler, which he was asked to describe, that he does away with a large number of stays and the large flat surfaces at the back of the combustion chamber, which I consider a good feature. The arrangement, too, of the furnace and tubes effects a great reduction in the thickness of the shell. The circulation is a great improvement upon that of the ordinary cylindrical boiler, but of course there is no "head" in this type similar to that in most water-tube boilers. This boiler cannot, however, be termed a water-tube type, as the gases pass through the tubes and not the water.

Mr. Donaldson thinks that more water-tube boilers would have been in use if they had not so many disadvantages, which he says are not of a very serious nature; but my impression is that the troubles which have occurred with one type have been so largely written about that either the advantages of others have been overlooked or that all types have been thought to possess the same drawbacks. When, however, we come to consider the hundreds of water-tube boilers which are yearly manufactured for electric light and power stations and other purposes, all working at high pressures, and the very few accidents, we, as marine engineers, surely ought to be able to adapt the type to marine purposes, and be able to suggest alterations to any little details of which we do not approve, or which are not suitable for marine work, as we cannot but agree that the principle of splitting up the water in small quantities and arranging for certain definite lines of circulation, augmented by a "head," must mean the raising of steam more rapidly, and consequently must save coal, besides giving us the means of using higher pressures, and still further economising.

Mr. Donaldson regrets that mention of the Stirling boiler was not made in the Paper, but I have not heard of its being used afloat to any great extent. I believe, however, that a set of boilers are just now being tried in a merchant vessel.

As regards the circulation in the Babcock and Wilcox boiler, I cannot agree that the steam and water rising from the lower tubes loses heat as it ascends, for although the globules of steam on their upward journey pass through a mixture of water and steam, and may part with heat to the water and again reform, there is no heat lost.

Mr. Lawrie's remarks principally refer to the Belleville type, about which he gives a lot of particulars condemning it, and appears to regret that I did not say more in the paper; but as the Boiler Committee's Report was so well known, and had been so much discussed, I thought it unnecessary to go into further details. Certainly the long run from Gibraltar did not impress one with the capabilities of the type, but, of course, the fact that the *Minerva* beat the *Hyacinth* in speed has nothing to do with the economy of a boiler. On the first trial of these two boats—about which Mr. Lawrie gives no details —which lasted a sufficiently long time to give reliable results, the Belleville came out better than the cylindrical, and it was only on fitting retarders —or in other words baffling the gases—that the cylindrical and Belleville types were brought about equal in economy at full power. The highest evaporation per lb. of coal from and at 212 deg. was for the *Minerva*, when retarders were being used, 10·34; for the *Hyacinth*, 11·46; so that it is possible, even with the Belleville, to get an evaporation equal to that of the cylindrical. Then, again, the Boiler Committee tested and recently published the results of trials on the *Sheldrake*, *Espiègle*, *Seagull*, and *Fantome*, fitted with Babcock and Wilcox and Niclausse boilers, where the highest evaporation came out at 11·02; and as far back as 1889 Professor Kennedy tested a Thornycroft boiler and obtained an evaporation of 11·5 lb., so that the water-tube boiler is not so bad as Mr. Lawrie would have us believe.

The Committee in their report certainly say "it appears that no type of water-tube boiler *on general service* is as economical as the cylindrical," by which I take it they mean, such as supplying steam for distilling, heating and general deck purposes, where large quantities of salt water would of necessity have to be pumped into the boiler as a make up, and as the boiler only contains a small quantity of water to begin with, it follows that there would have to be a great loss of heat through having to use the blow-down often.

As regards raising steam on a large cylindrical boiler in three hours, we know it must put heavy stresses on the riveting and stays, and even if it does not show itself at the time, there is a probability of leakages later on; at any rate, I do not think the boiler would last for twenty-five years if it was done often. We hear of boilers this age still in good condition, but we must not forget that the probable working pressure is about 80 lb., not 180, and that the tubes may not be so efficient in transmitting heat as they might be, on account of the scale which is often left on.

Mr. Lawrie thinks the gain in raising steam rapidly is hardly worth talking about, but when it is considered that in such a case there is very little necessity to lay under banked fires for any length of time, I think he must admit that for certain trades it must mean a considerable saving in coal, as the fires may be allowed to die out.

Mr. Lawrie's remarks about dirty tubes are not at all clear, and many allude to soot or scale, or both, and I think he must have misunderstood the paragraph in the paper. What I wished to make clear was that soot would accumulate and remain in larger quantities on a concave surface than it would on a convex surface, consequently the nearly horizontal tubes in a water-tube boiler would be more efficient than would be the tubes in a cylindrical, after some days' steaming.

Mr. Murray's remarks on the cost of repairs to several steamers show that the water-tube boiler need not be more expensive to keep up than the cylindrical, and as regards the weight of the two types, that the water-tube is far and away the lighter.

The number of casualties that have occurred during the last five years as given by the Board of Trade have been made much of, but, as I pointed out at the Cardiff discussion, they can be used in a very misleading manner. Everyone knows that by the law of averages the total number of casualties would decrease as the number of boilers increased; and that taking a percentage on fifty boilers of one type and comparing it with a percentage on 5,000 on another, is no guidance.

In conclusion, I wish to express my thanks to Messrs. Babcock and Wilcox, Thornycroft, Yarrow, and Messrs. Willans and Robinson, the makers of the Niclausse type, for the trouble they have taken in supplying me with information, drawings, diagrams, and photographs, and also to the two first-named firms for the loan of a large number of lantern slides, and trust that members, after having heard such a good discussion, will now feel more inclined to look upon the water-tube boiler without prejudice, and as a type that deserves a more extended use in the mercantile marine.

DISCUSSION CONTINUED

AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, MARCH 30th, 1903.

CHAIRMAN:

MR. J. E. ELMSLIE (MEMBER OF COUNCIL).

