Recent Progress in Marine Machinery

T. J. Haddy R.N.

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RECENT PROGRESS IN MARINE MACHINERY

(Translated from the "Rivista Marittima" for September," 1892,
by T. J. HADDY, R.N.

Actual Practice followed in the Construction and Working of the Motive Apparatus of Ships of War.

FORCED draught, high boiler pressures, multiple expansion, and high speed of revolution introduced in the motive machinery of ships of war in order to economize weight, space, and fuel have produced inconveniences, neither few nor slight, in order to lessen or eliminate which modifications and improvements have been rendered necessary in the engines and boilers; other improvements have been suggested by the progress of science and of the mechanical arts and by the continued study brought to bear on marine machinery, and of these improvements from the above sources I propose to make a summary.

Boiler Construction.—No considerable change has taken place in the general design of the boiler, but in the details only, and on which I will now remark. First of all I may mention that the reduction of the test pressure has resulted in a sensible reduction in the thickness and weight of the boilers. In the mercantile marine the proof pressure is now, as it was in the past, twice the working pressure of the boiler, whatever that pressure might be, and the thickness of the plates and stays, both for the shell and the parts exposed to the action of fire, are calculated on the proof pressure so established; on the other hand, in the English Navy, and later in ours, for boilers with over 90 lbs. working pressure it has been considered sufficient to limit the proof pressure to the pressure on the safety valve *plus* a constant of 90 lbs., and to calculate the thickness of the shell plates from this basis. The motives which have suggested this measure are—

1st. That with the old rule, the greater the working pressure the greater the factor of safety became, with the result that the latter was excessive in the case of modern boilers with high pressures.

2nd. That this margin of resistance was uselessly high for the shells of boilers, which are not exposed to the action of heat, and the strength of which can be precisely ascertained from reliable data.

3rd. That the high proof pressure necessitated the employment of very thick plates for the shells of ordinary return tube marine boilers, which plates are difficult to produce and to work, and which do not present, especially in finished work, the same guarantee of good quality and solidity which thinner plates afford.

4th. That with the new rule, as the thickness of the shell plates is reduced about 18 per cent., there is a considerable saving in the weight of the boiler.

5th. In conclusion, the new rule has the sanction of experience, having been for some time in general use for locomotive work. This new rule, which has also been adopted by other navies, has given good results, and it is probable that it will also be shortly accepted by the Board of Trade, Lloyd's Register, the Bureau Veritas, Registro Italiano, and other institutions which regulate boiler construction. On this question the late Richard Sennett contributed an important article included in the "Transactions of the Institution of Naval Architects" for 1888.

Forced Draught.—Forced combustion in boilers naturally has limits which it is not possible to surpass, and which depend on the capacity of the heating surfaces to transmit to the water the heat from the furnace, and to resist without damage the elevation of temperature in the plates. But lately, during the trials of new machinery in the English Navy, serious defects have been manifested in the boilers run under natural draught, and in a degree never known before forced draught was introduced. These defects generally consisted in sudden leaks and bursts of water and steam from around the ends of the tubes in the tube plates exposed to the fire.

These defects have occurred in double-ended boilers with combustion chambers common to all the furnaces (that is, not having separate chambers with water spaces between them and plates to absorb the heat), in addition to which the spaces between the different nests of tubes were somewhat confined. Accurate theories and experiments have induced the belief that the defect is principally due to the structure of the boilers of this class, in which there is a deficiency of surface in the combustion chamber to absorb the heat of combustion in conjunction with a defective circulation of the water in contact with the tube plate, which favours the formation of a stratum of vapour in the neighbourhood of this plate, little fitted to extract the heat from it. It seems, in fact, that under forced draught the intensity of the heat thrown on the tube plates, and on the ends of the tubes, is such that these parts are soon injured unless kept cool by an abundant afflux of water, or in some other way. This explanation has been confirmed by experience; the defective boilers have been improved by leaving out some vertical rows of tubes, in order to improve the circulation of the water, and later boilers having been constructed with a separate combustion chamber to each furnace with the different nests of tubes well separated, have given results under forced draught in every respect satisfactory. In the English Navy single-ended boilers are much in favour, and are preferred to the double-ended type, because it is thought that in the first the circulation of the water is more regular. This may be true, but to me it appears doubtful if on the whole this preference is justified, since for the benefit of a regularity in the circulation of the water, which could be obtained by other means, the greater advantage is given up of having the steam generated in a few boilers of large power to subdivide it

among double the number of boilers of smaller power, the collective management of which must necessarily be more difficult.

