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FOREIGN SECTION.

This portion of the Number is reserved for Articles, either Original or Compiled, on Professional Subjects connected with Foreign Naval and Military matters; also for Notices of Professional Books, either Foreign or English.

It is requested that communications or books for review may be addressed to Colonel Lonsdale Hale, at the Royal United Service Institution, Whitehall Yard, London, S.W.

ON BELLEVILLE BOILERS AND THEIR APPLICABILITY TO OCEAN-GOING VESSELS.

Translated from the Russian Naval Magazine for July, 1890, by
Major WOLFE MURRAY, R.A.

In the course of the last ten to twelve years, with the constant increase of steam pressure in boilers for engines of, at first, double expansion, and, subsequently, of triple expansion (with the latter of which trading vessels and war ships have been exclusively supplied of late years), it has been observed that the life of the boilers has become shorter and shorter, especially with pressure in excess of six atmospheres. The destruction of the boilers has arisen chiefly from leaks in the seams of the furnaces and of the fire boxes. Even with conscientiously made boilers it frequently happens that furnaces, fire boxes, and tube plates have to be renewed after three years' service. These costly repairs—for in the case of such repairs only the cylindrical body of the boilers and the flat plating at the back remains intact—necessitate the idleness of the vessel for a considerable period of time. Accordingly, in 1884, the Messageries Maritimes determined to try Belleville boilers, and ordered from the Belleville works boilers for their new vessel the "Ortegal," then under construction.

The steam transport "Ortegal" was launched in 1884. Her hull and engines were built at La Ciotat, near Marseilles, at the yard and works of the Messageries Maritimes. The boilers were made at St. Denis, near Paris, at the Belleville works.

Length of vessel	337 ft. 10 in.
Width	45 " 5 "
Draught, fully laden { bow	19 " 4½ "
stern	22 " 0½ "
Displacement, fully laden	5,850 tons

Engines and Boilers.

Diameter of small cylinder.....	36 $\frac{1}{8}$ ins.
" large "	64 $\frac{3}{8}$ "
Stroke of piston.....	43 $\frac{1}{8}$ "
Steam pressure	6 atmospheres
Cut off	{ from $\frac{2}{3}$ to $\frac{1}{2}$ the stroke of the piston.
Number of boilers	8
Space occupied by boilers along the length of vessel.....	32 ft. 7 $\frac{1}{2}$ ins.
Length of tubes with boxes	6 " 0 $\frac{1}{8}$ "
Area of grate surface { original.....	243 sq. ft.
diminished.....	180.9 "
Heating surface	6,913 "
Steam space in boilers.....	301.56 cub. ft.
Water space "	96.93 "
Number of furnace-bars	354
Diameter of funnel	7 ft. 2 $\frac{1}{8}$ ins.
Height of funnel from grate-bars	59 " 4 $\frac{1}{2}$ "
A casing along all the height of the funnel and distance between the sides of the funnel and the casing	1 " 11 $\frac{3}{8}$ "
Interior diameter of safety valves	1 $\frac{1}{8}$ "
Number.....	16

The trials of the engines and boilers of the vessel were carried out from 11th to 25th April, 1885, and the runs on the measured mile gave the following results:—

Number of revolutions	81.00
Speed in knots	13.38
Indicated H.P.....	2110.50
At this trial the mean draught was	14 ft. 2 $\frac{1}{2}$ ins.
Difference.....	4 " 7 $\frac{1}{2}$ "
Area of immersion of midship section	521.32 sq. ft.

Service on Board the Steamer.

The first trip was from Marseilles to London and back, from 8th to 29th May, 1885. In the course of this trip the steamer was under steam 396 hours, including blowing off and getting up steam, and the total run was 4,146 miles.

When the vessel started, both from Marseilles and from London, the boilers were filled with fresh water, and during the trip the inevitable loss of water in the boilers was made good by taking in sea water. The blowing off of the boilers was carried on uninterruptedly, and although the saltiness of the water did not exceed 6 degrees (with the salimeters used in France 0 degree corresponds to the density of distilled water, and 10 degrees to the density of water completely impregnated with salt), saline deposits occurred on the lower surfaces of the four lower rows of tubes. On the run from Marseilles to London twenty tubes were burnt; and the leak of each burnt tube resulted in a diminution of steam in the boiler, to which the burnt tube belonged, for the time requisite for patching up the tube. On arrival in London the inner surfaces of the tubes were inspected, and saline deposits of five-sixteenths of an inch were discovered on the lower surfaces of the tubes. On the return journey from London to Marseilles the same features made their appearance, and again twenty tubes were burnt.

This experiment of making good the inevitable loss of water in the boilers by filling up with sea water, even on an uninterrupted run of only 2,000 miles, appeared to be thoroughly unsatisfactory, a conclusion in which

M. Belleville was compelled to acquiesce; for during the above trips from Marseilles to London and back again an engineer from M. Belleville's works was on board, and it was, therefore, impossible to ascribe the unsatisfactory results to the carelessness of the engineers of the "Ortegal." The "Ortegal," however, never made a trip from France to South America and back, trying her boilers exclusively with sea water, as M. Dubuis stated before the Naval Technical Committee.

Repairs to the Boilers after the above Second Trip, Alterations and Refitting of the Boiler Apparatus, and also Supplementary Work and Fitting for Ensuring the Supply of the Boilers exclusively with Distilled Water.—From the 8th June to 11th July, 1885, that is, after the vessel had done 4,116 miles, feeding her boilers with salt water, the following alterations were carried out:—

a. The two rows of lower tubes in all the boilers were changed, but the original thickness of the tubes (5 mm.) were adhered to.

b. The water levels were reduced by 14 cm., and the direction of the feed water into the purifying reservoirs for the steam and for the feed water was changed. The funnel was divided into four parts, by means of a cross-shaped partition; each part served to carry off the products of combustion of two boilers. The capping of the funnel was lengthened.

At the same time, to diminish the loss of fresh water and to ensure the supply of the boilers with distilled water, the following measures were taken:—

c. In order to attain more complete combustion, air was passed into the furnaces instead of steam, an air-pump being erected for the purpose, which was driven by a beam, which set in motion an air-valve.

d. The water which accumulated in the jackets of the steam cylinders, that arising from the blowing off of the steam cylinders and valve boxes, that from the blowing off of the general purifiers, and also the water from the boxes of the safety valves, was taken away into the condenser or into the fresh-water tank.

e. The exhaust steam from the auxiliary engines was passed into the condenser.

f. A special condenser was constructed for condensing the exhaust steam from the auxiliary engines, when the main engines of the vessel were not working.

g. To make good the loss of water in the boilers, a distilling apparatus, with boilers and condensers, was fitted up. The water from the condenser was carried off into the fresh-water tank.

