INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1896-7.

President :—SIR EDWYN S. DAWES, K.C.M.G.

Volume VIII.

SIXTY-THIRD PAPER

(OF TRANSACTIONS)

WATER TUBE BOILERS,

BY

Mr. E. PETERSEN

(MEMBER).

READ AT 58, ROMFORD ROAD, STRATFORD, E.,

ON MONDAY, MARCH 30th, 1896.

DISCUSSION CONTINUED

ON MONDAY, APRIL 16th 1896.

PREFACE.

58, ROMFORD ROAD,

STRATFORD, E.,

April 13th, 1896.

A Meeting of the Institute of Marine Engineers was held here this evening, when a Paper on "Water-Tube Boilers," by Mr. PETERSEN (Member), read at a Meeting held on Monday, March 30th—when the Chair was occupied by Mr. J. H. THOMSON (Chairman of Council)—was further discussed.

A. J. DURSTON, Esq., C.B. (Past President), presided over the Meeting this evening.

In the interval between the reading of the Paper and the Adjourned Discussion, an opportunity was given to Members to inspect the special boiler referred to in the Paper, by the kind arrangement with Messrs. Fraser, Millwall.

The Paper will be found in the following pages, and the Discussion thereafter. Arrangements are made for reading the Paper at Cardiff, on Wednesday, April 29th.

JAS. ADAMSON,

Hon. Secretary.

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WATER-TUBE BOILERS,

BY

MR. E. PETERSEN (Member).

READ AT 58, ROMFORD ROAD, STRATFORD,

ON MONDAY, MARCH 30TH, 1896,

Chairman—MR. J. H. THOMSON.

It affords me much pleasure to have the opportunity of reading a Paper before the members of this Institution on my patent compound tube water-tube boiler. The first boiler of this type, of about 400 horse-power, was made for experimental purposes by Messrs. John Fraser & Son, Millwall Boiler Works, and has been under steam above 100 times during a period extending over ten months. The trials were of from two to six hours' duration, and not the slightest hitch of any kind has ever occurred. The water used was obtained from the East London Waterworks Company, which contains much solid matter, but nevertheless the boiler inside is to-day as clean as it was before the first trial took place. The cause of this can only be accounted for by the special arrangement of the feed applied in connection with the construction of the boiler. The feed water enters, not directly into the steam drum, but through an internal pipe, which is carried into the drum just below the crown, and extending about two-thirds of its length. The end of this pipe is closed up and the under part is perforated over the whole length with 200 $\frac{3}{16}$ in. holes, so that the feed water, which is heated by passing through the furnace in an 8 in. solid drawn Mannesmann steel tube, enters the steam drum at a temperature considerably above that which is required to precipitate sulphate or carbonate of lime into powder. The powder, however, does not remain in the feed-heater pipe, but is carried, probably by the steam and circulation, up into the steam drum, where it is kept in a floating state by the very rapid circulation kept up continuously through the tubes as long as the boiler is in action. This can be the only reason why all the tubes inside are, after over ten months' trial, quite free from deposit, as, when the boiler has been opened up for inspection, a powder deposit was found in large quantities in the bottom water chambers in a sludge state, which was simply removed by washing it out. Samples of this can be inspected upon the table.

The peculiarity of this boiler is that it is put together by screws and nuts, and that all screw joints are outside of the flames or hot gases, so that after any period during which the boiler has been at work it can be easily taken down, transported, and re-erected in a very short time. All the joints, being metallic, are made by softened copper rings, cut from a solid drawn tube.

Another novelty in this boiler is the compound tube, which consists (if made for burning coal, coke, wood or other smoky fuel) of nine tubes, each of one inch diameter; or if made specially for liquid fuel, of 16 tubes, each of $\frac{3}{4}$ inch diameter, which are fastened into cups, thereby having only one inlet and one outlet. Therefore, a compound tube represents one split-up tube, and instead of having nine or sixteen holes in the drum, only one is needed. Reducing the number of holes in this manner, as you will easily understand, gives much greater strength to the boiler. In the case of a compound tube for liquid fuel, the space between the tubes is only half as large as that for the ordinary compound tube. Thus about 50 per cent. more heating surface can be put into the same space and into the same size cups, which, it may be mentioned, are made of forged or the best crucible steel.

Another very important point is that the tubes are not expanded in, as in other boilers, but are pressed into the cups hydraulically in one process, and, therefore, when once tight, can never become leaky. The tubes being about $\frac{1}{100}$th part of an inch larger than the holes in the cups, the inner ends are beaded over after having been pressed into their places.

The upright feeding pipes that supply the compound tubes (the down-comers) are outside the fire, and are made either in crucible steel or in malleable castings, as also are the bottom water-chambers, which, for the largest boiler, need only be eight inches in diameter. All the joints upon these chambers are outside and easily accessible, and the circulating legs can be made of solid drawn steel tubes. As will be seen from the drawing, no brickwork is required. The baffle plates are provided with ledges so as to fill up with flue ashes, this being a splendid non-conductor, and at the same time preserving the baffle plates.

The large air space between the baffle plates and the outside casing gives little chance for radiation to any extent. If several boilers are situated in a row, only the end ones will require side-casing doors, as under such circumstances (all being in communication by their upper parts) doors may conveniently be placed in front in the spaces between the water-tubes.

Other very important advantages are derived from the very large combustion chamber, and by the radial formation of the compound tubes, placing them in such a position that the hot gases strike them almost at right angles, besides leaving between each row additional combustion chambers, where the gases are re-ignited, and to a great extent consumed. These additional combustion chambers afford great facility for sweeping the tubes externally, and also for connecting, disconnecting or replacing any compound tube, which can be done in a few minutes. For cleaning and replacing any tubes the baffle plates are drawn out from the front, for which purpose small doors are provided in the casing, and for convenience they are made in three pieces, each of about 30 inches in length.

All compound tubes are effective heating surface, and point to the centre of the steam drum. They are all interchangeable in their rows, and are capable of being turned round on their axes, so that after a lapse of time when the one side of each tube has been subjected to the full force of the fire it can be turned so as to expose a fresh surface to the more intense heat of the gases. The two lower rows, being of the same dead length, can be interchanged as well as turned on their axes, thus ensuring an exceptionally long life. Liquid fuel burning is now coming more and more to the front, and it can only be a question of time when it will be generally adopted for special purposes, and more particularly in the navies for torpedo catchers, cruisers, and launches, and later on, probably, for battleships, mercantile steamers, and for land purposes. We shall then have no more obstacles in the way such as soot, smoke, and ashes, but perfect combustion; and the principle of compounding the tubes will become obvious, because only by this principle is it possible to really benefit by oil burning, by getting a tremendously large heating surface, and, consequently, large power in a small space, with comparatively very little weight.

The steam from this boiler is absolutely dry, and there is no priming whatever. This, however, is easily explained, as the tubes are very short and straight, the two lower rows being but 33 inches long, and the upper ones decreasing in length, so that the top row is only 23 inches long. The steam bubbles which are formed on the inside of the tubes (which latter discharge their contents almost equally over the whole length of the steam drum) are carried off with the rapid circulation over the whole surface of the water in the drum, each discharge being in the direction of the centre. Here the streams of bubbles collide, and having only to pass through a column of water a few inches in depth, they, consequently, are delivered into the steam space almost as hot and dry as when formed, and without having any chance of disturbing the equilibrium of the water in the steam drum. In fact, experiments have proved that it is impossible to make this boiler prime, not even when the water level was pumped up to within six inches of the roof of the drum, and, under full pressure of steam, the stop valve was suddenly fully opened.

I wish also to point out that by the principle of keeping the gases confined in a space proportionate to their decreasing volume due to absorption of heat in passing through the rows of tubes there is an advantage, inasmuch as more work is got out of the top rows than would otherwise be the case.

The temperature of the escaping gases, taken at two feet above the base of the funnel in my boiler, has been found to vary from 450 deg. to 500 deg. Fahr., and when a jet of steam for inducing more draught was applied occasionally, the pyrometer has shown as high as 550 deg., but as the tubes are only $\frac{7}{8}$ths inch outside diameter, and having $\frac{9}{16}$ths inch space between them (which I find is rather too much), it is expected that the result in the boilers now under construction, both in this country and on the Continent, will show an improvement in evaporative power, in consequence of their having one-inch tubes, pitched at the same distance apart and in the same sized cups, the space between the tubes being thereby reduced to $\frac{7}{16}$ths inch.

