INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1903-1904.

President—SIR JOHN GUNN.

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

VOLUME XV.

ONE HUNDRED AND NINTH PAPER

(OF TRANSACTIONS).

SCOTCH, OR CYLINDRICAL MULTITUBULAR, BOILERS.

BY

MR. E. NICHOLL, R.N.R. (MEMBER).

READ AT

3 PARK PLACE, CARDIFF,

ON

WEDNESDAY, FEBRUARY 11th, 1903.

CHAIRMAN:

MR. W. SCOTT (MEMBER OF COMMITTEE, B.C. CENTRE).

AND AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, MARCH 9th, 1903.

CHAIRMAN:

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

PREFACE.

58 Romford Road,
Stratford,
March 9th, 1903.

A meeting of the Institute of Marine Engineers was held here this evening, when a paper by Mr. E. Nicholl, R.N.R. (Member)—read on February 11th at 3 Park Place, Cardiff, before the Bristol Channel Centre—on "Scotch, or Cylindrical Multitubular, Boilers," was read by the Hon. Secretary, in the absence of the author, and discussed. The chair was occupied by Mr. J. R. Ruthven (Member of Council). The discussion was adjourned till the re-opening of the session in the autumn.

Jas. Adamson,
Hon. Secretary.

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CHAIRMAN:

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IN introducing this subject to your notice I feel that some apology is necessary, as most people would naturally consider that there could be little new to say about Scotch, or cylindrical multitubular, boilers.

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When I say "Scotch," of course you will understand that I refer especially to the cylindrical multitubular marine boiler as used in the merchant service to-day. The word "Scotch" seems to have come more into use, as applied to boilers, since the introduction of water-tube boilers, to distinguish them from the latter.

It will, perhaps, be argued that we already know how to make safe boilers, and that the laws which govern us in the strengths of the various parts are well known. The first assertion is true, but I wish to create a discussion and to obtain your opinions whether you do not think we are making them too safe and too heavy, and commercially handicapping ourselves. Who amongst the members of our Institute ever heard of a marine boiler exploding when built to the Board of Trade or Lloyd's rules?

When we look back five or six years and think of all the inflated talk about the water-tube boiler, especially in popular magazines, and also in some engineering periodicals, how it was going to displace the cylindrical, etc., one would expect to have almost looked upon the latter by this time as a curiosity, fitted only for a museum, to show our sons what stupid methods their fathers employed in the generation of steam. Well, gentlemen, the inevitable reaction has set in, and once more we find our old friend brought back into public favour. It will be interesting to recall what were the supposed advantages of the water-tube boiler over the cylindrical type, and to inquire how the predictions of the advocates of the former have been fulfilled or falsified.

In the first place, the water-tube was expected to give more economic results, but, instead of this being the case, it has ended with a Scotch verdict of "Not proven." For corroboration of this I need only refer you to the excellent report of the Boiler Commission on the boilers in the Navy, and to the recent test of H.M.S. *Minerva* and *Hyacinth*. Personally, I am of the opinion that, had inquiry been made into the working of water-tube boilers in the merchant service, much more startling results could have been obtained, showing reasons against their general adoption and in favour of the superiority of the cylindrical boilers.

2nd.—Power for power, the water-tube has a considerable advantage in the matter of quick steam raising, and this we must readily grant, although, with proper care in circulating when getting up steam, the cylindrical will take a lot of beating.

3rd.—The water-tube has the advantage in the matter of weight over the cylindrical, variously estimated at from 25 to 30 per cent.

Now, it is to this latter point I wish to draw your special attention this evening, with the hope as previously stated of bringing about a good discussion, and inviting your opinions on the following in respect to cylindrical boilers.

Are the boilers too heavy, and is the cold water test, to double the working pressure, injurious and too drastic?

Let us consider if anything can be done to reduce the weight of cylindrical boilers without detracting from their safety or efficiency. To that I may say Yes, and very materially too.

Of course, in the matter of boiler scantlings, we in the merchant service are entirely in the hands of the Board of Trade, Lloyd's Registry, British Corporation, or some other body of surveyors, and have to conform to their rules. Now, I have nothing to say against any one of these institutions; they are, no doubt, all very necessary for the protection of the public, and admittedly have done good work, but such bodies are very prone to become crystallised, and it is only by continually stirring them up by discussions at such institutions as our own that we can hope to make any impression upon them. The individual is powerless. Combined opinion with combined action is now the order of the day, and the only way to succeed in such circumstances.

First let us take the boiler shell. Here we find the Board of Trade insist on a factor of safety of 4·5 with first-class construction, but, under certain conditions, such as imperfect workmanship or design of joints, it may be 6· or over, but I will assume that the design and workmanship are of the best.

Let us assume we want a steel boiler 16 ft. diameter, the plates to have a tensile strength of from 27 to 32 tons per square inch, and the longitudinal joint to be designed to give 85 per cent. of the solid plate, which can be obtained with a treble riveted double strapped seam. The pressure to be 160 lb. per square inch.

The thickness of plate would be as follows:

$$\frac{\text{P} \times 4{\cdot}5 \times \text{dia.}}{\text{Tons} \times 2240 \times 2 \times \%} = t$$

Where P = boiler pressure, t = thickness of plate in inches, diameter in inches.

$$\frac{160 \times 4{\cdot}5 \times 16' \times 12}{27 \times 2240 \times 2 \times {\cdot}85} = 1{\cdot}344'' \text{ or } 1\tfrac{11}{32}''$$

Lloyd's rule for the same boiler would give the following thickness:

$$\frac{\text{P} \times \text{dia.}}{\text{C} \times \%} + 2 = t \text{ in sixteenths.}$$

Where P = boiler pressure, t = thickness of plate in sixteenths. C = constant = 21.

$$\frac{160 \times 16' \times 12}{21 \times 85} + 2 = 19{\cdot}2 = 1\tfrac{3}{16}''$$

From the above calculations it will be noticed that Lloyd's would allow a plate over 11 per cent. lighter than the Board of Trade for the same pressure. Of course this advantage would disappear when dealing with a boiler of small diameter or low pressure requiring thin plates, but this is as it should be, the same allowance—viz., two sixteenths—being required as much in the boiler with thin plate as in that with thick, if not more so.

Now here we have the two chief authorities dealing with shipping differing in opinion as to the thickness of plate required, the former asking for a plate

11 per cent. heavier than the latter in order to make the boiler safe for the pressure. Why should such eminent authorities differ so much?

It is evident that either the Board of Trade are asking too much or Lloyd's are passing boilers which have not a sufficient margin of safety; but I contend that both are allowing more than is necessary for safety.

The Board of Trade, as I have previously stated, ask for a factor of safety of 4·5, whereas Lloyd's are content with 4·; but wherein comes the necessity of even 4·?

Of course I shall be told that if you test your boiler to double the working pressure your factor of safety must be at least 4·, or perhaps a little over, as the elastic limit of the steel is about 50 per cent. of the ultimate strength, and may be a little less; but why the necessity for testing to double the working pressure? The water test, as far as my knowledge goes, is primarily put on as a test of workmanship, and not to determine the strength of the boiler, for the latter has been determined beforehand by calculation.

I think you will agree with me that any person who determined his working pressure by the result of a water test was, to say the least, lacking in discretion.

The Admiralty and most of the Boiler Insurance Companies would, I find, be content with a water test of one and a half times the working pressure, and this in my opinion would be ample.

Again, I may be told that it is necessary to obtain a factor of safety of 4·5 to allow for corrosion, but Lloyd's—very wisely, I think—allow for this by addition of two-sixteenths to the thickness, but the Board of Trade evidently make no distinction between thick and thin shells.

I would ask any gentleman here how many shell plates he has found badly corroded in modern boilers to such an extent as to impair their safety. My experience has been that if you find any corrosion at all it is purely local, mostly external, and that after years of work.

Well, gentlemen, considering all the circumstances, I think a factor of safety of 3·5 would meet he requirements, and, presuming this, let us see what reduction in weight of shell would follow its adoption.

Taking the same boiler we have the following:

Board of Trade $\frac{1\cdot344'' \times 3\cdot5}{4\cdot5} = 1\cdot045''$ barely $1\frac{1}{16}''$

This represents a reduction in shell of about 22 per cent. If the large factor of safety is needed to provide for corrosion, I would point out that a nominal factor of 3·5 represents really over 4· in the solid plate, for corrosion at the butt straps need not be considered, as they are considerably more than the thickness of the shell.

Lloyd's stipulate that the inside butt strap alone must be at least three-quarters the strength of the longitudinal joint.

Next let us take the furnaces, which are invariably of the corrugated or ribbed type. As far as I can gather, a factor of 5· is allowed, the formula having been deduced from actual experiments. If we take the Board of Trade rule we find we require a plate of the following thickness:

$$\frac{P \times D}{14000} = t$$

Where P = boiler pressure, D = diameter in inches, and t = thickness in inches.