Service of the Vessel from 11th July, 1885, to 14th February, 1889.

With boilers fed exclusively with fresh (distilled) water, the "Ortegal" made two trips from Marseilles to London and back, one trip from Marseilles to Bordeaux, and ten trips from Bordeaux to the coasts of La Plata and back. In the course of these, i.e., from 11th July, 1885, to 14th February, 1889, the steamer ran 112,807 miles, and was under steam 13,020 hours, or 542½ days; 1,908 hours or 79½ days getting up steam; in all 622 days with steam up.

Repairs to Boilers and their Appliances from 11th July, 1885, to 14th February, 1889.—a. Repairs from 7th October to 1st November, 1885.—The 100 patent furnace bars were repaired. The doors, closing the space in which the boiler tubes are situated, were lagged with asbestos and wood. The brick bridges of the boilers were repaired; 33 kilogrammes of zinc were placed in the boilers; the zinc is placed in the collectors of the feed water and in the reservoirs for purifying the steam and the feed water.

b. Repairs from 18th March to 11th June, 1886.—All the sections were taken out of the boilers; 520 rings at the junctions of the tubes with the

boxes, and 128 tubes were cut out. The two lower rows of tubes, in all the boilers, were replaced by thicker ones, viz., with 10-mm. tubes in place of 5-mm. tubes. This alteration was done at M. Belleville's instigation, but was not called for by the unserviceability of the tubes. The outer casings of the boilers and the smoke boxes were repaired, as they had become bent; the former, moreover, appeared weak, and had to be strengthened with additional angle irons. The area of grate surface was diminished from 243 square feet to 180.9 square feet, in order to make the combustion in the boilers more effective, and thus to increase the efficiency of the circulation of the water. An area of 180.9 square feet corresponds to 1,160 ind. horse-power, by developing which the steamer makes its long runs with a mean speed of 10½ knots. The cross-bars of the grates and the ash-pits were repaired.

Observations regarding the Working of the Belleville Boilers and Method of Looking After them on the Eleventh Journey of the "Ortega" from Bordeaux to South America and Back.

This trip lasted from 16th February to 25th May, 1889. During the trip, the vessel was sixty days under steam, throughout which the boilers and their appliances acted satisfactorily, with the exception of the injuries noted further on. During the passage the heel of the vessel reached as much as 25 degrees, and for two days the steamer was steaming against a fresh head wind, which reduced her speed to 5 knots.

Notwithstanding all this, though there was considerable motion, the engines acted satisfactorily, and there was no priming.

During the course of this trip the steamer ran with a mean speed of 10½ knots; the engines made about 68 revolutions, and developed about 1,160 ind. horse-power. Generally seven boilers were used; the eighth boiler was only used when the coal was of bad quality.

The injuries on the run from Bordeaux to Buenos Ayres were—

a. The fusible plugs, which are retained in position solely by friction, were frequently driven out by the pressure of the steam. They were readily and rapidly replaced by spare plugs.

b. The flange of one of the feed pipes was torn off, namely, that flange by which the feed pipe is attached to the flat side of the separator for the steam and feed-water.

c. The connection for driving the air-pump was broken.

Cleaning the Boilers and Inspection of the Boiler Appliances after Thirty Days' Steaming.—From 18th March to 22nd April the steamer for the most part was lying in the ports of South America, as the passage between ports occupied only seven days, and only six boilers were employed. During the thirty-four days of the vessel's stay off the South American coast, the cleaning of the eight boilers was gradually carried out, and a portion only of the boiler appliances were overhauled, as on account of the limited number of engine-room hands, it was not possible to inspect all the boiler appliances. With regard to the cleaning and overhauling of the boilers and their appurtenances, the following points must be mentioned :—

a. *Cleaning of the Boilers.*—In each of the boilers the following were cleaned from the deposits formed in the separator for steam and feed-water; the four lower rows of tubes in each boiler and all the deposit was removed. The five upper rows of tubes are cleaned with scrapers only once a year, i.e., after 180 or 200 days' steaming. When the boilers are cleaned, a deposit of 1 to 3 mm. is removed. The thicker deposit was found on the two lower rows of tubes, and principally in the central sections of the boilers.

b. *Time required for Cleaning one Boiler.*—When three stokers were employed for nine hours a day, three days were required for cleaning, washing

out, putting together again, and testing the boilers with hydraulic pressure, with the view of seeing that the ends of the tubes were satisfactorily set up.

c. Bending of Tubes and Boilers.—In cleaning the boilers it was clearly apparent that in all the boilers the tubes of the lower rows were bent, and that this was especially the case with the central sections. This bending constantly increases with the period of service of the boilers. In one of the boilers the bending of two of the tubes was considerable, and accordingly they were replaced by spare ones. In removing these tubes their washers and rings had to be cut out. After they had been taken out the amount of their curvature was measured, and in one case it was found to be 1 inch, in the other $\frac{1}{2}$ inch.

N.B.—In all the boilers the above curvature of the tubes is found to be in one and the same direction, that is to say, the convex surface of the tube is always downwards towards the fire grates.

d. Changing the Zinc.—In cleaning the boilers, all the zinc plates were renewed. These should be renewed approximately after twenty-five to thirty days' steaming.

e. The brick bridges for the boiler furnaces, after the run from Bordeaux to Buenos Ayres, were in a satisfactory condition: that is to say, in each furnace a few bricks had fallen out, and they were replaced in all the furnaces by new ones by two stokers in two days.

f. The automatic water-gauge cock of the separator, during the trip from Bordeaux to Buenos Ayres, allowed the water to rise 5 inches beyond the middle of the water-gauge. On taking the apparatus to pieces it was found that the float of the apparatus was partially filled with water, in consequence of the passage of steam into the junction of the float with the upright stem (the stem is screwed into the float). After the water had been driven out of the float, and after the upright stem had been firmly fixed by means of a new washer placed under the shoulder of the stem, the automatic water-gauge cock was put together, and it acted without failure in the subsequent runs.

g. The automatic feed apparatus were not inspected for want of time, and as they had acted accurately during the run from Bordeaux to South America, we confined ourselves to renewing the packing of their lubricating arrangements.

