

DESCRIPTION OF HARRISON'S CAST IRON STEAM BOILER.

By MR. ZERAH COLBURN, OF LONDON.

The importance of high pressure steam as a condition of steam engine economy has long been understood. Trevithick as early as 1804 worked an engine at what was then regarded as an enormous pressure, 50 lbs. per square inch. His American contemporary, Oliver Evans, recommended a still greater pressure, 150 lbs. per square inch, cut off at one third of the stroke; and from the records of the department for supplying Philadelphia with water, it appears that Evans actually employed not only this pressure, but still higher pressures, on the large scale of pumping engines. In 1817 one of his engines was started at the Fairmount Waterworks, Philadelphia, and was worked regularly at from 194 to 220 lbs. per square inch; the engine cylinder was 20 inches diameter and the stroke of the piston 5 feet, the usual working speed being 25 revolutions per minute; steam was supplied from four cylindrical boilers, 30 inches diameter and 24 feet long, fired externally. A Boulton and Watt engine of 44 inch cylinder and 6 feet stroke had been started two years previously at the same waterworks, having a cast iron boiler with vertical wrought iron flues, with a steam pressure of only $2\frac{1}{2}$ to 4 lbs. per square inch. Both these engines pumped through a 16 inch main, 239 feet long, into a reservoir 102 feet above the level of supply. Trials of twenty four hours' duration showed that the low pressure engine had rather the advantage over the other in point of economy: the former pumped into the reservoir in twenty four hours 1,763,104 gallons of water with a consumption of 896 cubic feet of wood, being 1968 gallons per cubic foot; while the high pressure engine, in raising 3,124,891

gallons through the same main, consumed 1664 cubic feet of wood, or at the rate of 1878 gallons per cubic foot.

Steam of rather more moderate pressures than Evans employed, or of about 100 lbs. per square inch, continued subsequently to be employed in America, notwithstanding the frequent explosions of high pressure boilers. In England the boilers for Trevithick's engines were made of large diameter and of cast iron; and many of them were made at the Bridgenorth Foundry with an internal diameter of 8 feet, and in 8 feet lengths, which were connected together by flanges and bolts up to any length required. Such boilers were unquestionably dangerous, although many wrought iron boilers of equal or greater diameter and probably of less strength are worked up to the same pressure now. An occasional explosion of a Trevithick boiler, and the influence which the practice of Boulton and Watt then exercised, soon occasioned a general return to low pressures, except in Murray's, Stephenson's, and Hedley's locomotives, which were worked regularly at 50 lbs. per square inch.

Within the last thirty five years however, or in fact coincident with the progress of improvements in boiler making, there has been a corresponding tendency to return to high pressures. The locomotives on the Liverpool and Manchester Railway worked in 1830 with steam of 50 lbs.; by 1843, pressures of 75 lbs. and 80 lbs. had become common upon railways; 100 lbs. to 110 lbs. was regularly maintained in 1851; and at the present time 120 lbs. is the usual, and 160 lbs. an occasional pressure in locomotive boilers. The last named pressure is not very much below that recommended for locomotives by the late Jacob Perkins, nearly thirty years ago, who preferred steam of 200 lbs. cut off at one eighth of the stroke. In marine engines an ordinary working pressure of 25 lbs. has been reached, while some of the Liverpool and Montreal vessels are worked at 40 lbs., and the Pacific Mail steamers at 50 lbs. per square inch. For ordinary land engines even 100 lbs. pressure has been adopted in many cases; and this and still higher pressures are already employed by some makers of portable and traction engines.

Although the construction of boilers has been much improved, in order that higher and higher pressures might be maintained, it is certain that great room for improvement is yet left. The old boiler fired externally is objectionable; while for internal firing it is necessary either to have a firebox and tubes, or to have flues large enough to allow the fireplaces to be formed within them. The multitubular boiler, unless supplied with good water, requires much care to prevent choking with scale; and its repairs are in all cases greater than those of the Cornish and Lancashire boilers. The Lancashire or two-flued boiler is that most used in the manufacturing districts; but its diameter is necessarily so large as to render it imprudent in most cases to load it with steam of much more than 50 lbs. pressure, and this is not the high pressure to which present steam engine practice is tending. A diameter of 7 feet is common for Lancashire boilers; and if made of $\frac{1}{2}$ inch Staffordshire plates, single-rivetted, their bursting pressure may be taken as 333 lbs. per square inch. This estimate is made upon Mr. Fairbairn's usual allowance of a loss of 44 per cent. in the strength of the solid plate at single-rivetted seams; and the estimate of course assumes that no flaws are hidden in the iron, and that the workmanship is good, the rivetting being fairly done so that the boiler shall not have been-injured by the use of the drifting tool. This then is the limit of strength when the boiler is new; and it would be manifestly imprudent to press to more than 50 lbs. or at the utmost 70 lbs. a boiler which was certain to burst at 333 lbs., and to be permanently injured by a much lower pressure. It is shown moreover by the reports of the Manchester Boiler Association that many boilers are subject to weakening from corrosion or furrowing of the plates. A leakage of steam, however slight, from any part of the boiler into the adjacent setting is almost certainly attended with corrosion. Condensed steam, that is distilled water, appears to exercise a strong solvent power upon iron, as is known in the cases of boilers supplied with very soft water or peat water or more especially those fed with water from surface condensers. As has been shown in the case of several recent boiler explosions, the thickness of boiler plates is often wasted nearly through by unsuspected corrosion.

This source of danger to a certain extent neutralises the means occasionally resorted to for securing great strength in boilers, such as the use of steel or homogeneous metal plates, double rivetting, thick-edged plates, welded joints, &c.

Whenever a failure unhappily occurs in the plates or rivetting of a boiler, the destructive effect appears to depend, not merely upon the pressure under which the failure takes place, but also and probably still more upon the quantity of water contained in the boiler. The effect of the boiling water in an explosion may be considered as analogous to that of gunpowder; and, as in the case of gunpowder, the effect is proportionate to the quantity exploded. It is preferable therefore, while increasing the strain upon boilers by increasing the pressure of the steam, to diminish at the same time the quantity of water contained in them; doing so of course without exposing any part of the boiler to the direct action of the fire on one side of the plates where there is no water present on the other. In a large Lancashire boiler the object of carrying so much as from 15 to 20 tons of water is mainly to ensure that all the heating surfaces shall be fairly covered; and with this construction of boiler a smaller quantity of water will not answer that purpose. A certain body of water is indeed necessary to prevent sudden fluctuations in the pressure of steam; but in the majority of cases a few hundred gallons at most is quite enough for this purpose; and especially where means are employed for drying or superheating the steam, there will be neither sudden alterations in the pressure nor difficulty in respect of priming, even where only a small body of water is maintained in a boiler and where the water level or surface from which the steam rises is of but small area. Moreover it should not be forgotten that with all steam boilers the whole or nearly the whole of the fuel employed in raising steam from cold water at starting is lost when the boiler stops work at the end of the week, especially where the boiler has then to be blown out. To heat 20 tons of water from its ordinary temperature in the open air to 300° Fahr., the temperature corresponding to a steam pressure of 50 lbs. per square inch, will seldom take less than 15 cwts. of coal, in addition to that lost in heating the brickwork setting of the boiler.

On this account therefore it is desirable to work boilers with as small a quantity of water as will suffice for every necessary purpose.

The Cast Iron Boiler about to be described has been constructed with reference to the foregoing considerations. It was the object of the inventor, Mr. Joseph Harrison of Philadelphia, United States, to provide great strength against bursting, and to obtain also a large extent of heating surface in proportion to the weight and external dimensions of the boiler: it was important moreover to obtain perfect circulation for the water. The experience with this boiler for several years in America and for upwards of two years in London and Manchester, in one case with a boiler supplying steam to the extent of 200 indicated horse power, has proved that these objects, as well as other important advantages, have been secured.

The boiler is shown in Plates 19 to 23. Fig. 1, Plate 19, is a longitudinal section; Fig. 2, Plate 20, a front elevation; and Figs. 3 and 4, transverse sections. Figs. 5 and 6, Plates 21 and 22, are longitudinal and transverse sections to a larger scale.

The several parts of the boiler received different forms in the earlier experiments several years ago, but these led to the adoption of the present hollow cast iron spheres, connected by hollow necks, and secured together by bolts, as shown in the longitudinal sections, Figs. 1 and 5, Plates 19 and 21. Figs. 7, 8, and 9, Plate 23, are enlarged sections of one of the castings, which includes four spheres, each 8 inches external diameter, $\frac{3}{8}$ inch thick, and connected by necks of $3\frac{1}{8}$ inches opening. Each of these castings is called a "unit." Each "unit" of four spheres has eight openings, $3\frac{1}{8}$ inches internal diameter, the edges of which are faced up to a true surface, so as to bear fairly upon the corresponding faced surfaces of the adjoining units. Each joint has a shoulder and socket, as shown full size in the section, Fig. 10, Plate 23, so as to steady the units in their place. Steam-tight caps are provided to cover the external openings, as shown in Figs. 8 and 9; and the whole series of units, forming a vertical slab of rectangular or other shape, are held together by bolts of $1\frac{1}{4}$ inch diameter, passing inside the spheres and through the water or steam which they contain.