The boiler at Millwall occupies a floor space of 9 feet by 8 feet, and is 9 feet 3 inches high to base of funnel. The heating surface is 1,000 square feet, and the grate has an area of 21 square feet. The weight of the boiler under steam is ten tons. It was found by experiment that by reducing the grate surface one-third, so that it was about 1 to 70 in proportion to the heating surface, that 13 lbs. of water could easily be evaporated, from and at 212 deg., with 1 lb. of good Welsh coal, but the quantity of water evaporated per hour was about 20 per cent. less.

In addition to the many advantages that I have set forth which this boiler possesses over other types, I cannot help mentioning one more, and one which by no means is an unimportant one, *i.e.*, that it can be manufactured on the same system as an American watch, as all its component parts can be made according to size or power to templates, and kept ready in stock and in a small space. It can then be put together in a very short time, and even tried under steam on the manufacturers' premises, if required, before being taken again to pieces ready to transport to its destination. Moreover, it is a boon to small manufacturers, as the whole plant of machinery for manufacturing the boiler does not require large capital.

I have heard people remark, and have even read that boilers with small tubes are suitable for small craft, torpedo catchers, &c., but would not answer for battleships or cruisers. This, I contend, is not so. What is required is high-pressure steam as dry as possible, and plenty of it, produced cheaply in a small space, in generators of the least weight and the greatest safety. As the dryness of the steam is in proportion to the inside radius of the tubes, and the distance of travel from the place where it was created or formed, to its delivery into steam space, so it is obvious that the smaller and shorter a tube the drier must be the steam in equal circumstances; but, of course, small tubes are not applicable to all water-tube boilers.

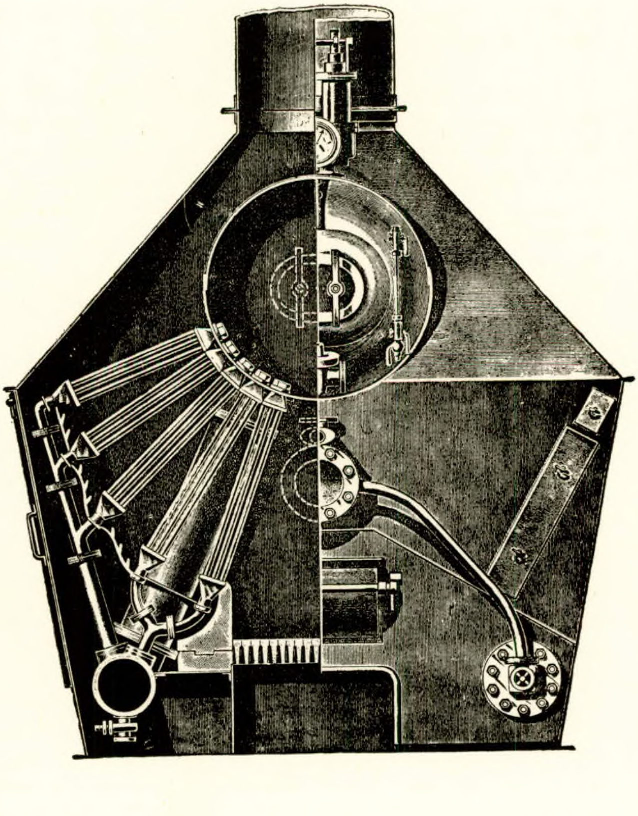
It is hardly necessary for me to point out what a benefit boilers of this principle will be to shipowners especially. By those who can see somewhat ahead of the times they will be generally adopted. The greatest advantages for shipowners may be summed up as follows:—Economy in fuel; great saving in weight and space; longer life; re-boilering ships without loss of time and without cutting away deck beams, cabins, &c. These and many other advantages will make a large difference in the profit and loss account on a year's balance-sheet.

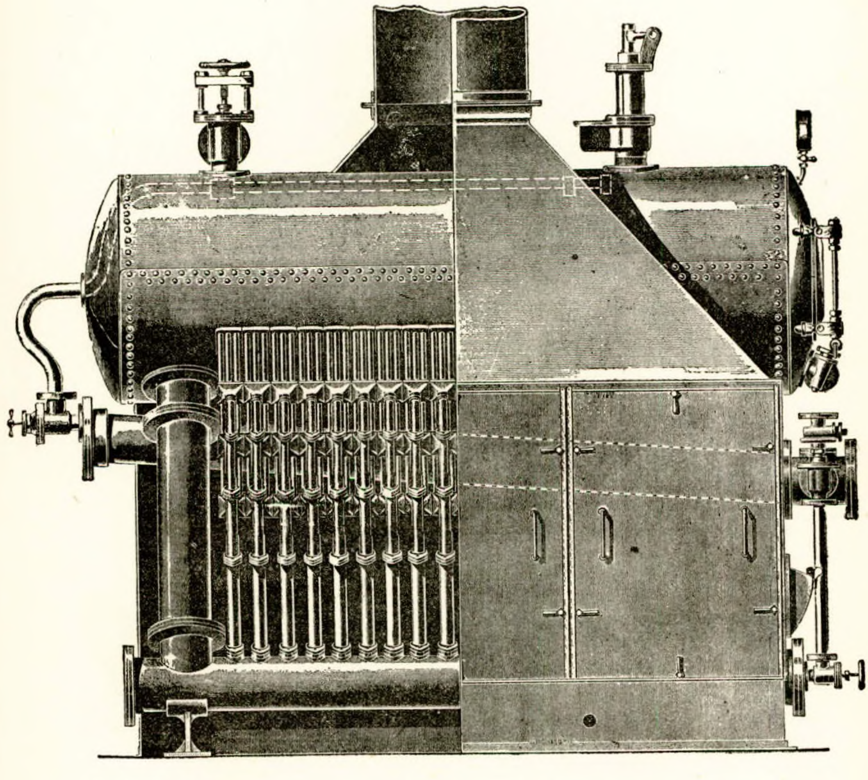
For boilers that have to be exported long distances, far away from any railway, over bad roads and up-country, or where other difficulties of transport exist, the steam drum can be made in several pieces screwed together, having flanges inside. The ends can be put on by studs and nuts, the same as a cylinder cover. In a case such as this, the heaviest piece in a 100 i.h.p. boiler need not exceed three cwt.

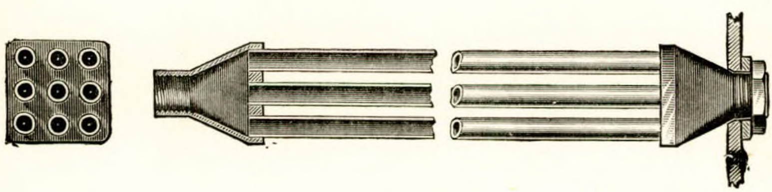
I take the opportunity on this occasion to show the members present one of the compound tubes, which has been subjected to a cold hydraulic pressure of 3,000 lbs. per square inch. The tubes are of about No. 18 wire gauge, and are guaranteed by the manfacturer to stand a cold pressure of 4,500 lbs. per square inch. Hereafter it will be seen that there is not the slightest difficulty in making boilers on this principle to be perfectly safe even with 500 lbs. pressure, or, at least, to stand a far greater pressure than we are able to make use of in present engines.

Before I conclude I would like to say a few words about safety. Such a thing as real safety cannot in high-pressure water-tube boilers be guaranteed simply by the manufacturer or by the thickness of metal in the tubes, &c. In my opinion, real safety lies more in the principle and construction of the boiler, and the first essential condition for safety and long life is that the circulation should be of the utmost rapidity, as, however strong tubes are made, they are liable, after a certain period of wear and tear, to fail. In my belief real safety exists only in the boiler that would not endanger human life in the event of the bursting of any tube; and that could only be the case in a boiler, the tubes of which are small. Therefore, I have no hesitation in saying that, as regards safety, my boiler stands in the foremost rank.

I desire further to mention that one obstacle still exists respecting the general employment of water-tube boilers, viz., that they require so much attention in the matter of the feed supply, and it is, therefore, of the first importance that a good automatic apparatus should be used in connection with them. I have pleasure in laying before the members drawings of my patent "Automatic Equilibrium Boiler Feed," with which is also combined in one apparatus an oil and deposit abstractor and feed-water heater. One such apparatus is capable of regularly feeding a battery of boilers, working at any pressure and keeping each water level at the same height without attention, no matter whether the main engines are stopped or moving. In the event, from any cause, of the feed being insufficient, the auxiliary pumps are started and stopped automatically, as required. If, on the other hand, the feed is in excess, the surplus is led away to the hotwell or special tank, such overflow ceasing when the level again becomes normal. Should the working limits of the water level be dangerously exceeded in either direction, the movement of the piston-valve causes a whistle to blow to call attention to it, the position of the piston-valve at all times being seen by the indicator in the glass tube. I am having one of these feeders made in this country, also one on the Continent, and thus it will be soon practically tested, and when experience has been obtained I shall be only too pleased to describe it more fully before the members of this Institute, if requested so to do.







