RESULT OF EXPERIMENTS ON THE TRANSVERSE STRENGTH OF SCARPHED BATTENS
(BARLOW.)

Battens 4 feet in length, Fixed at One end, and Loaded at the other.

[*Note.*—Dimensions of battens not given.]

Scarph, 12 inches in length, small end up, and one inch from face of fulcrum, .	Broke in the neck of the scarph, close to the fulcrum,	87 lbs.
Scarph, 12 inches in length, large end up, and one inch from face of fulcrum, .	Fastenings of small end of scarph drew out, .	101
Scarph, vertical, .	Broke in the scarph, .	211

(To be Continued.)

*The Cylindrical Spiral Boiler.** By JOHN ELDER.

The object of the construction of this boiler is to obtain a form with all the useful properties of the simple cylindrical high-pressure boiler on shore, adapted to steamships. The following advantages appear to be attained over the ordinary marine boiler, namely:

1. A form of boiler capable of carrying higher pressure and presenting more heating surface, and of a more effective description, from a given weight of material.

2. A boiler capable of being easier cleaned and repaired in both water and fire spaces.

3. A boiler capable of producing superheated steam to any practical temperature.

4. A less average specific gravity of water whilst working at sea with the usual amount of feed and blow-off, and a more perfect combustion-chamber, and better formation of flue surface.

5. The pressure being altogether internal, it is not liable to collapse, a danger lately ably demonstrated by Mr. Fairbairn; and as the diameter of the various cylinders are reduced to the minimum size for permitting the tradesmen to pass through, clean and repair them, the boiler when formed of ordinary thickness possesses enormous strength without stays.

6. The expense of the boiler per square foot of heating surface is about the same as the ordinary boiler, and is capable of carrying five times the pressure.

The general construction of this boiler is as follows:—There are twenty-four round boilers or tubes, of not less than 19 inches diameter each, twenty-two of these forming, when bound together, a cylindrical vertical shell; the twenty-third, a centre boiler concentric to that shell; and the twenty-fourth, a spiral coil-boiler winding spirally round

* From the London Civ. Eng. and Arch. Jour., September, 1860.

between the centre boiler and those composing the circumference shell. These boilers contain the water, and the spaces between them the fire.

The feed-water passes first into the spiral compartment, or No. 24, and from it into the centre compartment, or No. 23, and into each in rotation, and blows off at the last compartment, or No. 1, thus rendering the water in No. 24 nearly pure sea-water, and gradually from compartment to compartment more dense, till it blows off at No 1 at the usual density, and thus makes the average specific gravity of the water less than usual.

The twenty-two outside boilers are 24 feet long, 19 inches diameter, and $\frac{5}{8}$ -inch thick; the bottom ends are conical for 3 feet, and knee'd outwardly to give a larger diameter of furnace, say 12 feet diameter. There is a furnace door for every alternate tube, or say 11 furnace doors, equally divided round the base of the boiler, giving great facility to the firemen for doing their work efficiently. In firing it is proposed to charge all the fresh coal round the circumference of the fire, in order that the hydrogen of the coal may be consumed separately from the carbon; and as the furnace has great altitude, the combustion will be completed in vertical flames from the coals, and will thus prevent the carbonic acid gas given out from the combustion of the carbon coming so much in contact with and preventing the combustion of the hydrogen, as is usual in ordinary furnaces.

The centre compartment, or No. 23, is 30 feet long, 34 inches diameter, and $\frac{3}{8}$ -inch thick, with 3 feet at the bottom and top conically reduced to 18 inches diameter, forming a man-hole door; the upper end of this vertical tube forms a reservoir for the steam of the whole twenty-four compartments, and acts as a superheating apparatus, and may be carried up the funnel to the extent necessary to superheat the steam to 400°. The steam-pipe is taken from the top of this boiler to the safety-valve chest, fastened on the front of the boiler low down, which serves as a water-trap during the discharge from the safety-valve chest, the steam-pipe to the engines being taken off the same pipe at a higher level than the escape steam. The spiral compartment, or No. 24, is about 100 feet long, 34 inches diameter, and $\frac{3}{8}$ -inch thick, made of the best iron boiler-plate; the ends are conical for 3 feet formed into man-hole doors; this spiral boiler makes four or five convolutions close round the centre one, and is bound close to the circumferential boilers by hollow stay-bolts, and fastened to the centre one at each end only; in the same manner the steam and water flows through the whole boiler by these hollow bolts or rivets, and completes the entire circulation of water and steam. The whole of these 24 compartments or boilers terminate at the bottom about 1 foot below the fire-grate, and are supported on six stanchions from the ash-pit beneath, making a free passage for the air under the grate bar; the circumferential compartments or boilers terminate at the top 6 feet above the ship's deck, and have each a man-hole door forming the cover; the funnel is made conical at the bottom to embrace the internal diameter of the boiler shell and draw off the smoke in the usual manner. This completes the whole boiler proper, but in order to prevent radiation of heat,