h. The "regulator-détendeur" was taken to pieces, cleaned from dirt, and put together again. This work was done in one day, by three stokers.

i. The port Belleville donkey engine.—The pump of this donkey engine was taken to pieces, and it was found necessary to replace the piston rod of the pump. This rod is of steel, and has no bronze sheathing. It was found to be eaten away by the action of the galvanic current in that part of it which does not work in a lubricating packing; and on that portion of it which does work in a lubricating packing there were deep longitudinal grooves. This rod was replaced by a spare one, and this occurred a second time during the four years' service of the "Ortegale." The body of this pump is of cast iron, with a bronze lining. The remaining work was the same as in ordinary boilers, and therefore not worth detailing.

k. The condenser was tested with hydraulic pressure of 1 atmosphere, on arrival at Buenos Ayres, and it was found that some tubes leaked slightly; their collars were tightened, and the condenser was again tested by hydraulic pressure. At this trial of the condenser the inner surfaces of the tubes were carefully cleaned from the grease which had accumulated in them.

During the forty-eight hours' run from Buenos Ayres to Bahia Blanca, it

¹ This is elsewhere stated to be an apparatus peculiar to the Belleville boilers.—J. W. M.

was observed that the boilers did not require filling from the reserve tank of fresh water. This circumstance, together with the greater saltiness of the water, gave cause for doubting the reliability of the tubes of the condenser, and accordingly, on the arrival of the steamer at Bahia Blanca, the condenser was again filled with water, and it was found that one of the tubes had got shifted in the direction of its length, and that one of its packings was leaking. As a general rule, on board the steamer it was laid down that the tubes of the condenser were to be looked to as frequently as possible, with a view of averting the possibility of any escape from the tubes into the packings. An inspection of the tubes is, moreover, compulsory on the arrival of the steamer in South America, and on her return to Bordeaux, *i.e.*, approximately after every thirty days' steaming. At these inspections the interior surfaces of the tubes are cleaned by hand by means of flexible rods. In the condenser of the "Ortegal" the steam is passed through the tubes, and the water circulates round the tubes.

The injuries on the return journey from South America to Bordeaux were:—

1. A considerable leak was observed under the nut of a steel bolt, which secured the bronze lining in the cast-iron cylinder of the pump of the port donkey engine from shifting in a longitudinal direction. To prevent the loss of fresh water this donkey was taken to pieces, the bolt, which had been eaten away by the action of the galvanic current, was replaced by a spare one. This work took a whole day. According to the statement of those serving on the steamer this was the second time this bolt had been eaten away in four years.

2. The flange of the feed pipe of one of the boilers, which runs from the graduated stopcock to the automatic feed, was torn off. After steam was lowered in this boiler, the injured pipe was replaced by a spare one.

3. Some hours before arriving at the Canary Islands a leak was discovered in one of the parts of the feed pipe, which runs from the port Belleville donkey engine, and which is situated in the hold. On inspection, it appeared that there was a small circumferential crack in the pipe, and near the flange. This portion of the pipe was shut off, and subsequently during the twelve hours' stay at the Canaries it was soldered.

4. On weighing anchor at Las Palmas, in the Canary Islands, a leak of water and steam into the furnaces of the port bow boiler was observed; accordingly this boiler was disconnected from the others, and steam was lowered in it. On the next day, in order to fix the position of the leak, this boiler was filled with water, by means of the donkey, and when filled the leak was found to be from the fourth section (reckoning from forward), so that this section was removed from the boiler. On inspection it was found that the uppermost tube of this section had, on its lower surface, a hole $6\frac{1}{2}$ inches long, and $\frac{1}{4}$ inch wide, and so it was determined to replace this tube with a spare one. In order to remove the tube from the section, both the ring of this tube and the tube itself were cut off near the after uniting box, and the short portion of the tube which remained screwed into the plate was then cut off, and so, having flattened the portion of the tube which was cut off, it was screwed out of the box.

After the worn-out tube had been replaced by a spare one, steam was got up in this boiler, and it continued to work successfully with the others. Two working days were required for shifting the worn-out tube.

According to the statements of the commander and chief engineer of the vessel, who had served on her since she began her career, this eating away of the tube now occurred for the first time, that is at the commencement of the fifth year of the vessel's service.

N.B.—On a careful examination of the tube which had been eaten away,

after its removal, it was found that this eating away had already commenced in another place in this tube, also on the lower portion of its interior surface, and that in a short time a similar hole to that already discovered would have been formed.

5. It was observed that in blowing off boiler No. 3 on the port side, the movement of the water in the blow-off pipe was slow, and, therefore, it was decided to examine the ejector of this boiler. On steam being got down in this boiler, and, on the water being emptied out, the cap of the defector was removed. Much mud was found on the bottom of the ejector, and the blow-off pipe, which goes down almost to the bottom of the ejector, was found to be stopped up with bits of zinc. After the ejector was cleaned and also the blow-off pipe entering into it, steam was again got up in the boiler.

6. Fracture in the connection which drives the air pump.—This fracture took place eight hours before the arrival of the steamer at Dunkirk, and necessitated the stoppage of the engine for three-quarters of an hour to disconnect this pump from the engine.

Salinity of the Water in the Boilers.—In spite of the feeding of the boilers with distilled water, and of the great care taken of the condensers, the salinity of the water reached 3 degrees, and recourse had to be had to surface blowing off of the boilers for a short time to maintain the salinity of the water at 2 to 3 degrees.

The Bottom Blowing Off was carried out twice in the twenty-four hours through the blow-off cock of the ejector. At each blow off the cock was rapidly opened and closed twice, and this was quite sufficient for the removal of the sediment which had accumulated in the lower part of the ejector.

Pressure of Steam in the Boilers.—Efforts were made to keep this at 8 atmospheres, which was effected when Cardiff coal was used. With other sorts of coal the pressure varied from 5 to 7 atmospheres. When the tubes were being cleaned by steam and also when the furnaces were being cleaned, the steam pressure, with bad coal, fell to $3\frac{1}{2}$ atmospheres.

The Quantity of Fresh Water required for making good the waste of water in the boilers, varied from 2 to 3 tons per twenty-four hours. An expenditure of 4 tons only happened towards the end of the voyage, for the apparent loss by leaking through the packings became considerable after ten hours' uninterrupted working of the engines.