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Volume VIII.

DISCUSSION

ON THE

SIXTY-THIRD PAPER

(OF TRANSACTIONS)

WATER TUBE BOILERS,

BY

Mr. E. PETERSEN

(MEMBER).

DISCUSSED AT

THE INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD

ON MONDAY, MARCH 30TH AND APRIL 13TH, 1896.

INSTITUTE OF MARINE ENGINEERS

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SESSION 1896-7.

President—SIR EDWYN S. DAWES, K.C.M.G.

DISCUSSION

AT

58, ROMFORD ROAD, STRATFORD,

On MONDAY, MARCH 30th, 1896,

ON

A COMPOUND WATER-TUBE BOILER.

CHAIRMAN:

Mr. J. H. THOMSON *(Chairman of Council).*

The CHAIRMAN: Now, gentlemen, you have heard Mr. Petersen's paper read, and we are all very much obliged to him for it, and to Mr. Atkins for the way in which he has read it. We regret that we did not have the paper sufficiently early to get it printed, as it would have facilitated discussion a good deal if we could have had it printed and circulated before it was read. However, Mr. Atkins has put it very distinctly before us to-night, and if there are any questions which any gentleman may desire to ask I have no doubt he will endeavour to answer them. Some of these diagrams are on rather a small scale, and perhaps it would be desirable, before we commence the discussion, to give the members present an opportunity of examining them. There is also this tube taken from the boiler which gentlemen may like to look at.

After an interval of ten minutes, during which members came to the table and examined the drawings—

The CHAIRMAN continued: I am sure that Mr. Atkins will now be ready to answer any questions on the subject. Seeing that water-tube boilers are now gaining such importance it ought to be a very popular subject, and any information we can get ought to be very acceptable. I should now like to hear some of you ventilate your ideas on the subject.

Mr. ATKINS (Member): There is nothing said in the paper about a rather important item, and that is as to the time within which steam can be raised safely in this boiler. Numerous trials have been made with the boiler at Messrs. Fraser's works, and the shortest time that has elapsed between the application of the match to the fire, the boiler being filled with cold water, and the blowing off of the safety valve at 150 lbs. pressure, was $21\frac{1}{4}$ minutes. As a rule the needle in the pressure gauge began to move in ten minutes after the lighting of the fire, and the bottom part of the steam drum became sensibly warm to the touch in two or three minutes after lighting up, and that can be done without danger. I venture to say that in the older boilers such a thing is impossible. Even if it were possible the boilers would suffer from leaky tubes or other diseases.

Mr. F. W. SHOREY (Member of Council): I think, in the first place, that we have had a very instructive paper, and that the question has been brought very clearly before us. I admire the system of metallic joints in this boiler; all the joints being metallic there will not be much difficulty with them. But I should like to ask if there is any difficulty in the feeding of this boiler, as I know that with some water-tube boilers they have had some difficulty with the water supply. Again, supposing one of the tubes gives out, what are you going to do? You know what happens when a tube gives way in a boiler of the ordinary type. What are you going to do if one of these water tubes gives out? I see that the feed pipe goes through the centre of the furnace. I did not catch from the reading of the paper the temperature at which the feed water enters the steam drum, but I take it that it must be a very high temperature, so that it must be practically steam which goes into the drum. If this be the case—if the feed enters the drum in the shape of steam—how is the water maintained in the boiler? When I saw this boiler tried the question did occur to ask how you managed to keep the water in it. It appeared to me that the whole contents must be steam. Again, I asked Mr. Petersen—and the reason is not clear to me yet—why it does not lift the water when you open the stop valve fully. That is a great failing with water-tube boilers at present, but I noticed that when this stop valve was opened full, the water in the glass was comparatively steady. It may have lifted just a little, but it settled down again at once. At the end of the paper the author also spoke about this patent automatic equilibrium boiler feed, but it seems to me that if we get these things to such a state of perfection engineers will have nothing to do. The engineer will simply have to go into his cabin and wait for the whistle to blow to tell him when his attendance is required. I begin to fancy I should like to go to sea again.

Mr. W. W. Ross (Member): I should like to ask this question: Supposing one of the tubes bursts, what is the course of procedure? Do you have to knock the boiler off altogether before you can repair it, because as a rule you have not got so many boilers on board ships that you can afford to knock off a boiler every now and then.

Mr. Henwood (Visitor): The reader of the paper did not mention what Mr. Petersen, I know, provided for and discussed with me before this boiler was made. The question has been raised, how he would stop the exit of the water in the event of one of these compound tubes bursting. Mr. Petersen provided a means of closing both the entrances automatically in the event of a tube giving out. He placed a ball valve at the entrance to each cup in the drum, and he closed the orifice at the lower cup by means of a similar device, both ball valves coming into action automatically immediately a tube burst. You know the ordinary safety water gauge fitting, whereby, if the glass breaks, the ball flies up and stops the water from coming out, and this is something after the same idea. The reason these ball values were not fitted is, that it was considered preferable to avoid what might be considered a complication in the first boiler. In the case of an explosion with an ordinary circular shell boiler containing several tons of water the back of the boiler may be blown out, as recently occurred on a French warship, when all the unfortunate men below were terribly injured, if not scalded to death. But in the event of a tube bursting in one of the Petersen boilers, the small amount of water that would issue through a leak in a tube of an inch or three-quarters of an inch in diameter would only be sufficient to extinguish the fire, and the steam that came out would in all probability find its way up the funnel. So that you would avoid the scalding of your unfortunate stokers. Another question which has been raised is as to the water in the main feed pipe running just underneath the drum. Well, it was found that the water is heated there to such an extent, that, practically, the majority of the solid matter held in suspension does not rise into the upper pipe leading into the drum, but assuming that a small portion of the solid matter does rise, it passes out through the drum. The circulation of the water is so extremely rapid that the small amount of solid matter is carried out of the steam drum into the mud drum at the bottom, where it is passed out without injury to the boiler. A question was asked by one speaker as to whether the water in the Mannesmann was heated to such an extent that only steam was thrown into the steam drum. Well, it has been found before now, that it is far preferable to feed your boiler with water which is on the verge of turning into steam, and you thus maintain your water level. (I saw an arrangement made by another gentleman fitted into a steamer, by which he carried all the feed water into the steam space, and passed it through a number of small pipes perforated with small holes, and this was found to answer very well indeed.) I saw this boiler fired—I think it was the second time the fire was lighted—and I afterwards took down an official connected with one of the foreign Governments to witness the lighting-up from cold water. There had been no fire in the boiler for a week, and steam was raised on that occasion to 150 lbs. in 22½ minutes. The official with me was highly delighted. There are many other points connected with this boiler which I think I might fairly speak of, inasmuch as Mr. Petersen conferred with me before this boiler was made, and I then expressed an opinion, and put it in writing, as to the advantages of this boiler. That opinion, expressed before this boiler was contracted for, has, I think, been fully borne out, and I shall always be glad to see it pushed, for I maintain that it is considerably in advance of any other boiler of its class for various reasons. One reason is this—that you can fit it up in a vessel without having to cut up the whole of the decks. This, as every one will admit, is a very important matter. In the matter of weight it compares very favourably with all other water-tube boilers.