Here it is not out of place to note the influence which the combination of the two causes above cited had on the bad results obtained with double-ended boilers with combustion chambers common to all the furnaces, since by the suppression or amelioration of one of them the lamentable defects were sensibly diminished, whilst it cannot be said that one cause, that is, the deficiency in the circulation of the water in contact with the tube plates of the combustion chamber, has the greatest influence in the phenomenon, because there are boilers, for example, those of the torpedo-boats of the "Schichau" type, which have given splendid results under forced draught, and in which the tubes are so close together as to undoubtedly make the circulation difficult and limited. But in these boilers the furnaces are very wide and present a large surface for the reception of heat from the fire before the flames strike against the tube plates into which the tubes are screwed and beaded over; this may explain the good results obtained. Forced draught in boilers has been the subject of an interesting communication from Mr. A. F. Yarrow, at the Institution of Naval Architects in March, 1891, in which he has shown the necessity of giving the greatest possible liberty of expansion to the various parts of the boiler, and also to contraction and modification of form under the changes of temperature. The observations of Mr. Yarrow refer more particularly to boilers of the locomotive type, but they have much value also for those of the ordinary marine type, and of those I shall treat further on.

It is probable that it may soon be possible to produce a type of boiler for sea service that in conjunction with other requisites will possess that of being able to withstand a highly forced combustion, above what has yet been attempted, but in the meantime it has been considered advisable in England to abandon the common combustion chamber type, and to abstain from forcing the boilers beyond the limit which also in the mercantile marine has been found possible and practicable. This limit for ordinary boilers corresponds to a developed power not exceeding by more than a third that which the same boilers could develop under an air pressure equal to one inch of water. It is well to note that the use of forced draught within moderate limits is gradually extending in the merchant service, by which is obtained not only economy of weight and space, and greater independence of atmospheric conditions, but also economy in fuel consumption, which in many cases, with a proper proportion of grate surface, has reached 15 per cent., and with the advantage that coal of an inferior quality can be used with more economy than with natural draught. Amongst the various systems of forced draught in use, viz., with closed stokeholds, closed furnaces, and aspirators in the funnel, it is not very certain which merits the preference. Forced draught with closed stokeholds is very simple in action and has been as yet the plan most generally adopted; but it has the defect that it prevents or renders very difficult communication between the stokeholds, engine rooms, and other parts of the ship, con-

sequently exposing the personnel to greater risks in the event of accident to the boilers, steam pipes, or hull of the ship. On the other hand, it has the advantage that it maintains a supply of fresh air in the stokeholds, and so the work of the stokers is rendered less arduous than with other systems. This system has been applied to nearly all the new ships of our Navy. The system of forced draught with closed furnaces is gaining ground, from the fact that it allows as free communication between the stokeholds, engine rooms, and other parts of the ship as under natural draught. This system also lends itself more readily than the first mentioned to the device of warming the air previous to its supply to the furnaces, resulting in economy, (although slight) in fuel and better preservation of the boiler. It would seem to be a fact that in boilers forced in this manner, on account of the reduced current of cold air which is admitted to the furnaces during the management of the fires, leaks at the tubes are neither so frequent nor serious. This fact is more evident still in boilers worked with liquid fuel, and in which, in spite of the quick combustion and very high temperature, leaks of the tubes are of rare occurrence on account of the great regularity and uniformity of the combustion and the complete absence of currents of cold air. The closed furnace system has been applied with complete success in our own Navy in some of the torpedo-cruisers of the "Partenope" type, or the torpedo-catchers of the "Aquila" type, and in all the sea-going torpedo-boats. The third system is as yet in the experimental stage, not having entered into the practical, there being still many difficulties in the way of its adoption. It appears, however, from the point of view of the preservation of the boiler that it would be well if it could be employed.

Particulars of Boiler Construction.—The rules actually followed in the details of boiler construction, the fruit partly of recent experiments made for the purpose of eliminating defects or finding the cause of them, are the following. They refer especially to boilers designed to work under forced draught.

Furnaces and Combustion Chambers.—In the ordinary marine boiler it is necessary that each furnace should have an ample combustion chamber to itself, separated from those of the other furnaces by its metal sides and the body of water between them. Large boilers having four furnaces on the same front are an exception to this rule, as by reason of space it is preferable to couple two furnaces to one combustion chamber.