Suppose diameter of furnace to be 40 in.:

$$\frac{160 \times 40}{14000} = \cdot457'' \text{ or } \frac{29}{64}''$$

By Lloyd's rule $\frac{P \times D}{1259} + 2\cdot = t''$ in sixteenths.

$$\frac{160 \times 40}{1259} + 2 = \frac{7}{16}$$

Here we find those two eminent authorities in near agreement; although at higher pressure Lloyd's allow thinner furnaces than the Board of Trade on account of adding two-sixteenths for corrosion, which is, of course, as it should be. But where again is the necessity for a factor of 5·? When did anyone hear of one of these furnaces collapsing on account of initial weakness? In fact, a well-known engineer, with a very large experience, both practical and experimental, has expressed the view that we do not know what the collapsing pressure of a furnace is. In every case that I ever heard of it has been due to grease, shortness of water, or something abnormal, and when this is the case it matters not what thickness of plate you may have, the result will be the same. I think we could with perfect safety reduce the thickness from 10 to 15 per cent.

Of course I am quite aware that the strength of a furnace tube is largely dependent on its circularity, but at the present day I do not think there is much to complain of in this respect.

In the case of the stays, we find that the different authorities seem to agree fairly well, and allow a stress of 9,000 lb. Lloyd's, I believe, only allow 7,500 lb. on combustion chamber stays less than $1\frac{1}{2}$ in. diameter. But suppose we take 9,000 lb. as the standard. The bars from which the stays are made must have a tensile strength of twenty-seven tons according to Board of Trade rules, and twenty-six tons with Lloyd's. If we take the latter we have a factor of safety of:

$$\frac{26 \times 2240}{9000} = 6{\cdot}47, \text{ nearly } 6\tfrac{1}{2}$$

Now, I ask, why a factor of safety of $6\frac{1}{2}$? Is this the corrosion bogey again? I have had boilers which have run a dozen years, and many others here have, I am sure, and never had occasion to renew a stay on account of corrosion.

We often hear of combustion chamber stays breaking, although I have never had this experience, but in no case has this been due to stresses produced by pressure, but rather to strains set up by alternate heating and cooling; and as long as builders are allowed to design boilers with absurdly narrow water spaces and, consequently, short stays, this trouble will continue. It may be said that the stresses are very unequal on the stays, and there is, no doubt, some truth in this; but surely it does not call for a factor of safety of $6\frac{1}{2}$? Suppose we make a concession to those who hold the latter view, and give a factor of 4·5, we should have a reduction of:

$$\frac{6{\cdot}5 - 4{\cdot}5}{6{\cdot}5} = 30 \text{ per cent.}$$

Lastly we have the flat plates in a boiler.

Here I am at a loss to know what factor of safety has really been allowed by the different authorities, as the formula is largely empirical, but from practical experience I have come to the conclusion that it is quite as high as for any other portion of the boiler. It does not matter what part of the boiler the plate may be in, the factor of safety is the same, which is surely absurd. If we wish to allow for corrosion it would appear more reasonable to allow for it where we find it most frequent. We rarely find corrosion to any extent in the top end and mid back plates, but on the other hand the lower portions of combustion chamber plates suffer considerably from this cause.

Well, gentlemen, I have written this paper primarily with a view to promote discussion, and I hope everyone will have something to say and help to bring this subject to the notice of the powers that be; for I feel sure that the only reason there can be for not reducing the scantlings of boilers is the apathy of steam users generally to the subject, and unless the latter move in the matter we cannot expect the authorities before mentioned to do anything. I read somewhere recently the opinion of an American in connection with the question of British *versus* American locomotives, in which he said that the Americans were not given to manufacturing heirlooms. I do not know what truth there may be in this insinuation with regard to locomotives, but certainly there is a great deal in it if applied to marine boilers, especially the shells, which are generally found good when the ship has become obsolete.

In conclusion I would like to say, and feel sure that every member will agree with me, that it is a very difficult matter to write a paper that can be generally acceptable to all, and create sufficient interest to promote a good discussion. I must ask you to overlook any shortcomings, as everyone will admit much more interesting data might have been written; but the object I had before me when writing was to induce a sound, practical argument. Are the boilers too heavy? Are they very far beyond the strength for the work they have to do? What is your experience?

We cannot deny that the interest created by this and kindred institutes on the subject of propeller shafts undoubtedly brought about a greater margin of safety, as shown by the alteration of Lloyd's and other Corporation rules. Following this, can we recommend a lighter multitubular boiler, and, by doing so, still more closely approach the advantages claimed for the water-tube boiler, which I contend has not proved itself a very strong rival to the multitubular boiler, and this is undoubtedly evidenced by the latter's gradual return to favour in our warships now building, the order being four-fifths water-tube and one-fifth multitubular boilers.

The discussion was postponed till February 18th.

DISCUSSION

AT

3 PARK PLACE, CARDIFF,

ON

WEDNESDAY, FEBRUARY 18th, 1903.

CHAIRMAN:

MR. W. SCOTT (MEMBER OF COMMITTEE, BRISTOL CHANNEL CENTRE).

MR. J. CHELLEW said he did not think it was necessary to alter the Board of Trade or Lloyd's rules. He believed if the factor of safety was reduced, the boiler would not last long. He also agreed with the practice of testing the boiler to double the working pressure, as calculated to show, besides other things, imperfections in material and workmanship.

Mr. EVAN JONES said the rules as to thickness of boiler plates, etc., had been framed as the result of long experience, and they were not justified in hastily seeking their modification. They might possibly be justified in reducing the shell a little, but not the flat ends or the furnaces. Supposing they did reduce the thicknesses as suggested, would Mr. Nicholl say what advantage would be gained, say, in a set of boilers—two or three—in a particular ship.

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 down to 20 per cent. This was rather a "tall order." Let them think what this 20 per cent. meant. Furnaces were required to be half an inch thick; when they had wasted away to, say, a quarter of an inch, he thought that was about the irreducible minimum. 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 furnace which had got only four-tenths. Therefore, its margin of life was ·5 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 motion, or, in other words, steam. He recalled the instance of a boiler floor. When it was nine years old this floor underneath the boiler was examined, and it was found to have wasted half its thickness, or seven-tenths down. 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 no floor left at all. This he attributed to nothing else than vibratory action on a thin plate. It took nine 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 dont 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 a wasting of plates. During the last ten years he had had to cut out two fronts altogether, plates from thirteen-sixteenths down to one-quarter in places—entirely due to the bad system of baffling, and nothing whatever to do with the water inside. With regard to the water test, he was entirely in favour of, in the first instance, doubling the working pressure. They would perhaps remember a case that happened on the Tyne about fifteen years ago, when a boiler shell split longitudinally, under close upon double the working pressure. It was a boiler about 14 ft. in diameter and 160 lb. pressure. Had this not happened under the water test—had it happened at sea on the trial trip—he shuddered to contemplate results. Steel and triple expansion boilers were then in their comparative infancy, and had the shell of this 14 ft. boiler, at 160 lb. pressure, burst at sea, it would probably have retarded the use of steel, and the progress of the triple expansion, for many years. Of course, he would not insist upon a double water test with an old boiler with all its old mountings, after, say, a simple repair, and the rules of the several institutions left a case like this to the discretion of the surveyors.

Mr. SHELTON said the factor of safety now employed was none too great, and until it could be proved that greater efficiency could be obtained—

less consumption of coal, less trouble to those who had to work the boilers, and fewer repairs—he was not in favour of lighter scantlings.

Mr. ALLAN JOHNSON demurred to an all-round comparison being made between the Scotch and the water-tube boiler. The ordinary type of boiler was in a class of vessel where it was generally dealt with by men merely from port to port, who did not take that care of the boiler which was necessary to preserve it. Then, again, the feed of the water-tube boiler, so far as they knew and had read, was always fresh water, whereas the feed of the boiler on the ordinary cargo boat was almost anything that could be put into it. If the same efforts had been made to reduce the weight of Scotch boilers as had been exerted in order to reduce the weight of the water-tube boilers, they would have saved something ere this. On the other hand, Mr. Nicholl quarrelled with the water space arrangement, and immediately he did that, and they had not got sufficient water space in the back end, they were going to add weight. With regard to the stay question, he certainly agreed with Mr. Nicholl that a stay would last longer if good and sufficient spaces were made for circulation. As to the double water test, he concurred with Mr. Darling about having it in the first instance, but he did not agree that it was necessary to test the efficiency and quality of plate. At the present time the greatest care was taken by the Board of Trade, by Lloyd's, and other classification societies, to see that the quality of material was properly preserved for shell plates. That day he had looked at a boiler twenty-three years old, and he had heard of instances of marine boilers still older, but the majority of them had been fed entirely with fresh water, special care having been taken for providing supplies on board ship. As to weight saving, he agreed with Mr. Darling that it was a matter dangerous to trifle with, because this saving must in the main be effected in connection with the shell by making it thinner, with a greater tendency to corrosion, an element which could only be eliminated by boilers being placed in such a position in vessels as to be considerable distances from surrounding iron work —a contingency which could not be provided against in trading vessels. Mr. Nicholl had done good service in calling their attention to the whole subject of saving weight in steam generators. Personally he had dreams of generating power for driving engines by means of high explosives. We were making good progress with gas and oil engines, and his dream was that the high explosive power of gun cotton might be reduced down to a pressure that would drive an engine, but they had not the time or the money to investigate the problem. They read a good deal about Mr. Carnegie giving of his millions to enable people to luxuriate in libraries, and even of being desirous of flinging a few hundreds of thousands into the lap of the Venezuelan, but if Mr. Carnegie wanted to permanently benefit mankind, let him do it through engineering, and endow some institute in order that experts might develop the principle of high explosive engines.