a thin outer casing of iron is made (9 inches) clear of the boiler all round, terminating about 7 feet from the stoke-hole floor; and above, at the level of the galley or funnel-house, this casing is lined with felt and thin wood, to keep the deck and the adjacent parts cool and retain the heat. The twenty-two straight cylindrical boilers or compartments are constructed in the sides by four plates 24 feet long and 16 inches broad, rolled to a $9\frac{1}{2}$ -inch radius curve at the iron works, leaving no plate-setting for the boiler-maker of this description.

The plates of boiler No. 24, or the spiral compartment, are delivered flat by the iron-maker, and are bent to the spiral curve by one blow of a large spiral concave block falling upon a counterpart convex one, prepared by the constructors of the boiler. This operation has been found to simplify the making of this spiral cylindrical boiler to about the same amount as the straight cylindrical boilers. The conical ends are bent in the same manner as the spiral plates, and the whole work of plate-bending reduced as far as possible to machine work. The products of combustion, after leaving the furnace, have to travel spirally upwards a distance of 100 feet, and must of necessity be continually rotating during that time, and prevent the possibility of any portion passing off without being brought frequently in contact with the heating surface of the boiler, and will therefore be cooled down to the minimum temperature compatible with a given amount of cooling surface, or the greatest quantity of heat extracted from the products of combustion before their escape to the atmosphere.

This spiral coil and all the heating surfaces will keep more clear of flue-dust than usual, and will consequently be more efficient in that respect, as well as save the usual trouble and loss by spunging experienced in the ordinary tubular boilers at sea. Also, as the products of combustion must pass off at the rate of at least 7 feet per second, in this as in ordinary boilers, it will take upwards of 14 seconds from the time it leaves the furnace till it arrives at the top of the boiler; whilst if the boiler were of the ordinary tubular type it would pass in about two seconds along the whole heating surface of the boiler; the gas has, therefore, seven times more time to give out its heat, and its revolving tendency will not admit of the same stratum of gas passing along the passages after it is cooled down, as is the case with the ordinary boiler, but will bring the hot products of combustion usually occupying the centre of the tubes of a tubular boiler into contact with the cooling surfaces, and reduce the whole products of combustion to one temperature before entering the chimney.

In cleaning the salt or sludge out of these boilers the man and sludge hole doors are taken off the top and bottom (and the hose of fresh water may be played down through from the top, and the refuse run out at the bottom). The man in charge can also pass down through the whole boiler; the dimensions necessary for this purpose being made the minimum and maximum of the various compartments of the boiler; and are specially constructed to maintain to the engines steam at a much higher pressure than usual, in order to admit of a much larger amount of expansion to be developed by the engines, which are all on

the double cylinder expansive principle. The constructors are now making the boilers for three steamships on this principle, two of which are for carrying Her Majesty's mails on the Pacific between Valparaiso and Panama (as described by the writer at the meeting of the British Association at Leeds); and it has long been his desire to be able to construct boilers for marine purposes without stays, and with no surface exposed to the collapsing tendency, which in so many cases has been the cause of loss of life aboard of steam-ships. The boilers now described have no large flat surfaces and no stays, the whole tendency of the pressures being to inflate the boiler plates, and, if possible, to give them a stronger form; the smallest diameter is large enough to give access to the men in charge, and the largest diameter is 34 inches, and $\frac{3}{8}$ -inch thick,—dimensions that can carry several hundred pounds pressure on the square inch before rupture could take place. Such a form the writer adopts with great satisfaction to himself as a constructor sending machinery abroad, where the usual form of boiler gives him considerable anxiety. In comparing the construction of this boiler with that of the ordinary tubular one, in the latter angle-iron ribs and stays now compose a large portion of the weight and expense; contribute no heating surfaces; and if one stay breaks, which is no uncommon occurrence, the next is placed in great danger, and if it gives way the whole may follow in rotation and a serious accident be the result. In the former boiler, however, the plates may be reduced to a very small amount of thickness by tear and wear before explosion could be expected.