Mr. KEAY (Member): The author states in his paper, that the tubes of this boiler are cut the 150th part of an inch larger than the holes in the cups, and that they are then pressed into the cups by hydraulic pressure. I am afraid that it is hardly within the practice of ordinary boiler making, to construct tubes and cups with so fine a difference, and if the fit of the tubes at the ends is not the same in all cases, it would appear that some of the tubes would go further into the cups than others. With regard to the design of the boiler, I think there is a good deal of surface about it that is not utilized, which might be utilized for heating purposes. I think it is a good point to keep the joints out of the flames, but I think the design might still be adapted so as to use to advantage much of the surface that is not used. I think the four down pipes, for instance, might be used for heating the water. Mr. Yarrow has shown that the application of heat to a down pipe is no detriment to the circulation; on the contrary, it rather improves it. I think also that the design might be improved with regard to the application of heat to the up pipes. Mr. Petersen gives the heating surface as 1,000 square feet and the total weight as 10 tons. This means a weight of ·01 tons per square foot of heating suface. Mr. Thornycroft, in a paper read some time ago, stated that in his "Speedy" type of boiler, one square of heating surface had been got per ·007 ton of total weight of boiler. From more recently published particulars, I find that about 100 I.H.P. can be got per ton weight of boiler, including water and all fittings. At maximum power, about two square feet of heating surface are required per I.H.P. This gives ·005 ton weight per square foot of heating surface. In general terms, Mr. Petersen's boiler is about half as heavy per square foot of heating surface as the cylindrical boiler at the highest rate of forcing, and about twice as heavy per square foot of heating surface as the lightest express boilers now in use in torpedo boat destroyers. With regard to the arrangement for the inlet of the feed, personally I am inclined to think that it is a very good thing, but we want practical experience before we can say whether the arrangement is sufficient to save that pipe from burning. I should also like a little more information as to what has been done with the boiler; for instance, the I.H.P. per square foot of heating surface.

Mr. J. R. RUTHVEN (Member of Council): With regard to the evaporative efficiency of this boiler, it is stated in the paper that the boiler will avaporate 13 lbs.

of water per pound of coal. It would be interesting if we could be told how this result was arrived at—how it was done.

Mr. S. C. SAGE (Member of Council): I am not prepared to criticise this boiler at the present time, but I may say a word or two with regard to the remarks made by some of the gentlemen who have preceded me. In the first place, as to the leakage in the event of one of these tubes bursting, I think that the tubes being of such a small diameter the leak would be small also, and if the leakage was only slight the probability is that the fire would immediately evaporate whatever water escaped into steam. The boiler would not be disabled unless the leak was so serious that the feed would not overcome it until such time as it became possible to get out the defective element. In my opinion the great disadvantage attending the use of these boilers at sea is that you have to get into the steam drum in order to remove a defective element and plug the hole up, and I think it is not beyond the scope of mechanical ingenuity to connect the tubes to the steam drum in such a way that in the event of a tube failing it would not be necessary to wait until the steam drum had cooled down sufficiently to enable a man to go in and detach it. We have seen some very interesting experiments here with some longer tubes than those in this boiler, and they were curved while these are straight, and I must say I was led to believe that there would be considerable priming; but when this boiler was tried and the stop valve was opened at 150 lbs. pressure there was no priming and no escape of water with the steam. I am inclined to think that the greatest deposit from the feed water will be in that Mannesmann tube, which being in the hottest part of the fire will have to be carefully watched. The gravitation of the deposit on the bottom of the tube might cause it to burn, and that, I think, is the greatest element of danger. There is no doubt that this boiler has been the outcome of many years of careful and anxious thought. The provision of those little ridges in the baffle plates for collecting the soot is a very ingenious idea, and it prevents the heat attacking those parts which are not serviceable for evaporating water. I think it is a boiler that has a future before it. I think it is the best water-tube boiler that I have seen, and I am sure that it is not beyond the power of mechanical skill to arrange some method of fixing the tubes to the steam drum so as to avoid going into the drum in order to detach or plug a tube in the event of one bursting.

Mr. SHOREY: With regard to these compound tubes, it occurred to me that if one of the small tubes should give out you might still reach port with it all right. How would it be to cut the defective tube away entirely and plug the holes top and bottom from the furnace without going into the drum at all, or waiting for it to cool down?

Mr. ROSS: Supposing the centre tube burst, how would you get at the holes in that case so as to plug them?

Mr. SHOREY: I was merely speaking of those tubes most likely to burst — those which come most into contact with the fire.

The CHAIRMAN: It has been suggested that Mr. Wilson should discuss this boiler from an oil-fuel point of view. Will he kindly do so?

Mr. H. C. WILSON (Member): I think I have already pointed out a boiler that is specially adapted for burning liquid fuel. But there is certainly one question I should like to ask about this boiler, and it is as to the amount of waste gases running away up the funnel. It appears to me that there is a lot of waste heat running away up the funnel, and whatever heating surface you may have, there is still a great deal of heat thrown away. It appears to me that there is a very great area there for the escape of the gases. Another point is, that I am rather surprised that Mr. Petersen should have so pinned his faith to copper tubes. I believe that other makers of water-tube boilers, as the result of great expenditure and many trials and experiments, have discarded copper tubes for this purpose, and I do not know why Mr. Petersen should have constructed his boiler with copper tubes. I do not think that that arrangement of furnace would be at all suitable for liquid fuel—you would get an intense heat, and you would dissociate your fuel so that the gases would run away up the chimney without doing any great amount of work. With regard to the figures that have been given as to the evaporative efficiency, I should like to ask how the feed was measured?

Mr. Atkins: By a tank, the exact dimensione of which were known.

Mr. Wilson: Did it go through a meter?

Mr. Atkins: No, it did not require to.

Mr. Atkins: In answer to another question asked by a gentleman present, I may say that, with 14 feet of grate surface, the boiler evaporated 13 lbs. of water per pound of coal, but with 21 feet of grate surface the evaporation was something over 11 lbs. per pound of coal.

Mr. Henwood: When I spoke just now I omitted to say anything about the advantages of this boiler when oil fuel is used. The last speaker said that he did not consider this boiler particularly suitable for the use of oil fuel. From that view I entirely dissent. I maintain that this boiler, by reason of the ability to place a very great accession of heating surface into the same space by bringing the tubes so much closer together, will give a vastly increased efficiency. An additional advantage secured by this boiler is, that you can dispense entirely with your solid fire bars and make the lower part of your furnace of water tubes covering them with fire bricks, and so increase the efficiency of the boiler to a very considerable extent. As it is the desire of every engineer to obtain the greatest-possible-efficiency-from-the-least-quantity-of-fuel, it will be apparant to any one that his ultimate success will be proved by the attainment of the greatest evaporation from the smallest amount of fuel.

Mr. Atkins: Well, I will do my best to reply to the various points that have been raised by the several speakers with reference to this boiler. I have Mr. Petersen by my side and I can refer to him when necessary. Many of the speakers to-night have spoken about the supposed difficulty of one of the water tubes bursting. No doubt it is a serious matter more or less, more serious than in the case of the old fire tubes, which could be plugged, but inasmuch as that objection applies to all water-tube boilers, I do not see that there is any special difficulty with this boiler, more than with one of Mr. Yarrow's or Mr. Thornycroft's boilers. In the case of any slight leak, the small amount of water escaping would be flashed immediately into steam, and so far it would not have the same effect upon the fire as if the boiler were working at a lower pressure. With regard to the temperature of the feed when it reaches the end of the Mannesmann tube, if I understood one of the speakers rightly, he inferred that there is sufficient heating surface in that tube to evaporate the whole of the water in the boiler—I fail to see how that can be. This tube is eight inches in diameter and nine feet long, but there is 1,000 square feet of heating surface to do the whole of the duty of the boiler. Mr. Keay mentioned the mechanical difficulty of any ordinary boiler-maker making all these tubes of the proper size, and fixing each one the same distance into the cup or socket. There is no doubt that is so. This boiler is not a boiler-maker's job; it is an engineer's job—speaking as a practical engineer, I foresaw the possibility of difficulty arising in the exact sizing of these tubes and cups—I do not know what the system adopted is, but judging by results, it is a perfect system. If you look at this compound tube, you will find that every tube enters practically the same distance into the cup, and that implies very precise sizing. Mr. Ruthven asked how the evaporative efficiency of 13lbs. per pound of coal was arrived at. The feed was run in from the East London Water Company's supply into a couple of rectangular tanks each holding 300 gallons, and the surface of the tanks was such that the use of 85lbs. of water caused a fall of an inch in the height of the water in the tank. As soon as the injector was put on, the height of the water in the tank was taken and the fall noted. While one tank was running out the other tank was being filled, and I do not think that there was much opportunity for any error to creep in on that score. Then Mr. Sage spoke about the escape from a small leak, and the power of the pumps to overcome it. I do not think there is much doubt that that would be the case provided, of course, that the tube was not blown right out. But there is no doubt that in the case of any small leak it would not be necessary to throw the boiler out of work. As to the "downcomers," Mr. Keay suggested that they should be put among the heating surfaces, but that would mar the whole design of the boiler. In this boiler Mr. Petersen has endeavoured to keep every joint out of the draught of the gases, and to put all those joints in the gases would, in my opinion, be simply inviting disaster. As to the ribs in the baffle plates, I think Mr. Petersen deserves very great credit for that arrangement. Then we come to the automatic arrangement to come into operation in the event of a tube bursting. Although Mr. Petersen provided for it in his specification, it was considered that as this boiler was really an experimental one it was not advisable to complicate it by this addition. Time will show whether the application is a valuable one or not, but so far as this experimental boiler is concerned, we did not feel that we should be justified in putting it in. Then there was something said as to the amount of gases going up the chimney. The paper says that the temperature of the escaping gases was from 450 to 500 degrees. Now I do not call that a very high temperature for funnel gases. There appears to be a lot of space there for the gases, but the area of the funnel is only equal to one-seventh of the great area, which is about the usual thing in other furnaces, and, therefore, whatever space there may be about it is restricted by the area through the ash pit and fire bars. I suppose Mr. Wilson meant the large space between the tubes and the side of the casing, but I do not know that that has anything to do with the free escape of the gases.