Each slab, whatever number of units it may be composed of, may be regarded as a separate vessel, throughout which the water or steam can circulate freely, both vertically and longitudinally. Any number of slabs may be placed side by side in the same fireplace; in the boiler here shown there are eight, as seen in the transverse sections, Figs. 3, 4, and 6, Plates 20 and 22. They are connected together by a feed-water pipe A at the bottom and by a steam pipe B at the top. The water level is usually maintained so that about two thirds of the whole number of spheres will be constantly filled with water, as shown in Figs. 5 and 6, and by the dotted line in Fig. 1; the remaining spheres forming a steam space. The full heat of the fire is prevented from coming upon the upper spheres which contain only steam, by small firebrick screens or cast iron plates C C, Figs. 5 and 6, which are placed loosely between the slabs, a little below the water level, so as to confine the direct action of the heat chiefly to the spheres filled with water. The upper spheres are at the same time enveloped in an atmosphere so hot as to ensure the steam being completely dried. The slabs are fixed with an inclination in the direction of their length, as shown in Figs. 1 and 5, sufficient to ensure the complete drainage of all the spheres when the boiler is blown out. This inclination serves at the same time to bring the largest body of water to where the action of the heat is most direct, and to provide the largest steam space over that part of the boiler where ebullition is probably the least active. The earlier experiments have shown that, although the units may be bolted together into slabs of a total length of even 20 feet, a length of 9 feet is preferable, since the strain upon the bolts in screwing up is correspondingly less: and as in the latter case there is no observable tendency to sag in the centre, the complete tightness of the joints is thereby secured.

The spheres weigh each about $22\frac{1}{2}$ lbs., a unit of four spheres weighing rather more than $\frac{3}{4}$ cwt. Hence there are very nearly one hundred spheres to the ton; and it has been the habit thus far to rate these boilers by their weight, as a 4 ton boiler, an 18 ton boiler, &c. The nominal horse power of the boiler may be generally taken as three times its weight in tons. Thus a 10 ton

boiler may be rated as of 30 nominal horse power; and from experiments it appears that a boiler of this weight may be counted upon to evaporate 40 cubic feet of water per hour, corresponding to about 80 indicated horse power. Each sphere contains seven pints of water, a unit of four spheres containing $3\frac{1}{2}$ gallons. The external surface of each sphere is rather more than $1\frac{1}{4}$ square feet, and the internal surface a little more than $1\frac{1}{8}$ square feet. In round numbers it may therefore be said that each sphere presents a square foot of heating surface and contains a gallon of water; while a ton of one hundred spheres represents three nominal horse power, the proportion of weight to power being thus about the same as in Lancashire boilers of the ordinary type.

Although it cannot be said that cast iron is in itself a strong material for boilers, yet it will be seen that, in the form now described, it affords greater absolute strength against bursting than is possessed by any form of plate iron boiler at present in use. The units are cast upon green sand cores, so placed that they cannot alter their position in the flask by any force short of what would be sufficient to crush them to pieces. The thickness of metal in the spheres is therefore uniform throughout, as has been proved by breaking great numbers of units taken at random. In a unit of four spheres, each sphere having an internal diameter of $7\frac{1}{4}$ inches, the whole area of the plane in which a bursting pressure would act, taken through the eight openings of the four spheres, as in Fig. 8, Plate 23, is 220 square inches; while the least section of iron resisting this pressure in the same plane is $27\frac{1}{2}$ square inches. The iron employed is an equal mixture of Glengarnock, Carnbroe, and scrap: a mixture selected for its free running quality, and much used for small machinery castings. Its tensile strength may be safely taken as $5\frac{1}{2}$ tons per square inch. At this rate the bursting strength of the units would be 1540 lbs. or nearly three quarters of a ton per square inch internal pressure. The first experiments actually made to test the bursting strength of the units were made more than two years ago in Brussels for the Belgian Minister of Public Works. In this case a pressure of 98 atmospheres or 1440 lbs.

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per square inch was applied. This was as high as the force pump employed could go, but the spheres were not burst.

A further series of experiments for the purpose of testing the bursting strength of the cast iron spheres have recently been made at the Gorton Foundry, Manchester. A high-pressure Schaeffer's gauge graduated to 1000 lbs. per inch was attached to one of the units or castings of four spheres, to which the caps had been accurately ground, and water pressure was then applied by means of a force pump. The pointer of the gauge passed the 1000 lbs. mark to an extent indicating from 1150 lbs. to 1200 lbs., but the spheres did not burst. The pressure gauge was then checked by comparison with a Bourdon gauge up to 500 lbs. per square inch, and found to agree within 10 lbs. By calculation from the weight applied to the force pump lever and the dimensions of the pump it was estimated that the total force applied, including the friction of the pump, was about 1470 lbs. per square inch. Another similar casting was afterwards tested in the same way with a similar result. The castings were subsequently broken with a sledge hammer, and showed a uniform thickness at all parts and a good quality of iron. A safety valve was then arranged for the purpose of ascertaining the bursting strength of the spheres; the seat of the valve was 1-4th square inch area, and the head of the valve $1\frac{1}{4}$ inch diameter, the valve being ground carefully to its seat. The spheres were burst at a pressure calculated at 1850 lbs. per square inch; but on comparing the safety valve with a pressure gauge it appeared that water must have worked its way over the ground seating of the valve, allowing the pressure to act upon a greater area than 1-4th square inch, and that the true pressure could hardly have been so much. The head of the valve was then reduced to a diameter of $\frac{7}{8}$ inch, and the spheres were burst at a calculated pressure of 1650 lbs. per square inch; but it was still found that some water must have worked over the valve seating, and the experiments with the safety valve were not therefore altogether satisfactory, but there appeared no reason to doubt that the bursting pressure was not far short of 1500 lbs. per square inch. All these experiments were made upon castings having their covering caps ground carefully to

them, and the bolts were only about 9 inches long between the caps covering the opposite openings of the units. When however a slab of say one hundred spheres is bolted together, the bolts being upwards of 9 feet in length become so far stretched by a strain considerably below the bursting pressure as to cause the joints to open everywhere and relieve the pressure. In this way every joint becomes a safety valve. This never occurs with any practicable steam pressure, but it did take place in many of the earlier experiments made to burst the spheres, although leakage seldom commenced until a strain of nearly or quite half a ton per square inch had been applied.

The above experiments were all made with new castings, and at the time they were made no other spheres could be had which had been more than twelve months in use; and the condition of these was clearly the same as when new. It would appear therefore that the boiler now described possesses the same degree of safety under a pressure of 230 lbs. per square inch as a 7 feet Lancashire boiler under a pressure of 50 lbs. If however one of the units of the cast iron boiler should burst, it could not do more than empty itself, and open one or more $3\frac{1}{2}$ inch apertures into the units adjacent to it; whereas if an ordinary boiler, containing say 20 tons of highly heated water in one compartment, should burst, the consequences would be most disastrous. In some of the earlier boilers of the kind now described the setting was such that an excessive strain was brought upon one or more joints; and here, in order to prevent leakage, the bolts had to be tightened with great force, and in two or three cases castings forming a part of the boiler were thus cracked from one joint to another. The consequence was an escape of steam or water, but no further damage ensued. In one of these instances a unit thus cracked was worked continuously for three days, and it might perhaps have been worked for a still longer time; but it was thought prudent to replace it by a sound casting. No instance of a fracture has occurred in the cast iron boilers with the present mode of setting, and all the boilers of this kind yet erected are quite free from leaks at the joints.

The bolts securing the castings together have a strength much beyond even that at which the spheres would burst. They are under a certain initial strain before any pressure is raised in the spheres ; but the amount of this initial strain is known and under control, for in screwing up the slabs a 27 inch wrench is employed, and the strength of but one man is applied to it. If however a great strain be put upon the bolts, the crushing strength of the castings is found to be greater than the tensile strength of the bolt. In a series of experiments made at the manufactory of these boilers by Mr. Luders a slab of units bolted together to a length of 9 feet was screwed up with great force ; a wrench 10 feet long was employed and the force of three men applied. In every case the castings were compressed to the extent of 1-8th inch in a length of 9 feet, when the bolt commenced to stretch, and after elongating $1\frac{1}{4}$ inch it broke. This experiment was repeated twelve times with the same result, the castings remaining uninjured. The castings when laid loosely upon a brick pavement require a powerful overhead blow from a heavy sledge hammer to break them. They have also been heated in a forge to a bright cherry red colour, and then plunged in cold water, without cracking : though there is no doubt that the iron was seriously injured by this treatment, and it might have been expected that the spheres would break to pieces. Their endurance is to be referred to their form and to the tough quality of the metal from which they are cast ; a sharp blow with the edge of a hammer indents the iron nearly the same as if it were boiler plate.