In ordinary marine boilers the length of the combustion chamber in the direction of the axis of the furnace, if possible, should not be less than nine-tenths of the diameter of the furnace. It is a good rule, also, to protect the lower part of the combustion chamber opposite the tube plate with refractory brickwork. In boilers of the locomotive type, of large dimensions, in order to afford a larger surface to absorb the radiant heat of the furnace, it is considered better to divide the furnace longitudinally into two parts with a vertical body of water between them. In these boilers the furnaces should be long, whether there are two or one, so that the tube plates

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FIG. 1.
STAYS TO FIREBOX IN MARINE BOILERS
OF THE LOCOMOTIVE TYPE.

FIG. 2.
FURNACES WITH CORRUGATED PLATES FOR MARINE BOILERS.

FIG. 3.

FUNNEL SHAPED FERRULE FOR THE TUBES OF MARINE BOILERS.

FIG. 5.
BELLEVILLE BOILER.

FIG. 4.

LAGRAFEL AND D'ALLEST BOILERS,

FIG. 7.

YARROW BOILER.

FIG. 6.

THORNYCROFT WATER TUBE BOILER.

may be less exposed to the direct impact of the flame. To the same end it is usual to have diaphragms of fire-brick corresponding with the fire-bridge, so as to cause the flame to make a longer circuit before arriving at the tube plate.

The importance of preventing the direct impact of the flames on the heating surfaces has been well shown by Dr. Fred. Siemens, in his excellent work, "New Method of Heating with Free Development of Flame." It is necessary, however, not to go too far in this direction, at least in boilers of the locomotive type, since by lengthening the furnace the difference between the expansion of the internal lateral walls and the corresponding parts external to the furnace is augmented, and, in consequence, the deformation thus caused throws a great strain on the stays supporting them, with the result that these are often carried away. This defect is one of frequent occurrence in locomotive boilers, and to remedy it in some measure various expedients have been resorted to. 1st. Drilling the stays nearly through in the direction of the axis, so that when one is ruptured the slight escape of water which takes place through the end gives evidence of the fact and shows which is the defective stay which must be replaced. 2nd. Allowing free expansion at the outer stays to the furnace plates, where the expansion is most felt. 3rd. Giving more elasticity to the stays by turning them down in the central part to the diameter of the bottom of thread of the screwed ends.

Fig. 1 shows an ordinary stay, one which allows of free expansion of the plates, and one of the drilled stays. None of these precautions are necessary for the stays to the crown of the furnace, because, by reason of their length, they can adapt themselves readily to follow the deformation and relative displacement of the parts which they connect. The crown of the furnace in locomotive and of the combustion chambers in ordinary marine boilers is supported by vertical stays connected either to the shell of the boiler or to strong traverses supported by the sides of the furnace or combustion chamber. The first system is generally followed in marine boilers of the locomotive type, and is also sometimes used in the ordinary type. It has the advantage that it relieves the sides of the furnace or combustion chamber of all strains due to the vertical pressure of the steam on the crown, but with the defect that it makes the boiler inaccessible where these stays are fitted, and increases the resistance to free expansion of the furnace or combustion chamber. For these reasons many manufacturers prefer the traverse supports. In the same figure (Fig. 1) is shown one of the tubular stays, an idea of Mr. Yarrow's, to admit of the stays themselves being replaced from inside the furnace. It has also been proposed to corrugate the crown of the furnace in the locomotive type in order to strengthen them and at the same time give them more freedom of expansion, but as yet this idea has not been carried out in our Navy. In ordinary boilers with return tubes the furnaces are almost always corrugated to give them the necessary strength without unduly increasing the thickness of the plates. With respect to this, Mr. A. Blechynden, in

his "Review of Marine Engineering in the last Decade," read at the Institution of Mechanical Engineers in 1891, expresses himself thus: The internal conductivity of the metal for heat relatively to the absorbing and emitting power of its surface being very great, it would not appear to be injudicious to make the plates thicker in order to strengthen them without making them corrugated, and, in fact, there are makers of marine engines who have used plates for furnaces of 20 mm. thickness with much success. However, the rules of the Board of Trade limit this thickness to 16 mm. The various systems of corrugation are shown in Fig. 2, and it is not yet certain which of them merits the preference. A late improvement has been made in the furnaces to make them removable or interchangeable, as it is considered that in modern boilers the furnaces are more subject than other parts to injury and deterioration, so that the importance of making them easily renewable can be understood.