Expenditure of Coal per hour per indicated Horse-power, and quantity of Coal burnt per hour per square foot of Grate Surface.—During my tour of service on the steamer three different sorts of coal were used, viz. :—1. Cardiff of the ordinary quality found in the trade. 2. Coal sold as Cardiff, and similar to it in appearance, but actually, as was found on burning it, something between Cardiff and Newcastle. 3. Cheap *briquettes* (15 francs a ton), which were obtained at Dunkirk. In order to attain the ordinary twenty-four hours' run of 250 miles, the engines must do about sixty-eight revolutions and develop about 1,160 indicated horse-power, and, under these conditions, using seven boilers, the area of grate surface of which was 158 square feet, the mean daily expenditure of coal was :—

a. For Cardiff of ordinary quality, 35 tons or 85,400 Russian funts, which makes 3 funts per indicated horse-power per hour, and gives a consumption of $22\frac{1}{2}$ funts per hour per square foot of grate surface.

b. For coal sold as Cardiff.—33 tons or 92,720 Russian funts = 3.3 funts per indicated horse-power per hour, and 24.43 funts per square foot of grate surface per hour.

c. For the cheap *briquettes*, 42 tons or 102,480 Russian funts = 3.63 funts per indicated horse-power per hour, and 27 funts per square foot of grate surface per hour.

N.B.—The French ton = 1,000 kilogrammes = 61 puds. Using the coal like Cardiff, and also the cheap briquettes, it is very difficult with seven boilers to get sixty-eight revolutions out of the engines, and so, in order to ease the work of the stokers, the 8th boiler was used after three or four days' steaming.

Fire Grates.—Experience showed that Belleville's patent iron corrugated grates are not practical, because they frequently bend and they require considerable time to put them right. Accordingly, on the "Ortegal" they now use ordinary cast-iron bars, of which they keep a considerable reserve always.

Special Valves for the Passage of Steam from the Boilers into the Steam Exhaust Pipe.—The safety valves of the boilers of the "Ortegal" have no appliances for opening them at will, and, accordingly, on the forward ends of the steam conducting pipes, which run along each stokehole, there are valves, by means of which the steam can be driven through the steam exhaust pipe.

Special Valves for Passing the Water from the Boilers into the Hold.—The Belleville boilers, while not working, are kept filled with water, and in order to lower the water to the working level or to empty the boilers, there are valves on the forward ends of the blowing off pipes, which are situated in the hold. The water is passed into the hold through these pipes.

Fresh Water Tanks.—On board the "Ortegal" near each Belleville donkey engine, there are two fresh water tanks. The capacity of each of these tanks is $1\frac{1}{2}$ tons. These tanks communicate with one another as well as with the reserve fresh water tank, which holds 4 tons, and which is supplied with water from the condensing apparatus or from overboard when the vessel is lying in a river.

N.B.—Near each Belleville donkey two of the fresh water tanks which communicate together are made so that each of the tanks can be placed between two ribs of the vessel, and thus a considerable portion of the tank can be accommodated in the hull below the engine-room floor.

Special Donkey for Pumping the Fresh Water out of the Condenser.—While the vessel is at anchor the steam is passed into the condenser. The waste steam from the auxiliary engines can also be passed into the condenser, accordingly there is a special donkey for pumping the water out of the condenser into the fresh water tank, while the vessel's engines are not working.

Spare Parts of the Boilers and their Appliances.—On the "Ortegal" there are spare sections for two boilers, and boiler appliances as well; in addition to this there are several spare boiler tubes with their uniting boxes. Generally, on board the "Ortegal," there is a reserve supply of 25 per cent. of all boiler fittings, not excluding the movable parts of the Belleville donkeys.

Time necessary to get up Steam.—Although it is possible to get up steam in the Belleville boilers in half an hour, recourse was never had to such rapidity, but steam was ordinarily got up in two hours.

Time required for Emptying the Boilers and Filling them again.—Although M. Belleville proposes to blow off his boilers immediately the fire has been raked out of the furnaces, and to refill them immediately with water, recourse was never had on board the "Ortegal" to such operations, and usually, in case of changing the water in the boilers, it was allowed to cool, and then passed into the hold.

N.B.—The engineers of the "Ortegal" find that when steam is got up rapidly and when the water is renewed in the boilers rapidly, the bending of the tubes, which occurs at present, would be much more considerable, and probably a leak would occur in the joints of the tubes.

Testing by Sounding the Interior Surfaces of the Tubes of one of the Boilers of the "Ortegal" during its fifth year of Service.—On the return of the vessel

to Bordeaux I tested by sounding the interior surfaces of the tubes of the starboard bow boiler, and found that in the five upper rows of tubes there were fifteen tubes, in the walls of which erosion had commenced. In the four lower rows of tubes, however, no erosion of the walls was discovered. As the boiler was selected at haphazard, and as all the boilers had been subjected to the same conditions during their four years' service, we may suppose that in all the boilers there was similar erosion of the tubes; but of this I was unable to convince myself, because it was proposed to clean the boilers by turns during the two months the vessel lay at Bordeaux for repairs to her engines.

Notes as the Service of the Boilers of the s.s. "Sindh" of the Messageries Maritimes.

On the 15th of June I inspected at Marseilles the boilers of this steamer, and I collected the following details regarding the service of her boilers. I got these details from the chief engineer of the vessel, who was instructed to afford me every information, which he did most willingly, placing, moreover, the ship's records at my disposal:—

1. There are twelve Belleville boilers on the vessel. The engines are compound and the steam comes into the engines at a pressure of 6 atmospheres.

2. The boilers have entered their third year of service, reckoning from the day when steam was first got up.

3. During the two years' service of the boilers they were under steam 400 days, of which fifty days were getting up or keeping up steam.

4. The steamer makes voyages with an average speed of $13\frac{1}{2}$ knots. To attain this speed the engines should develop 1,800 to 2,000 indicated horsepower, with a daily expenditure of coal (Cardiff) from 50 to 55 tons. The steamer usually runs with eleven boilers.

5. The boilers of the steamer are always fed with fresh water, obtained by means of a condenser, provided with a boiler and condensing apparatus. The quantity of fresh water required to fill the twenty-four hours' waste of water in the boilers is not more than 5 tons. On the "Sindh," as on the "Ortegal," not a drop of water is lost either in blowing off the boilers or in passing off the exhaust steam from the auxiliary engines.

6. The boilers are cleared of sediment after twenty-six days of steaming, and then the thickness of the deposit does not exceed 2 mm.