Mr. A. E. MILLS, continuing the discussion, said: I gather from Mr. Nicholl's paper that he doesn't think much of the water-tube boiler, as compared with the cylindrical; at the same time he brings forward three, and three only, of the supposed advantages, and then attacks them. In the first place, he mentions that the greater economy of the water-tube type has not been proven, and refers us to the report of the *Minerva* and *Hyacinth* trials. I would remind Mr. Nicholl that in those trials the actual evaporation per pound of coal of the water-tube boilers was, at 2,000 I.H.P., 9·65 lb.; 5,000 I.H.P., 9·33 lb.; 8,000 I.H.P., 9.39 lb.; whilst those for the cylindrical were 8·56, 8·84, and 7·93 respectively, which shows a considerable advantage for the Belleville type. With retarders in the cylindrical type, however, and the boilers working at about

8,000 I.H.P., the evaporation was increased to 8·84, making a difference of ·55 lb. in favour of the water-tube type whilst working at this power.

Again, in 1889, Professor Kennedy accurately tested over long trials the capabilities in regard to the economy of a Thorneycroft boiler in a torpedo boat under working conditions where the H.S. was 1,837 sq. ft., and the G.S. 30 sq. ft., and found the evaporation per pound of coal from and at 212° F. to be 13·40 lb., which he believed to be the highest on record. The evaporation per pound of coal from and at 212° of the *Minerva* boilers when using retarders was 10·34.

Now, as Mr. Nicholl suggests that there would have been many more startling results against the water-tube boilers being adopted had they been tried in the merchant service, I should like to mention a few particulars about the ss. *Tasso*, one of Wilson's boats, fitted with Babcock & Wilcox boilers and trading to Trondhjem, from the owners' point of view.

In six voyages, when fitted with ordinary boilers, the total consumption was 1,072 tons, average speed 11·45 knots; and in six voyages when fitted with Babcock & Wilcox boilers, the total consumption was 981 tons and average speed 12·05 knots. A difference of ninety tons in favour of the water-tube, and of 0·6 knots in speed, a result calculated to be equal to 130 tons of coal saved.

Mr. Nicholl mentions that with proper care the cylindrical boiler would take a lot of beating in the matter of raising steam; but, although steam has been raised rapidly in the cylindrical, I should not wish to be responsible for raising a full pressure of steam in a cylindrical in something under half-an-hour, which is done with most water-tube types.

The next point the writer mentions is the lighter weight of the water-tube type, and he then proceeds to try and cut down the weight of the cylindrical boiler. As regards the shell, by Board of Trade rules, I am of opinion that such could be done with safety, although I have seen shells very extensively corroded at and above the water line, so badly as to impair their safety. I, however, agree with Lloyd's factor of safety of four, as one has not only to consider the pressure a boiler has to stand, but also the heavy racking strains caused by the unequal expansion of the parts when raising steam, and also, to a lesser extent, when under steam, so that I see no reason why a water test of double the working pressure should not be applied, which allows a margin for these unknown stresses, and consequently tests the seams which have to withstand these stresses, as well as the working pressure.

As regards the furnaces, I notice the author has made a slight slip in his calculations. In the case of the Board of Trade rule, D is the least outside diameter, and in Lloyd's, D is the greatest outside diameter, so that a thickness of $\frac{15}{32}$ gives 160 lb. for the Board of Trade rule, and 157 lb. for Lloyd's, taking 40 in. as the least diameter.

In reference to the stays and flat surfaces, I would mention that these are interdependent upon one another, so that if we reduce one we must leave the other; but I don't consider any reduction should take place in these parts, as, with stresses set up by unequal expansion, combustion chamber wing stays have often fractured, even during the first voyage of a vessel.

The author suggests that the water space should be larger, but this would necessitate either lifting the furnace higher and having a larger body of water under the furnace, or else doing away with tubes, and, consequently, heating surface, so that in summing up I uphold Lloyd's rules as fit and suitable, considering that the boilers are not always attended by careful men. As regards the water-tube boilers, I cannot agree that the order given by the Admiralty for 4-5ths water-tube and 1-5th cylindrical in ships under construction is evidence of the latter type returning to favour, as at the present time we are trying new types, and appear to be following in the path of the Germans, who first went in for 40 per cent. water-tube boilers, then 70 per cent., and have now discarded the cylindrical type altogether.

In conclusion, although I have replied in the negative to Mr. Nicholl's question, I wish to thank Mr. Nicholl for so lucidly putting the matter before us.

Mr. KENDALL said Mr. Johnson had advocated fresh water feed. He (the speaker) looked upon fresh water as a curse to boilers when they were new. He had in his mind three boats with boilers thirteen years old, 160 lb. pressure, no evaporator, and no corrosion, which he entirely attributed to the use of plenty of salt water. He was not in favour of reducing the thickness of boiler plates.

Mr. WIDDAS submitted that it was fallacious to say that the factor of safety was four and a-half. The elastic limit of steel was approximately half of its ultimate strength, and therefore they had only about half the factor of safety which was claimed. To his mind this was little enough. He should not like to see any material reduction in any part of a marine boiler.

Mr. ROBERTS said there might be a certain reduction of weight of shell allowable provided material and workmanship were beyond question, but they had to allow for defects in material which were not visible on inspection, as well as in workmanship, and the water test, although harsh and excessive as a test of workmanship, was a very fair test of the strength of material when it was not applied too suddenly. But the conditions of the cold water test were not to be deemed equal to a steam test, because the plates had not expanded as under heat, and his opinion was that this expansion was one of the principal causes of the strains set up which broke the stays, and if they lightened the plates these stays would require to be increased. He did not think any great improvement in the matter of weight could be effected without some radical alteration in the construction of boilers. They had improved appliances for making circular furnace tubes; why not make the furnace chamber a tube instead of a square box? The furnace would be flanged on a curve as regarded the top and bottom of the chamber, which could be made a spherical plate — a fish-plate whose form would be at least as strong as the cylinder. This would do away with the necessity of side and back plates. The tubes entering this form of combustion chamber would require to be curved at the sides, but there was no reason why they should not be. Certain types of water-tube boilers were made with curved tubes entering the drums. By this modification there would be a saving of weight, because a circular rolled furnace tube adopted for a combustion chamber would save the overlapping; there would be less leakage, and no risk of stays breaking, because they would not need to stay the back of the combustion chamber to the outside shell at all. The furnace and the combustion chamber would be at liberty to expand as far as they liked without any resistance. It was only by the adoption of some such design as this that, he believed, the Board of Trade and Lloyd's could be induced to alter their rules.

Mr. FRED. JONES contended that the lighter they made the boiler the sooner it would have to be renewed. As to corrosion of main stays, many had to be renewed under twelve years old, because they were eaten away towards the end.

Mr. A. W. DAVIDSON said: I do not quite agree with the position taken up by Mr. Nicholl regarding the rules used for determining the strength of the different parts which make up a steam boiler. The only standpoint I think from which we would attain the desired result, viz., the reduction of the scantlings of steam boiler parts (for it is not confined only to the Scotch type of boiler), is founded on the fact that numerous boilers in daily use, standing a uniform working pressure and wearing equally well, were originally calculated from rules vastly different in their results. As an instance, take a Scotch boiler for ship's auxiliary use, 12 ft. 7 in. diameter, 7/8 in. shell plate, longitudinal joints, double riveted, double butt-strapped, with straps of equal width. The working pressure is:

By Board of Trade rules	111 lb.
,, Lloyd's ... ,,	116·8 lb.
,, B.C. ... ,,	118·6 ,,
,, Bureau Veritas ,,	110·8 ,,
,, U.S. Board of Supervising Inspectors of Steam Vessels ...	139 ,,

Difference about 28 lb., or, roughly, 25 per cent.

As another instance, take top end plates $\frac{3}{4}$ in. thick, stays 15 in. apart:

By B.T.	W.P.	...	144·3 lb.
,, Lloyd's	,,	...	128 ,,
,, B.C.	,,	...	127·9 ,,
,, B.V.	,,	...	130·9 ,,
,, U.S.B.	,,	...	184·3 ,,

Difference, 56 lb., or, about 44 per cent. I might also remark upon the variations made by individual surveyors in the practice of the rules. The shell formula is generally followed as given, although I have seen drawings of boilers submitted and passed showing a small part of longitudinal seam riveting only, which, when fully drawn out by the boilermaker for full length of boiler would work out at a difference in pitch of $\frac{1}{2}$ in. from the original drawing; also I noticed a boiler passed in which the combustion chamber side stays passing through shell of boiler were 8 in. pitch with stays $1\frac{3}{4}$ in. diameter, while the pitch of longitudinal riveting was $8\frac{1}{2}$ in., with $1\frac{3}{8}$ in. diameter rivets. I may say that the percentage strength of riveting for this boiler was worked out to three decimal fractions, as suggested by the surveyor. There seems to be a great difference of opinion amongst surveyors regarding the staying of flat surfaces in boilers; some surveyors will tell you that the bottom row of longitudinal stays staying the top plates support an equal amount of surface vertically on each side. As a case in point, take vertical pitch of stays as 17 in. and distance between top row of tubes and bottom row of stays as 13 in., total vertical height to be supported by stays $\frac{17+13}{2} = 15$ in. Other surveyors will tell you that stays support as much surface vertically on the one side as the other. In the preceding case this will be 17 in.; if the former case is correct why are we not allowed to reduce the diameter of bottom row of stays? The same difference of opinion exists regarding wide water-space staying. The foregoing instances show the great difference of practice even in existing rules for boiler scantlings. If the minimum scantling arrived at by calculation is ample, why use the maximum? If under the high pressure now maintained the maximum is needed for safety, is it not time to increase the minimum. I think the call is for a universal standard set of rules fully defined and explicit in all details of standard construction. I hope that the unfavourable criticism on water-tube boilers will be replied to next Wednesday, with a searching comparison of the boilers on their merits. Personally, I must congratulate Mr. Nicholl on his able paper.