Successive Combustion Chambers.—Mr. F. W. Webb, engineer of the London and North Western Railway, considering that the heating surface of the tubes has its maximum efficiency at the ends nearest the furnace, where a length of 30 cm. produces an evaporation equal to that produced by the whole remaining length of the tube, and considering besides that, beyond the tube in the smoke-box, where the gases meet before ascending the funnel, if the combustion is much forced, as it generally is in locomotives, it frequently happens that the gases remaining unconsumed and becoming mixed with air, are ignited and a second combustion is produced, which is not only useless, but injurious; the idea occurred to him to divide the tubes into two parts about the centre of their length, and to interpose between the two parts another combustion chamber, where the gases from the first collection of tubes could mix, and ignite if unconsumed, giving up the heat to the walls of this combustion chamber and to the second rows of tubes before finally escaping to the smoke-box and funnel. The interposition of this second combustion chamber between the two nests of tubes would also have the effect to divide between four tube plates, instead of two only, the longitudinal expansion of the tubes, and so lessen one of the causes of the frequent leaks which take place at the junction of the tube and tube plate. This idea, which has given good results in practice, as it would appear from the experiments which have been made with a locomotive boiler, might probably be applied with advantage not only to marine boilers of the locomotive type and direct tube or gunboat type, but also to ordinary return tube boilers. With the application of the successive combustion chambers, one of the principal causes of leaky tubes, however, still remains, that is to say, the relatively unequal expansion and deformation which takes place at the tube ends, and the corresponding holes in the tube plate, caused by the different variations of temperature and the different strains to which those parts are subject, and which they must obey; on this point I have more to say further on.

Tube Plates.—The tube plates are about the best supported of any of the internal parts of the boiler, the tubes independent of the stays

giving them much support. For this reason it does not seem necessary that they should be thick in order to withstand the internal pressure of the boiler, and since their flexibility and facility which which they are traversed by heat and follow the variations in temperature which takes place in the tubes is the greater the less their thickness, and the nearer this thickness approximates to that of the tubes, it would appear necessary to limit this thickness to that required for a good hold of the tubes themselves, and the stay tubes. Mr. Yarrow, in his communication above cited, gives much importance to this point, and gives it as his opinion that the tube plates should not have a greater thickness than 12 mm. It is probable that this rule may be gradually accepted by all, but for the present it is the practice not to go below 15 mm. for the thickness of tube plates. For the same object, to facilitate the passage of heat and the uniformity of temperature between the tubes and the tube plates, Mr. Yarrow believes that the tube plates should be of copper instead of iron, and, in support of his opinion, quotes the results of direct experiments made by himself and of experience with his boilers in torpedo-boats and locomotives. It may be that Mr. Yarrow is correct in his views, and that tube plates of copper are preferable to those of steel in boilers of torpedo-boats, which are not called on to make long voyages or to remain long at sea; but it is doubtful if this would be the case in ships destined to remain a long time on active service, liable to be kept far from a repairing station, and to suffer rougher treatment than the former. In these latter boilers, galvanic action between the copper and iron might be the cause of considerable wear, whilst the sediment which would form on the tube plates would soon cause the superiority to disappear as regards the conductivity for heat, over the ordinary tube plates of iron or steel. Mr. Yarrow is also against the employment of stay tubes, which, in his opinion, while unnecessary, because the tube plates are well supported by the ordinary tubes, they render the tube plates less free to yield to the expansion and distortion of the ordinary tubes, and for this reason aggravate the defects arising from these changes. If stays must be fitted, according to Mr. Yarrow, they should be equal in thickness and quality of metal to the ordinary tubes, so that they may expand and contract to the same extent as these. The opinion of Mr. Yarrow finds much support in the fact that boilers of the locomotive type, both in locomotives proper and on board ship, have no stay tubes, and no defects have as yet occurred that can be properly attributed to their absence, while stay tubes which have been fitted in boilers with single combustion chambers on board ships, as the "Barracouta" and others in the English Navy, have not prevented serious leaks at the tubes and tube plates, which have caused such alarm and distrust of this type of boiler. With less reason would stay tubes be necessary in marine boilers with separate combustion chamber to each furnace, since in this case the tube plates are small and well supported at their perimeter by the sides of the combustion chamber. It is difficult, however, to understand that, while few object to the absence of the stay tubes in the locomotive type, very few indeed will accept of

their suppression in ordinary boilers, which are still constructed with stay tubes as formerly. Mr. Yarrow, always in agreement with his principle to give to the different parts of the boiler sufficient freedom to adapt themselves to the variations in temperature to which they are subject, also condemns the practice of fitting stays, stay tubes, or even ordinary tubes, too closely to the angles of the combustion chamber, and suggests, if stays are fitted in these parts, they should be so fitted as to allow of free expansion, as before mentioned, in speaking of the furnace stays of locomotive boilers. Since one of the principal causes of leaks at the tube plates around the tube ends is the too high temperature to which these parts are exposed under forced draught, it has been endeavoured to prevent this by applying a shield in front of the tube plate, which, while it does not prevent the passage of the gases and their ingress into the tubes, will protect the tube plate and the ends of the tubes from the heat of the furnace.