Mr. S. C. SAGE (Member of Council) said, although he had no personal knowledge of water-tube boilers, he knew that they had been working for many years on the Continent most satisfactorily in large works; but, of course, under such conditions as would be impossible on board vessels because of the large area of ground space they occupied and their very great weight due to the increased brick-work. With regard to merits of the water-tube boiler as a quick steam raiser, he thought that most of their members had had some very severe experience in getting steam up rapidly with the shell boiler. He had had experience of that nature, but they did not think of the injury it was going to do to the boiler. It was a case of "Get steam up quickly, connect your boiler, and get away." They would find that the majority of the vessels running on short voyages treated their boilers in a manner that the advocates of the water-tube boiler would consider ruinous, but they found that the cylindrical boilers lived to a good old age. He could conceive of no harder usage than that which was experienced by the boilers of colliers running between London and the Tyne or the South Wales coal ports. They were left for a few hours in port, under banked fires, and were practically working night and day. Yet many of those boilers were from eighteen to twenty-five years old, and were still doing satisfactory work at their original pressure. He considered the principle of the water-tube boiler was wrong. To fill a round tube with water and to expect to get steam from it rapidly and effectively and at the same time to keep the tube cool, was, he considered, the wrong way to raise steam. They had only to try it with a glass tube and a Bunsen burner, when they would see that where the impact of the flame came there was no water at all, but only a gaseous mixture that could not keep the tube cool. That would account for so many burstings of water-tube boilers. The advocates of the tubulous boiler contended that the circulation was so good that that was impossible. Theoretically impossible things, however, often occurred, to their great surprise and disaster. There was no method the average life of the tubes as compared with the cylindrical boiler? He would have liked if the author had given them the coal consumption registered per I.H.P. for the different types of water-tube boiler mentioned in his paper. That was an important factor, and had they had those figures they could have made a comparison with the cylindrical boiler. He believed that the Admiralty Boiler Committee's report of last year stated that no water-tube boiler had up to the present been found as economical as the cylindrical boilers.

Mr. W. M'Laren said, in his opinion, the most suitable boiler for the mercantile marine was a boiler that would steam for 100 days, and with that continuous steaming not have to slow down more than three times to sweep out the tubes, etc.; that he thought they got with the cylindrical boiler. He understood that they used the steam jet to clean out the water-tube boiler, but he considered that was a brutal force to use on any boiler. They were told with the water-tube boiler furnaces that they could get plenty of grate surface, but they heard nothing of the brickwork and the expense of the upkeep thereof. With the water-tube boilers he did not think they got the maximum heat from the gases. He would like to ask the author what was the temperature of the gases escaping through the funnel, and also the space occupied and the weight of the boiler.

Mr. James Adamson (Honorary Secretary) read a communication from Mr. H. E. Metcalf, in which that gentleman stated he had had about fifteen years' experience with marine boilers. The first half of that time was with cylindrical boilers, the latter half with those of the water-tube type. Amongst the different types he had come into contact with were the Niclausse, Yarrow, Belleville, Thornycroft, and Babcock and Wilcox. He quite agreed that the consensus of engineering opinion was more and more on the side of the water-tube boiler. The Boiler

Committee's report contained a paragraph relating to the performance of the Babcock and Wilcox boilers fitted in the Wilson liner *Martello*. The paragraph stated that inspections had taken place at the end of every round voyage for fourteen months, and the committee's opinion was that those boilers had stood the test of usage in the mercantile marine extremely well. The vessel had run about 91,000 miles since the boilers were put in, and had usually been less than a week in port at either end, and the only repairs required had been those of the ordinary upkeep of any boilers, such as fire-bars, brickwork, etc. Only six tubes had required renewal. That opinion was strengthened by the inspection of boilers of the same type fitted in the *Numidian*, the *Buenos Ayrean*, and the *Turret Cape*. The boilers of the last mentioned vessels had been in use seven years, and would not have been as well looked after as they would have been in the Navy. Their condition, when recently examined, was, however, satisfactory.

Mr. ADAMSON then gave particulars of the boiler power decided on by the Admiralty for the five first-class cruisers of 1901-2 programme, now under construction as follows: H.M.S. *Hampshire*, four-fifths Yarrow, one-fifth cylindrical; H.M.S. *Carnarvon*, four-fifths Niclausse, one-fifth cylindrical; H.M.S. *Roxburgh*, four-fifths Dürr, one-fifth cylindrical; H.M.S. *Argyll*, four-fifths Babcock and Wilcox, one-fifth cylindrical; and H.M.S. *Antrim*, four-fifths Yarrow, one-fifth cylindrical.

It was ultimately decided that the further discussion on the subject should be adjourned until the opening of the next session.

A vote of thanks to the chairman, proposed by Mr. G. SHEARER, seconded by Mr. WILTSHIRE, concluded the meeting.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1903-1904.

President—SIR JOHN GUNN.

Local President (*B. C. Centre*)—LORD TREDEGAR.

VOLUME XV.

ONE HUNDRED AND TENTH PAPER
(OF TRANSACTIONS).

WATER-TUBE BOILERS

BY

MR. A. E. MILLS (MEMBER).

READ AT 58 ROMFORD ROAD, STRATFORD

ON

MONDAY, MARCH 23rd, 1903.

ADJOURNED DISCUSSION

MONDAY, SEPTEMBER 28th, 1903,

58 ROMFORD ROAD, STRATFORD.

CHAIRMAN:

MR. D. HULME (MEMBER OF COUNCIL).

PREFACE.

58 Romford Road,
Stratford.
September 28th, 1903.

A meeting of the Institute of Marine Engineers was held here this evening, presided over by Mr. D. Hulme (Member of Council), when the discussion on the paper "Water-tube Boilers," by Mr. A. E. Mills (Member), read on March 23rd, and discussed on March 30th, was resumed. In order to facilitate further discussion, the paper and part of the discussion which took place during the spring was published and issued, with a view to the subject being studied by members in the interval, that on the re-opening of the session the contributions to the discussion might be made more valuable. Mr. Mills was unable to attend this evening.

JAS. ADAMSON,
Secretary.

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The CHAIRMAN: This paper having already been read and partly discussed—this being a continued discussion—we shall be very pleased to hear any gentlemen who will re-open the discussion.

Mr. C. W. MURRAY (Member of Council), who stated that his remarks had been prepared in response to a suggestion thrown out by some of the members at a previous meeting, then gave a lengthy description of the construction and working of the marine type of the Babcock & Wilcox water-tube boiler, elucidating his remarks by reference to detail drawings.

That boiler, he said, consisted essentially of a steam and water drum, of sections of tubes inclined at an angle of 15 degrees from the horizontal, a mud drum, in which the solids were deposited, and a furnace or fire-box, in which the combustion took place. Each section of tubes consisted of two headers—one front and one rear—and the connecting tubes, the tubes being fixed in the headers by ordinary expanded joints. The headers were sinuous boxes of rectangular section, made entirely of wrought steel plates, welded by hydraulic pressure. The front headers were connected at the top to the bottom of the steam and water drum by short tubes or nipples, and likewise at the bottom to the mud drum. The rear headers were connected to the steam and water drum by two rows of horizontal tubes. There were two types of the Babcock & Wilcox marine boiler at present being manufactured. In one type, the whole of the inclined or section tubes were $3\frac{1}{4}$ in. outside diameter, this type being generally used for vessels in which the question of weight was not of the first importance. In the other type, known as the "Combined," the lower two rows of inclined tubes were 4 in. or sometimes $3\frac{1}{4}$ in. outside diameter, and the remainder $1\frac{7}{8}$ in. outside diameter. The latter type was installed in ships where the weight had to be curtailed as much as possible. The "Combined" type possessed the advantage of having a larger amount of heating surface for a given weight and space, but as the tubes were of less diameter and in greater number than in the $3\frac{1}{4}$ in. type, the operation of cleaning could not be carried out with quite equal facility.