The CHAIRMAN remarked that there had been very little change in the rules affecting boilers in comparison with the improvements effected in quality of material and workmanship. He did not, however, think it would be safe to reduce the thickness of the furnace. As to flat surfaces, the only thing they could do would be to reduce the shell, and that would not be worth the trouble. The unequal expansion of the bottom of a boiler compared with the top was great. The bottom was forced out probably $\frac{3}{8}$ in. to $\frac{1}{2}$ in. in the expansion of a boiler between its being cold and getting the working temperature. As to tests, he did not object to the double pressure, but let it be warm, and give the boiler a chance. Some years ago he set himself to design a boiler the idea of which was to do away with unequal expansion and reduce the weight. He had a model made about an inch to the foot, with a safety valve on, and in different parts of the boiler he had glass tubes to show how the currents ran. Immediately he put the Bunsen burner into the furnace he found the heat at the bottom equal to that at the top, due to natural gravity. He had taken out a patent, but had done nothing with it as yet. The boiler worked out much lighter than the ordinary boiler, the greatest thickness of shell for 120 lb. pressure being about $\frac{1}{2}$ in. There were longitudinal stays in the steam space, but there were no combustion chamber stays.

Mr. ROBERTS suggested that the Chairman should exhibit his model at the next meeting, when Mr. Mills's paper on water-tube boilers would be read.

The CHAIRMAN said he should have great pleasure in doing so.

Mr. E. NICHOLL replied to the discussion as follows:

Mr. Chellew says the question of reducing the shell plates is simply a matter of opinion, to which I reply that unless opinion is founded on experience and reason it is not worth anything. I say experience justifies us in departing from the formulæ made by our fathers.

In answer to Mr. Evan Jones, I estimate the weight of a boiler such as I have indicated in my paper to be about forty tons, without mountings, fire-bars, etc. You must understand I have only done this very roughly, but I think the weight would be approximately correct. The reduction in weight would be about seven tons. I have not allowed for any reduction in tubes, as these being very thin would not perhaps allow of much reduction.

I quite agree with Mr. Darling that if a furnace were wasted from $\frac{1}{2}$ in. to $\frac{1}{4}$ in. thick, uniformly, it would not be very safe, but did he ever see such a case, or even hear of one? He has no doubt seen furnaces wasted to $\frac{1}{4}$ in. in local spots, covering a few square inches in area, but that would not render the boiler dangerous. Now, with regard to his statement that if the furnace is reduced from $\frac{1}{2}$ in. to $\frac{1}{4}$ in. the life is reduced from twenty to eight years, I must confess that I am at a loss to understand his deduction. Let us for a moment take his own limit of safety, viz., $\frac{1}{4}$ in.

The $\frac{1}{2}$ in. plate has to corrode away $\frac{1}{2}$ in. $-$ $\frac{1}{4}$ in. $=$ $\frac{1}{4}$ in. $=$ ·25 in.

The ·4 plates $\cdot 4 - \frac{1}{4} = \cdot 4 - \cdot 25 = \cdot 15$.

Now, $\cdot 25 : \cdot 15 :: \frac{\text{years}}{20} = \frac{20 \times \cdot 15}{\cdot 25} = 12$ years and not eight years. But even this is a pure fallacy, because, as I said before, a furnace never corrodes uniformly.

With regard to a ship's floors wasting away to one half in eight years, and the remaining half in eight months, when there was nothing left, this strikes me as being pretty good. Surely there must have been something abnormal to account for this. It also shows that there was 100 per cent. too much floor to commence with. I suppose he will not agree with me there. I am afraid he will have to look a long time for a 15 ton boiler in a 5,000 ton ship. When he finds a cylindrical main boiler of that weight in such a ship I shall cease to advocate any reduction in weight.

Then he speaks of finding a boiler shell, six years old, corroded, caused by raking the boiler out with an iron rake. This was not corrosion at all, but purely a mechanical action, and was local, in which he unconsciously confirms what I have stated in my paper. Then will he tell us to what extent this local abrasion had, in his opinion, injured the safety of the boiler.

With reference to the case mentioned of a boiler giving out during the water test, this had nothing to do with the thickness of the shell, but was due to inferior steel, of which there were any number of cases when steel was first introduced, and sometimes cases still occur, but not often. I understand Lloyd's keep surveyors stationed at the steel works to look after the quality of material, so that danger from this cause should be reduced to a minimum. There have been plenty of cases when boilers have given out at less than double the working pressure, but that is no argument, because it is the rare exception, and not the rule. Yes, I say boilers with lighter shells would give less trouble, as they would be able to make a better job of the thinner plates at the joints.

I am pleased to think Mr. T. A. Johnson is in error in supposing that engineers in the merchant service are only concerned in taking a ship from port to port. I have engineers who have been under me for years, and take a very keen interest in the machinery under their charge. Mr. Johnson says that the double pressure does not test the efficiency of the plate. That being the case it can only test the workmanship, and I say $1\frac{1}{2}$ times would do it equally well.

I suppose those boilers mentioned 23 and 24 years old had the original shells, and I presume were in good order, probably better than the ship. Fresh water is no doubt a very good thing, but I have had boilers running for years with salt water, and very little corrosion. The idea that salt water is responsible for the corrosion of boilers is, in my opinion, much exaggerated.

Mr. Mills quotes two cases of water-tube boilers, but does not give any particulars of value. He says that there was a saving in weight of 20 tons. It would have been more interesting had he given us the consumption of fuel in those cases. I venture to say that the 20 tons would soon have been discounted. Can he give us the cost of upkeep of these boilers, say for five years, and compare them with a cylindrical of equal power? I am afraid these are items that are not to be had for the asking.

The idea of allowing from Monday night until Wednesday for getting up steam has gone out of date, and with proper means for circulating the water in the boilers there is no reason why steam should not be got up in two or three hours without the slightest injury to the boiler, and I may say it is done daily. Mr. Roberts says the trials of the *Minerva* and the *Hyacinth* are not finished. Personally I do not think they are likely to be, for the simple reason that they cannot keep the latter running long enough. I see she broke down on the run home since my paper was read at our former meeting.

I have come to the conclusion that we shall not be able to run water-tube boilers in the merchant service until we get a big subsidy either from the Government or the boiler makers. Mr. Scott is evidently the only man who agrees with me, but I have not been attacked by any one of the speakers in a manner that would bring conviction to anyone. To say that the rules for boilers are the result of years of experience is no argument, because the rules were framed many years ago, when the conditions were totally different, and when boilers were not preserved as they are now and when the workmanship and material were immensely inferior.

In conclusion, we can now so accurately rely on the uniformity of material and on the fact that formulæ for such structures err on the right side, that there is no reason, in my opinion, for twice the working pressure test; 1·5, or even 1·25, is ample, because it is only a test for leaky seams. When the cold test is made there are seldom, if ever, any measurements taken. Perhaps the furnaces are gauged, but if this water test is to be of any value, all parts should be carefully gauged—flat surfaces with straight-edges, and circumferences of shell with steel tapes, whilst the pressure is on. But instead of this—with the greatest possible respect I say it

—the surveyor glances at the plates, taps the gauge to make sure the last pound is on, and all is right. But you all know how possible it is for a man to lift half a ton, but in so doing will so internally injure himself that he will never lift another pound; and so with the boilers, in cases of early defects arising, such as fractured plates, etc., there is little doubt in my mind but that excessive pressure in the first cold water test has been the cause.

A vote of thanks was cordially passed to Mr. Nicholl for his paper, on the proposition of Mr. DARLING, seconded by Mr. SHELTON.

A similar compliment to the Chairman closed the proceedings.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1903-1904.

President—SIR JOHN GUNN.

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

DISCUSSION

HELD AT

58 ROMFORD ROAD, STRATFORD,

ON

SCOTCH, OR CYLINDRICAL MULTI-TUBULAR, BOILERS,

MONDAY, MARCH 9th, 1903.

CHAIRMAN:

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

The CHAIRMAN: We have met to-night to hear a paper which has already been read before the members at the Bristol Channel Centre, Cardiff, when it was also discussed. The author of the paper, Mr. Nicholl, is unable to be with us this evening, but the Honorary Secretary has consented to read it on his behalf. Mr. Adamson has also a communication from Mr. Berry as a contribution to the discussion. I will now ask Mr. Adamson to kindly read the paper.

Mr. JAS. ADAMSON (Hon. Secretary) said that about a year ago he had a communication from Mr. E. Berry, and one or two like-minded superintending engineers, with a view to some action being taken to bring about a conference with the Board of Trade on the subject of Boilers and the rules at present in force as to weight and water-pressure tests, but not to the extent Mr. Nicholl had advocated. However, when the paper was in form he sent a copy to Mr. Berry, inviting him to attend and if he could not do so to send a communication on the subject. The latter alternative having been accepted, he proposed to read Mr. Berry's communication as an opening.

February 17th, 1903.