7. During runs of thirteen days the salinity of the water in the boilers is not permitted to exceed 2 degrees, which is easily attained by moderate blowing off.

8. The patent Belleville grates, as they get damaged, are replaced by ordinary cast-iron grates.

9. In all the boilers there are many tubes bent in the lower rows, especially in the third row, reckoning from below. The amount of curvature varies from 2 mm. to 28 mm. During two years' service twelve tubes in the lower rows were changed, owing to their becoming excessively bent, and also some of the uniting boxes had to be changed, as the threads were spoilt when the tubes were screwed out.

10. During the two years the tubes were in use there was no instance of a hole being formed in them, but when tested by sounding it was found that erosion had commenced in several tubes of the upper rows in all the boilers.

11. The smoke boxes and iron casings of the boilers were bent, as was the case on the "Ortegal."

12. The tube and furnace doors are bent, and do not shut closely.

13. The brick bridges work satisfactorily.

14. The condensers are frequently tested with hydraulic pressure, to see that the packings of the tubes are in proper order.

15. There were instances of stoppage at the knees in the tubes, where these had been bent at right angles, which served as a communication from the columns of the water-gauge apparatus with one of the tubes of the second row in each boiler, and the result of this stoppage was that the water-gauge glass showed a false level, while there was no water in the boiler, and the tubes were red-hot.

16. The automatic apparatus acts satisfactorily in every condition of the sea.

These replies of the Chief Engineer of the "Sindh" go to support the results of my observations on board the "Ortegal."

Notes regarding the Service of the Boilers on board the Cruiser "Milan."

I made a trip on this cruiser of 15 miles from the roadstead of Hyères to Toulon, lasting 1½ hours, and of course I was unable personally to convince myself as to how far the problem of feeding the two boilers of the cruiser with sea water had been satisfactorily solved. Accordingly I had to confine myself to questioning the Commander and the Chief Engineer, who were both in their second year of service on board the vessel. Their answers were as below:—

1. There are twelve Belleville boilers on the "Milan," and they have entered their fifth year of service, reckoning from the first getting up of steam.

2. Two boilers are devoted to keeping up the supply of fresh water in the boilers, and they are fed with sea water. For this purpose there are special feed pipes by means of which, and of one of the four donkeys, these two boilers are supplied with sea water. But after six days' steaming these two boilers have already on the sides of their tubes a deposit of 2 mm. thick, and consequently after every six days' steaming these boilers have to be cleaned, which is scarcely feasible in war time, and so the Commander of the vessel is asking that condensing apparatus may be fitted up to supply fresh water to replace the daily loss of water in the boilers.

3. The formation of the above-mentioned deposits 2 mm. thick in the course of six days' working of the boilers takes place in spite of the fact that the salinity of the water was never allowed to exceed 3½ degrees.

4. The number of days the "Milan" has been under steam does not exceed sixty, i.e., three times less than the "Ortegal" and the "Sindh."

5. The "Milan" ordinarily steams at a moderate speed, and only runs three times during the year, and then each time only for three hours it makes runs with its greatest speed of 17 knots.

6. The tubes which were formerly on the "Milan" for the two lower rows in the boilers, 6 mm. thick, had bends in them amounting to as much as 26 mm., and they were changed a year ago for tubes 10 mm. in thickness; in these new tubes the bends are as yet insignificant.

7. After three years' service of the boilers, holes were formed in the fifty tubes of the upper, and erosion was observed in 200 tubes. Accordingly a year ago these 250 tubes were replaced by new ones. A recent testing of the tubes by sounding did not discover new erosions.

8. The patent Belleville grates were replaced by ordinary cast-iron grates as they became damaged.

9. The automatic boiler fittings act satisfactorily.

10. The iron casings of the boilers, the smoke-boxes, the tube, and furnace doors warp.

11. The boilers are filled with fresh water at every convenient opportunity.

The boilers of the s.s. "L'Australien," the third vessel of the Messageries Maritimes fitted with Belleville boilers. The s.s. "L'Australien" was launched in May, 1889; she was built at the company's works at La Ciotat, between Marseilles and Toulon, and she has a displacement of 8,400 tons. Her engines were built at the same works, and should develop 7,000 indicated horse-power, and give a speed of 18 knots.

For these triple expansion engines there are twenty Belleville boilers, which are slightly different from those on the "Ortegal" and "Sindh."

1. In each of the boilers there are also eight sections, but in each of the sections there are eleven rows of tubes instead of nine rows, as in the "Sindh" and "Ortegal."

2. The limit of pressure of steam in the boilers is 16 atmospheres, and the steam is admitted to the engines with a pressure of 12 atmospheres; while on the foregoing vessels the limit of pressure is 12 atmospheres, and the steam reaches the engines with a pressure of 6 atmospheres. The diameter of the tubes is 125 mm. instead of 160 mm.

3. On board the "Ortegal" and "Sindh" there are double plates for the two lower rows of tubes.

4. The thickness of the nine upper rows of tubes is 6 mm. in place of 5 mm. The two lower rows, however, are 10 mm. thick, as on the "Ortegal" and "Sindh."

5. The separator has an inner partition of different construction, and, on account of the construction of this partition, the aperture for draining the reservoir is twice the size of that on the "Ortegal" and "Sindh."

6. In place of the patent Belleville grates ordinary cast-iron ones are used.

7. The external iron casings of the boilers and the smoke-boxes are so made as to expand, and not bend in as on the "Ortegal" and "Sindh."

8. The funnel is 22 m. high, reckoning from the grates, and is provided with a casing which runs the whole length of the pipe, and which is at 355 mm. from it.

9. The doors of the tube chambers are in four parts, instead of two, as on board the "Ortegal," where the doors warp and do not shut closely. These doors are of three sheets of iron, viz., the first, or inner, sheet is of corrugated iron, then there are two parallel iron plates. The interstices between the above sheets are filled, the first with asbestos, and the second with cork. In addition to this, parallel to the last sheet, and at 15 mm. from it, there is a sheet of gun metal which serves to reflect the heat. There is asbestos packing in the grooves of the frames of the doors, to enable them to be closed tightly.

10. The furnace doors on the "Ortegal" are of three parallel sheets, of which the first, or innermost, is of cast iron, and the other two of wrought iron; nevertheless, the inner sheet often burns and the doors warp. To avoid these defects on board the "Australien," the inner plate is made of corrugated cast iron, and is fastened to the iron plates by means of a single bolt, so that the inner plate can be readily replaced in case it is burnt. In order that the doors may shut closely, their edges are carefully fitted to the door frames.