In the Babcock & Wilcox boiler the steam and water drum under normal conditions contained water up to nearly the centre of the drum. When the fire was lit, the water in the section tubes receiving the heat followed a path up the tubes and into the rear header; it then ascended to the top of the rear header and over through the lower horizontal return tube into the steam and water drum. The cold water in the drum, by reason of its greater density, travelled down through the front header and passed into the inclined tubes, where it received an increment of heat. That went on in a continual cycle, and it had been found that the temperature of every part of the boiler was, within certain limits, equal. The difference of temperature, obtained by careful experiment, was very small in amount. The water was put into the boiler at a temperature of say 110° Fahr., and that temperature increased with regularity as the circulation went on, until at last they got the temperature due to the steam pressure, and during the whole time every part of the boiler had expanded in a practically equal degree. There was only one part of the boiler which was fixed to the foundations, and that was the mud-drum. Every other part was free to expand, and with the perfect circulation of the water inside, they got what they might legitimately call a perfect expansion over all the parts of the boiler.

Mr. Murray then at some length, and by reference to the detail drawings, explained the staggering of the boiler tubes. The tubes were staggered with a view to making the path of the gases of combustion as tortuous as possible as they passed upwards to the chimney, and thereby ensure that the gases should come into contact with the whole of the tube surface. In the $3\frac{1}{4}$ in. type boiler, it was usual to fit a system of baffling known as the "Alert," the term being derived from the name of the ship in which the system was first adopted. By this arrangement the gases practically swept over the tube surface three times. Their path was shown by the curved lines and arrow marks on the drawings. The baffling consisted of: (1) A set of fireclay bricks fitted over the second row of inclined tubes. (2) Two frames of cast iron plates at approximately right angles to the inclined tubes, the rear frame being faced with thin firebricks. (3) Baffle plates extending from the top of the front frame of cast iron plates to the rear headers. These baffles, while not absolutely airtight, were sufficiently tight to prevent the gases of combustion short circuiting. Although it might be thought that these cast iron plates would become distorted by the action of the flame, such was not the case. Probably their contact with the tubes served to conduct the heat rapidly away. At any rate, baffles which had been in hard worked boilers for many years showed no appreciable wear or distortion. One reason why the Babcock boiler possessed so much economy over other types of boiler was because of the "Alert" system of baffling with which the boilers were equipped. A certain amount of soot was deposited where the gases came down and turned round abruptly at the bottom of the front frame of baffles, and it would be observed that there were doors fitted at each side of the boiler to allow this soot to be raked out at intervals as found necessary.

There were no screw joints of any description about the Babcock boiler. Every joint was made by the simple boilermaker's expander. A man with no previous knowledge of the boiler could, if he were a fair mechanic, take the different parts of one and erect them in place, and with ordinary care that boiler would be absolutely tight under both the hydraulic test and working pressure.

MR. MURRAY then exhibited a model of the handhole doors that were fitted opposite the end of each tube. These doors were, he said, by automatic machinery turned out almost mathematically true. They were stamped out of solid forged steel. The $3\frac{1}{4}$ in. doors were fitted with a 3-ply seamless asbestos wire woven ring and drawn up on the inside of the header plate by means of an outside dog or cap and nut. When it was necessary to examine a tube they took off the doors at each end, and, by holding a light at one end and looking through the other, it was possible to see the condition of the tube from end to end, or they could pass an electric light through the tube by means of a rod, when they would be able to examine every square inch of the surface of the tube. That, he thought, could not be done in any other type of water-tube boiler except those constructed on the same principle. As regards the examination doors for the $1\frac{7}{8}$ in. tubes, these were fitted metal to metal without any asbestos joint. As would be seen from the specimen he exhibited, the door was coned, as was also the inside of the hole in the header. On the outside was a cap nut, the joint of which, together with the header plate, was accurately faced. There were thus, so to speak, two joints, one inside, formed by the cone of the door and header, one outside, formed by the face of the cap nut in contact with the header.

With regard to furnaces; in the commercial type of marine boilers, 9 in. firebricks were generally used throughout; but for battleships, and more especially cruisers, something lighter was required. The Admiralty could not afford to allow weight which might, perhaps, be more valuable used in other directions, and they therefore had to scheme something which, while light in weight, would stand the wear and tear of actual service. They fitted tiles of standard size and much less in thickness than an ordinary brick. In these tiles were holes for bolts and recesses for the bolt heads, which recesses were perhaps say $2\frac{1}{2}$ in. deep in a tile of 4 in. thickness. The tiles were bolted up to the furnace side and rear plates and the recesses afterwards filled up with fireclay. Between the tiles and the furnace plates was a layer of non-conducting composition. It was usual to make the tiles in the vicinity of the firebars somewhat thicker than the tiles in the upper part of the furnace, principally to withstand the wear and tear of the tools used in cleaning the fires. These were 4 in. thick, and although it might seem strange, they found that the furnaces were cool outside and the tiles could well stand the wear and tear of active service. The torpedo gunboat *Sheldrake* had furnaces of the tile description, and although she had been in commission about five years, the furnaces had had very little repair up to the present time. At the back there had been no repairs at all. It was only in the vicinity of the furnace doors that repairs had been needed, and they attributed the necessity for such to the slamming of the doors more than to anything else.

With regard to the arrangement of the downcomer tubes, which they would observe on the drawings, for ordinary working at the rates obtaining in commercial service, they took it that all the water required to supply the inclined tubes would come down the front headers; but at high rates of combustion such as was sometimes required in naval service—say burning 28 to 30 lbs. of coal per square foot of grate per hour—they had thought it well to provide for an additional supply of water; that was done by means of the downcomer tubes. In such case, in the ends of the steam and water drums, which were pressed out hydraulically, a pocket was formed. In this pocket holes were drilled to receive one, two, or three tubes as might be required, and the tubes were inserted and taken down into the main sediment box, and either one or two auxiliary sediment boxes which were connected to the main sediment box. There was thus at each side of the boiler a passage for the water from the steam and water drum into the main sediment box, and as the main sediment box was connected by nipples, or short tubes, to the bottom of each header, the supply of water to the inclined tubes was thereby supplemented. They found that a considerable amount of circulation took place through these downcomers. There was an additional advantage in fitting downcomer tubes, and that was, that when any solids came down with the water through these tubes a large proportion, if not the whole, settled in the main and auxiliary sediment boxes, and of course could be got rid of whenthe blow-out valves were opened.