"DEAR MR. ADAMSON,—As per my previous letter, I now enclose you remarks on the subject of Mr. Nicholl's paper on the Scantlings and Twisting of Modern High Pressure Marine Tank Boilers. I also enclose you a photo. of the donkey boiler at present working in s.s. *Diomed*, showing the distortion of the boiler due to being short of water. The stays shown between the combustion chambers were entirely pulled out of the holes, and the two marginal vertical rows of tubes at centre were pulled out of the holes as shown. I also enclose a print of the boiler mentioned, now being built by Messrs. The Caledon Shipbuilding and Engineering Company, Limited, of Dundee, with the round top combustion chambers. I hope, if possible, to be present as per your kind invitation on March 9th, as this is a question we all feel very much interested in.

"As regards treating this paper as private, I may mention that I have shown the paper and my remarks thereon to my principals, Mr. Alfred and Mr. George Holt, as some of the matter contained relates to their property, and I may state that they both entirely agree with my remarks as enclosed.—With very kind regards, yours sincerely, E. BERRY."

"The subject of this paper is one of great importance to shipowners, and must sooner or later be taken up by them and dealt with in their own interests.

"Dealing with the questions put by the writer: 'Are the boilers built to Board of Trade and classification societies as now used in our mercantile marine too heavy?' and 'Is the cold water test to double the working pressure injurious or too drastic?'

"As regards the first question, I am at one with the writer in asking for a reduction in the scantlings of the boiler shells, but think too much is being asked by Mr. Nicholl in requesting a reduction of the factor to 3½ in., and would be quite content to accept from the Board of Trade a factor of 4. But as regards the internal and vulnerable parts of the boiler I cannot agree with the writer in asking any reduction from the present rules and practice of the Board of Trade and classification societies. On the contrary, our practice is always to specify an excess over and above the scantlings produced by the rules in the matter of furnaces, combustion chambers, and screwed stays. For instance, in getting out scantlings for boilers working at 190 lb. per square inch, we arrange our furnaces, combustion chambers, backs, wrappers, and screwed stays for a working pressure 15 to 20 lb. over and above the working pressure—say 205 or 210 lb. These are, as before stated, the vulnerable parts of cylindrical tank boilers, and in my humble opinion any superintendent engineer would be badly and unwisely advised in allowing these parts to be reduced below the scantlings produced by the present rules.

"We maintain that the modern high pressure marine boiler to Board of Trade rules is immensely safer than the low pressure boiler of the same type, and our experience trends that way.

"Stating a case. One of our steamers, fitted with a single-ended marine type auxiliary boiler, with two plain furnaces and two separate combustion chambers, working pressure 170 lb., was recently on a voyage from China to Singapore. River water having been used in this boiler at Shanghai, the engineers decided to open up the boiler to see if there was any deposit, and to examine furnaces, etc. This was done, and the boiler pumped up with fresh water out of one of the ballast tanks. Fires in the boiler were lighted, and about three or four hours after the boiler was found to be in a sorry condition, no water being in the boiler, the furnaces, combustion chambers, etc., being red-hot, and distorted and twisted into such a condition that it would need to be seen to be realised. The main blow-off valve was found to be about half open, and thus the boiler had been emptied of water whilst steam was being raised. Some of the gentlemen present have possibly seen these parts, as the boiler was repaired in London by Messrs. A. W. Robertson & Co.

"For the information of those who did not see the boiler, the photos will give them a very good idea of what had occurred and the force necessary to distort the parts as shown, and yet the boiler shell bottling up this 'torment toso' was uninjured.

"We maintain that had this boiler been a low pressure boiler of the same type the shell would have ripped and blown overboard, the boiler being on the upper deck.

"I may mention that new furnaces, combustion chambers, stays, etc., have been fitted to the old shell, and the boiler tested by hydraulic pressure to 20 lb. above double the working pressure, although seven years old. The old shell simply needed a little caulking to stop leaks. But for the fact of a considerable leakage at some of the stay-nuts at back end, and being pushed hard for time, it was our intention to have subjected this boiler to a pressure that would have obtained, providing the Board of Trade were allowing us a factor of 4 for same instead of 4½.

"The boiler is working satisfactorily to-day at its original pressure.

"Having actually seen two vertical upright boilers explode and fly into the air, both from fire-box ruptures, and having in view the many troubles and anxieties experienced with distorted boiler-furnaces, combustion chambers, and innards, we could not possibly support any action for reducing the scantlings of furnaces, combustion chambers or their necessary stays.

"We may mention, however, that there are building in this country at the present moment some high pressure marine boilers to Board of Trade requirements, being very large (four furnaces and single ended), where, as shown per print handed round, there is a considerable reduction in the weight of the boilers produced by fitting cylindrical tops to the combustion chambers, entirely dispensing with the ordinary combustion chamber stays and girders.

"It is, as far as we know, the first instance where anyone has been so bold as to introduce this type for a working pressure of 200 lb. per square inch and to work as main boilers under Howden's forced draft system. The behaviour of these combustion chamber tops will be watched with great interest by many.

"*Double Water Pressure Test. 'Is it injurious or too drastic?'*

"1st. What is the object of the hydraulic test of a new boiler? Is it to test the work, or to try to burst the boiler? My idea is that it is simply a test of material and workmanship. The idea of bursting the boiler never entered our heads. The question needs qualification as to how and when applied. As regards new boilers, some strong measures are needed to keep makers and their work-men up to their highest standard in supplying and producing the best work, and when they have constantly before them the fact that their boilers, when finished, have to face the ordeal of a double pressure water test, they know that for very high pressures only the very best material and workmanship will stand the test, and I think that we are all agreed that only the very best material and workmanship should find its way into the modern high pressure marine boiler.

"It will thus be seen that in this way, with new boilers, the fact of the hydraulic test to double the working pressure having to be faced has a good effect in preventing shoddy work and unreliable material being introduced.

"As to whether the test should be double the working pressure or something less, that is a matter for argument, but personally I should have no respect for new high pressure boilers that would not stand double the working pressure, nor for the folks that built the boiler.

"Now, as regards old boilers. Few of us contemplate the many and varying strains to which these are subjected, brought about mainly by difference of temperature of the different parts under working conditions. Take, for instance, the staying of the ends of a double-ended boiler where the furnace in one end is common with the furnace in the other. These being attached to the end of the boiler take their part with the through stays in holding the ends when the boiler is built. When new, the stresses on these parts are normal, but when put under steam the large stays being in the water and steam spaces of the boiler are at the same temperature as the water and steam, whilst the furnaces and combustion chambers, being in contact with the incandescent fuel and flame under best conditions, will be at least 100° to 150° in excess of the water, thus setting up stresses which are bound in time to become permanent, these, when the boiler is reduced to normal temperature, setting up a thousand and one stresses in the structure that we are at present ignorant of. This is, in my opinion, the main cause of the curious fractures that often occur to the furnaces where attachment is made to the combustion chamber wrappers, etc.

"The Board of Trade surveyors are, we believe, the only persons who ever ask shipowners' represen-

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tatives to test old boilers to double the working pressures, and our contention is that such a test on an old boiler that could be thoroughly inspected in all its parts is not only very injurious, but very injudicious, and that the causes of trouble developed in old boilers when tested under normal conditions entirely disappear when the boiler is under working condition, and there is reason to believe that there were boilers that would have been working satisfactorily to-day had they not been exposed to such barbarous treatment.

"My owners have a fleet of steamers sailing under the Dutch flag from Amsterdam, and it has been my duty to arrange in getting these vessels transferred from the British to the Dutch flag, and in the matter of surveying these vessels *re* their boilers, we think our Dutch friends are ahead of us in their practice, which is as follows: The boilers, main and auxiliary, are stripped entirely of their lagging and furnace castings, the brickwork is cleared out of the backs, and all thoroughly cleaned inside and out. The boilers are then thoroughly examined by two competent surveyors and compared with the original tracings. Doubtful places are bored to test thickness and any reduced parts are asked to be made good, after which the boilers are tested by hydraulic pressure, which is as follows: Boilers whose working pressures are 50 lb. and under, to double the pressure; 50 lb. to 100, $1\frac{2}{3}$ working pressure; at 100 lb. and over, to $1\frac{1}{2}$ times the working pressure; and we maintain that this is quite sufficient and that no old boiler should be subjected to hydraulic test to more than 50 per cent. above its working pressure, and we shall continue to resist hydraulic testing to double the working pressure being put on any of our old high pressure boilers. As regards allowances for corrosion, etc., that is a matter the Board of Trade and classification societies should leave to owners and their representatives; seeing they inspect the boilers annually, they have their remedy, whenever they find wasting taking place, in reducing the pressure.

" The firm to which I belong have working the largest high pressure marine boilers afloat, as far as we know—17 ft. 3 in. mean diameter, 20 feet long, working pressure being 160 lb. We have eight such boilers working under forced draft, old type Navy system, at about $\frac{3}{4}$-in. air pressure. These boilers are now eight years old, and we are taking 1,700 to 2,000 I.H.P. out of them regularly to-day, and they are now as good as when new.

" The superiority of the large marine type tank boiler as an economical steam generator for marine purposes is well known, and recently we have been considering the advisability of fitting two such boilers as those mentioned in some large ships in place of three similar smaller boilers, the saving effected being more than 290 tons of coal bunker space in the ship and a considerable reduction of the water carried in the boilers, to say nothing of the extra strength of the vessel caused by having the sides tied up and strengthened by the extra bunkers, carlings and hatches.