11. The ash-pits can be easily taken out of their recesses, and so the portion of the bottom plating under them can be frequently cleaned and painted.

Table showing the principal Details of the Belleville Boilers on the Messageries Maritimes Steamers.

	"Ortegál."	"Sindh."	"Australien."
Number of boilers	8	12	20
Grate surface	243 sq. ft.	295 sq. ft.	596 sq. ft.
Heating surface	7,414	11,050	23,059
Ratio of heating to grate surface	30·50	37·16	38·7
Weight of water in the boilers when filled to working level	7·4 tons	9·6 tons	20 tons
Weight of boilers and appliances	130 "	190 "	250 "
Number of H.P.	2,100	2,400	7,000

From this table it results that per indicated horse-power :—

a. The grate surface varies from ·095 to ·12 square feet.

b. The area of the grate in the boiler does not exceed 30 square feet, and the length of the furnace (fore and aft) is not more than 6 feet, and its width (athwart ships) not more than 5 feet.

c. The weight of the boilers with water and appliances varies from ·043 to ·083 tons.

Upon the basis of these data deduced from the foregoing table, we will attempt to determine the question, whether there is any gain in the space occupied by the boilers, and in their weight, if the ordinary boilers are replaced by Belleville boilers on a cruiser, the engines of which can develop 12,250 indicated horse-power with natural draught.

For such a cruiser we should propose eight double cylindrical boilers, 15½ feet in diameter, 17½ feet long, with a grate area of 1,152 square feet (·092 square feet per indicated horse-power), and with a heating surface of 34,000 square feet. The weight of these boilers with water and appliances would be 970 tons. The space occupied by these boilers with their stokeholds would be, fore and aft, 124 feet, and athwartships 37 feet 8 inches, i.e., 18 feet 10 inches right and left of the central bulkhead. If sixteen ordinary cylindrical boilers were used, their weight with water and appliances would be 1,053 tons, reckoning ·086 tons per indicated horse-power.

Let us see how many Belleville boilers would be required to replace the above double cylindrical boilers, and of what dimensions they ought to be.

Taking for the Belleville boilers, from the above table, ·1 square feet of grate per indicated horse-power, the grate surface for all the Belleville boilers must have an area of 1,225 square feet. Taking the total area at this figure, it is easy to fix the number of Belleville boilers.

In fixing the dimensions of each boiler, we naturally keep to the dimensions of the boilers of the above-named vessels of the Messageries Maritimes, since their boilers had been found satisfactory in practice.

From the above table, it appears that the grate area of each boiler does not exceed 30 square feet (viz., 6 feet wide and 5 feet long), and the external dimensions of the boiler are, length, 8 feet; width, 6½ feet, and, taking these as the dimensions for the boilers of the cruiser, the number of them should be 40.

If these boilers are to be disposed as they are arranged on the Messageries vessels, i.e., back to back, furnaces outboard, this arrangement will be most advantageous both for ventilation of the boiler rooms, and also for the manage-

ment of the boilers in all respects, as well as for the arrangement of the donkeys, ventilators, openings to the coal bunkers. If the boilers are so arranged, it may be asserted with certainty that the temperature of the stockholes, even in the tropics, will not exceed 41° C. But, unfortunately, with the above dimensions of forty boilers they will occupy 160 feet of the vessel's length, *i.e.*, 36 feet more than the double cylindrical boilers. Moreover, the length of the engine-rooms will have to be increased by 8 feet to allow for the separators and the *regulator-détendeurs* with the boxes for the safety valves—apparatus which are peculiar only to the Belleville boilers.

This increase by 44 feet of the space occupied by the boilers and machinery along the length of the vessel is compensated for partly by the increase in width of the coal bunkers on each broadside by 2 feet, and that for a length of 168 feet on each broadside. Thus the contents of the broadside coal bunkers is increased by 14,784 cubic feet. Taking 43 cubic feet per ton of coal, the coal supply is increased by 343 tons, or 18 per cent., as with the double cylindrical boilers, 1,917 tons can be placed in all the coal bunkers. Unfortunately the space occupied by the engines and boilers on the cruiser cannot be increased by 44 feet along the length of the vessel, and accordingly we must give up the idea of arranging the Belleville boilers in the manner which is most advantageous in all respects.

Let us see how much the space occupied by the Belleville boilers on the vessel must be increased if we retain the above dimensions, and arrange them so that the furnaces of the boilers should be turned towards the transverse watertight compartments. In this case, the space occupied by the Belleville boilers along the length of the vessel would be 150 feet, that is, even then, 26 feet more than that occupied by the double cylindrical boilers. Adding another 8 feet for the increased length of the engine-rooms, for the accommodation of the general steam purifiers and regulators, with the boxes for their safety valves, the total increase of space occupied by the engines along the length of the vessel with the Belleville boilers will, even with this arrangement, be 34 feet more. But the width of the broadside coal bunkers will then be increased by 1 foot for a total length of 158 feet on each broadside. Owing to this increase of width of the broadside coal bunkers, their contents will be increased by 6,952 cubic feet, and therefore the coal supply will be increased by 160 tons, and will be 8 per cent. more than with the double cylindrical boilers.

In spite of the increase of the contents of the coal bunkers when using Belleville boilers of dimensions identical with those of the boilers of the vessels of the Messageries Maritimes Company, there is no possibility of affording 34 feet more space for the engines of the cruiser than with the double cylindrical boilers, not to speak even of an increase of space of 44 feet, which would be required if the boilers were to be arranged in the most advantageous manner. Thus we have to give up the idea of arranging the boilers most advantageously on the cruiser, and also of retaining the dimensions of the Belleville boilers which exist on the vessels of the Messageries Maritimes Company.

Let us see what ought to be the dimensions of the Belleville boilers so that the space occupied by these boilers along the length of the cruiser should not be more than the space occupied by the cylindrical boilers, *i.e.*, not more than 124 feet. For this purpose we would need to use boilers the external dimensions of which will be: length, 8 feet 8 inches, and width, 7 feet 8 inches, and the grate surface of each boiler 43·60 square feet. The length of the grate will be 6 feet 1 inch, and the width 7 feet 2 inches. Against a width of grate of 7 feet 2 inches no objections can be urged, but a length of grate of 6 feet 1 inch will be 20 per cent. more than the length of grate of the boilers of the vessels of the Messageries Maritimes Company, and therefore it will be much

harder for the stokers to keep up effective heat in the furnaces, which is especially required with Belleville boilers. Moreover, the increase of length of the grate surface will result in an increase of length of the boiler tubes of 20 per cent., which is most undesirable, because, with a length of tubes not exceeding 5 feet, the amount of curvature when the tubes become bent reaches $1\frac{1}{16}$ inches; but if the length of the tubes were increased to 6 feet 1 inch, the amount of their curvature would certainly increase, and probably more than proportionately to the increase of their length.