Mr. MURRAY then described in detail the construction of the steam and water drums, explaining the manner in which the shells were first rolled from thick plates and annealed, and afterwards planed down in such a manner that the factor of safety in the vicinity of the tube holes was fully equal to the factor of safety through the riveted joints, much weight being saved by this method of construction. There was, of course, a manhole door in the drum. The absence of much gear inside the drum rendered it an easy matter to make a minute examination. The only fittings inside these boilers were a dry pipe, which was simply a double pipe having saw slits on the top of the outside pipe and on the bottom of the inside pipe, the purpose of which was to prevent any possibility of priming when the stop valve was opened suddenly; boxes to contain zinc blocks to minimise any corrosive tendency; wash plates to prevent undue motion of the water when the ship was rolling heavily, and a dash plate that filled the office of separating the steam and water, or rather caused the water which passed through the horizontal return tubes to be deflected downwards; the steam went up at each end. These dash plates were made with a hinge at the top, and were secured at the bottom by means of simple bolts and wing nuts. It was an easy matter to take off the nuts and lift the plate on its hinges, and so examine that part of the shell in the vicinity of the horizontal tubes. In the main and auxiliary sediment boxes there were also fitted handhole doors and zinc blocks. The handhole doors were so arranged as to allow a thorough examination of the interior of these boxes, and also the zincs to be fitted with metallic contact.

Babcock boilers were almost invariably installed with their stokeholds right across the ship. In one of the steamers of the Russian Volunteer Fleet, the makers of a water-tube boiler of another type had a tremendous amount of trouble, because the stokeholds were placed fore and aft, and as the ship rolled the circulation in the tubes got reversed. In the case of the Babcock boiler, with the stokeholds running across the ship, the alteration of the angle of the tubes with the horizontal would be but slight, even when the ship was pitching very heavily, and they would agree that the ship would have to pitch enormously in order to make any appreciable difference in that angle.

In the outside casings of the Babcock boiler there were doors provided for the purpose of cleaning the outside of the tubes. The method of cleaning was either by the use of steam or compressed air. Attached to these doors, which were generally not less than 12 in. in clear width, were little flaps opposite the spaces between the tubes. To clean the outside of these tubes when running at sea all they had to do was to lift up a flap, insert the steam or air lance, turn on the supply cock, and sweep the lance to the front or rear between the tubes, when all the soot would be blown off. When in port, with the fires out and with no steam or compressed air available, they sweep the tubes by means of a specially constructed brush mounted on fairly stiff but not rigid handles.

With regard to the space occupied, it was sometimes such that in this respect the water-tube boiler had no advantage over the cylindrical type. He thought, however, if they reflected a moment they would admit that the fact of the Babcock boiler being almost a perfect square, proved that for space occupied it gave more capacity for power than the cylindrical type of boiler. In boilers of the Scotch type, with two furnaces, they had a space between the furnaces and also between the furnaces and the shell of the boiler where there was no fire-bar surface. With the Babcock boiler, however, the grate bars were taken right to the edge of the square, thus giving a fire-bar surface of great width. Assuming the length of the boiler to be the same in either case, they would agree that in the Babcock boiler the fire-bar surface must be much greater than in the cylindrical boiler. In the three furnaces of a cylindrical boiler the dead-plate levels would be different, and in some cases which had come under his notice, he had observed that a man had to raise the coal as high as 4 ft. 6in. or more in order to get it into the furnace at all. The coal got inside the furnace, it was true, but did they get anything like the full value of it? In the Babcock boiler the fire grates were all on the same level and at the most convenient height above the stokehold plates. The fireman could always see exactly what part of the fire required attention and put on the coal to the best advantage.

On a previous occasion remarks had been made of a very adverse character as regarded the coal consumption and expenditure for upkeep of the Babcock boiler. If he remembered rightly, on that occasion he instanced a Babcock boiler which had been installed by a firm of Midland manufacturers alongside a cylindrical boiler of the latest and best type that could be designed, with a view of finding out the relative coal economy. He had given figures which showed that with bituminous coal the Babcock boiler showed an efficiency of over 72 per cent. against an efficiency of the cylindrical boiler of 62 per cent. These boilers were worked with assisted draught, and were put down nearly two years ago. They had recently an opportunity of examining the Babcock boiler, which, after more than eighteen months of hard work with a draught of sometimes not less than 2½ in. of water pressure, was found to be in perfect condition. There was not a tube in the boiler showing the slightest sign of leakage, there was not a tube which showed any distortion, and there was not a leak about the boiler shell. Also, the figures he had given at the previous meeting as to the economy of the boiler had been borne out by the work it had done in continued service.

He would be pleased if the Institute would accept the drawings he had brought with him that night, and find a place for them on the walls of that room. They might be of interest to those members who cared to study the subject at their leisure.

Mr. W. E. FARENDEN (Assoc. Member) thought they were very much indebted to Mr. Murray for explaining the boiler so graphically. He would like to ask a question with reference to an explosion that occurred in a Babcock land boiler in May last, whereby two men were killed and others injured. The disaster was due to one of the tubes bursting. He understood that that particular boiler was originally fitted with iron weldless tubes and fed with condensed water from the hotwell of the shop engine. Trouble was early experienced owing to the tubes blistering, and those tubes were renewed from time to time, being finally replaced by solid drawn steel tubes. A filter was afterwards fitted for extracting any matter that might be held in suspension in the feed-water, and ultimately canal water was used, that water being properly treated by a softening process. The boiler, he believed, was cleaned out about every two months, and after each cleaning was hydraulically tested. The tube that gave way was one in the lower row immediately over the fire, and the life of the tubes in this boiler varied from eighteen days to one year. At the Board of Trade inquiry it was, he thought, stated that the accident was due to overheating, causing the metal to waste in the locality of the fracture, that overheating being caused by the deposit of scale in the tube somewhere near where the explosion occurred. He would like to know the thickness of tube generally put in those boilers, and whether they were now made of iron or steel. Also, could any method be adopted for getting over the difficulty of overheating of tubes, thus making them safer? The upkeep of the boiler to which he had referred was rather expensive on account of the boiler tubes, and appeared to him to require more than ordinary attention and care.