" But going into the scantlings of these boiler shells for 190 lb. pressure, with a factor of $4\frac{1}{2}$, we find that by the following calculation the thicknesses would come out as follows: the shell plates in 29 ton steel would need to be 1·6 or $1\frac{39}{64}$ in thickness; in 32 ton steel they would need to be 1·45 or $1\frac{29}{64}$ in thickness, at the factor of $4\frac{1}{2}$. This factor may be increased by the Board of Trade rules on account of the length of the boilers (being double ended). By reducing the factor to 4 with 32 ton steel the thickness would become 1·29 or $1\frac{19}{64}$. It will thus be seen that the reducing of the factor would mean a saving of $\frac{5}{32}$ in the thickness of the shells. This thickness on the mean diameter in these large shells would mean a reduction of something over three tons in the weight in each boiler.

" Seeing that these shells would run into a weight of over 100 tons (without water), built to a factor of $4\frac{1}{2}$, there are only one or two firms in the kingdom that could tackle them.

"Double ended marine boilers 17′ 3″ × 20′ 0″ long.

"Built of steel at 29 tons tensile for 190 lb. W.P., shell thickness at factor 4·5 will =

$$T = \frac{190 \times 4{\cdot}5 \times 17{\cdot}25 \times 12}{29 \times 2240 \times 2 \times {\cdot}85} = 1{\cdot}6'' \text{ or } 1\tfrac{39}{64}''$$

If built of steel at 32 tons per sq. in., factor 4·5,

$$T = \frac{190 \times 4{\cdot}5 \times 17{\cdot}23 \times 12}{22 \times 2240 \times 2 \times {\cdot}85} = 1{\cdot}45 \text{ or } 1\tfrac{29}{64}''$$

If built of steel at 32 tons per sq. in., factor 4,

$$T = \frac{190 \times 4 \times 17{\cdot}23 \times 12}{32 \times 2240 \times 2 \times {\cdot}85} = 1{\cdot}29 = 1\tfrac{19}{64}''$$

Saving in T by reducing shell factor from 4·5 to 4 would = $\frac{10}{64}$ in 17′ 3″ boilers.

"It will be interesting to note what is being done as regards the two new Cunarders to be built under an Admiralty subsidy. As it is understood that the Admiralty will have something to say *re* the design of these vessels and their machinery it will be interesting to know what is being done regarding the main boilers of these vessels, as to their scantlings and hydraulic testing—as to whether the Admiralty practice will be followed in this respect or whether the Board of Trade practice will be followed. It appears to us that in this matter two departments of the Government, whose practices differ, will clash, and we trust that the Cunard Company's Superintendent will very strongly urge his owners to adopt Admiralty practice in saving weight and displacement in the boilers as against Board of Trade practice, seeing the very hard task they are taking on *re* power and speed in these vessels.

"This point will be watched with great interest by many, and it is hoped that a precedent will be established as to the boilers in these two vessels, in introducing Admiralty practice in the mercantile marine of this country *re* boiler shells and testing.

"With Mr. Nicholl, my faith in the marine type tank boiler is as good to-day as ever it was, especially the large double ended boiler, and when looked after and carefully treated they will last for years, and as steam generators under proper management and working conditions they will, I venture to assert, hold their own against any type of water-tube boiler yet introduced in the mercantile marine.

"The cruisers of H. M. Government one sees laying up at the various ports just now being reboilered after only about four years' working is a serious matter for the British taxpayer to face, and in the case of merchant shipowners would mean bankruptcy and ruin to many of them in these times of low freights and severe competition.

"It will possibly interest some of the members to know that at the present time we have vessels running fitted with two double ended boilers 16 ft. in diameter × 19 ft. long, each fitted with six furnaces 3 ft. 8½ in. internal diameter, with funnels 110 ft. long, heating surface 10,400 sq. ft. and grate surface 205 sq. ft. in both boilers, and that we are taking daily out of them 3,600 I.H.P., burning anything up to 30 lb. of coal per sq. ft. of grate with Scotch, Staffordshire, Japan or Australian coal, the results being very satisfactory, and in our opinion comparable with anything realised with water-tube or any other kind of boiler at present in use in the mercantile marine as regards power generating and economy."

The CHAIRMAN observed that one of the points of Mr. Nicholl's paper dealt with the reduction of weight, with a reference to the less weight of the water-tube boiler. Of course, if weights were reduced, the weight of water-tube boilers would be reduced also, so it was hardly a point of sufficient importance to compare the water-tube boiler in that respect, because the factor of safety in water-tube boilers of the best class agreed with the Board of Trade regulations, although the large shell would have the greater reduction.

Mr. G. SHEARER (Member) said it was rather a delicate point to make an alteration in the weight of shells. They certainly had seldom or never heard of the explosion of a marine boiler—at least, of the shell of a marine boiler; it had always been the internal portion, the furnaces, combustion chambers, or some other internal part. Yet he could not suggest anything in the way of reduction of shells. They could not go on reducing and experimenting until they blew up two or three hundred people. They must have a margin of safety, and so far as their experience went he considered they had nothing safer than what the Board of Trade and Lloyd's Register allowed them. For the internal portion they found these allowances were very often too little. With regard to furnaces and combustion chambers coming in, he did not mean to say that it was due to the weakness of the metal in its original state, but rather to the accumulation of scale, and principally by oil. He had been fortunate enough never to have anything of that kind happen. He had had combustion chambers bagged between stays, but had never had a furnace crown come in. The combustion chambers bagged entirely through a certain class of oil being used. After these combustion chambers had bagged he found the deposit of oil upon them. This took place a good number of years ago, and at that time they were using oil in the cylinders. Upon examination he found the oil deposit on the chambers, and it resembled india-rubber solution. It would neither scrape nor chip off, and it was difficult to remove it. There was no shortness of water to account for the mishap. That was his only experience of heating surfaces coming in. They all knew that very few furnaces were exactly circular; they all varied apparently, and eventually took up a permanent set slightly off the round. Why should that be? The furnace must be strongest when a true circle. Still, they came down out of that circle and remained there. If they thinned down the plates they would only be bringing disaster into their ships. He did not mean to say but that they were above the limit, but he thought their limit was the limit of safety, and it was safety that they required. With regard to the cylindrical as compared with the water-tube boiler, he thought they all knew that the cylindrical was much more economical than the water-tube boiler. The water-tube boiler was an express boiler, and with it they could get steam up much quicker. But even in the case of a warship, what was the advantage in the difference of time? Take the case of a modern cylindrical boiler with all its circulating connections, where the water was drawn from the bottom of the boiler and discharged at the top, and well distributed through the entire length of the boiler. That was the general marine type of feeding. He had got up steam in $1\frac{1}{4}$ hour in the largest boilers built at the time, which was not many years ago. It was a case of necessity when he got up steam in that time, and he did not apply the thermometers; he used his judgment, and simply applied his hand to get the variation of temperature in the bottom and ends of the boiler. He found no bad results from getting up full steam in that time. It was purely a matter of circulation. In the Navy they could get up steam in twenty to thirty minutes with some water-tube boilers, but what was the use of it? Was a vessel ever wanted in so short a time? If a ship were lying at anchor with her boilers cold, he expected her engines would also be cold. Would any engineer be able to put those engines ready for working or get them under steam in half an hour? Surely they must have as much time to heat up the engines as was required to heat up the boilers, and if they could get steam up in $1\frac{1}{2}$ hour with a cylindrical boiler, certainly they required $1\frac{1}{4}$ hour to put the engines into a safe condition. If they got steam up in half an hour with a tubular boiler they would have to wait another hour for the engines. He could not see the advantage. Of course, in small torpedo-boats they might heat up without much danger; in such vessels there was certainly much less risk than with heavier engines. He had had a good deal of experience of the cylindrical boiler, and also of the different types of water-tube boiler, the Belleville, Yarrow, and Thorneycroft, but he considered they were only suitable for torpedo craft, and the life of them was short. There was no water-tube boiler that he had ever heard of that was economical, and he was in full favour of the old cylindrical boiler. With regard to the double-pressure testing of boilers, he considered it a very foolish practice, and he thought it meant straining the metal. The author spoke of the double pressure test as not for the proof of the boiler, but as a proof of the workmanship. There was no doubt that hydraulic testing was to a great extent a proof of the workmanship, but they had known of hydraulic tests being applied as a proof of the boiler. Many Board of Trade inspectors had put on a pressure for the testing of the boiler and not of the workmanship. He would advocate $1\frac{1}{2}$ as a maximum pressure for high pressure only. He thought there was a great mistake made in the hydraulic testing of boilers, in that, he considered, no boiler should be tested with cold water; he held that it should be tested with water at a temperature certainly above blood heat. He would much prefer to test boilers with water at a temperature of 120 degrees. With water at, say, 33 or 34 degrees temperature they were much more apt to damage the boiler. When testing with water at a temperature of 120 degrees they gave the boiler plates and everything else a better chance. When an apprentice in locomotive work he remembered they used to test with cold water until one inspector instituted the warm water test. Afterwards they always used hot water for testing, and they found that they got better results and did not have leaky joints.