Having thus described the objects of the spiral boiler, it might not be out of place to give the following statement of the comparative evaporative power and temperature of the gases in the furnace and chimney of the spiral boiler, with three of the ordinary types of boiler now in general use.

Figs. 1, 2, and 3.

The three types experimented upon, were, first, a common cylindrical land boiler (Figs. 1, 2, and 3), 33 feet long, 5 feet 6 inches diameter, with two round flues 19 inches diameter through the centre; this boiler had 40 feet of heating surface to the nominal horse-power

of the engine; the two flues contained 20 feet, and the shell 20 feet per nominal horse-power; the furnace was below the boiler at the fore end, had a fire-grate of 26 square feet, the fire passed underneath the boiler to the opposite end from the furnace, and returned along the sides, and then passed back again through the flues to the chimney. The temperature above the centre of the fire was found to be, on one occasion, 3200° ; at the top of the bridge 1730° ; the temperature of the gases gradually reduced as they passed back the remaining length of 26 feet under the boiler and along the side flues, till they entered the flues at 1163° , and left them at 800° . Thus the furnace containing a surface of 2 feet per nominal horse-power reduced the heat about 1500° , the shell of the boiler behind the furnace of about 18 feet per nominal horse-power reduced the temperature about 600° , and the flues containing a surface of 20 feet per nominal horse-power reduced the temperature about 350° . The temperatures of the gases in the flues were found to be about the same in the centre as at the top; but at the bottom of the flues, the temperatures of the gases were at the fore-end rather less than at the top, but towards the back-end the temperature of the bottom of the flues reduced gradually below the temperature at the top to the extent of 300° . Upon another occasion the temperature over the centre of the fire was found to be 3610° ; at the top of the bridge 1739° ; and the different temperatures of the flues were as indicated in Fig. 2, where the average temperatures of the flues at $B^1=826^{\circ}$, $B^2=879^{\circ}$, $B^3=937^{\circ}$, $B^4=959^{\circ}$, and at $B^5=981$. The temperatures at the top of the flues at $C^3=982^{\circ}$, $C^4=1034^{\circ}$, $C^5=1087^{\circ}$. The temperatures at the bottom of the flues at $A^1=571^{\circ}$, $A^2=603^{\circ}$, $A^3=678^{\circ}$, $A^4=764^{\circ}$, $A^5=822^{\circ}$. It would therefore appear that, notwithstanding the large amount of surface in this boiler, the evaporative power is very inferior, as the amount of heat taken out of the gases per square foot of heating surface is very small; and the natural conclusion is that the gases pass along in straight lines, and only the thin strata in contact with the surface is cooled down. In the results of the spiral boiler (Fig. 6) three times the quantity of heating surface was found to reduce six times the quantity of gas from the same temperature of 3200° to a temperature of 480° instead of 800° , showing that a more complete turning over of the gases is much wanted in our land boilers. The water evaporated per hour in the land boiler referred to was found by meter to be 2000 lbs., and the coal, best Glasgow quality, found to be 300 lbs. per hour; making about $6\frac{1}{2}$ lbs. of water per pound of coal. During the measurement of the water evaporated by the meter, indicator diagrams of the engine were taken with a view to calculate the weights of steam by the ordinary method, and the calculations were found to agree with the meter; these calculations can be repeated and substantiated at any time.