Mr. A. E. Battle (Member) said he understood that the Babcock boiler was a boiler that would not stand forcing, and that it would only take about one standard of evaporation. He would like some information on that point.

Mr. George Shearer (Member) said the Babcock boiler had never come under his supervision, but from what he had heard of it, especially that night, he thought it was one of the best constructed water-tube boilers that he had seen. The last speaker had asked, Would this boiler stand forcing? From its construction he saw no reason why it should not stand forcing. He quite agreed with Mr. Murray in his ideas of a fire-bar area. There was not the slightest doubt that they got much more fire-bar area with the water tube than with the cylindrical boiler. One great advantage possessed by the water-tube boiler was that they had all the furnaces on the same level. As most of them knew, there was a difficulty in firing a large cylindrical boiler of the four-furnace type. As a rule they had either to have special men or special platforms for firing those high furnaces. He did not see anything extraordinary in the baffling of the Babcock boiler; in fact, in all water-tube boilers that he had had to do with the baffling was much the same. There was one good point in the top baffle under the funnel; all soot coming from the entire length of the funnel and its windings would drop right down into the front or over the furnace door, which was a very good position to get it extracted. Speaking of economisers, he would consider the horizontal return tubes leading into the steam drum to be much the same as an economiser. They were, in fact, economisers or superheaters. They acted in both ways. With regard to the scale in the tubes, he had heard a good deal about tools specially made for boring out the scale, i.e., the incrustation from the water. But he had not seen them, only illustrations. He would like to see one of those tools at work. So far as his experience went, it was a most difficult matter to remove the scale in the interior of a tube where they could not use percussive force. Even in boring common salt much difficulty was encountered, and salt was a very soft substance compared with scale. It might be said that that depended on the men who were running the ship if they allowed that amount to be deposited, but, however careful men might be, and however good they might be, scale would form there, unless distilled water was constantly used. They got leaks from condensers and a certain amount of salt water was sure to get into the boiler. He would like to know what the funnel temperature was with those boilers, also in the different air passages.

Mr. A. O. WALKER (Member), referring to the headers at the back of the boiler, asked if there was any trouble with the plates of those headers where the flame impinged direct. Was there any trouble with the burning of those plates?

Mr. JAMES HOWIE (Member) said he thought Mr. Murray had somewhat missed a point in his very clear and lucid explanation of the boiler, and that was with regard to the circulation. There had been a good deal of talk of the circulation not being quick enough in all water-tube boilers, although Mr. Murray had said that the boiler had the same temperature all over in a very short time after the fires were started. He raised the question because he had seen a water-tube boiler—the tubes were $1\frac{1}{4}$ in., he believed—that had so bad a deposit in one of the tubes that that tube was burnt away in a short time. It was stated very clearly that the deposit was due to slow circulation, and he thought that the boiler in the Midlands that had been mentioned by Mr. Murray might perhaps have been of quicker circulation. Had the circulation of those boilers been improved at all? He would not like to make a great point of the space occupied by the boiler. In small steamers of large I.H.P., there was no doubt that the water-tube boiler was somewhat difficult to place as compared with the cylindrical type. He did not think there would be any difficulty whatever in larger steamers, but in small vessels they had to break up the decks to get the boilers in. The question of firing had been raised: although a greater surface was given with the water-tube boiler he believed that surface was required. He would not like to say so definitely, but he had been informed so by those who have had more experience than himself. Mr. Farenden had raised what was perhaps the most fatal objection to that type of boiler when he referred to explosions. Of course, all types of boiler were susceptible to that accident, but in the cylindrical boiler they had not the same danger as in the water-tube type, where the breaking of a tube might cause an immediate loss of life. Then there was the question of price. The Babcock boilers had a very great sale and he thought still more of them would be used if something like one-third could be knocked off the price. He would not like to say that people would rush for them, but he thought they would be appreciated a good deal more. He would like to have a lecturer to come and give them a description of the working of the Belleville or any other water-tube boiler. The Belleville seemed to have obtained new lease of life, judging from recent trials of war vessels, and a lecture on that boiler would be a source of education.

Mr. K. C. BALES (Member) asked Mr. Murray for the coal consumption of the Babcock as compared with the cylindrical boiler. He did not desire a comparison such as might be obtained from the Navy, where trained firemen were employed and picked coal used. He would like an ordinary every-day comparison, such as they would expect to get in the Merchant Service. Would Mr. Murray also tell them what standard figures he took for the evaporation of water when designing boilers for a given horse-power?

Mr. A. BROWN raised a question as to whether the lower rows of tubes did not get scaled quicker than any tubes in the boiler. Regarding circulation in the boiler, the baffles in the centre of the boiler did distribute the whole of the flame throughout the different tubes. There was another point, however, the cylindrical part was planed to a certain thickness at the top and a different thickness at the bottom, and he would ask if the way the cylindrical part was planed was not out of proportion to the pressure it had to stand? Also, he would like to know if the top tubes from the cylindrical part did not expand much more than the rest of the tubes? He did not know much about the marine type of boilers, but he happened to know a little about land boilers, because he was on a committee which had given an order to Messrs. Babcock & Wilcox for fourteen boilers. His experience had been that the lower row of tubes got scaled much quicker than the others, and there was a difficulty in cleaning those tubes, and also in cleaning the soot off the lower part of the boiler. The great difficulty, however, was the expansion between the cylindrical part of the boiler and the top tubes.

Mr. W. MCLAREN (Vice-President) referring to the distribution of the circulation, said he noticed that some extra down-coming tubes had been introduced. He would like to ask a question about the steam and water drum. Was it not on the small side that they had not sufficient weight of water to assist the circulation? Also, had the steam anything to do with the hindrance of that circulation? Speaking of the float, he thought it would not be required where one single water-tube boiler was in use. Had Mr. Murray ever known one of those floats to stick? Mr. Murray had mentioned the *Sheldrake* as having used water-tube boilers for five years. He would like to know the longest time that she was under steam. If they knew the time in days and hours it would give them something to go upon. If she had run 100 days it would be a good test for any boiler. With regard to the trouble that they had in the bottom rows of tubes; he was inclined to think that it was caused by the water being driven off. He believed the water was driven from the bottom side of the tube. It was something after the style of spheroidal heating that was attempted in days gone by when they tried to raise or fetch a furnace crown up by heating it and then douching it with water to cause it to return to its spheroidal form. The question of stoking had been referred to; there was no doubt that a difficulty existed in firing a four-furnace boiler of the marine type, owing to the height of the furnaces. The ordinary sea-going fireman was, however, equal to the occasion, and a special fireman was not required. With the water-tube boiler, however, it would be a very difficult job for an ordinary fireman to supply the furnace with coal. To get the best results he would require to gain experience and qualify himself. He recently saw at Ilford a marine type of water-tube boiler doing work ashore. He would like to know why they were using a marine boiler when they had a Babcock & Wilcox boiler there.