Mr. WILSON : My point was that 400 or 500 degrees was rather a large amount of heat to throw away. If you could bring it down to something like 100 degrees it would be more reasonable. With liquid fuel the surplus gases are thrown away at a temperature of about 100 degrees.

Mr. ATKINS : Well, referring to another point, we know that copper tubes have been discarded, but this is an experimental boiler, and must only be looked upon as such. The copper was the more workable material in this case. The whole crux of this boiler was the fixing of the tubes in these cups, and it was thought that for the purposes of this experimental boiler the tubes should be brazed into the cups. Well, the brazing was determined upon, and I believe it takes more kindly on copper than steel. But these tubes which look like copper are not copper, it is a bronze—a copper and tin alloy. I have not much to say about the liquid fuel question. Mr. Henwood takes one side and Mr. Wilson the other, and I must leave those two gentlemen to fight it out.

The CHAIRMAN : Gentlemen—It is proposed that the discussion on this paper be continued on Monday, April 13th, and before that time the paper will be printed, so that those gentlemen who care to call at the Institute before the meeting will be able to obtain a copy.

Mr. SHOREY : Before the meeting closes I should like to propose a vote of thanks to the author for his valuable paper. We, as engineers, must make ourselves acquainted with water-tube boilers, for it is the coming boiler in the future. Mr. Petersen has evidently considered most of the points, and we are greatly indebted to him for his valuable paper.

Mr. SAGE: And that we add the name of the reader of the paper to the vote of thanks.

The motion, with the addition suggested by Mr. Sage, was carried unanimously.

Mr. PETERSEN: Gentlemen—I thank you very much for the interest you have shown in discussing this boiler. We all have to learn and there is plenty more to be said. This may be one of the best boilers, but we must all try and find something better. I have done my best, and I have been at it for years. For myself, I may say I have spent a whole fortune on it. It has only been my perseverance, and but for that a good many would have thrown it up before now. From the beginning I had a belief it was a good thing, and so I persevered. Every one who has seen it, so far as I know, has told me that it is the best boiler they have seen. It may have faults, but, if so, we must try and improve it. Nothing is perfection all at once. There has been nothing done to this boiler since it was put up. It is now just as it was made by Messrs. Fraser, and no alteration has been made in it. In the boilers now in course of construction there will be some improvements, and I am sure it will be with better results.

Mr. RUTHVEN asked whether some arrangements could not be made by which members could see the boiler in operation, and

After some discussion it was agreed that the members of the Institute should be invited to witness a trial of the boiler under steam at Messrs. Fraser's Works at Millwall, on Saturday, April 11th.

A vote of thanks to the Chairman concluded the meeting.

ADJOURNED DISCUSSION

AT

58, ROMFORD ROAD, STRATFORD,

MONDAY, APRIL 13th, 1896,

ON

A COMPOUND TUBE WATER-TUBE BOILER

CHAIRMAN:

A. J. DURSTON, Esq., C.B., R.N. *(Past President).*

The CHAIRMAN: I believe there are several here to-night who were not present at the reading of Mr. Petersen's paper, and it is suggested that before we re-open the discussion, Mr. Atkins should read the salient points of the paper over again. I will therefore first call upon Mr. Atkins.

Mr. ATKINS then called attention to the principal points of the paper, observing that the great feature of the Petersen boiler was the compound tube system. With the aid of drawings and diagrams, he also explained the system of ball valves, included by Mr. Petersen in his specification for preventing the escape of water and steam in the event of a tube bursting. The ball, which was an inch and a half in diameter, would, if made of aluminium, weigh practically an ounce in air. The net weight of the ball in water would be an eighth of an ounce, so that practically it would float.

Mr. Atkins then called attention to some remarks made at the last meeting, as to the necessity for a man to enter the steam drum, in order to disconnect a tube in the case of a breakdown. He stated that a plan had been devised by which this necessity was obviated, and he sketched on the blackboard an arrangement by which, he said a defective tube could be removed without anybody going inside the steam drum. Explaining this sketch he said that the sets of tubes in this arrangement were placed in a sloping position (say 20 deg.) below the steam drum, at right angles across its axis, and in parallel rows (say six) one above another. Each set of compound tubes constituting an "element," instead of delivering directly into the steam drum as at present, was carried into a vertical delivery main which discharged into a horizontal steel pipe of sufficient size, lying parallel to the steam drum, and connected to it at intervals by short neck pipes. In this construction all the compound tubes (with the cast portions of the delivery main at the one end, and the feeding main at the other) were exactly alike so as to be interchangeable, and the ends being also symmetrical, they could be turned end for end and upside down. The feeding mains at the lower ends of the tubes were connected to a horizontal pipe or drum of the same construction as the upper pipe already mentioned, and receiving its water supply from the steam drum by means of large down-comers similar to those on the present boiler. The joints connecting the various castings of the upright delivery and feeding mains proposed to be made with copper rings, somewhat on the present principle, but instead of each joint having its own bolts, a long strap (in halves) was passed over the steel pipe, tied in by a cross bolt on the opposite side and extending past all the joints. This was finally screwed and passed through a pair of lugs on the end casting, at which point the whole series of joints could be tightened up by means of a couple of nuts only, thus making it easy to remove rapidly any one compound tube from the fire, or dry side. These bolt straps, in thus passing entirely round the steel pipe, reinforced it and compensated for the weakening caused by the holes which received the joint of the first casting. The construction at the feeding end was exactly the same; but, on account of the necessary position of the water drum at the bottom, the whole system at this end was reversed, top for bottom. By this arrangement, he thought, they had overcome the difficulty of a man having to go inside the drum in the event of either of the tubes failing.

Mr. BLAKE (Member): I have not had an opportunity of reading the paper, but should be glad if Mr. Atkins could give us some information as to the construction of the tubes in this boiler, and as to the material of which they are made.

Mr. ATKINS: The tubes in this particular boiler are made of copper, but inasmuch as this boiler was started nearly two years ago before copper had been entirely discarded for water-tube boilers, we can only make that excuse for using them. No doubt the tendency has been to throw out copper in favour of steel, but it is a matter of option whether you use copper or steel.

Mr. BLAKE: What is the diameter of the tubes if of copper?

Mr. ATKINS: These are 16 gauge—seven-eighths diameter outside. I may state that Messrs. Clark, Chapman & Co., who are now making these boilers in the north of England, are making these tubes of steel —galvanized electrically.

Mr. J. H. THOMSON (Chairman of Council): I was in hopes that some of the gentlemen who were down at the works on Saturday and saw this boiler under steam would relate their experiences.

Mr. JAMES ADAMSON (Hon. Secretary): Mr. Thomson has thrown down the gauntlet, and, as one who witnessed the test on Saturday, I had better take it up. I was particularly interested and edified by our visit to Messrs. Fraser's works at Millwall. It was the first time that I had had an opportunity of seeing this boiler, and I was sorry that so few of our members were able to take advantage of the kindness of Messrs. Fraser and Mr. Petersen in giving us this opportunity of seeing the boiler under steam. I do not know if I can give the particulars exactly, but after we had viewed the boiler with the baffle plates off it was closed up and the fire lighted. I think it was ten minutes after the fire had been lighted that the pointer on the steam gauge began to move indicating steam, and in 21 minutes we had 150 lbs. of steam. From the time of the fire being lighted until steam was blowing off full bore at quite 150 lbs. pressure only $21\frac{1}{4}$ minutes elapsed, and when the stop valve was fully opened I was particularly struck with the steadiness of the water as compared with other water-tube boilers that I have seen. I remember particularly my experience with one up the river a few years ago. The difficulty was to know whether there was any water in the boiler or not, on account of the way in which the water ran up and down the glass, so that I was specially pleased with the steadiness of the water in this test we had on Saturday. There are one or two points in regard to which I should be glad if Mr. Atkins would furnish us with some further information. I understood that the heating surface of this boiler is represented by 1,000 square feet, and the grate surface by 21 square feet. I also heard incidentally that this boiler was meant to represent 400 I.H.P., that, I apprehend, is the allowance usually made, and we may probably consider it the basis for the type as regards grate and heating surface per indicated horse power.