It might have been apprehended that the expansion of the castings, when in service in a boiler, would be such as to cause unequal strain upon the joints. No leakage however can be detected at any of the joints of a single slab of castings ; and as each slab is supported chiefly at its lower corner, and all the slabs of a boiler are separate from one another, except at a single point at top and bottom where the steam and water connections are respectively made, it is found that the slabs are under no injurious strain. Moreover all the spheres have a considerable amount of elasticity under strain, which would assist in compensating for unequal expansion, did this exist. These conclusions as to the

effect of expansion are derived from an experience of $2\frac{1}{2}$ years with one of these boilers of 12 horse power at the chemical works of Messrs. Denton at Bow Common, London; two boilers, one of 50 horse power and the other of 12 horse power, at the engineering works of Messrs. Hetherington, Manchester; and a 12 horse power boiler at the manufactory of these boilers, Openshaw, Manchester. The two boilers at Messrs. Hetherington's are often worked, collectively, up to 200 indicated horse power; the first was erected at their works about eighteen months ago. The boilers of this construction were originally bolted up in slabs 25 feet long, where considerable power was required; but in such cases it is now preferred to employ two or three slabs, one behind the other, as shown in Fig. 1, Plate 19, each slab being 8 or 9 feet long. When this arrangement was first employed, the steam space of the back slab was connected by a pipe with that of the front slab, the steam being taken off to the engine from the front slab alone; and the steam pipes connecting the front and back slabs being made of cast iron, and of a form which did not allow of the unrestricted expansion of the slabs, some of the pipes consequently cracked; but they are now made of wrought iron and of a curved form, as shown in Figs. 5 and 6, Plates 21 and 22, so as to yield readily to a moderate strain.

The inventor of this boiler, Mr. Harrison, had from the first expected an entire freedom from corrosion of the spheres; and the experience thus far has borne out this anticipation. Cast iron is well known to endure much better than wrought iron under the action of flame, water, and other corrosive influences. In the case of gas retorts for instance, plate iron would be immediately burnt through; whereas, previous to the introduction of clay retorts, cast iron answered very well. The pipes for heating the blast of blast furnaces were originally made by Mr. Neilson of plate iron; but although the blast was then heated to only 350° , it immediately became necessary to resort to cast iron heating pipes. The superior durability of cast iron forge tuyeres, especially when made hollow and lined with water, is also well known. In the case of the present boiler many castings have been purposely removed and examined

after being at work; but their weight has been found the same as when they went in, and the joints showed no degradation of their original surface.

The question which caused most apprehension in the first instance in connection with this boiler was the possibility of maintaining a clean surface within the spheres. The cast iron boiler may be said to belong to the class of water-tube boilers or those having small water cells. This class of boiler is about sixty years old, for one was fitted in Meux's brewery in London by Arthur Woolf in 1804; and in the same year a small screw steamboat was worked on the river Hudson by John C. Stevens of New York, the engine of which was made by Boulton and Watt, while the boiler had 81 water tubes, 1 inch diameter and 2 feet long. From the first however such boilers have generally failed on account of defective circulation and the difficulty of keeping the tubes free from internal deposit. Many attempts have been made to remove this difficulty. Circulating pumps have been employed in addition to the ordinary feed pump, to maintain a constant circulation of water through the tubes. The boilers of the first American steam fire-engines were thus constructed, and some time since a description of such a boiler was given in this Institution. Other forms of water-tube boilers have been made with different means for promoting a circulation of the water; but in all cases the whole of the inorganic matter contained in the feed water must remain in the boiler, unless it be blown out while working; and in the case of some salts held in solution by ordinary boiler water, these are inevitably and almost irremovably deposited upon some part of the internal surfaces. The boiler now described forms no exception to the general experience in this respect. The water with which Messrs. Hetherington's boilers and indeed most of those in Manchester are fed is such as to deposit a hard scale 1-8th inch thick after a few weeks' working. A tool had been contrived with steel scrapers so hinged that it might be entered through any of the openings in the spheres of the cast iron boiler and be then expanded out to the internal circumference of the spheres: by then working this tool within

the sphere the scale would be removed so that it could afterwards be blown out.

It has unexpectedly turned out however that no occasion has arisen for the use of this scraping tool. The boiler was blown out regularly at the end of every week, and it was found that the supply of steam continued good without any use of this tool, and that none of the spheres became overheated or leaking. After ten months' work of the 50 horse power cast iron boiler at Messrs. Hetherington's, it was desired to increase the boiler power at their works; and as the boiler then in use there was formed of units having only two spheres each, it was replaced with a new boiler having four spheres in each unit, excepting the units employed for breaking joint, which had two spheres as before. On taking down the old boiler little or no scale was found in any of the spheres, two of which, in the same condition as when taken down, are now exhibited to the meeting. One taken from the 12 horse power boiler at the same works was broken by the writer and is also exhibited. This was purposely taken from near the bottom of the boiler, and it had worked constantly for eight months without any examination. It will be seen that the broken pieces, which are in the same condition as when the casting was taken out and broken, contain no scale. In taking down the old 50 horse power boiler however a lump rolled out from one of the spheres; and this, the only piece of the kind found, is also exhibited. It consists of scales seldom larger or thicker than a sixpence, loosely cohering together by a clayey deposit from the water; in the mass it is very friable, but the fragments of scale are themselves of the same obdurate sulphate of lime as that which hardens in nearly all other boilers in the same district; yet these scales have in every case separated from the iron before attaining a thickness greater than 1-16th inch. It cannot be because the boiler is of cast iron that it so readily sheds its scale; for Trevithick's boilers and the cast iron "elephant boilers" long ago made by Mr. Hall of Dartford enjoyed no immunity in this respect as compared with wrought iron boilers fed with the same kind of water. In the Lancashire district too, the cast iron pipes of the apparatus used for heating the feed water for boilers are subject to choking with

scale in the same manner as if they were made of wrought iron ; and in some cases they become completely choked and can be cleared only by a boring tool. The fact that the spheres of this boiler shed their scale is not to be referred therefore to their being made of cast iron. It might perhaps be imagined that the water is occasionally driven from the internal surfaces, and that the consequent expansion of the spheres and their subsequent contraction on the return of the water would account for the scale becoming loosened and broken off. But the spheres show no evidence, as in this case they might be expected to do, of any irregular action of the fire ; and moreover those of the spheres which are placed far behind, where the action of the heat is moderated, are equally free from scale. It appears to be more probable that, as the spheres expand at all parts, and in cooling contract equally at the same parts, the scale is detached and crushed in this process of contraction. If this conjecture be correct, the unexpected separation of the scale may be attributed to the form and dimensions of the spheres themselves.

Whatever explanation may be offered, it is certain that with foul water and such as gives much trouble in other boilers the scale breaks off freely into small pieces in this cast iron boiler ; and this is perhaps one of its most valuable properties, although quite unforeseen. It would not be prudent to anticipate the result in the application of this boiler to marine purposes ; but in all the land boilers of this construction it has been found that with blowing off once a week they may be worked for an indefinite length of time without any accumulation of scale. It will be seen how readily this boiler may be laid open for examination, and it was recently thought expedient to open the large boiler at Messrs. Hetherington's works for this purpose. A small quantity of loose and broken scale, not above a tablespoon full, was found in each of the units examined ; but their internal surfaces, so far as they could be seen, were entirely clear.

The evaporative efficiency of the cast iron boiler depends, as in the case of all other boilers, upon the amount of heating surface exposed in proportion to the consumption of a given weight of fuel

in a given time. The boiler by which Messrs. Hetherington's works are now driven supplies an amount of steam which a single Lancashire boiler, 7 feet diameter, 30 feet long, and weighing 14 tons, was found inadequate to produce. Both the original and the present boiler are in connection with a chimney 165 feet high, which affords an excellent draught. The original boiler had two flues, each $2\frac{1}{2}$ feet diameter and enlarged at the fireplace to 3 feet. The area of the firebars was 36 square feet, and the total "run" of the heat was 90 feet in length before quitting the boiler. The cast iron boiler now in use has about 1800 spheres, weighing 18 tons, and presenting about 1600 square feet of surface in the water spheres and about 700 square feet in the steam spheres; the area of firegrate is 33 square feet. The usual quantity of water carried is 147 cubic feet or rather more than 4 tons, the quantity usually carried in the original Lancashire boiler being nearly 20 tons. The external dimensions of the present boiler are considerably less than those of the Lancashire boiler. Rather more than 3 cwt. of coal are required in the cast iron boiler for raising 50 lbs. steam from cold water, and the time occupied is about half an hour. In order to ascertain the exact evaporative efficiency of the boiler, it would be necessary to begin the observations when it was in full work, and to continue them uninterruptedly for a considerable time. As the boiler is now worked, the fires are lighted on Monday morning and let down on Saturday afternoon; but they are banked every day at breakfast time, at noon, and at night. The mass of brickwork which is thus alternately heated and cooled with the boiler is very great; and the quantity of heat that enters it, which is for the most part wasted on stopping, is correspondingly large. Except at the beginning of the week, the temperature of the water in the boiler on starting in the morning is at least 212° , while the feed water from the hot well is usually between 90° and 100° .