The second type of boiler tested was that of the ordinary steam-boat horizontal tubular boiler (Fig. 4); the example chosen was one in a first-class ocean steamer. The temperature of the furnace was found to be 3200° , and the inside of the funnel about 1100° . The heating surface of this boiler was 22 feet per nominal horse-power, and

the water evaporated about $8\frac{1}{2}$ lbs. per pound of coal according to the calculations from the diagrams. The coal consumed was about 20 lbs. per square foot of fire-grate, of the best Glasgow coal.

The next example taken was that of a first-class vertical tubular boiler (Fig. 5), on Mr. David Napier's principle, now universally liked on the Clyde for river steamers. This boiler had a surface of about

Fig 4.

Fig. 5.

22 feet per nominal horse-power; the temperature of the fire was found to be about 3300° , and in the funnel 1160° ; the weight of water evaporated was found by calculation to be $8\frac{3}{4}$ lbs. per pound of coal consumed, and the rate of combustion about 20 lbs. per square foot of fire-grate.

In the spiral boiler (Fig. 6) of the *San Carlos, Guayaquil*, and *Prinz van Orange*, the boilers were found to give the following peculiar results:—1st, that even with Scotch coal there was no smoke emitted from the chimney,

Fig. 6.

and no carelessness on the part of the fireman seemed to effect the formation of smoke; 2d, that the boilers showed a bright furnace, indicating first-class draft; the temperature of the funnel was found to be 480° while the fire was at its greatest energy. The heating surface was, in the case of the *San Carlos* and *Guayaquil*, 2200 square feet, the coal consumed 1400 lbs. per hour, and the water evaporated 11 lbs. per pound of coal consumed; the fire-grate contained about 76 square feet, and the rate of combustion about 20 lbs. per square foot of fire-grate. The heating surface of the boiler was 18 feet per nominal horse-power; the coal consumed was Glasgow best steam coal. The stoke-hole was found to be remarkably cool, and the boiler, which was loaded to 52 lbs. on the square inch steam pressure, and tested to 150 lbs. on the square inch water pressure, was found to be perfectly tight. In the case of the *San Carlos*, I may mention that the ship has now steamed about 20,000 miles, and has not been in any port more than three days; during that time she has been consuming soft Chili coal for a

considerable part of her voyage, and the merits of the long flue show a decided advantage in this boiler over the ordinary tubular boiler for the native bituminous coal of South America.

In order to give in a more extended form the comparative evaporative power of various flue and tubular boilers, the writer begs to lay before the Association the accompanying table. It shows several proportions of heating surface and evaporative power of several ships that have come under his notice. He can certify the accuracy of most of these particulars, except that shown in the last column, which is taken from Professor Rankine's report on the performance of the *Thetis*. This vessel has about six times more heating surface in her boilers in proportion to the coal consumed than any example the writer is aware of. The boiler is Craddock's patent boiler, though that inventor's name appears rarely to be mentioned in connexion with the said vessel. Efficient, however, as this boiler must be as an evaporator, it cannot possibly accomplish the quantity shown in the table.

Comparisons of certain Results obtained from Certified Diagrams of Steamers.

	Elk.	Earl of Ab'rd'n.	Valparaiso.	Pride of Erin.	Inka.	Europa.	Camb'n.	Thetis:
Nominal horse-power, indicated	250 780	380 780	320 826	400 960	80 272	648 1207	472 1072	80 226
Proportion indicated H.P. to nominal ditto,	3.28	2.05	2.581	2.4	3.8	1.863	2.272	2.82
Diameter of cylinder,	57 in.	70 in.	{ Two 52 Two 90 }	.72	{ Two 28 Two 48 }	90	77.5	{ One 21 One 42 }
Length of stroke,	5 ft. 6 in.	6 ft.	5 ft.	5 ft. 6 in.	3 ft.	8 ft.	7 ft. 6 in.	2 ft. 6 in.
No. strokes per minute,	25	17.5	24	22	32	15½	16	52
Boilers—flue or tubular,	Tubular.	Flue.	Flue.	Flue.	Flue.	Flue.	Flue.	{ Craddock's Patent.
Area of fire-grate,	144 ft.	190	130	252	50	314	247	
Area of heating surface,	4300	4300	2400	4400	480	7000	5400	Ab't 4000
Coals consumed per h.,	3360 lb.	3584	2520	4928	672	5100	4480	226
Quality of coal,	{ Glasgow best.	{ New- castle.	{ Welsh.	{ Welsh.	{ Welsh.	{ Welsh.	{ Welsh.	{ Good.
St. ev'd per lb. of coal,	7.354	6.87	7.74	7.159	8.1	7.7	7.509	Ab't 15 lb.
Estimate, water ev'd,	8.1	7.4	8.6	7.9	9.0	8.5	8.3	18 lb.
Coal consumed per I.H.P.,	4.071	4.385	3.05	5.126	2.47	4.2	4.17	1.018
Fire-grate per nom. H.P.,	.576	.5	.406	.63	.625	.484	.536	