If such boilers are to be arranged in the most advantageous manner in all respects, that is to say, back to back, furnaces outboard, the boilers will occupy along the length of the vessel 124 feet, that is, the same as the ordinary boilers. But, unfortunately, the total length of the engine-rooms will have to be increased by 8 feet to allow for the separators and the regulators, with their boxes for the safety valves, and the compensation for this valuable sacrifice of 8 feet along the length of the vessel will be insignificant, viz., an increase of 1 foot in width to the broadside coal bunkers for a length of 132 feet on each broadside. This will increase the contents of the coal bunkers by 5,708 cubic feet, or the coal supply will be increased by 6 per cent., for with the cylindrical boilers 1,917 tons can be placed in the coal bunkers.

Let us see what advantage will be gained in point of economy of space if the boilers are arranged in a different manner, viz., placing their furnaces towards the transverse watertight compartments. If they are arranged in this manner, 114 feet will be wanted for the boilers along the length of the vessel, that is, 10 feet less than for the ordinary boilers; but this 10 feet will be occupied by the separators and the regulators with their safety valves. This arrangement of the boilers will not involve an increase in length of the engine-rooms; but, on the other hand, there will be an increase to the width of the coal bunkers. This arrangement of the boilers cannot be recommended, for it will be very difficult to ventilate the stokeholes and to arrange for the tubes, donkeys, &c.

N.B.—I do not put forward a further arrangement of the Belleville boilers, viz., furnace to furnace, because such an arrangement, although it would lead to a saving of space along the length of the vessel of 4 feet, is quite inadmissible for Belleville boilers, because if they are thus arranged the heat will be unbearable, and the stokers will be unable to work. This arrangement may be admissible for ordinary boilers, but it is absolutely inadmissible with the Belleville boilers, because with the latter the walls and doors heat much more than with the ordinary boilers.

From what has been said before, it is clear that there can be no saving in space along the length of the cruiser if cylindrical boilers are replaced by Belleville boilers, even using those boilers of increased dimensions as compared with the dimensions of such boilers on the vessels of the Messageries Maritimes Company. The increase of the dimensions of the boilers, and the increase of length of the fire grate and of the boiler tubes by 20 per cent. which is involved thereby, is undesirable, both as regards the care of the boilers and also as regards the bending of the tubes.

It thus appears that as regards the space occupied by the Belleville boilers compared with that occupied by the ordinary boilers in the cruiser that we are considering :—

1. That, with the arrangement of the Belleville boilers which we should most wish for, and with boilers of increased dimensions, not only will there be no saving of space along the length of the cruiser, but, on the contrary, the engine-rooms will have to be lengthened by 8 feet to provide for the appliances which are peculiar only to Belleville boilers. The increase of contents of the broadside coal bunkers, due to the increase of their width, will augment the coal supply only 6 per cent.

2. Arranging the boilers in the way which is only a tolerable way, viz., furnaces towards the transverse water-tight compartments, the space occupied by the boilers will be decreased by 10 feet along the length of the vessel, but this 10 feet will be taken up by the apparatus which are peculiar only to the Belleville boilers.

And so, finally, the space occupied by the Belleville boilers will not be in any case less than the space occupied by the ordinary boilers. This conclusion is borne out by the project which has been put forward for Belleville boilers for the ironclad "George the Victorious," where the Belleville boilers with their appliances occupied 4 feet more along the length of the vessel than the ordinary boilers, viz., 108 feet, instead of 104 feet or 4 per cent. more, and that too with a grate surface per indicated horse-power of only '096 square feet.

Saving in Weight by Replacing Ordinary Boilers with Belleville Boilers.

The weight of the double cylindrical boilers of the cruiser with the water in them and their appliances will be 970 tons or '079 tons per indicated horse-power. The weight of the Belleville boilers with water and appliances, and also with spare parts for the boilers and their appliances, will be 612 tons, reckoning '050 tons per indicated horse-power, and so the saving in weight in favour of the Belleville boilers will be 358 tons, or about 36 per cent. Using sixteen ordinary cylindrical boilers, their weight with water and appliances will be 1,053 tons, reckoning '086 tons per indicated horse-power. By replacing these boilers by Belleville boilers there will be a gain in weight of 42 per cent.

Cost of Belleville Boilers.

According to the statement of the Assistant Manager of the workshops of the Messageries Maritimes Company, the cost of the Belleville boilers to the Company is 10 per cent. more than the cost of ordinary cylindrical boilers for the same indicated horse-power.

Conclusions.

From what has been said before, we may deduce the following conclusions:—

1. The Belleville boilers with their appliances cannot, in any case, occupy less space along the vessel than the ordinary cylindrical boilers; on the contrary, the Belleville boilers with their appliances, if arranged in the most advantageous manner, will occupy about 6 per cent. more than ordinary boilers along the line of the vessel.

2. If Belleville boilers are used, the saving of space along the width of the vessel will enable the coal supply in the bunkers to be increased by not more than 10 per cent., and this increased supply will be only apparent, for Belleville boilers expend 10 per cent. more coal than ordinary boilers per indicated horse-power.

3. The weight of the Belleville boilers with water appliances and spare parts will be from 36 to 42 per cent. less than the weight of cylindrical boilers for larger vessels.

4. The working and management of Belleville boilers present no difficulties even with voyages of thirty days' uninterrupted steaming.

5. All the automatic appliances of the Belleville boilers act thoroughly

¹ The "Georgiy Pobédonosets," now building at Sevastopol.—J. W. M.

satisfactorily, independently of the condition of the sea ; but the Belleville donkeys need some slight alterations to prevent the formation of a galvanic current in their pumps. The pumps should be made of bronze instead of cast iron with bronze linings.

6. The quantity of distilled water required for making good the inevitable waste of water in the boilers does not exceed 3 tons in the twenty-four hours for each thousand indicated horse-power, even on voyages of thirty days' uninterrupted steaming.