M. Normand, the renowned torpedo-boat manufacturer, has carried out this idea for his torpedo-boat boilers with great success, applying at the mouth of each tube a funnel-shaped ferrule much rounded over at the projecting lip, which protects the tube-plate and facilitates the entry of the gases into the tubes. These ferrules have also given good results in the ordinary double-ended boilers with common combustion chambers on the English cruiser "Barracouta," which gave so much trouble on her first trials under forced draught without these ferrules, and more recently in other ships in the same Navy. In our Service these ferrules will be gradually applied to all boilers destined to work under forced draught. Fig. 3 shows the most recent type of funnel-shaped ferrule adopted in the English Navy. Ferrules of cast iron, iron and mild steel, have been tried: the best results as regards resistance to the action of the fire appears to have been obtained with the latter material.

Tubes.—In modern marine boilers with engines fitted with surface condensers, by which internal incrustation is in great part eliminated, a frequent removal of the tubes is not necessary, and they are generally made of iron or mild steel, whilst formerly they were made of brass. In favour of this change is the reduction in cost of the tubes, and greater uniformity of material in the boilers, by which the differences of expansion are reduced, and consequently its bad effect on the hold of the tubes on the tube plates. On this point it would appear by recent experiments that iron tubes are preferable to those of steel, and there are, in fact, well known manufacturers who use iron tubes exclusively for marine boilers, in spite of their inferiority in point of strength, tenacity, and malleability to steel tubes.

Mr. A. Blechynden, engineer at Barrow-in-Furness, is of this opinion, and he has carried out some interesting experiments on the behaviour of iron and steel tubes when they are successively exposed to alternate heating and cooling at their junction with the tube plate. But one kind just as much as the other has the serious defect, especially for war-ships which must often remain for a long time inactive, that they corrode rapidly, also

when the boiler is laid up. This decay takes the form of a pitting corrosion, which is set up in the tubes, and being very thin they soon become perforated, and so a ship may be rendered un-serviceable whose boilers but a short time before had been considered in good condition. Perhaps this difficulty may be overcome by using tubes of nickel steel, which is not very liable to corrosion. It is a good practice to make the tubes slightly larger in diameter at the smoke-box end, to facilitate their removal when it becomes necessary to renew them. If this is done the tubes may be ordered with the diameter at the ends slightly in excess of the diameter of the holes in the tube plate, and the tubes then ground to fit exactly; in this way there is no necessity to use any excessive force with the mandril to fix them securely in the tube plate.

When the employment of the funnel-shaped ferrules has become general it will also be advisable to enlarge the tubes at the fire-box end, in order that these ferrules may be applied without unduly restricting the section for the passage of the gases. In the boilers of torpedo-boats, and also in ordinary marine boilers, the tubes have been screwed into the tube plates in order to lessen the risk of leakage at this part; but with the employment of the new ferrules this will not be necessary.

Disposition of the Tubes, and Space between them.—Much has been said on the best arrangement of the tubes to facilitate the circulation of the water, and the free escape of the steam between them, and of the space which should exist between them in proportion to their diameter. Some prefer a lozenge-shaped, others a rectangular, arrangement. The latter appears the best adapted to favour the circulation, and is generally observed in ordinary cylindrical boilers with return tubes. The lozenge-shaped disposition has the advantage that it utilizes the space better; for this reason it is frequently adopted for the locomotive type of boiler, in which, the combustion being very active, it is necessary to provide a large heating surface in proportion to grate surface. The lozenge is usually elongated, and it is preferable to arrange the tubes so that the major axis of the lozenge is vertical. It is considered good practice to have a space of not less than 25 mm. between the tubes, and this rule is generally followed in ordinary marine boilers; but it is doubtful, in my opinion, whether either the disposition of the tubes or the interval between them has so much influence as many believe on the good circulation of the water, or at least on the good hold of the tubes, since in the boilers of torpedo-boats of the "Schichau" type very good results have been obtained as regards the hold of the tubes, although they are arranged lozenge fashion, with an interval of only 9 to 12 mm. It must in justice be added, however, that these tubes, instead of being simply expanded, are screwed into the tube plate at the furnace end.