Mr. ATKINS: Yes, that is so, but we have never had it attached to an engine.

The CHAIRMAN: May I say that in boilers of a similar type we usually allow $2\frac{1}{4}$ square feet of heating surface per I.H.P., and that would be about the figure at which it would work out in this case—400 and 1,000.

Mr. ADAMSON: The explanation given as to the action of the ball valves for preventing leakage in the case of a tube bursting appears to be somewhat similar to what we are used in some water gauge columns which have an automatic arrangement to shut off the water when a glass breaks. As to the way in which the tubes are put into the sockets, it is not clear how you insure that the tubes shall run through the same distance in both sockets to secure a perfect job. I should say it would be a rather difficult matter to adjust things so nicely as to avoid the ends coming through too far in some cases. I do not know whether you have had any experience with the tubes leaking at the ends or where they enter the cups.

Mr. ATKINS: In this experimental boiler we brazed the tubes into the sockets or cups so as to make a joint we could swear to.

Mr. ADAMSON: Mr. Blake has asked a question with regard to copper tubes. I understood that the tube we had here last week was not of copper, but of a composition. I do not know whether Mr. Blake's question hinged upon that point—whether a composition of copper was better than steel. We know that copper tubes have been discarded in favour of steel, and the point I want to bring out is, whether these composition tubes that you referred to a fortnight ago were used preferably to steel?

Mr. ATKINS: It is immaterial. We can fix steel tubes into the cups just the same as this composition.

Mr. ADAMSON: But the point is, which is preferable?

Mr. ATKINS: I am afraid only time will show that.

Mr. ADAMSON: But this is a point in regard to which possible users of the boiler would expect some definite advice or opinion. If a shipowner or a superintending engineer were proposing to fit up one of these boilers he would ask the makers of the boiler "which material do you propose, from your experience, for the tubes, steel or copper; which do you recommend." He would want to be guided by the result of your experience in respect to this and along with it, other details. The Mannesmann tube is set at an angle, and

I should like to ask if there is any particular point or certain fixed angle at which the tube is set relatively to the steam drum, and, if so, what was the reason for adopting the angle?

Mr. Atkins: There is no particular reason.

Mr. Adamson: The explanation given by Mr. Atkins, and the sketch which he has shown us on the blackboard, certainly clears away one of the difficulties that was put before the meeting this day fortnight. I am not quite clear on the point yet—whether that would meet the whole of the difficulty that was raised in reference to the nuts in the steam drum itself, it seems to me more complicated, although the difficulty as to screwing up or removing the nuts is met.

Mr. Atkins said he thought it would meet the whole of the difficulty, and by further reference to the sketch on the blackboard he again explained the operation and effect of the device in question.

Mr. J. R. Ruthven (Member of Council): I should like to ask Mr. Petersen whether, after the experience he has had with this experimental boiler, if he were to make another, he would make any material alteration in the mode of construction or in the metal used. For instance, with regard to the tubes, would he abandon copper and use steel; or would he make any alteration in the manner of fixing them? It would be interesting if he would kindly tell us what alterations, if any, he will make when he makes another boiler, as the result of the effects he has found in the present boiler.

Mr. Blake: Mr. Atkins when he described this boiler made the remark that the only deposit from the water was thrown down in the shape of a fine powder. The water used in this experimental boiler was, I understand, supplied by the East London Water Co., and according to my experience, the carbonate of lime contained in this water is not thrown down in the shape of powder. My experience is, that at very high temperatures the carbonate of lime attacks the shell of the boiler. It appears to me that a pressure of 150 lbs. per square inch would facilitate the formation of a very hard scale on any surface coming in contact with the water, and I do not therefore understand why in this form of boiler there is no formation of scale, and that everything is precipitated in the form of powder or mud. The temperature of the flue gases has been stated at 450 or 500 degrees, but in order to explain that we ought to have the amount of coal consumed at the time. I do not know the reason why this particular temperature has been mentioned, but I think the information is slightly misleading in the absence of any data as to the amount of coal that was being burned at the time. My point is that when the temperature of the flue gases is given, there should be taken into consideration the amount of coal being burned, because the temperature depends entirely upon the amount of coal being consumed. With regard to the evaporation, it is stated that this boiler evaporates 13 lbs. of water per pound of coal, and that is a very high degree of evaporation indeed, but it would be interesting to know how this figure was arrived at. Does it represent merely the amount of water pumped into the boiler during the experiment, or the actual amount of water evaporated into steam, because it does not follow that the amount of water pumped into the boiler is the amount evaporated. For instance, take the case of a boiler priming, water would then pass into the engine in a liquid form. With regard to the distribution of the heating surface, I have had no experience with water tube boilers, but I feel very much interested in the subject, and one of the vital points appears to me to be the arrangement of the tubes. The first line of tubes over the fire grate would appear to me to be in such a position that if made of copper they would suffer to a great extent. If the tubes are of copper and the boiler is worked at 150 lbs., I should be afraid that the composition of the steam within the copper tubes would give rise to the formation of hydrogen gas which would have a very serious effect upon the copper of the tubes. The metal of the tubes is only one-sixteenth of an inch, and it seems to me there would be a great tendency of the tubes to rupture. It also appears to me that the tubes farthest away from the first row will be doing very little of the work. It has occurred to me that the tubes nearest the fire might be increased in surface and increased in thickness. My fear is that these copper pipes being very sensibly liable to decomposition and corrosion would constitute an element of danger in the boiler.

Mr. ATKINS explained that when the tubes were forced into the cups or sockets they were supported by plates, otherwise they would bend. Up to the present time this boiler had only been used with natural draught, the tube had never warped.

Mr. KEAY (Member): Mr. Petersen's boiler, like others, is a compromise. A designer attacks a problem with fixed ideas as to the essential points, and having made due provision for these, the details are arranged on sound principles as far as circumstances will allow. Mr. Petersen's great aim seems to have been to design a boiler, which could readily be transported and erected quickly, without skilled workmanship, and this object has been achieved in a wonderful degree. Comparing this boiler with ordinary tubulous boilers, its good points are:—(1) Rapid raising of steam without distressing the boiler, and (2) good circulation and absence of deposit on the tubes. The absence of scale, may almost be taken as a proof of good circulation. I do not think it is quite clearly understood why the lime salts do not adhere to the heating surfaces in such boilers, but as those of the Yarrow and Thorneycroft types have given no trouble from this cause, it seems reasonable to suppose that Mr. Petersen's experience will be similar. Perhaps the rapidity of circulation is a sufficient reason for the absence of scale. In the tubes and steam drum the water is in violent motion, and the impurities, finding that the only quiet place is the lower drum, settle there in the form of mud. Another good point in the boiler is the radial arrangement of the tubes. It is evidently good practice to have the gases impinging on the tubes at right angles. The area for the flow of gases decreases in proportion to their fall in temperature, and this probably enables a more perfect extraction of heat from the escaping gases to be attained. Another good point is the reduced weight, as compared with other marine boilers. Though rather less than half the weight of the ordinary marine boiler per square foot of heating surface, the Petersen boiler is still about twice as heavy as the lightest express boilers made. There are moreover several points in the design which are open to criticism. The feed arrangement is peculiar, and I am not quite sure that the eight inch Mannesmann tube is altogether safe, running as it does almost horizontally along the top of the furnace, and exposed to the fierce heat. There cannot be proper circulation through this tube, and scale may deposit. Again, the question occurs to me—What will happen if the feed supply to this pipe should for any reason be stopped? I am informed that an automatic connection is to be made between the lower drum and the Mannesmann tube, so that there may be no risk of burning the tube, unfortunately automatic arrangements are not always reliable. The next point I would refer to is the down pipes. There are four large pipes, having a total area of section, about equal to that of the tubes. They are inside the casing, but are carefully bricked off, so that no heat may get at them. I think it was shown conclusively by recent experiments, which some of us had the privilege of witnessing, that there is no objection to applying heat to down pipes, but rather an advantage in the form of higher evaporation and increased circulation. One of the claims made for this boiler is its lightness, but I think that utilizing the down pipes as heating surface would enable a considerable increase of power to be obtained from the same weight of boiler. With regard to the material used for the tubes, copper has been used in the experimental boiler, as it can readily be secured to the cups by brazing. Mr. Petersen purposes using a hard bronze, and the cups are to be forced on to the tubes by hydraulic pressure. I would like to ask however, why bronze is being used in preference to steel; the steel used for such tubes is exceedingly ductile, and almost as soft as copper. Has any difficulty been experienced in trying to force the cups on the steel tubes? I would also like to ask a few questions, the answers to which, I think, will be of general interest. How is the heating surface measured in the boiler? *i.e.*, what surfaces are included in the thousand square feet? Up to what rate of working has this boiler been forced, and what air pressure was used? How long did the evaporation trial last, and how many pounds of coal per square foot of grate area were being consumed during this trial? The evaporation of 13lbs. of water per pound of coal means an efficiency of about 90 °/ₒ, and one gentleman has doubted the possibility of this result. It is certainly a wonderful performance, but in the results of some trials, conducted by no less an authority than Professor Kennedy on a Thorneycroft boiler, a similar evaporation was obtained at a very low rate of working. I would also like to inquire if the tubes nearest the fire have given any trouble? Being only about three quarters of an inch internal diameter, and the longest tubes exposed to the fiercest heat, there can be little fear of the other elements if those nearest the fire behave well. Have any of these tubes warped? It would probably be good practice to make the tubes nearest the fire of an increased diameter. Another question is—Is the area through the socket equal to the area of the nine tubes connected thereto? Mr. Adamson referred to the steadiness of the water level in this boiler, compared with that of some other types of water tube boilers. The quantity of water in the boiler is stated as 2½ tons for 400 I.H.P. This means that the boiler carries as much water as it will evaporate in about 45 minutes. In the Yarrow and Thorneycroft boilers, the contents are evaporated in from 10 to 15 minutes. The water level is therefore steady in Mr. Petersen's boiler on account of the quantity of water carried. Possibly it may not be necessary to fit automatic feed arrangements, though I understand that Mr. Petersen has designed such an apparatus.