In February last the writer made a series of careful observations upon the working of this boiler, more especially to ascertain its evaporative efficiency. The coal was of good quality, from the Oldham Pits, and was carefully weighed; and the feed water was made to pass through one of Worthington's water meters on its

way to the boiler. The indications of the meter were ascertained to be accurate, by its registration of $147\frac{3}{4}$ cubic feet in filling the boiler up to a point known to correspond exactly with that quantity. In the first day's trial, between 5.40 a.m. and 12.55 noon, with an interval for breakfast, the whole consumption of coal was 38 cwts. and of water 442.7 cubic feet. If this quantity of water evaporated were to be divided by the gross consumption of coal, the result would be only 6.48 lbs. of water evaporated per lb. of coal : but in heating the boiler and its contents to the working point, and in the loss at breakfast time, the consumption of coal was such that 24 cwts. were burnt for evaporating the first 200 cubic feet of water ; while the remaining 14 cwts. held out for the time during which 242.7 cubic feet of water were evaporated. Allowing for the lowering of the fires at the hour for stopping work, the quantity of coal actually expended in evaporating the 242.7 cubic feet of water may be taken as 16 cwts., corresponding to an evaporation of 8.43 lbs. of water per lb. of coal. Towards the end of the day's trial, in a period of 1 hour 40 minutes, 8 cwts. of coal were burnt and 142.7 cubic feet of water evaporated : but as this would correspond to an evaporation of 9.91 lbs. of water per lb. of coal, a portion of the water must have been evaporated at the expense of the heat already in the water and in the boiler and its brickwork setting. That this was the case is shown by the fact that in the last 50 minutes of the trial only 2 cwts. of coal were burnt while 80 cubic feet of water were evaporated ; a proportion which, were the total evaporation due to the quantity of coal actually burnt within the same period of time, would have corresponded to an evaporation of 22 lbs. of water per lb. of coal, which would of course have been impossible. In making these observations there was always the uncertainty attending the quantity of coal that should be assigned to heating the boiler, and its contents and setting, up to the working temperature, and the quantity that was to be set down to evaporation alone.

In the second day's trial, starting on Monday morning with water at about 45° temperature, 5 cwts. of coal was consumed in raising steam to the working pressure, the time occupied being half an hour.

Including the coal burnt in raising steam, 2 tons 18 cwts. were consumed during the day, and 657 cubic feet of water were evaporated, corresponding to an evaporation of 6.30 lbs. of water per lb. of coal. But as a greater quantity of heat was manifestly left in the boiler and brickwork on stopping at night than when work was commenced in the morning, and as there was a waste of heat during the breakfast and dinner hours, not more than $2\frac{1}{2}$ tons of coal at most can be fairly charged to the water evaporated, and this is probably in excess of the actual quantity. This corresponds to 7.31 lbs. of water evaporated per lb. of coal. The evaporation from noon until the hour of stopping at night averaged 7.56 lbs. of water per lb. of coal, while for the last four hours of the experiment the apparent rate of evaporation was 8.71 lbs.

In the third day's trial, steam having been kept in the boiler over night, the consumption of coal from 6.0 a.m. till 2.30 p.m. was 2 tons 6 cwts., which included the loss during the breakfast and dinner hours, and the evaporation was 519 cubic feet, corresponding to 6.27 lbs. of water evaporated per lb. of coal.

In a whole week of $57\frac{1}{2}$ hours an average of 77 cubic feet was evaporated per hour, the maximum evaporation being about 82 cubic feet per hour, and the average consumption of coal was 6.25 cwts. per hour. This corresponds to 6.85 lbs. of water per lb. of coal; but, allowing for the sources of loss already pointed out, nearly 8 lbs. may be taken as the effective rate of evaporation. The temperature of the escaping gases, as indicated by Gauntlett's pyrometer, was about 600° on the average, the steam of 50 lbs. pressure showing the normal temperature of about 300° by a thermometer inserted for the purpose. The average rate of combustion was 21 lbs. of coal per square foot of firegrate per hour. When the fires were not driven so hard the rate of evaporation per lb. of coal was increased, and the temperature of the escaping gases fell to 525° . The flame penetrated freely between the spheres for a distance of 8 or 10 feet from the bridge, and three fourths of the whole evaporation probably took place within this distance. The spheres in the slabs at the back of the boiler were generally covered with a light coating of soot, which was swept off every week, all

the spheres being within easy reach for this purpose ; soot never formed however upon the spheres near the fire. The water level was very steadily maintained within a small range of oscillation ; and as the feed water entered the boiler at the back, there could be no doubt, when it stood at its proper height in the glass gauge in front, that its level was properly maintained throughout the whole length of the boiler. A small cock tapped into one of the steam spheres a short distance above the water level showed damp steam, indicating a vigorous circulation of the water below ; but in the engine room the steam blown from the cylinder cock was quite dry, showing the value of the superheating surface formed by the upper or steam spheres of the boiler.

In reference to the mode of making the castings of the boiler and forming the joints, the system pursued in the foundry is such that, with green sand cores, the units are moulded with about the rapidity and economy of plate moulding. The cores are well rammed on the eight prints upon which they rest in the sand, and there is no chance of their being displaced in pouring the metal or otherwise, except by a force sufficient to break them in pieces. The two halves of the moulding boxes are drawn apart in such a manner as to prevent any chance of breaking down the sand, and little or no sleeking is required. Each casting is critically inspected ; but as the moulders are not paid for imperfect castings, very few are made.

The joints are faced up by special and powerful machinery. The spheres are 9 inches from centre to centre in the same unit, and the facing machines not only preserve that distance exactly between the openings on the same side of each unit, but also face the joints on the opposite sides of the unit to the precise gauge of $8\frac{3}{4}$ inches apart. Each machine has two headstocks, with eight spindles and rose cutters in each headstock ; and the castings being securely held in a clamp are faced in pairs, a roughing cut being taken on the eight joints of one casting, while a finishing cut is going on upon the joints of the other. Twenty-five tons of castings pass under the roughing cutters before they require grinding ; and

100 tons of units are completely faced by the finishing cutters before these require to be re-ground. By a special adjustment the finishing cutters may be set up in their spindles to the one-thousandth part of an inch, whenever, from the dulling of the cutting edges, the distance between the opposite joints of the units is found to exceed the length of the standard gauge by that quantity.

Out of a number of castings, any two exactly correspond, and when placed together the bearing surface at each joint is 3-16ths inch wide all round, and it is finished with a truth not inferior to that of a good slide-valve face. If a sheet of oiled paper be placed upon a smooth board and two units be placed upon it, one above the other, they may be filled with water without any perceptible leakage at the joints even after the lapse of a week.

In conclusion it is considered by the writer that the boiler now described possesses several important advantages. It is believed to be absolutely secure from explosion, and, so far as experience has gone, free from any liability to choke with scale. It is durable, easily taken apart and put together, and may be erected in almost any form adapted to the space in which it is to be placed. The parts are very portable, and may be taken through any opening where a boy can pass. Any part of the boiler may be readily renewed if necessary; and an existing boiler may at any time be readily enlarged, and that to an indefinite extent, by adding to the number of slabs, either at the sides or at the back. The economy of the boiler in first cost is obvious; and with proper proportions between the firegrate and the heating surface, as high an evaporative efficiency may be obtained as with most other constructions of boilers. The quantity of water contained in the boiler being comparatively small, steam may be raised with a small quantity of fuel and in a short space of time. Water may be left standing in the boiler for almost any length of time without injury. Every part of the boiler is at all times under ready observation without disturbing the connections; and the outsides of the spheres may be easily swept. The setting of the boiler is such that the steam may

be dried to any extent desired in the spheres themselves, without any other provision for superheating. It is thought that this boiler especially meets the present increasing tendency to use high pressure steam, and that the description now given will therefore prove interesting to this Institution.

Mr. COLBURN exhibited a set of spheres from the boiler, forming one complete slab, and also specimens of the steam and feed connections at top and bottom of the boiler, together with one of the spheres that had been broken open after eight months' constant work, to show the state of the interior surface and its complete freedom from corrosion or scale. He showed also specimens of the thin small scales blown out from the boiler, which was all the deposit there was to be found; and of the thick hard deposit chipped off from the interior of an ordinary Lancashire boiler using the same water.

The CHAIRMAN had seen the new boiler at work in Manchester, and considered it an important step towards the use of steam at a higher pressure than could at present be adopted. It was much more simple in construction than would at first sight appear; and with the facilities now possessed for multiplying parts of the same size and shape, he did not see any reason why it should not be put together easily and at a very small cost. He enquired what was the temperature of the waste heat passing off from the new boiler into the chimney, as that was an important criterion of the economy of a boiler.

Mr. COLBURN had not had an opportunity of ascertaining the temperature of the waste heat from this boiler, but by increasing the length of it the heat at the chimney end could be reduced as low as desired. At Messrs. Hetherington's works in Manchester there were originally two ordinary Lancashire boilers, but when

the new boiler was added only one of these was worked with it; the waste heat from both however passed into the same chimney, so that there was no opportunity of trying the temperature from the new boiler alone. The boiler at those works was in the first instance longer, but was afterwards shortened by the removal of some of the spheres at the further end. The water was left in the boiler during the night, and in the morning was still at a temperature of 212° Fahr., owing to the heat retained in the mass of brickwork surrounding the boiler; and from this point steam was got up in 10 or 12 minutes to a pressure of 50 lbs. per square inch above the atmosphere. There was great convenience for readily inspecting the boiler by means of the manhole doors, by which access was obtained at once to the whole boiler, with a clear sight through the entire length, and a man could get in and sweep the whole of the spheres clean without any difficulty at all.