The theoretical quantity of water capable of being heated from 90°, and evaporated at, say 212°, with an infinite quantity of heating surface and a perfect fire, is somewhere about 13½ lbs. per pound of coal; whilst from the diagrams represented in Prof. Rankine's report of the *Thetis*' performance, 18 lbs. weight appears to be about the quantity of water per pound of coal. This calculation I have made from the diagrams published, and any party interested may repeat the calculations.

The calculation is made as follows:—The area of the large cylinder as shown in the diagram is 1380 square inches, or 9.583 square feet. The four revolutions of piston marked on the diagram, 49½, 52, 53, and 52 revolutions per minute, with a stroke of 2½ feet, or say 258.12 feet per minute, gives 258.12 × 9.583 × 60 = 146433 cubic feet per hour. And if we take the average pressure shown in the four diagrams at the end of the piston stroke, supposing the barometer to be 14.5 lbs., we find the weight of that steam to be about 44 cubic feet per lb.; this number, therefore, divided by 44, gives the quantity of steam as 3300 lbs.

per hour; to this must be added one-twentieth for contents of ports and clearance, which makes 3465 lbs. of steam.

This clearly gives the weight of the steam per hour given out of the cylinders after the work is performed; to this, therefore, must be added the quantity of heat that must have disappeared during the performance of the work; this in the case of the *Thetis* is about $\frac{1}{2}$ of the entire heat; we must, therefore, add $\frac{1}{2}$, or, say, $3465 + 693 = 4158$ lbs. of water must have been raised from a temperature of about 100° and evaporated, or say 18 lbs. of water to the pound of coal said to be consumed. This result is about equal to 20 lbs. of water evaporated at 212° to the pound of coal consumed; a quantity quite absurd.

It would therefore appear, before a proper comparison could be established between the merits of the *Thetis*' boiler and that of any other boiler, a correct trial of the former would be necessary. In the meantime we have but to consider that the report of Prof. Rankine was based on one hour's consumption of, say 230 lbs. of coal, and compare that with a mass of boiler, water, and fire-brick weighing 20 tons, at a temperature of, say 300° , it is evident that the mass of heat in proportion to the coal consumed is so great that no conclusion should be made from such an experiment; also, that when the quantity of coal said to be consumed, viz., 230 lbs., is compared with area of fire-grate, say 40 square feet, it is evident that the result should not be depended upon, as no ordinary comparisons could be made of the condition of the fires before and after the experiment. In conclusion, let me ask of every one present to consider the trial trips of steamships and boilers in their true light, and before drawing any inference from such trials, make a perusal of results obtained from sea voyages. The evaporative power and economy of boilers is one of the most important subjects for this Society to consider. We need only to refer to the report drawn up by the Steam Shipping Committee of the British Association to show how mixed up the question of the relative efficiency of the boilers and engines is generally considered. Indeed, the American navy returns form the only reports showing the evaporative power of the boilers in this list, and the whole merit of a good evaporating boiler is often sacrificed to the character of the engines. With regard to the *Thetis*, I would recommend any mistake to be remedied as soon as possible, as there are many contracts of a most responsible nature formed in consequence of this report, that will lead to serious loss and disappointment to the steam shipping interest and to the engineering profession of this country.

*A Sheet of Paper Four Miles Long.**

A sheet of tissue paper has been exhibiting at Colyton, Devonshire. It measures in length four miles, being 21,000 feet long, and is in breadth 6 feet 3 inches. The weight of it is but 196 pounds. It was manufactured in twelve hours.

*From the London Builder, No. 906.