Serve Tubes.—With the object of extracting more heat from the gases in their passage through the tubes, M. Serve has employed tubes with a system of internal radial ribs, except for a short space at each end, where the tubes have to be expanded into the tube plates. Naturally these ribs offer a resistance to the passage of

the gases, and increase the weight of the tubes; but these inconveniences may be compensated for by the better utilization of the heat; by the experiments made, it would appear that there was an increase of about 10 per cent. efficiency in this particular.

Water-Tube Boilers.—One of the methods by which the difficulties inherent to the use of forced draught, can be radically solved is, no doubt, the employment of water-tube boilers. In these boilers, and more especially in the more perfect of them, the various elements of which they are composed are disposed and combined in such a way that they are free to expand and contract under the influences of the variations of temperature; and, besides which, the extremities of the tubes where they are connected to the other parts of the boiler are not exposed to the direct action of the fire: so that the risk of injury to this union from the above cause is avoided. There already exist a great many types of these boilers, of which I will only enumerate the principal.

1. Boilers with a collection of straight tubes slightly inclined to the horizontal, and which connect two opposite plane and rectangular chambers of water, or two columns of water, which communicate with the steam chamber above. Of these types are the "d'Allest" (Fig. 4), used in various ships of the French Navy, and the "Towne" boiler with transverse crossed tubes.

2. Boilers with collections of tubes, forming so many independent zigzag windings, in directions slightly inclined to the horizontal, and which lead from a water chamber at the lower part to an external steam chest above, and having an external circulating tube between these two chambers. Of this type are the "Belleville" (Fig. 5) and the "Temple" boilers, used in the French Navy.

3. Boilers with a continuous serpentine tube, which have for prototype the American "Herreschoff" boiler, used in steamboats.

4. Boilers with concentric tubes, that is, in which the water tubes are traversed by tubes of smaller diameter, through which the products of combustion pass, and which serve as stays to the sides of the water chamber. The "Bartlett" boiler belongs to this class.

5. Boilers with collections of tubes leading upwards in straight or curved lines, and connecting two lateral water chambers below to a central steam chamber above, and having exterior circulating tubes connecting the water chambers to the steam chest. The "Thornycroft" (Fig. 6), the "Yarrow" (Fig. 7), and the "Normand" boilers belong to this type.

These boilers have been used with great success on board torpedo-boats; the last named is very similar to the "Yarrow" boiler. The water-tube boilers have three great advantages, and these are extreme lightness; with some of them it has been possible to obtain 100 h.p. per ton of boiler, including the weight of water; great security against explosion; less risk of injury or leakage when used at maximum power. Against these advantages, water-tube boilers are not so easily managed as ordinary boilers, especially if there are a considerable number of them on board the same ship, in consequence of the large and rapid variations in the steam pressure and

water level to which they are subject; they are also less easily repaired in case of any damage to the tubes of which they are composed. Besides this, they require that distilled water, exclusively, should be used for them; and, their maximum power being as yet limited to about 1,000 h.p., a much larger number of them are required on board ship in comparison with what would be required if boilers of the ordinary type were employed; whence the difficulty of management and the probability of defects arising are relatively greater.

From the larger number of water-tube boilers required on board a ship it would happen, in certain cases, that the space required for them would be greater than would suffice if ordinary boilers of the locomotive type were used. But marine tubulous boilers are, one may say, still in their infancy, and it is very probable that, in time, they may be brought to such perfection as to make them in all respects preferable to the boilers now in use.

(To be continued.)

Note.—It is worthy of note in the above article that M. Normand is credited with the introduction of the protective ferrule for the ends of the boiler tubes, and it appears to be inferred that M. Normand's plan has been copied by the British Admiralty; whereas I believe the Admiralty ferrule, a section of which is shown in Fig. 3, is entirely an original idea due to an Officer at present serving at the Admiralty. It is also worthy of note that the form of protective ferrule proved to be the most effective in England is at once made familiar to the Officers of the Italian Navy through the medium of a naval technical journal. An English naval technical journal which would collect and reproduce all published information with descriptive sketches, relating to inventions and improvements introduced into foreign naval services, would supply a great want, and is almost a necessity to all Officers of our own Service who would keep themselves at the head of their profession. No doubt the Foreign Section of the R.U.S.I. Journal could be so developed as to supply this much needed information in a form most acceptable to busy men, and there are hopeful indications in its pages lately of a rapid growth in this direction.—THE TRANSLATOR.