As regarded the freedom of cast iron from any tendency to corrosion, when used as the material for steam boilers or for other purposes where it was exposed to a high temperature, he was informed by Mr. Jaffrey of Hartlepool that he had employed cast iron for superheaters with success, and four cast iron superheaters fitted on board steam colliers showed no sign of corrosion when examined in October last, after four years of almost constant work; the pipes when cleaned looked almost like new castings, almost as clean as when first put in.

Mr. G. A. EVERITT thought the new boiler would be very useful in connection with puddling or heating furnaces, where the waste heat from the furnace was made use of for generating steam; it appeared very suitable for such applications on account of its safety and the small space it occupied, and he enquired whether it had been employed for that purpose.

Mr. T. L. LUDERS replied that he was now about to put up one of the boilers to be heated by the waste heat from three puddling furnaces: there were eight sections of spheres in the boiler, and the heat from the furnaces was made to circulate completely through the set of spheres in each section by means of firebrick partitions, making the passage to the chimney the longest possible. The boiler was

carried entirely upon a pair of cast iron columns in front and the brickwork upon which it rested at the back, independent of the brickwork of the furnaces ; so that the latter could be pulled down for repairs without disturbing the boiler, while the boiler also was completely accessible at all times without requiring any part of the brickwork of the furnaces to be removed. The boiler had thus the important advantage for such an application that it could be placed over the furnaces without occupying any of the room of the forge or hindering the repairs of the furnaces. By means of suitable dampers the amount of heat allowed to pass through the boiler could be regulated as desired, according to the generation of steam required ; and the heat from any one of the furnaces could be conveyed away direct into the chimney, without passing at all through the boiler, if only a smaller quantity of steam were wanted to be raised.

In the earlier boilers that he had made, the spheres were set at an inclination of about 15° , but in the most recent ones they were placed at 45° , which was found to answer the best, because it gave a complete drainage of every sphere in the boiler into the bottom blow-off pipe ; while the point of taking off the steam being the highest in the boiler was the furthest from the water line. Near the level of the water line the steam would of course be damp from contact with the water ; but the surface of the spheres above the water line being exposed to a high temperature, say 650° Fahr., the steam became moderately superheated to a temperature due to that exposure before passing off from the top of the boiler, and it was then found hot enough to continue dry after passing through 40 feet of unprotected pipe to a low pressure engine worked by it.

The CHAIRMAN enquired what was the cost per horse power of the new boiler.

Mr. T. L. LUDERS replied that the cost of the boiler was £15 per ton at the works in Manchester, and the power was reckoned at about 3 horse power per ton, making the cost per horse power about £5. In reference to the temperature of the waste heat escaping from the boiler, he had found the waste heat from an ordinary Lancashire boiler doing rather less work than the new boiler was from 580° to

600°: while the waste heat from the new boiler was from 500° to 600°. The extent of variation in the latter case was accounted for by the quantity of coal consumed per square foot of grate per hour, amounting to 21 lbs. of coal; and it was evident that as the consumption of coal was increased, and the rapidity of the draught also increased by opening the chimney damper in order to burn the larger quantity of coal, the heat escaping into the chimney must also be proportionately increased. The Lancashire boiler experimented upon was one with a moderate draught, but having a larger firegrate area and burning its fuel much slower than 21 lbs. per square foot of grate per hour. That would give a much higher evaporative efficiency, and the temperature of the waste heat escaping to the chimney would be lower, owing to the draught being less keen and the heat being more fully taken up by the boiler.

Mr. C. W. SIEMENS remarked that certainly the new form of boiler was emphatically a strong form, inasmuch as a sphere of 1 foot diameter had as much strength to resist internal pressure as a pipe of half that diameter, the thickness of metal being the same. Moreover the spherical form was a very good form in cast iron he thought for a boiler, because it yielded to expansion equally in all directions: cast iron readily gave way when exposed to unequal heat, and in ordinary plate boilers the wrought iron often gave way in consequence of unequal expansion in different parts. But he did not expect that the new boiler would give way by any part being overheated in comparison with the rest, because every portion of a hollow sphere could yield freely to local expansion by heat. He had at various times used cast iron heated to a high temperature, and had found that, to make it stand, the question of expansion had above all things to be attended to. The heating surface in the boiler appeared likely to be highly efficient, because the flame was continually broken in its passage over the interrupted surface presented by the balls, instead of passing through a long plain internal tube in a continuous unbroken current, as in an ordinary boiler, where the interior mass of the flame came comparatively little in contact with the boiler surface. He therefore hoped the

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new boiler would receive a fair trial at the hands of those using steam boilers. The several balls composing the boiler must require to fit together with very great nicety in order to prevent leakage at the joints, and he enquired whether they had ever been found to leak at the joints; and whether they were not found to give way at the joints after working for a considerable time, in consequence of the alternate heating and cooling, since cast iron by being heated and cooled very often was known to become permanently enlarged.

Mr. T. L. LUDERS replied that there had not at present been a very long experience with the new boiler of which to speak, but so far as the tightness of the joints had hitherto been tested by time their durability had been surprising, as they had never shown the slightest sign of a leak. Very much depended in practice upon the facing of the joints being truly accurate machine work, and this was ensured by the mode of facing the two sets of cutters of the machine in which the joints were faced simultaneously on opposite sides: while the cutters were all revolving, firmly wedged in their holders in their permanent working position, but of soft steel not yet hardened, a facing tool sharpened at both edges and made by a standard gauge to correspond to the exact distance between the joints was passed transversely across the machine, grinding the cutters to the exact length required for facing the joints accurately to the proper length. The joints then fitted together perfectly without the slightest force being used, and when the bolt was passed through to hold them together they were quite steam-tight under any pressure of steam at which the boiler would be worked. There were 1800 balls in the last boiler made for Messrs. Hetherington's works, and not a single leakage had been detected in all that number. The result of two years' experience with the boilers at Messrs. Sellers' machine works in Philadelphia was that there had been no leakage; while at the same time the boilers had been so economical that more than 100 tons of the ball castings for new boilers had been ordered from England for works at the same place, and would be put up in the place of good boilers at present in use there. The new boilers had now worked in America for

eighteen months with only once being opened at the end of eight months for the purpose of clearing the balls if that should be necessary, and then only a little scale and mud was raked out of the bottom row of balls; and during the ten months that had elapsed since that time they had not been opened at all. The experience in all cases had been the same as to the absence of scale or deposit, even after a long time of working.

With regard to the manner in which the new boilers stood the test of rust, one of them had been exposed for four years to the most severe test for rust that was likely to be met with. The boiler was 70 feet long and 1 foot high, in a greenhouse, where it was fired during only about three months in each year, and the remaining time it was allowed to stand full of water, which was no doubt the severest test it could be put to for rust. With plate boilers under such circumstances the plates were generally found to rust very rapidly. But this had not been the case with the new boiler: although the joints had been made four years they still continued perfectly water-tight, notwithstanding the fact that at the time the boiler was made there was no machinery for facing the balls, and the joints were merely planed and ground up with emery. The present machine-made joints were all found to remain perfectly tight.

The reason for setting the boiler in an inclined position instead of level, independent of the advantage of the balls emptying themselves completely when set inclined, was the fact that, in consequence of the difference of temperature between the water space and the steam space at the time of raising steam from cold water, the boiler could not be used if it were brought down level. For it was found by experiment that when the lines of balls were set horizontal a conflict resulted at the water line between the parts above and those below, in consequence of the difference of temperature, the cooler portions below the water line pulling against the more expanded parts above; and the strain produced would so rack the joints as to render the boiler a failure. This conflict disappeared however as soon as the lines of balls were set at the inclination of 45° that had now been adopted, as there was

then no sudden change from hot to cool between any two adjacent lines of balls; and though all the tie bolts crossed the water line at different portions of their length, and thereby became unequally expanded by the hot steam space, yet the change was gradual from one bolt to the next, and no two adjacent bolts pulled against each other; and the expansion of the whole boiler thus took place without throwing a strain upon any part.

The feed pipe was connected to the bottom corner of the boiler in this inclined position, and the steam pipe was taken off from the top corner with a long bend, in order to allow perfect freedom for the expansion of the boiler, the effect of which would be all concentrated at that point. In the first boilers the steam connecting pipe was a cast iron transverse pipe with straight branches on the underside, to which the sections of the boiler were directly attached, forming a rigid connection at each section. But it was then found that the several connections in this case were so difficult to make in the first instance, from the difficulty of setting all the sections of the boiler in their places with sufficient accuracy, and when set the irregular expansion of the different sections was so apparent, from the unequal heat of the fire at different parts before the steam was fully up, that there was a pushing and pulling action at the connecting pipe which gave a great deal of trouble by breaking the castings, the pipe being stronger than the castings. This was however quite obviated by the present curved wrought iron pipes, forming the connections from the castings to the steam pipe, as seen in the specimen exhibited; these were screwed into sockets in every alternate casting, and allowed perfect freedom for the expansion of any section of the boiler, independent of the rest, so that there was now not the slightest trouble, nor any strain that could produce leakage at any of the joints.