Mr. H. C. Wilson (Member): I had something to say on this subject at our last meeting, and I do not know that I have much more to contribute to the discussion. I have really only had an opportunity of glancing the paper through, and I am not in a position to say much about it. I see that one advantage claimed for the boiler is its adaptability for liquid fuel, and in the course of his paper the author says: "Other very important advantages are derived from the very large combustion chamber and by the radial formation of the compound tubes, placing them in such a position that the hot gases strike them almost at right angles, besides leaving between each row additional combustion chambers where the gases are re-ignited and to a great extent consumed." Well, for my own part, I do not quite see where the re-ignition comes in. I should be rather inclined to think that the gases at that temperature——

Mr. Atkins: The author there is speaking of coal.

Mr. Wilson: This particular paragraph, I think, does refer to coal. Of course, as I said at the last meeting, I do not think that with that form of fire grate this boiler, as now used for coal, would be at all advantageous to use for liquid fuel. I think you would have a tremendous amount of loss through splitting up your hydrogen and carbon into their different elements. You would have dissociation set up, and the hot gases would simply pass away in a divided state. I do not know whether this boiler has yet been tried with liquid fuel, but I anticipate that there will be difficulty. I do not say that you will not get better results than with coal, but whether you will get the best results that might be got with liquid fuel I very much doubt. There is another point I should like to refer to, and that is as to the amount of water evaporated per pound of coal. I think the figure given here is 13 lbs., and I believe that Mr. Atkins stated on the last occasion that the water was measured at the tanks. I have had the privilege of seeing this boiler under steam more than once, and I carefully noted the arrangement for the feed measurement, and it appears to me that inaccuracy to some amount might very easily creep in. The tanks were not square tanks, and they were not closed in, and a very small misreading over the surface exposed would make a very great difference in the amount of water that was apparently evaporated. Therefore, I am inclined to think that if a proper meter had been used it would have given us rather a different result. My point is that very possibly—very probably—there was some slight inaccuracy in the measurement of the water put into the boiler.

Mr. E. N. HENWOOD (Visitor): It will be interesting, I believe, to the members of the Institution, to be informed of some of the difficulties which beset the inventor's and my endeavours to even get the boiler made, and I may briefly say that although I have no pecuniary interest in the boiler, yet acting on the firm conviction that it was constructed on right principles, that it would be a reliable and safe boiler, and that it was far ahead of any other ever designed, I communicated by letter and personally with all the leading engineering firms and boiler makers in Great Britain as to their making one, or taking it up as a special manufacture; but I regret to say they all, with one exception, declined the manufacture, stating they would prefer to see it tried first. On my inviting the one excepted firm to discuss with me at my office the merits of the boiler, they did so, and then contracted to make it; therefore, in my opinion, great credit is due to Messrs. John Fraser & Son for their foresight and skill in carrying the experiment out so successfully. I may mention that the practically endless objections made by all parties had been discounted and refuted by Mr. Petersen and the speaker. Among the objections I may mention one that was specially held to be fatal—viz., that the area of the orifice of the "cup" or "reducing socket" in the steam drum would have to be at least equal to the collective area of all the nine or 16 tubes entering the larger end of the "cup."

Now, I must ask Mr. Petersen to state whether he has any fear about his boiler being able to withstand such heat as 5,000° Fah.; such as he saw was created or evolved by oil-fuel or "green oil" at the Electric Light Works in London (last year) on my system. I may add that I have no fear at all on the matter.

I may just make an explanation as to what was discussed by Mr. Petersen and myself before this boiler was contracted for, as to the advantage of having the faces of these cups made square instead of round. I strongly advised him, and he agreed to make the faces square and put in nine tubes, and I think every one will see the advantage of having them so made. A question has been asked by Mr. Wilson as to whether the large amount of space in this boiler would not lead to loss when using oil-fuel. I may mention that I also discussed this point with Mr. Petersen, and an arrangement has been devised so as to prevent any undue admission of air, the only air being admitted through the orifice surrounding the oil injector. I was present at the works not only on Saturday last, but last November. In fact I was present last year at a trial of the boiler evaporation for three hours. I noticed carefully the measurements taken by the gentleman who had charge of the experiment, and I was particularly struck with the care that he took in making the measurements. I quite admit that in measuring a large body of water from tanks of that kind there is a liability to err, but on the question of whether it was 13 or 12½ lbs. per pound of coal is not of much moment. I think the accession of heat you would get by applying fuel in its concrete form would be such that there would be such an increased evaporation as to render half a pound of water per pound of fuel not worth consideration. I have arranged for this boiler to be fitted into a certain small vessel now about to be constructed. The boiler that I saw at first covers all the ground, and secures all the advantages which could be comprehended in a water-tube boiler. We have to remember with regard to other water-tube boilers which have been spoken of, the difficulty experienced in the event of a tube giving out and the long time occupied in replacing it. But in the case of this boiler it does not take a long time, and I should suppose that one of these compound tubes might be taken out and the boiler got to work again in a couple of hours at the outside.

Mr. WILSON: I am very much obliged to Mr. Henwood for the information, more or less, that he has given us, but with regard to the liquid fuel aspect of the question my point is, not that we should get too much air into the space, but that we should get too little. My point is for getting more air in so as to ensure complete combustion and prevent dissociation taking place.

Mr. BLAKE asked if there had been any tendency of the flue dust to accumulate between the tubes so as to cause each compound tube to become a solid column, so to speak. If the flue dust accumulated on the little shelves on the baffle plates it would also accumulate, he should imagine, in the spaces between the tubes.

Mr. HENWOOD: Mr. Petersen originally provided, and he has provided in this boiler, a series of scrapers which travel up and down the compound tubes, but it was found that the rush of the gases through or between the tubes was so strong as to prevent the accumulation of anything like soot or the barrier suggested by the gentleman who has just sat down. Therefore there is no need to use the scrapers at all.