Mr. JOHN MACLAREN (Member) said that the water tube boiler had heen condemned to some extent by reason of the inexperience and want of knowledge of the marine engineers placed in charge. Mr. Murray had said that the temperature of the boiler was the same throughout. He could not quite see how the temperature could be the same throughout, especially in the case of the top and bottom tubes, the latter being of a heavier make were liable to more expansion and contraction. He would also like to know if Mr. Murray had any experience of the difference in the wear and tear of the top and bottom tubes? What difference did it make while firing? Is not the lowering of the temperature by opening and shutting the furnace doors bound to affect the lower tubes and cause more expansion and contraction of them?

Mr. J. H. SILLEY (Member) raised the question of spare gear required to be carried with water-tube boilers. He understood in the Messageries Maritimes, fitted with Belleville boilers, running to Australia, they had to carry a large distilling plant consisting of two distilling boilers. They also had to carry parts equal to two complete boilers, besides an additional 20 per cent. of fittings. Objections had been raised to the straight tubes on account of leaking. Was there any such trouble with the Babcock tubes? The bottom rows of tubes were much thicker, to make up for the extra wear and tear, and possibly they would last as long as the top tubes.

Mr. RUTHVEN said he did not wish to add to the discussion, except to say that Mr. Murray had not mentioned half the good points of the boiler.

The CHAIRMAN: Has any gentleman any further questions to ask?

Mr. A. BROWN: How often has Mr. Murray found it necessary to renew the bottom tubes?

The CHAIRMAN, after expressing his obligation to Mr. Murray for the clear way in which he had explained the boiler, said he was sorry that there were no other representatives of water-tube boiler makers with them that evening to give them some of their experience. He noticed in the door, the front hand or light hole joint, that it differed somewhat from the old type of boiler. At the present time he had three of the Babcock boilers under his charge. One he had had for over eleven years, and during that time they had only had to renew four of the tubes. When that boiler was fitted they found that it was too small for the work required, and they had to force it. He found it very easy to force. Then they installed another boiler, and that also was found to be too small, so yet another one was fitted. The first of those three boilers was specially designed to go in a certain position, necessitating short tubes of small diameter. Each of those boilers had different sized tubes. Could Mr. Murray tell them what was a safe velocity to generate steam with the fifteen degrees of elevation in the tubes? One of the 3,000 lb. per hour boilers they ran up to 5,000 lb. per hour during some experiments with induced draught. With regard to the small holes that were put in for cleaning purposes, he found they gave him an opportunity of watching what was taking place inside. He found that he could get the red flame right through to the back of the tubes. He thought the back of the boiler was kept cool to increase the circulation. He had found that unless the feed-water was heated to a temperature of over ninety degrees the soot adhered to the tubes very rapidly on an economiser. One gentleman had spoken of tubes—he thought the tubes were weldless tubes. So far as his experience went he was pleased to say that the boilers under his charge had run for a number of years. Recently they had had a few repairs made; he trusted they would not require any further repairs for some time, for they knew how to charge for repairs as well as for the boilers.

Mr. MURRAY then replied to the numerous questions that had been put by the Members.

With regard to economisers, it was not now, he said, the practice to fit them. In some of the early boilers they were fitted, but the results were not sufficiently satisfactory to encourage them to make it a practice for marine installations. When feed water heaters of the "Weir" or similar type were fitted, they did efficient work and he did not think there was any occasion to put in economisers. It was more valuable to have a super-heater to superheat the steam and thus get increased economy. That plan had been tried with great success by a well-known firm of shipowners, although not on a very large scale; it was perhaps more of an experiment, but in one ship it had been in use for over two years. In that ship the super-heater tubes were now as good as when first put in, and the economy was stated by the superintendent engineer to be considerably above ten per cent.

Mr. Farenden had referred to an explosion which took place in May last. That accident, he believed, was found by the Board of Trade to be due to scale. A large piece of scale had lodged in one of the bottom tubes, which piece had probably been detached during boiler cleaning and allowed to remain in the boiler. No welded tubes were now fitted to the Babcock boiler, these were things of the past. Solid drawn weldless tubes alone were used. For the merchant service they were hot drawn, for the naval service cold drawn and afterwards galvanized, the galvanizing being with a view to ascertaining whether there were any defects which might not otherwise be detected. The thickness of the tubes varied according to their position in the boiler and depended also on their diameter and the steam pressure carried. The upper rows might be 8 or 9 L.S.G., the lower rows $\frac{3}{16}$ in. or $\frac{1}{4}$ in. thick. It had been suggested by one of the members that the return tubes might be viewed in the light of an economiser. He did not think that was quite correct. He would rather consider that the upper tubes would act as a kind of super-heater. Broadly speaking it was found that the water came through the lower return tubes and the steam through the upper. At least this was proved by experiments made with large working models.

With regard to boiler cleaning tools, until about two years ago the cleaning of the interior of the tubes presented some difficulty, but since that time they had been using a turbine cleaner fitted with cutters and actuated by water under pressure. With this it was possible to clear away the scale evenly from the tubes, which could be left as clean as a gun-barrel if desired. He, however, considered that it was better to leave a very thin layer of scale—say about the thickness of an egg-shell—than to clean the tubes right down to the metal. The turbine cleaner, whilst removing scale effectually, did not injure the metal of the tubes. The cleaner was put in from the upper end of the tube. All a man had to do was to take off the handhole fittings, put in the cleaner, and work it gradually down the tube. All the deposit would be washed down into the mud-box below. They had found it necessary only in rare cases to clean the top inclined tubes at all. The largest proportion of scale was found in the lower, second, third, and fourth rows. A few days ago he inspected a boiler which had been in constant use at sea for eleven months. The bottom two rows of tubes had been cleaned out about once in every two months. When he examined that boiler he found that the upper rows were in such a condition that he would not recommend that they should be touched at all—they had a scale deposit certainly not more than one-sixty-fourth in thickness. With a turbine cleaner of the type he had described the only expense in working was that of keeping steam in a donkey boiler sufficient to work a force pump which would give a water pressure in the turbine of about 70 lb. per square inch. When the scale was so hard that the turbine cleaner could not remove it, they used a borer fitted with three adjustable cutters, which borer was worked by manual labour.