The inclination of the balls at 45° gave the greatest length of water line, since the water line was then the diagonal of a square. It also allowed the steam to escape with great readiness from the water, as fast as it was generated, passing off without meeting or obstructing the water that was rushing in through another opening to take its place; and in consequence of this advantage the water

level seldom oscillated more than $\frac{1}{2}$ inch: indeed that amount of variation in level was considered a great disturbance in the boiler.

Mr. F. W. WEBB enquired whether the joints of the balls were put together simply metal and metal, or whether any red lead or oil was used for making them.

Mr. T. L. LUDERS replied that the joints were put together metal and metal, as in the specimens exhibited, just as they were left faced by the cutters of the machine, without any subsequent grinding, and without any oil or red lead or any other material in the joint. The cutting machine was made wide enough to take in one of the four-ball castings of the boiler, having four pairs of the revolving cutters, so as to cut all the four joints on each side of the casting simultaneously. The time occupied by the operation was about 8 minutes for each casting, from the time of putting the rough casting into the machine with the cutters drawn back, until it came out with all the eight joints finished ready for being bolted together at once in a boiler without any further preparation of the surface of the joints. The revolving cutters were advanced by a pair of eccentrics having $\frac{5}{8}$ inch throw, and were fed up by hand at first to bring them up to the surface of the casting, after which the self-acting feed motion of the machine was put in operation. The cutters came in contact with the metal when the eccentrics were at half stroke, having the quickest motion for advancing the cutters; and the forward motion then gradually diminished until the full throw was reached, at which time the speed of the revolving cutters was also diminished, so that at the last the tools gave nothing but a scraping finish to the face of the metal at a slow speed.

Mr. C. F. BEYER remarked that the new boiler was composed of a great number of separate parts put together, and at first sight it would appear that there must be considerable difficulty in making so great a number of pieces go together with sufficient accuracy to prevent leakage at the joints. He had however seen the machinery that was used for facing the joints, and thought it admirably adapted for the purpose; the accuracy with which it did the work was certainly very great, and there appeared no reason why the joints shaped by that machinery should not be water-tight and

steam-tight under all pressures at which the boiler would work. The construction and working of the machinery were moreover such that the shaping of all the joints in the several castings of a boiler would form but a small item in the total cost of the boiler.

Mr. E. REYNOLDS enquired what became of the scale that was formed in the boiler during the week's work: whether it remained in the boiler until blown out at the end of the week, or whether any of it got carried over with the steam into the engine. He knew a pair of 50 inch cylinder engines upon the pistons of which an accumulation of from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thickness of scale was frequently found.

Mr. T. L. LUDERS replied that the boiler was not blown out at all except after working hours at the end of each week. From the result of observation he supposed that all the scale formed during the week's work became deposited on the surfaces of the balls in a layer about as thin as an eggshell, just in the same manner as on the surfaces of an ordinary plate boiler, so that the whole of the inside of the boiler became coated throughout the water space with a thin scale. In blowing out the boiler at the end of the week, the brickwork having been maintained during the week at a temperature of about 600° on the inside, it was only allowed to cool till the red heat had gone out of the bricks in the bridge wall, and then the boiler was blown out. But as there was still a temperature of as much as 500° in the brickwork, the whole mass of the empty boiler became very hot, and the scale either became altogether detached then by the expansion of the metal, or else the loosening of the scale was completed subsequently he presumed, when the boiler became cold, the contraction of the balls in cooling having the effect of crushing down the thin and friable scale in all directions and causing it to shell off from the metal in small pieces, or at least to become completely loosened from the metal, so that when the water was next put into the boiler it could get behind the scale and throw it off. The loose scale would then lie in small pieces at the bottom of the balls until the end of the week; and the scale formed in one week was therefore he imagined blown out at the end of the week following. The constant repetition of this process was he thought

the reason of the balls being kept quite clear of scale. As to any scale being found in the steam pipes or cylinder of the engine, such an occurrence had never been met with in the working of any of the new boilers; but he thought it probable that, if the boiler were worked too long without blowing out, the balls would become choked with mud. He had however known every one of these boilers that had been put up at present, and had never found any incrustation larger than the small pieces of scale now exhibited, scarcely thicker than eggshells. This specimen was only collected by letting the water run out of the boiler slowly, and then opening the lowest ball and collecting the pieces of scale from it by hand, so that there was no doubt that was a fair sample of the weekly production of the boiler. This scale presented a great contrast to the other specimen exhibited of the scale obtained from an ordinary Lancashire boiler working with the same water, which was the usual description of scale found in all ordinary plate boilers, about $\frac{1}{8}$ inch thick and requiring to be broken from the inside of the boiler by blows of a hammer.

Mr. J. M. HETHERINGTON said they had now had the new boiler in use at their works in Manchester for the last eighteen months, during which time they had made many experiments to test it in a variety of ways with most satisfactory results. The joints of the balls had been found entirely satisfactory, for he did not know of a single instance in which the joints in a good casting had given way. The castings as they came from the machine that had been described had all the joints faced so perfectly true that to put any cement or tallow or oil on them appeared to make them worse than the clean surface of metal to metal; and they remained completely steam-tight and water-tight under the expansion and contraction of the boiler. At the time of putting up the boiler at their works, when all the sections were screwed up and fixed in their places and the fire first lighted, he believed there was not a single leaking joint in the whole boiler.

The temperature of the waste heat escaping into the chimney from the new boiler he believed to be about the same as from an ordinary Lancashire boiler, between 500° and 600° Fabr.; but in the new boiler the whole of the heating surface being in such close

proximity to the fire was more efficient than in ordinary boilers, where the further end of the boiler was sometimes as much as 90 feet distant from the fire, so that much of the surface could receive but little heat. The draught was much keener in the new boiler than in an ordinary one, and they had had some difficulty at first in so far checking it as to burn only the same amount of coal per square foot of grate as in ordinary boilers; but this difficulty had now been overcome. No doubt a reduction in the temperature of the waste heat would be advantageous, and it could be obtained by increasing the area of firegrate, so as to burn the coal more slowly and thereby give time for a little more of the heat from the fire to be retained by the boiler.

The practical result obtained with the new boiler at their works had been that it had effected a saving of 20 per cent. on the total cost of coal for raising steam: and in consequence of the capacity of the boiler for generating a high pressure of steam with perfect safety, they were now about to make use of steam of 100 lbs. per square inch pressure, or 120 lbs. in the boiler, by adding a high pressure cylinder to exhaust into the cylinder of their present condensing engine; and they intended to adhere to the cast iron boiler for the future, in place of the ordinary wrought iron boilers.

Mr. I. SMITH enquired whether the water used in the boilers at Manchester contained sulphate of lime or carbonate of lime. He could understand sulphate of lime being deposited as a scale in the new boilers and being blown out at the end of the week, as had been described: but in the neighbourhood of Birmingham the water contained besides sulphate of lime a large quantity of carbonate of lime, which was deposited in boilers in the form of mud, and where the firing was below the boiler frequently caused damage to the plates by overheating. Hence if this water were used in the new boiler, unless there were a daily blowing out of the boiler, he thought great damage would result to the lower line of balls, as there appeared no reason why the new boiler should be exempt from the same accumulation of mud which took place in ordinary boilers using such water.