Mr. FRANK COOPER (Member) said he entirely agreed with everything Mr. Shearer had said. He was of opinion that to reduce the thickness of the shell or of the furnaces of the boiler was running a very serious risk, and he did not think that the weight of the boilers would be reduced to such an extent as to induce anyone to do such a thing. Until he heard Mr. Shearer's remarks regarding the water-tube boiler he was inclined to think that it was the boiler for a man-of-war. He considered he had dealt with the matter in a very pithy way, and had even beaten Sir William Allan in his arguments against the water-tube boiler.

Mr. J. THOM (Member) said he agreed with some of the speakers, but not with all, regarding the reduction or non-reduction of the thickness in boilers. He thought the shell could probably be reduced slightly, but not to have a factor of safety of less than 4. With regard to the internal parts of the boiler, he thought there were many portions that could also stand a slight reduction. The thinner the furnaces were the quicker the heat got through. They could make a furnace thick enough that would collapse before it did its duty by heating the water on the other side. Of course, if they had to make preparation for oil and other commodities settling thereon, and on the combustion chambers, they could not make the plates thick enough. He thought the furnace made to a margin of 4 would give a better result than one with a margin of 4·5—it would last longer. The plate would never be of so high a temperature as with a margin of 5, and, therefore, he considered it would last longer. With regard to the comparison between Scotch and water-tube boilers, it was stated that for the same power the water-tube boiler was lighter, but he was not so sure of that, and was of opinion that they came very near the same weight as cylindrical boilers. In comparing boilers they must make their comparison extend over weeks in order to get the value of the output of those boilers. Also, he thought they ought to take into account the amount of coal consumed.

If the cylindrical boiler burnt $1\frac{1}{2}$ lb. of coal per I.H.P., and the tubular 2·3 lb. to 2·5 lb. of coal per I.H.P., he thought that should be taken into consideration with the weight of the boiler. With regard to the hydraulic pressure test for boilers, he considered that none of the high pressures should be more than $1\frac{1}{2}$. Also, he was strongly of opinion that the water that was used for that pressure should be heated. He remembered hearing of a different test for locomotives to that mentioned by Mr. Shearer. First of all the boilers were filled right up with cold water and a fire was then lit. That would not do with a cylindrical boiler.

Mr. JNO. SINCLAIR said there were one or two questions that he should like to ask. First of all, could anyone tell him whether the water-tube boiler weighed less than the cylindrical boiler? He wanted to know definitely. He was sent over from Australia some time ago to see some boats that were built by Messrs. Denny, and he had authority to go into the question of boilers with them. They thought of getting water-tube boilers, and considered the matter with the firm. They found that the weight of water-tube boilers would be very much greater, the space occupied much larger, and the price very much more than cylindrical boilers. He would like also to know if anyone could give him the factor of safety of a boiler under working conditions, as he believed the factor of safety could not be stated, for they knew nothing about the inherent stress of a boiler under working conditions. He would not advocate the reduction of the scantling of a boiler, but he would advocate making the same weight of boiler do a great deal more work. By proper circulation boilers could be made to do more work than they were doing now, and permit of very great increase of coal consumption per square foot of grate over what they were doing at the present time. So, instead of reducing the weight of the boilers, he advocated the retention of the weight, but suggested that it should be made to produce a great deal more steam. It was entirely a question of circulation, and he thought that would be dealt with soon. In Australia there had been a good deal of talk about water-tube boilers; he had found, however, that when they approached the makers of these boilers and said they intended taking out from a vessel the old Scotch boilers, and asked them to substitute water-tube boilers to give the same results, be of the same weight, and occupy the same space, they refused to take orders under such conditions. He would like to ask Mr. Shearer about heating engines. Because they took $1\frac{1}{4}$ hour to generate steam in the boiler it did not follow that they took the same time to get their engines up to the same temperature. In the first case they had to generate latent heat in the boiler, and they had that in the steam for heating the engines.

Mr. G. SHEARER, replying, said he did not mean to imply that it was necessary to occupy the same amount of time to heat the engines as to get up steam in the boilers. Suppose their engines were of 15,000 horse-power, they could not very well heat up engines of that size in one hour and a half; anyway, he would not like to take the responsibility of doing so. He would much prefer giving them two or two-and-a-half hours at the least.

Mr. MANNOX said he had not had much trouble when using a water-tube boiler. He had had one boiler under steam three months at a spell without opening it out. He had no idea of the efficiency they could get guaranteed with the Scotch boiler, but Babcock and Wilcox gave a very good guarantee. Regarding the weight of boilers, there would be a saving in the weight of the water in the boiler, but he would not say the same with reference to the boiler itself. They must remember that the makers of Scotch boilers had had a lot of experience of marine work, whereas the makers of water-tube boilers were all new to it. He did not think they could expect them to put in a water-tube boiler to occupy the same space, be of the same weight, and have the same consumption as the cylindrical boiler. It was rather early at present, but he thought they would do it eventually. One gentleman had said that they ought to increase the circulation. They got that increased circulation in the water-tube boiler. If they increased the circulation they increased what they took out of all boilers.

Mr. K. C. BALES (Member) said, so far as he understood Mr. Nicholl's paper, it had been written with the idea of advocating the reduction of weights of boilers as laid down by the Board of Trade and the various classification societies. It appeared to him that the discussion had developed into the question of Scotch *versus* water-tube boilers. As they had got on to that point, there had been a question raised as to the weights of the water-tube boiler compared with the Scotch boiler. Some few years ago it happened to be his privilege to be connected with the designing of some installations for express steamers where every pound of weight had to be considered. They went very carefully into the question of boilers at the time, and ultimately those ships were built and boilered with Scotch boilers on the Howden draft system. Mr. Howden demonstrated that he could give them a boiler with his forced draft, which, taking into account the coal consumed, was found to be identically the same weight as a water-tube boiler, either Yarrow, Thorneycroft, or Belleville. As regards the space occupied, the Scotch boiler occupied about 50 per cent. less space than the water-tube boiler, at least, so he understood. He would like Mr. Shearer to make clear a point that had occurred to him with regard to the heating up of engines. He was under the impression that warships, cruisers and so forth, even in the time of peace, were nearly always under steam. He certainly thought they would be in time of war. Therefore, when they came to speak of the time the water-tube boiler required for raising steam, and compared it with the safe time of heating the engines, the engines would already be hot if the vessel were laid under banked fires. It would be a decided advantage for such vessels as guardships and coast defence vessels if they could raise the necessary steam in half an hour and had their engines already hot.

Mr. G. SHEARER said so far as his experience went, warships did not lie under banked fires. They were something like merchant vessels, and were generally under an auxiliary boiler. Of course, they had steam enough there to warm up the engines. They had the same for increasing the feed water in the main boiler, and he did not see where the advantage came in. It was only in special cases, such as torpedo boats, or some small craft of that kind, where steam was wanted suddenly. He could not see that it was necessary either in a cruiser or a battleship. They could get steam fast enough, but it would not suit the Admiralty, and his private idea was that they could get steam up quick enough in a Scotch boiler for anything that was necessary. They had never had war declared and gone into action within twenty-four hours yet. One gentleman had remarked about water-tube boilers being new. He thought that was quite a fallacy. Water-tube boilers were not new; he saw water-tube boilers working thirty-three years ago ashore; from what Mr. Bales had said he understood that he meant they were introduced within the last decade or so.

Mr. W. McLAREN (Member of Council) said the author did not remember ever hearing of a marine boiler exploding when built to Board of Trade and Lloyd's rules. The explosion that took place at Barking some time ago was an over pressure explosion, and it was estimated that the pressure on that boiler was 400 lb., as evidenced by the distance some of the parts of the boiler travelled. It was a complete opening out of the shell, the internal parts being collapsed, and to the effects of the explosion he was an eye-witness. It was a two furnace boiler, and had been taken out of a steam trawler. They were testing the safety valves at the time, and the poor fellows were blown to pieces. The author had said "power for power, the water-tube boiler had a considerable advantage in the matter of quick steam raising." He would like to know at what consumption of coal did he get power for power out of the water-tube and cylindrical boiler. He admitted that with the water-tube boiler steam could be raised quicker, but he wanted to know at what price did they get it in consumption of coal. Surely steam could be raised easily enough with the cylindrical boiler if the circulation was kept up by pumping. Steam could be raised by the time the cylinders were warmed up, the water drained from the cylinders and the condenser cleared. That was not done in thirty-five minutes, as with a fire-engine boiler —the most express boiler he knew of—and he did not think it was necessary for them to get steam up in that time. The author had also said there was a reduction in weight with the water-tube boiler of from 25 to 30 per cent., but he was not prepared to accept that statement. At the same time, he thought there could be great improvements with the present type of cylindrical boiler without any reduction of weight, as had been suggested by Mr. Sinclair. With regard to the water test as advocated by Mr. Berry, he thought the Dutch system mentioned by that gentleman was on a proper scale. Surveyors always had a keen eye to see if there were any bulging when a boiler was being tested. The author said that ships were worn out before the boilers; on the other hand, many ships stood two sets of boilers. He was not prepared to see either the scantling of the boiler or the factor of safety reduced. With the corrosive action that took place, together with the wear and tear on the boiler, the thinner the plates got the sooner it was likely that some accident would happen. Whilst they retained that factor of safety they always had something to go by.