Mr. SHEARER: Are those cutters circular in plan?

Mr. MURRAY: Certainly; they are star-shaped, and revolve freely on the outer end of a short lever, the inner end of the lever being attached by a free joint to the revolving turbine head. The outer end flies out by centrifugal force, and the cutters are pressed into the scale while revolving upon it. Continuing, he said the action was simply perfect. When cleaned the tube was like a gun-barrel, and the cutters did not injure the metal of the tube.

Mr. BALES: How long would it take to clean a boiler with that tool?

Mr. MURRAY: That would depend on the number of tubes in the boiler and the state of the tubes as regards thickness of scale.

Mr. SHEARER: How long would it take to clean one tube?

Mr. MURRAY: Roughly speaking, from three to five minutes, in rare cases longer, but it would depend almost wholly on the character of the scale. He would not advise cleaning the tubes like a gun-barrel—it was better to leave a thin shell of scale. In designing a boiler for forced draught, they gave more tube surface in proportion to grate area than for natural draught; they so arranged that the temperature of the gases escaping to the chimney should not be excessive. If more coal was to be burned on the grate in a given time, the tube surface would naturally be increased. They endeavoured as far as possible to put in large grates, they obtained more satisfactory results when burning about 17 or 18 lb. of coal per square foot of fire-bar surface per hour than when burning 25 to 30 lb.; they obtained a greater economy and it was better for the boiler.

With reference to the headers being exposed to the action of flame—he had never known a header to fail for that reason—indeed, he could only recollect two headers that had ever failed at all. In his experience there had been no trouble whatever through over-heating of the headers.

The sizes of tubes had been referred to. The smallest tubes they fitted were $1\frac{7}{8}$ in. diameter, or to be more correct $1\frac{13}{16}$ in., the largest 4 in., but $3\frac{1}{4}$ in. diameter tubes were almost invariably used in the mercantile marine.

As to trouble caused through deposit of scale; if they did not treat the boiler properly, they were sure to get trouble, but every engineer would agree that the proper place for the solids in the water was outside the boiler. It was necessary to treat all boilers properly and supply them with water as pure as could be obtained. They always maintained that what would give trouble in a Babcock boiler would give vastly more trouble in a cylindrical boiler. It was a far more serious matter to have the furnaces come down than to have a few tubes bulge or blister.

Mr. Bales had asked how the coal consumption of the Babcock boiler compared with the cylindrical boiler. He regretted it was not possible for him to say much on that point. They had data of a very favorable nature, but shipowners would not allow their figures to be published—as he thought, very rightly. He had given them figures before regarding boilers which had been erected on shore and tested, and that, he maintained, was a fair criterion of the performance to be expected from them at sea. When a man had a cylindrical boiler he gave it the best attention possible; he employed firemen familiar with it and he obtained a certain result. When his firm designed and set to work a water-tube boiler, he considered they had an equal right to choose firemen who had been trained for the purpose. They wanted to get the best results out of their boiler just as much as the owner of a cylindrical boiler did out of his. Men who tried to fire a water-tube boiler by the old methods would certainly not meet with much success. Some years ago his firm boilered a tramp steamer of about 1,000 I.H.P. The trial went off successfully, and their representative left the ship as it started on its voyage. A few days after they were informed that the ship could not steam against the tide, and had to put into port. The captain was afraid to proceed. Investigation proved that the failure to make steam was almost entirely due to the system of firing; in small measure also to the very poor quality of the coal. He, Mr. Murray, on going below saw a fireman shovel coal into a furnace until it was absolutely blocked; there was not even a vestige of fire to be seen above the bars. How they could expect the boilers to make steam under such conditions he did not know, but the engineer's excuse was that the firemen had been accustomed to firing Scotch boilers, and they would do it their own way. A great deal of trouble was experienced in getting the men to appreciate that the right way was the best way, but by patience and persuasion they soon had the ship, which was fully loaded, going at least eight knots an hour, and proceeding on her voyage. That ship was running at the present time, and he understood that the results which were now being obtained were considered quite satisfactory. Firemen who did not understand the water-tube boiler piled coal on by hundred-weights, but no water-tube boiler would give good results under such treatment. Treated properly they gave as good and better results than could be obtained from a cylindrical boiler. They had proved that with the Babcock boiler.

With regard to the size of the steam and water drum : that differed according to circumstances. For slow running engines it was not advisable to put in a drum less than 4 ft. diameter—but for fast running engines such as the Admiralty usually specified, 3 ft. 6 in. would be ample, whilst for torpedo gunboats and like craft 3 ft. would suffice. The capacity of the drum bore a relationship to that of the high pressure cylinder.

Speaking of the Babcock & Wilcox feed water regulators—he had never known one to stick. Attached to and forming part of each regulator was a bridle, spindle, and lever by which the float could at any time he moved. In their printed instructions they directed engineers to work the lever up and down occasionally to ascertain if the float worked properly, especially when starting after the boilers had lain idle for any length of time. They had never had any trouble through the regulators failing to act. The water level in the boilers was practically constant —it was rare indeed to find a variation of more than $1\frac{1}{2}$ in. or 2 in.

Quoting from memory—he would say that the longest continuous run a vessel fitted with Babcock water-tube boilers had ever made was about 13,000 miles. The ship that made that passage was the *Marietta*, a U.S. gunboat. She came down the Pacific coast and round the Horn to take up her place at the blockade of Santiago; she required no overhauling at the end of that run; the only material required was a few firebricks.

As regards renewals, the lower tubes were more likely to require renewal than the top tubes; the renewals depended upon the treatment the boiler received; if they forced the boiler greatly above its designed capacity and treated it badly, they would probably in time have to renew some of the tubes: in cylindrical boilers under similar conditions they might have to renew the furnaces. If the water-tube boiler received proper treatment the tubes would last. He could not give them any exact data, as so much depended upon circumstances of each individual case, but the Chairman had told them of boilers under his supervision that had been in use for 11 years and had only required the renewal of three tubes. He thought that a very fair record.

In the British Admiralty it was the custom to specify a large amount of spare gear. The only spare gear required with the Babcock boilers was a few of the fittings such as he had shown them that evening and a few tubes. As the inclined tubes were all precisely of the same length and diameter, and the return tubes a little less in length and all of the same diameter, it was only necessary to carry a few of each of these sizes of tubes.