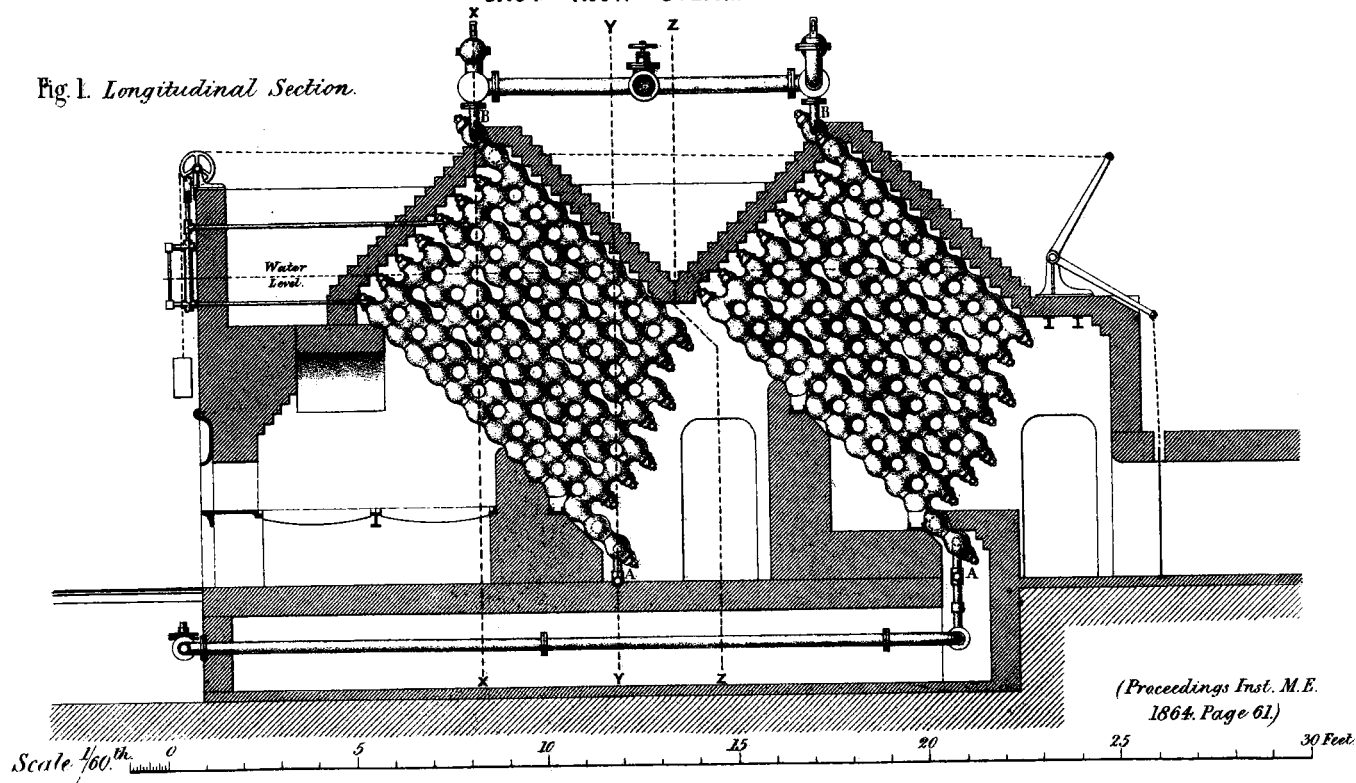
Mr. T. L. LUDERS replied that he had not any analysis of the water that had been used in the new boilers, and did not know what compound of lime it contained : the specimens of deposit now exhibited had the appearance of sulphate of lime, but he could not tell what would be the effect on the boiler if any deposit were ever formed that was elastic enough and sufficiently firmly fixed not to be cracked off the metal by the contraction of the balls in cooling. The expanding scraping tool described in the paper had been constructed to scrape out the scale in such cases if they ever arose ; but no instance of the kind had yet been met with in the working of the new boilers, but in every case the result had been the same as regarded the absence of deposit, in America, in London, and also in Manchester ; and he therefore thought there was reason to hope it would be the same in a great many other cases. In Philadelphia one of the boilers had now been working regularly for nearly two years, during which time it had only been opened once ; and another boiler there was not opened for a period of eight months, and at the end of that time the whole collection of deposit that was left from the weekly blowing out was cleared away in a few hours by simply scraping out the lower line of balls with the tool provided for the purpose. The broken casting that was exhibited from the boiler in Manchester had never been opened until broken by the hammer after eight months' constant work : and the interior surface was exactly in the same state as when broken open, showing complete freedom from scale in all parts, though the boiler had been as much exposed to the liability of forming scale as any boiler was ever likely to be.

The CHAIRMAN proposed a vote of thanks to Mr. Colburn for his paper, which was passed.

The following paper was then read :—

CAST IRON STEAM BOILER.

Fig. 1. Longitudinal Section.



CAST IRON STEAM BOILER.

Fig. 2. *Front Elevation.*

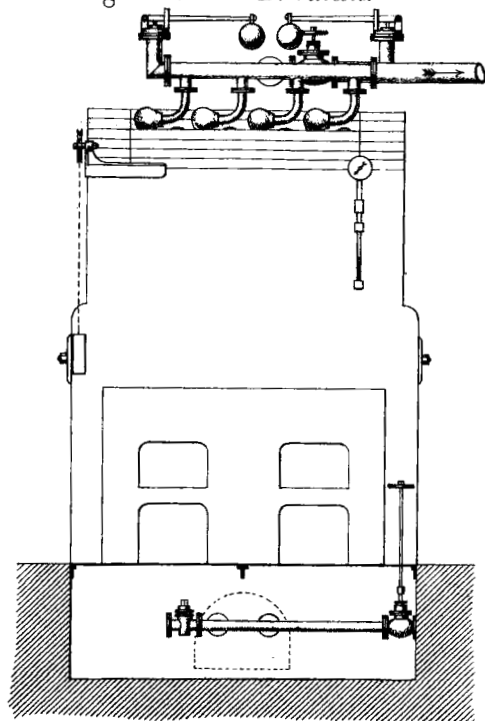


Fig. 3. *Transverse Section at XX.*

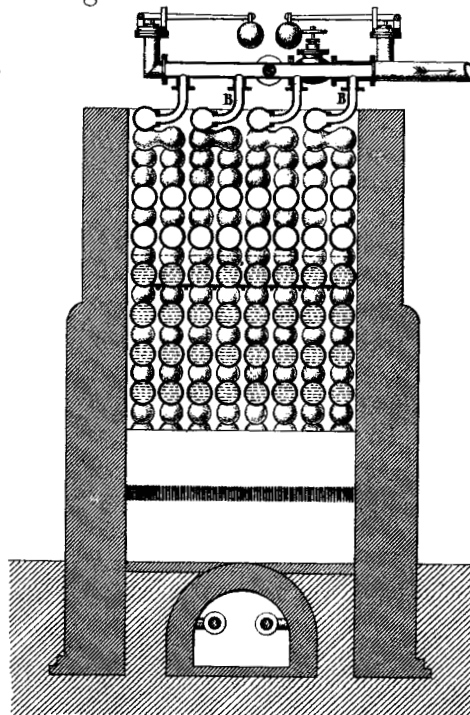


Plate 20.
Fig. 4. *Transverse Section at ZZ.*

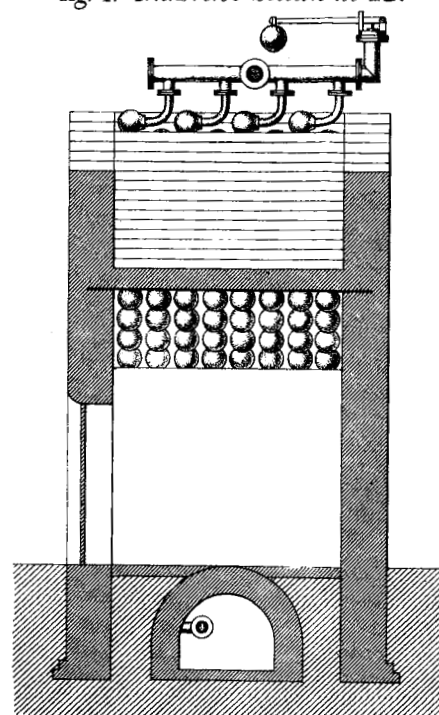
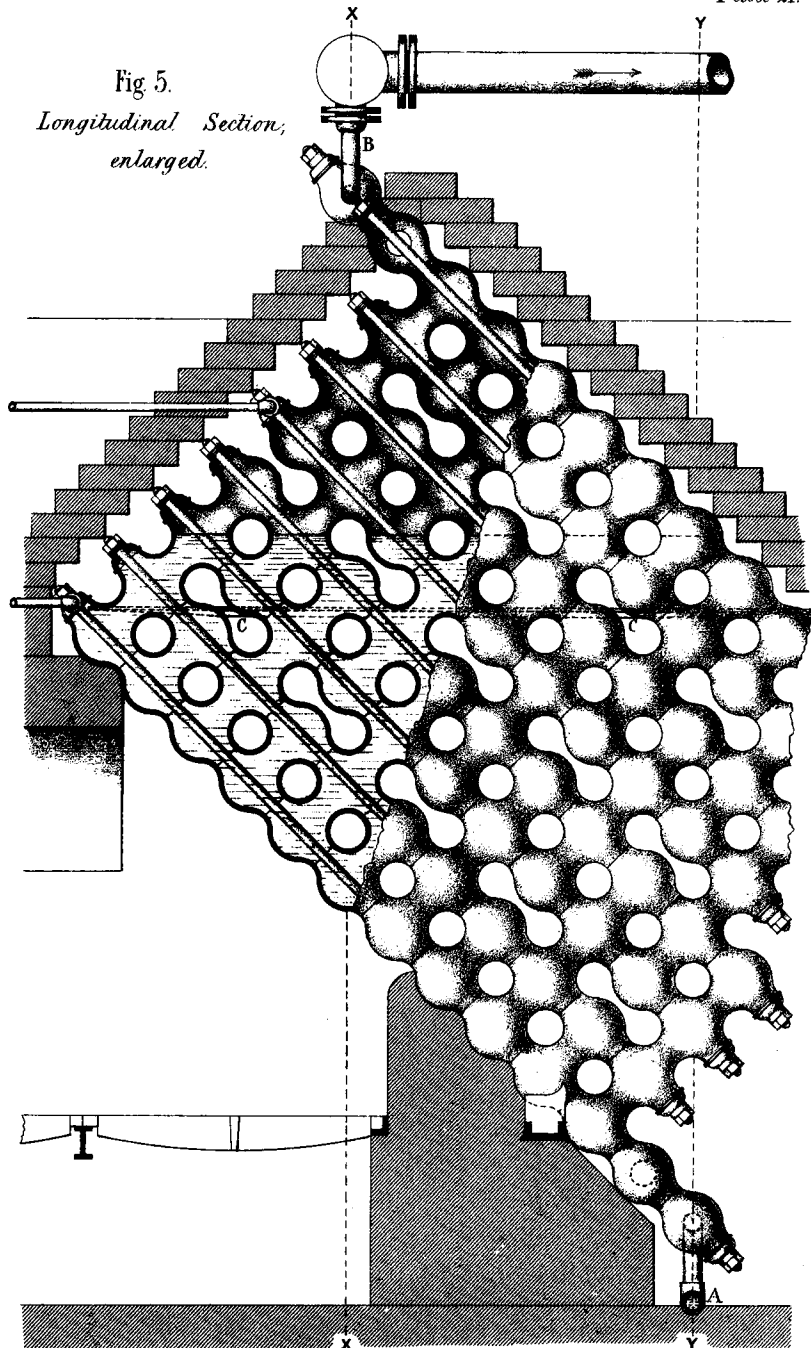