Mr. W. E. FARENDEN (Associate Member) agreed with previous speakers as to the water test, and questioned whether testing high pressure boilers to double the working pressure did not set up strains in the material to which it should not be subjected; thus to test boilers of 200 lb. pressure to 400 lb. was a very severe test. As the author had mentioned, it was really a test of workmanship, to see whether the boilers were tight, that there was no buckling of the plates to any extent, and that after the test the plates came back to their original condition. A boiler 15′ 6″ in diameter by 11′ 6″ long, working pressure of 185 lb., tensile strength 28 tons, percentage strength of joint-plate section 84·74, and taking 4·5 as a factor of safety, would have under Board of Trade rules a thickness of shell plate of $1\frac{15}{32}''$ as:

$$\frac{185 \times 4\cdot5 \times 15\cdot5 \times 12}{28 \times 2240 \times 2 \times 84\cdot74} = 1\tfrac{15}{32}''$$

Under Lloyd's rules the same boiler shell plate would require a thickness of $1\frac{11}{32}''$, or $\frac{4}{32}''$ less than the Board of Trade regulations demanded, as:

$$\left(\frac{185 \times 15\cdot5 \times 12}{21 \times 84\cdot74} + 2 = 1\tfrac{11}{32}''\right)$$

If the thickness of plate required by Lloyd's rules were ample as compared with the Board of Trade requirements, there might be a saving of some fifteen to twenty tons in weight of material for the shells, and consequently saving in cost in ships having, say, ten boilers of the above dimensions. With regard to the thickness of furnaces and stays the Board of Trade and Lloyd's were very much alike in their rules. He did not think it would be advisable to reduce these, but considered the shell plates might be reduced a little.

Mr. G. SHEARER said there was one case he recalled of the bursting of shell plates in the boilers of the *Livadia*—an extraordinary case which happened about twenty-three years ago. These boilers were built in Fairfield, and when they were under hydraulic pressure their longitudinal seams ripped up from end to end before they had half the pressure accumulated—due, probably, to a fault in the manufacture of the steel. They had different steel now to what they had then. Those boilers were entirely destroyed, being proved to destruction. The boilers were all punched in the usual form, and that was considered by the makers bad for the material. The plates were sent back to the manufacturers in Sheffield, and special furnaces were built to anneal them and do everything they possibly could to trace the fault, but I believe they never got to the bottom of the disaster, and he was of opinion that the punching of, and excess of carbon in, the plates was the cause of it. New plates and boilers were built for the *Livadia*. He had seen the boilers of the *Propontis*. They were the first tubulous boilers he had seen in this country. He was not on board the ship, but he saw them put in, and remembered the accident. Speaking from hearsay, he believed they had great difficulty in firing those boilers; they acted much the same as the Belleville boilers. As soon as one furnace was fired the water was lost in the gauge-glasses, and the water rushed to the other. They drove quite a number of engineers out of the ship with scare, and eventually the boilers burst up. They had a small explosion with some of the tubes, and then they had a larger explosion, when, he believed, some five men were killed or disabled for life.

Mr. A. WOOD (Member) said he agreed with keeping the strength of the shell of the boiler, for the Board of Trade had given them a very safe margin. He had been with several different sets of boilers, and had got up steam in a hurry, but there was a great strain on the shell, and also a lot of corrosion which had to be provided against. In all the well-known regular steamship lines they had a periodical overhaul, but it was different with tramp steamers, that were not so well looked after as mail and passenger ships. With regard to testing the boiler to double pressure, he thought $1\frac{1}{2}$ times the pressure was quite sufficient. He concluded by moving that a vote of thanks be accorded Mr. E. Nicholl for his interesting paper.

Mr. J. THOM seconded the vote, which was cordially agreed to.

Mr. JAMES ADAMSON (Hon. Secretary) pointed out to Mr. McLaren that the author had not used the word "old" in regard to the hull of the ship being done while the boilers were in good condition, but rather that the vessel had become obsolete; he thought they would agree with Mr. Nicholl upon that point. That was to say many ships, say, twenty to twenty-five years old, in which the boilers were still running with their original pressure, were certainly obsolete and would hardly pay in these days of low freights and in view of the improvements and economies effected during the last ten years.

With reference to an adjournment of the discussion, all the Monday evenings were occupied up till April 20th, so that they could not have an evening for the further discussion of Mr. Nicholl's paper until after Easter.

Mr. W. McLAREN proposed that the discussion should be adjourned until the reopening of the session. They would then have time to look over the question, and by then many points in connection with boilers would have been fought out. He moved that the discussion on Mr. Nicholl's paper be adjourned until after the summer recess.

Mr. K. C. BALES seconded the motion, which was unanimously agreed to.

Mr. FRANK COOPER proposed that a hearty vote of thanks be accorded to the Chairman for presiding that evening.

Mr. A. H. MATHER seconded, and the proposition was cordially agreed to.

The CHAIRMAN then announced that on Monday, March 16th, Mr. R. Balfour would read a paper on "Refrigerating Machinery and Appliances as Fitted on Board Ships."

Mr. NICHOLL'S REPLY.

"Perhaps the most remarkable point about the criticism of this paper is the consensus of opinion in favour of some reduction in the shells of cylindrical boilers, and this happens to be the point upon which I laid most stress.

"But with regard to the reduction of the internal portions the majority seemed to be opposed to it, but as far as I can gather from their remarks not one single argument has been brought forward that will bear investigation. I maintain that no boiler built to Lloyd's or Board of Trade rules has given way through initial weakness. Simply because furnaces come down due to accumulation of scale, grease or dirt is no argument, because had they been made double the thickness the same thing would take place.

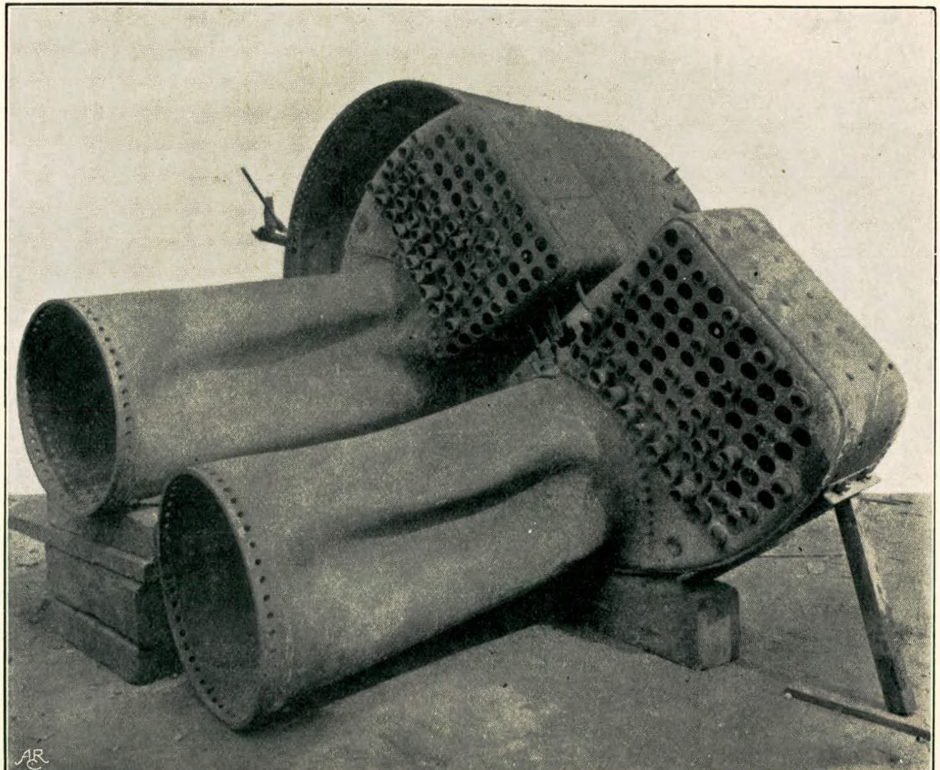
"Does Mr. Berry, for instance, think for a moment that had the 'innards,' as he terms them, of the boiler he quotes been made 50 per cent. heavier that they would not have collapsed due to overheating? I think not.

"Then with regard to the two vertical boilers he saw taking an aërial flight, he does not tell us to what this was due. If, as I presume, it was due to overheating or else undue corrosion, then it is no argument against the reduction I advocate. Under both circumstances it would be due to the want of proper supervision, which I say does not apply to marine boilers, and should not in any case.

"One gentleman puts forth the Barking explosion as an argument against the reduction of scantlings. In the first place, I should like to ask him if any person has the remotest idea what pressure was on that boiler when it exploded? I think one ingenious gentleman attempted to calculate the pressure from the force necessary to break windows by the air waves set up by the explosion, and he brought it out at about 400 lb., if I remember rightly.

"I quite agree with Mr. Berry that a boiler that will not stand double the working pressure is not entitled to respect, but when it has stood it I much doubt whether he has got any guarantee of the quality of material or workmanship for that matter. It is astonishing what a man with a caulking tool can do to make a boiler tight for the water test, but it may not be so for long under steam. The sketch submitted by Mr. Berry of the boiler with round top combustion chamber is very interesting, but I fail to see what he is going to gain by it. In the first place, the great thickness of plate required in the curved tops, I should say, almost nullifies any gain from doing away with the girders in a flat top. Then the additional weight of water to be carried to make up for the displacement of the usual square corners is considerable. I have no doubt the thing will work all right, but I certainly do not expect to see it adopted largely.

"I thank everyone for the kindly criticism, and trust the paper has afforded some opportunity for interesting discussion."



DONKEY BOILER, WITH COLLAPSED FURNACES, SS. *DIOMED*.