Mr. Battle had asked whether water-tube boilers would stand forcing. He had with him some figures appertaining to the boilers of the United States warship *Cincinnati*. In that case they worked a test boiler up to a combustion of 59 lb. of coal per square foot of fire-grate per hour, and an evaporation of 13·6 lb. per square foot of heating surface. After this trial there were no leaks or defects whatever. Regarding economy, as they would see in *Engineering* of the week before last, the trials of

H.M.S. *Challenger* had recently been carried out with very successful results. This vessel was fitted with Babcock and Wilcox boilers. On the eight hours' full-power trial the engines indicated a mean H.P. of 12,781, and the water used per I.H.P. was 17·5 lb., the indicated H.P. being that of the main engines only and the water that consumed for all purposes. Under these conditions the consumption of coal per I.H.P. per hour was 1·78 lb., which, he ventured to think, spoke well for the economy of the Babcock boiler. All the coal was carefully weighed and the water carefully measured, but owing to the feed water having to pass through large measuring tanks placed above the weather deck and exposed to the cold wind and spray, the temperature at which it entered the boilers was probably less than 80 deg. instead of the 110 deg. or more which it would obtain under ordinary circumstances. The evaporation per square foot of heating surface was rather more than 7 lb., the heating surface per I.H.P. being less than 2½ square feet. This, he thought, was forcing the boilers fairly well.

Mr. W. McLaren: I should like to ask a ratepayer's question—Why they put down a marine type of boiler at Ilford when they had started with the Babcock?

Mr. Murray: I do not know anything of that.

Mr. W. McLaren: To be quite fair I think I must repeat what I have heard to-night about the Shoreditch Electric Light Station. At that station they have gone in pretty solid for the marine type of Babcock boiler. Seemingly the land boiler did not give them satisfaction from the experience they had with it.

Mr. Murray: As the question of marine type boilers for electric light stations has come to the front, I will say that not only in Shoreditch but also in St. Pancras, Babcock marine boilers have been installed. They are likewise being put in at the Carville Electric Light and Power Station at Newcastle-on-Tyne, in this case in ten units, each capable of evaporating 28,000 lb. of water per hour and superheating the steam to a high degree. Orders have also been received for boilers and superheaters of like construction for the Havanna Electric Lighting and the Barcelona Electric Lighting Company.

Mr. JAMES ADAMSON (Hon. Secretary) then announced that on Monday, October 12, the further discussion on Mr. Balfour's paper "Refrigerating Appliances as fitted on Board Ship," would be proceeded with in the theatre of the London Institute. On October 26, they had agreed to continue the adjourned discussion on Mr. Terry's paper on "Auxiliary Pumping Machinery and Suggested Improvements." Mr. Gulston had also undertaken to give them another lecture on "Ice-breakers and their Services" on Monday, December 7. They were to have an illustrated lecture on Monday, October 19, which would be of special interest to those who were amateur photographers. The exact title of that lecture was "A Chat about Lantern Slides," and the lecture would be given by Mr. Ainsley. The illustrations at that lecture would, he believed, be very much appreciated. Ladies were invited to that lecture, as also to that to be given by Mr. Gulston.

The proceedings closed with votes of thanks to Mr. Murray and the chairman.

"SCOTCH, OR CYLINDRICAL MULTI-TUBULAR, BOILERS."

DISCUSSION

AT

3 PARK PLACE, CARDIFF.

THE following corrected remarks of Mr. Darling's are substituted for those appearing in the last issue on pp. 12, 13 and 14 in the above discussion.

Mr. W. DARLING said they ought to thank Mr. Nicholl for giving them the opportunity of discussing this question, but for his part he could not agree that they were justified in asking the various registration societies to reduce the scantlings of the boilers 20 per cent. This was rather a "tall order." Let them think what this reduction of 20 per cent. meant. A ribbed furnace of 48 in. in diameter at 160 lb. required to be half an inch thick, and he did not think anyone would like to go to sea with a furnace after it had wasted down to a quarter of an inch all along the furnace bars. Take 20 per cent. off to start with, and instead of half an inch, or ·5, they began with a ·4 furnace. Therefore, its margin of life was ·4 down to ·25, which was not a reduction of 20 per cent., but of 40 per cent. on the life of that furnace. Again, they knew that a thin plate would corrode much more quickly than a thicker one where-ever they had got movement. He recalled the instance of a boiler floor. When it was eight years old this floor underneath the boiler was examined, and it was found to have wasted half its thickness, 8/20 to 8/40. It was intended to repair it at the time, but the ship got chartered and did not get back for eight months, when there was in places no floor left at all. This he attributed to nothing else than vibratory action on a thin plate. It took eight years to waste the first half, but only eight months to finish the last half. If they were going to reduce boilers in the way suggested, they were going to take a good deal more than 40 per cent. off their lives. But supposing they did reduce the weight of the boiler to that extent, what really was it in a 6,000 ton ship? When they took 20 per cent. off the scantlings they reduced the life of the boiler 40 per cent., irrespective of the greater effects of corrosion in a thinner than in a thicker plate. It was all very well to say that corrosion was a bogey; but he was afraid it was a very active bogey. It was not found in so many cases as formerly, but where it was found it was quite as active as ever. Mr. Nicholl said that shells did not corrode. He (the speaker) found a boiler shell very badly corroded only the other day—a comparatively new boiler, six years old, and that was caused by what, perhaps, some people would hardly credit—raking the boiler out with an iron rake.

Mr. Nicholl: No plug in the bottom?

Mr. Darling: No; I don't believe in plugs in the bottom; you can syphon the water out, a much wiser plan. The heads of the rivets in the circumferential seams on the far side were half gone, and this was in a direct line with the raking out of the stuff. Then, again, he frequently found corrosion in the way of the up-take at the bottom, where, instead of having an inclined plate to slide off the soot and dirt at the bottom of the funnel, the up-take was built in square. The shell plates there had frequently been found to be corroded, due, in his opinion, to the heat contained in the soot. He had proved this by putting in a plate to make an inclined plane, and this had cured it. The same applied to bad baffling. If the baffling was not efficiently fitted and the soot got in at the back there would be

PREFACE.

58 Romford Road,

Stratford,

March 16th, 1903.

A Meeting of the Institute of Marine Engineers was held here this evening, when Mr. R. Balfour (Member of Council) read a paper on "Refrigerating Machinery as Fitted on Board Ship." Mr. Robert Clark (Companion) presided. It was expected that the Retiring President, Mr. D. J. Dunlop, would occupy the Chair and present the Denny Gold Medal to Mr. J. H. Silley, but having been called away to Scotland on business, Mr. Clark kindly agreed to take the Chair. The discussion on the paper was adjourned till the re-opening of the Session in the Autumn.

Jas. Adamson,

Hon. Secretary.