Fig 5.

*Longitudinal Section;
enlarged.*



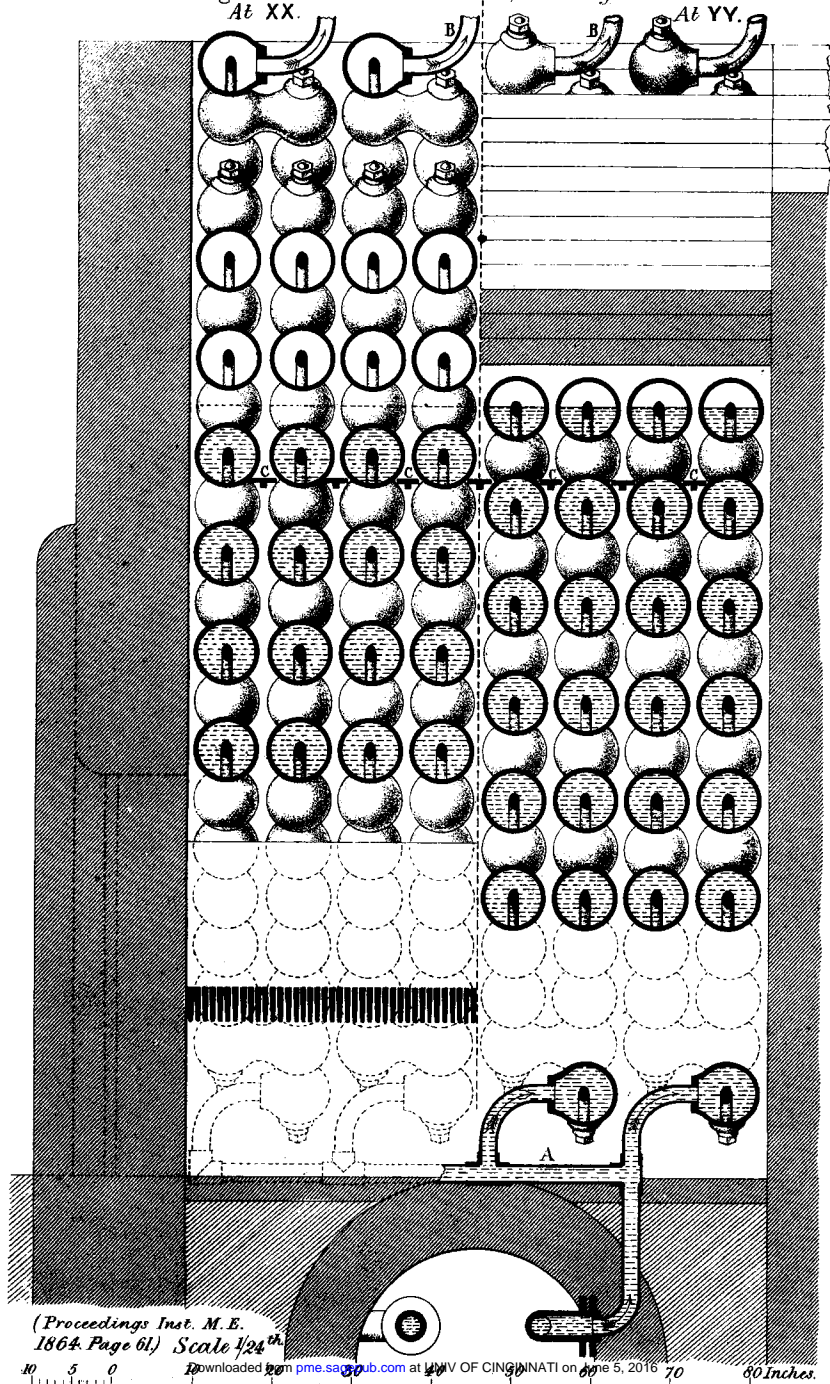
(Proceedings Inst. M. E. 1864. Page 61.)

Scale 1/24th.

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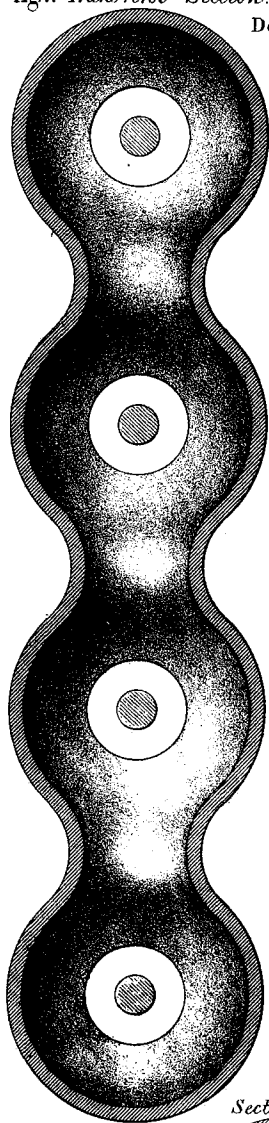
CAST IRON STEAM BOILER.
Fig. 6. Transverse Section, enlarged.
At XX.

Plate 22.



(Proceedings Inst. M. E.
1864, Page 61.) Scale $\frac{1}{24}$ "

Fig. 7. *Transverse Section.*



Detail of one "Unit"
of Boiler.

Fig. 8. *Longitudinal Section.*

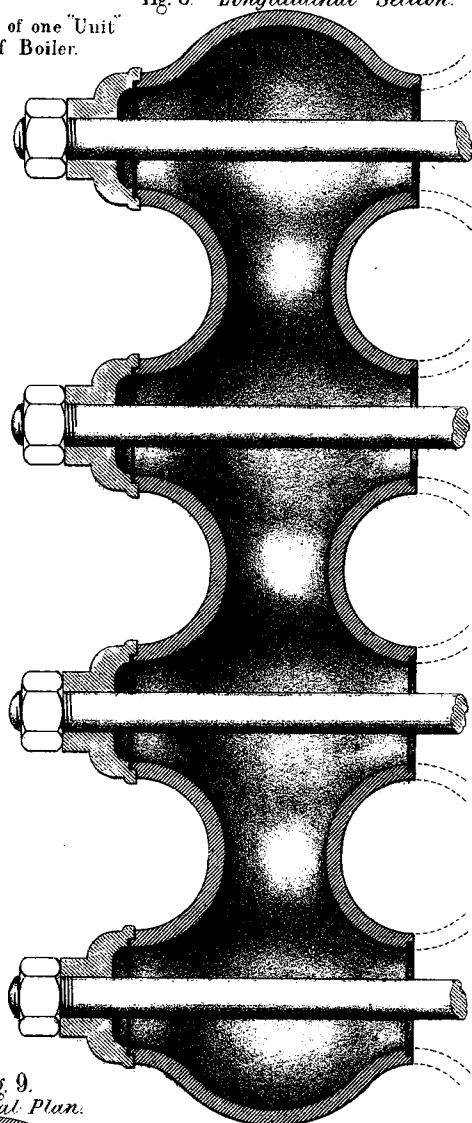


Fig. 9. *Sectional Plan.*

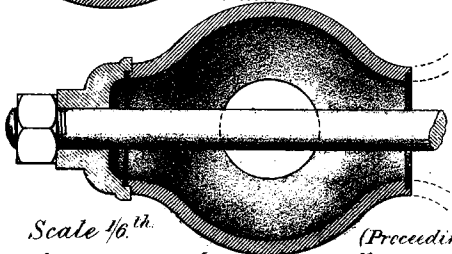
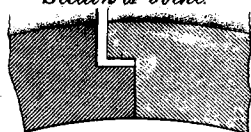


Fig. 10. *Full Size Section of Joint*



Scale $\frac{1}{6}$ in.

(Proceedings Inst. M.E. 1864. Page 61.)