The CHAIRMAN: It is perfectly clear, as Mr. Petersen has said, that this boiler as yet is in the initial stages of manufacture. It is now being fitted in one or two ships, but up to the present it has not been in use practically at sea, so that we are as yet without any results as to its value in marine practice. The water that has been in use in this boiler hitherto has been that supplied by the East London Water Company; it is not the greasy water that we have to use on board ship that comes from the condenser. I am afraid that if that water had been used there would have been a different tale to tell. I am not saying anything against the boiler, but I think the results would have been different. I will say at once that there are many very good practical points about the design. This boiler has been built up of tubes of copper, but now, I understand, Mr. Petersen uses tubes of hard bronze. We know now from our own experience that copper has failed as a material for the tubes of water-tube boilers, and Mr. Thorneycroft, as the result of his experience with brass tubes—not bronze, but brass—has had to give up that material also. Brass tubes were found to fail through overheating, and they burst; pieces used to blow out from the upper part of the tubes. It is certainly a very remarkable property that this boiler has of producing dry steam. Another point is, that the manner in which this boiler is constructed renders it very easy of transport, and it would also make the repair of a single tube easy. Mr. Atkins has shown us a special design to get over the difficulty of men having to go into the steam chest in order to disconnect or remove a tube, but I do not see why this difficulty should be so great an objection, and I do not see why in order to get rid of the difficulty you should introduce this complication. With regard to the ball valves that have been suggested as a means of stopping the leak in the event of a tube bursting, I think the less you have of them the better. Steel tubes do not give out every day, but when they do you must knock off the boiler for a time while the leak is plugged or repaired. The joints in the boiler are made with copper rings, and that is the system we have lately stipulated for in our machinery for these high pressures, and it has also been used by Mr. Thorneycroft and other engineers But in regard to that I may say that we have made some interesting experiments recently. A small boiler was made up and a plain bolted joint with a coating of red lead paint stood a pressure of 400 lbs. per square inch. This joint was afterwards heated on the outside by gas jets, and it stood perfectly, while a similar joint stood up to a pressure of over 900 lbs. on the square inch. That struck me at the time—and it was only recently that the experiments were carried out—as being rather an important factor in marine practice, as showing that if the flanges are only made stiff enough and the bolts strong enough, joints of this description are sufficient for the purpose, without anything special being introduced. We all give Mr. Petersen our heartiest best wishes for success in the undertaking of his new boiler, and we shall all welcome it on the results of the work it may be shown to have done.

The CHAIRMAN: It is now proposed that Mr. Atkins should reply to the points which have been raised in the course of the discussion.

Mr. ATKINS: First with regard to the question asked by Mr. Adamson, as to whether there is anything in the amount of slope in the Mannesmann tube. We put it at such a slope as would suit the design of the boiler—nine inches of slope in ten feet. The idea in giving it a slope at all was to assist circulation. Mr. Ruthven asked whether any alteration was contemplated in the way of fixing tubes, as to brazing them in. I think I explained that these tubes were brazed in as a matter of expediency, because the boiler being of novel construction we hardly knew where we were. We thought we would take the bull by the horns and make a joint we could swear to, and it was for that reason that copper tubes were used, because copper takes more kindly to the brazing than the steel. Mr. Blake spoke about the East London water, which he says contains carbonate of lime, which is usually thrown down in the form of scale, which sticks to the surfaces. That may be so theoretically, but we do not find it so in our practice. We do find a very small amount of scale at the entrance to the Mannesmann tube, but it is nothing of any consequence—not more than the $\frac{1}{32}$ of an inch. As to the chimney temperature, I think it goes without saying, that if you burn more coal upon a square foot of grate area you will get a greater proportion of escaping heat. These six hour trials were made by an independent engineer, Mr. Thomas. They were made entirely independent of us. We trusted him, and from what we could see we believe that he carried out his work conscientiously. Mr. Blake went on to speak as to the distribution of the heating surfaces, and a special point was made as to whether the first line of tubes suffered. A paper was read before the Institution of Naval Architects the other day, in which some trials with an experimental boiler were quoted, and it gave the percentage of evaporation due to each of the four or five rows of water-tubes above the fire. If my memory serves me correctly the first row of tubes was credited with 60 per cent, and the last row with ·05 per cent. That shows, upon this point, that the first two or three rows of tubes practically do all the work in the boiler, and there is certainly some argument for making these tubes, which bear the full brunt of the fire, larger. Mr. Keay says that this boiler is a compromise. Well, of course, it is. Everything is a compromise, more or less, in engineering. Ease of transport is certainly one point that recommends itself in this boiler; and on another point, scale certainly does not deposit in these tubes. One might suppose that scale would not form in these tubes, or how would Mr. Yarrow and Mr. Thorneycroft get on? They have been using bent tubes, which are longer than those used by Mr. Petersen, and if they do all right it would seem to follow that these will answer also. Now as to the "downcomers" being put in the fire. Mr. Yarrow's "downcomers" have not got a flanged joint at each end. His "downcomers" are the same size as the "up comers." But here I do not see how we should get on with these joints in the fire. I should not like it myself. I have already referred to what was said about the tubes in the hottest part of the fire, and a question was asked as to whether, as the result of the trials that have taken place, any of the tubes have been found defective. Whether any of them warped? This tube that was on the table at the last meeting is the only tube that has been removed from the boiler. It was taken from the hottest part of the fire, and although is was only removed very recently it will be seen that there is no defect in it whatever. This tube was taken out from one of the compound tubes immediately over the fire grate to see the effect upon the tube of the numerous trials that have been made with the boilers and you see the state of the tube now. With regard to liquid fuel, this boiler was not designed to burn liquid fuel, but I have no doubt that the grate can be so adjusted as to make it capable of burning liquid fuel. As to the measurement of the feed water in the tanks, there might be, in an individual instance, an error of a quarter of an inch in the amount of water taken out, but that error would not be cumulative. If we take 30 inches of water out of a tank the exact amount taken out each time does not matter so long as the total amount is taken out. It is suggested that we should have used meters, but I am not aware that meters are infallible. Indeed, I do not think, that they will guarantee meters under two per cent. of error. Then the question is asked if we have any fear about the boiler with 5,000 degrees of heat? Well, I don't know about that.

Mr. PETERSEN, interposing, said he believed that the boiler would stand a temperature of even 5,000 degrees because the circulation was so rapid. With such a circulation as obtained in this boiler it could do no harm, but if the circulation was bad damage would result.

Mr. ATKINS: Mr. Blake spoke of the ledges on the baffle plates, and suggested that if the ashes collected on the baffle plates it would also collect between the tubes. I do not see why. There is always a way between the tubes, but on the ledges on the baffle plates there is a *cul de sac*. At any rate, nothing has been found there except what collects on the top of the tubes. The scrapers were suggested before the boiler was materialized at all. They were in the original drawing, but experience has not shown them to be required. I am thankful to the Chairman for his remarks, more particularly when he said that this boiler was in the initial stages. It is hardly out of them yet, but I think it is in a fair way to do something. I am rather inclined to think that it is a bold departure in boiler making, and it is therefore not impossible that it may be improved upon as experience dictates. However, the point remains that the boiler is there. It has done fairly good work, and during all these trials that have taken place we have never had any serious breakdown or leakage in any part of the boiler. I think that those who were down at Messrs. Fraser's Works on Saturday, will agree that they never saw a boiler treated as that boiler was treated in the way of firing up. Of course, as the Chairman remarked, we have had no experience with greasy condenser water, but I suppose that this boiler is no worse off than any other boiler in that respect. I am likewise obliged to him for his statement as to the behaviour of copper tubes and alloys.

There is no doubt that all this points to the fact that galvanized steel tubes are the right thing for the future, so far as I can read and learn.

Mr. Ruthven proposed a hearty vote of thanks to Mr. Petersen and Mr. Atkins, for the manner in which they had brought this subject before the Institute.

Mr. F. Cooper (Member): I have great pleasure in seconding that. As marine engineers, we must all feel very much indebted to Mr. Petersen and also to Mr. Atkins. We cannot speak of the boiler, from the economical or the shipowner's point of view, because it has not yet been tried, but I think from what we have seen of the drawings, it is a boiler that will suit the marine engineer better than some we have seen. A marine engineer will always think well of a boiler that he gets good results from, but it seems to me that he will think more of a boiler which, while showing good results, gives him the least trouble. I think that Mr. Petersen in the arrangement of the tubes, has done away with one of the greatest difficulties, from an engineer's point of view, in the case of a breakdown at sea.

The motion was carried by acclamation.

Mr. Atkins: Mr. Petersen has asked me to reply for him to this vote of thanks, and I may also say that he asked me to speak for him in the discussion because he is not quite a master of our language, and being a little deaf he is not able to follow the various speakers. On his behalf I thank you for this vote of thanks. I am afraid the part that I have played has been only a subordinate one, Mr. Petersen brought this boiler into the office in which I was engaged and we have helped him with it. We made or suggested such modifications as we thought desirable, and the result is as you see on that diagram. But the principle of the boiler is there as it was before I saw it. It was only in minor mechanical matters that the design was altered. All credit is due to Mr. Petersen for having had the pluck to start such a new departure in boiler making at his age.