7. The Belleville boilers should not be fed with sea water except in case of the most urgent necessity, which could only happen under most exceptional circumstances.

8. If fed with distilled water, the Belleville boilers do not require to be cleaned until after thirty days' steaming ; but if they are fed with salt water, the tubes will inevitably burn through, even after eight days' steaming, as is conclusively shown by the trips of the steamer "Ortegal" from Marseilles to London and back.

9. The expenditure of coal per indicated horse-power, with precisely similar engines working under precisely similar conditions, is 10 per cent. more with the Belleville boilers than with ordinary boilers.

10. In the Belleville boilers there is a rapid formation of deposit in getting up steam, for the Belleville boilers necessitate the effective combustion of the fuel in their furnaces. While steam is being got up, that is, while the combustion is slow, there is a rapid formation of deposit in the tubes—a fact which M. Belleville himself does not deny, and which forms one of the disadvantages of the Belleville boilers, especially for vessels which are required to get up steam frequently, such as torpedo-boats and steam-launches ; and accordingly Belleville's boilers cannot be recommended for these vessels. Moreover, for small vessels, the weight of the Belleville boilers is more than the weight of ordinary boilers for the same indicated horse-power.

11. The patent Belleville grates did not appear suitable, and accordingly they were replaced by ordinary grates, both on the vessels of the Messageries Maritimes Company and on the cruiser "Milan."

12. Belleville boilers, if vessels are sent on a three or four years' cruise, should be supplied with spare parts, tubes, and uniting boxes, and also with spare boiler appliances and their parts, including the working parts of donkeys, to about 12 per cent.

13. The four years' service of the Belleville boilers on the steamer "Ortegal," and also the circumstances of the two years' service of the boilers of the steamer "Sindh," point to the conclusion that the Belleville boilers, when they are fed with fresh water, and when measures are taken to keep the condensers in proper order, and also for preventing the loss of fresh water, may serve without repair for the first four years. But after four years' service of the boilers, the tubes, which form the boilers, must be changed gradually. This changing of the tubes should be no hindrance to continuing the service of the boilers without a stoppage, for the changing of the tubes would take place gradually in the course of two years. By the end of the sixth year of service of the boilers, all the tubes should have been gradually replaced both on account of the erosion of the tubes, which was clearly shown in the boilers of the vessels above mentioned, and also on account of the bending of the tubes of the lower rows. The bending of the tubes of the lower rows took place in the boilers of all the above-named vessels, and the explanations of M. Belleville, both as regards the damage to the tubes by erosion and by their bending, are inconsistent ; because he ascribes these both to the fact that the instructions, regarding the boilers being kept filled with water during the time they are working, were not observed, and also to careless management of the boilers during the time

they were at work, which it is obviously impossible to admit, as the bending and erosion of the tubes took place in the boilers of all three vessels. Moreover, M. Belleville himself, as regards the damage to the tubes on the "Milan," officially declared, in his explanation to the French Minister of War, that the boilers of the "Ortegal" were continually kept filled with water while they were being worked; and, as a matter of fact, was actually carried out during my ninety-nine days' service on that steamer. Yet in spite of this, in the fifth year of service of the boilers of this steamer, holes were found in one of these tubes, and erosions were observed in the sides of fifteen tubes in one boiler, which I tested by sounding.

14. Replacing unserviceable tubes by spare ones can be easily carried out, and the boilers, with tubes replaced gradually during the course of the five or six years' service of the boiler, can serve for another four to six years, but at the expiration of ten or twelve years' service, the remaining portions of the boilers, viz, separators, the external casings of the boilers, the smoke-boxes, funnels, and other parts will become unserviceable, and new boilers with all their appliances will have to be put in.

15. In the course of ten to twelve years' service of Belleville boilers the cost of their repairs will be about 50 per cent. of their original cost, and when repairs are going on, the deck will not have to be broken up.

16. In the course of ten to twelve years' service of Belleville boilers, the steam pressure in them will not have to be decreased.

17. Belleville boilers contain ten times less water than ordinary boilers of the same indicated horse-power, and accordingly the danger in case of the explosion of a Belleville boiler will be less than with an explosion of an ordinary boiler. If a Belleville boiler bursts, there is no reason to fear the loss of the vessel.

18. Taking into consideration the unsatisfactory service of the ordinary ship's cylindrical boilers with pressures greater than six atmospheres, as is shown by the experience of the large French Steamship Companies, where the service of such boilers does not exceed three to four years, we may conclude that Belleville boilers can successfully replace ordinary cylindrical boilers, commencing with pressures of six atmospheres, for vessels of not less than 2,000 tons displacement.

19. For pressures less than six atmospheres, Belleville boilers cannot be recommended, for with these pressures ordinary boilers serve successfully from eight to ten years, and are cheaper than Belleville boilers, both originally and for purposes of repair.

20. The use of Belleville boilers as auxiliary boilers on board ship presents no advantage, compared with boilers of the locomotive type. In both cases, for the preservation of the boilers, they should not be fed with sea water nor used for the condensation of water, except with apparatus properly filled.

21. In case Belleville boilers should be adopted for the vessels of our fleet, the factory which takes upon itself the construction of Belleville boilers should be constantly on the look-out, for such improvements may be introduced, owing to the experience gained in the construction of new Belleville boilers for their vessels, by the Messageries Maritimes Company, who are constantly and energetically removing the disadvantages or defects which are observed in the boilers. Thus, for instance, in the steamship "Australien," the defects in the boilers (and particularly in their appliances) which have been discovered in the working of the boilers of the steamships "Ortegal" and "Sindh" are being removed. The Messageries Maritimes Company, generally speaking, is conducting the business of utilizing the Belleville boilers in an intelligent manner.

22. In the construction of Belleville boilers it is necessary to be most exacting as to the quality of the material employed, and also as regards the

perfection of manufacture of each detail of the boilers and their appliances ; because it is only by the accurate observance of these conditions that the boilers can do their work successfully.

N.B.—During the four years' service of the boilers on the above-mentioned vessels, the uniting plates of forged iron were not damaged, with the exception of some cases in which these plates had to be changed owing to the screw threads in them being damaged, when the tubes which had become unserviceable had to be screwed out of them, and so there is no reason for placing any limit of service upon these plates. One plate which I inspected, when a burned tube had to be removed, appeared to be in a satisfactory condition, as the wall of the plate had only been diminished 1 mm. after four years' service.