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Chairman – Mr. G. H. Burrows, A. M. I. Mech. E.

" BOILERMAKING, "

BY

L. DYER.

With Discussion.

It was not the intention to analyse in this paper the different materials from which steam boilers were made in their earlier history, but to make a few remarks as to boilermaking generally, from the earlier date to the present time.

It was recorded that when boilers were first made for the generation of steam they were of cast iron. Such were the boilers of the " Marquis of Worcester," " Savory," " Newcomen," and others, but probably none of these were subjected to any other than atmospheric pressure. Next came " Wolf," with his horizontal cast iron boilers made in segments, similar to those which had only recently been brought before the public as water tube boilers.

Wolf's boilers were composed of nine cast iron pipes, about one inch diameter, filled with water ; immediately over these were placed two more tubes, also of cast iron, the latter acting as steam receivers. It would appear that Wolf's boiler would resist a very high pressure, and could certainly claim at that time freedom from a disastrous explosion, but its use was discontinued shortly after an investigation that took place in 1817 in consequence of a fatal cast iron boiler explosion at London in 1815. The Parliamentary Committee which sat to investigate the matter recommended, among other things, that boilers should be made of wrought iron or copper.

A Yankee boiler, made by Mr. Joseph Harrison, was introduced about 1864, and was described in a paper read before the Institute of Mechanical Engineers in 1864 by Mr. Colborn. It was discarded after trials in England, being found unsatisfactory.

It was on record that Mr. Brindley, a Cornish Engineer, made a boiler of stone with internal copper tubes, the boiler being 20′ × 9′ × 8′ 6″, containing three copper tubes 20″ diameter ; and a Mr. Watt made a wooden boiler with a return copper tube, and worked it at the high pressure of $2\frac{1}{2}$lbs. About that time (1820) small wrought iron plates came into use for the construction of steam boilers, and as boilermaking at that time was found rather a difficult task, the softer material enabled the workmen to perform better work. In 1840, the work or trade of boilermaking became divided into two parts, viz. :—Plating, and riveting and caulking. Thus it continued for some time ; but as work increased so rapidly it had again to be sub-divided, some men taking one part of the trade and some the other.

About 1830, wrought iron came generally into use, and had held its own up to the present day, but it was more expensive than steel.

Strength was the first quality to be sought for in a good boiler plate to withstand without injury the sudden shocks and strains which the boiler would necessarily have to bear in its every day work, and toughness and ductility, combined with great tensile strength, its appearance when broken being fibrous, tough, fine, silky, close grained and uniform in texture. These properties, if found, would prove it to be of good iron, suitable for highly pressed boilers. Although plating and boilermaking were essentially the same trade, a plater may not be able to work on some portions of boiler work, especially repairs. A boilermaker may become so used to certain work that he would appear quite awkward if put to some other class of work. In modern shops, however, men were engaged as template makers, platers, riveters, angle iron smiths, caulkers, stayers, tubers, and hydraulic press men.

There were few branches of engineers' work to which so much patient study had been devoted, and which were so full of interest to the Chief Locomotive Engineer as that of boilermaking.

Boilers made of iron were more subject to corrosion than steel boilers, due to the water making its way inwards. This would remain quite undetected but for periodical examinations, while acting injuriously on the strength of the plates. The only corrosion to which steel was subject occurred on the surface, where protective methods could be adopted. There were a few exceptional cases of " pitting," which were attributed to chemical action.

Steel plates were now almost free from laminations, and this was greatly in favour of steel being used as a material for boilermaking. Grooving, which took place just above the foundation ring, went on with iron or steel.

Boilers in 1866, and for some time after, were of good iron, such as " Lowmoor," " Cooper " or " Bowling " iron, and worked at high pressure. Subsequently, steel was used for the wrapper plates and iron for other parts of the boiler ; but this practice gave way to the exclusive use of steel in all boilers.

Riveting by hydraulic pressure was extensively adopted now, being better known than pneumatic rivetting, and many different machines had been devised to perform all classes of rivetting. The cost of rivetting was certainly thereby reduced from quarter to one half and the work was very much better.

Dr. Siemen reported in the " Engineer " in 1878 :—

" I lately had an opportunity of witnessing at Swindon an attempt to burst an experimental steam boiler, representing a barrel of a locomotive. The internal diameter was 4′ 4″, made of $\frac{1}{2}$″ steel plate rivetted with $\frac{3}{4}$″ rivets, $2\frac{1}{4}$″ pitch, the joint being double-butt stripped and the workmanship extremely good (Fig. 1).

" At a pressure of 728 lbs. per square inch the end plate cracked between the rivet holes for a considerable distance round the end plate A. At 795 lbs. the increase on the original diameter of the barrel at the parts B, C and D was $\frac{1}{2}$″, whilst at the bands EF it was only $\frac{3}{16}$″. The hole in the top plate, into which was screwed the connections and pressure gauge, was stretched oval and the leakage at the crack and joints was so great as to completely overpower the pumps.

" This experiment would seem to indicate that in consequence of the great stretch of the material, the leakage at the joints in steam boilers, although double-butt stripped, would give warning of the excess of pressure long before bursting point was reached."

The features of a good steam boiler should be good materials, good

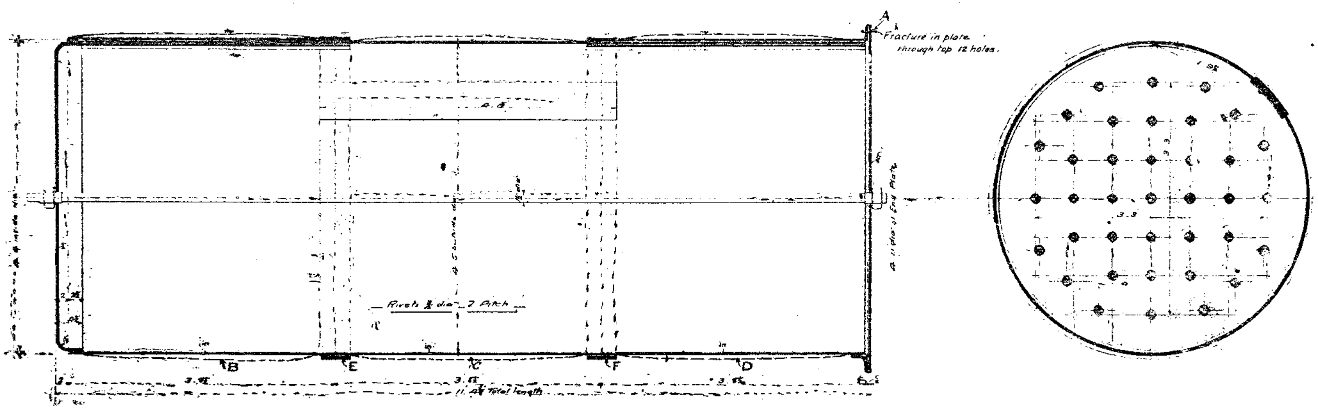

Fig. 1.—Experimental Steam Boiler.

workmanship, a large amount of effective heating surface, complete combustion of the fuel, free circulation of water, equal expansion and simplicity of form, combined with strength, and accessibility for cleaning and repair. Good circulation was essential, not only to free steaming, but also to reliability and freedom from cracking and leaking, and was obtained by wide water spaces around the firebox, wide spacing of tubes and freedom from sharp bends that impeded the flow of the water.

Overheating may be due to several causes, collection of scale, sediment, or restricted circulation, which prevented water from replacing steam as rapidly as it was generated, or to forcing the boiler beyond its power. The length of tubes or the manner in which they were secured to the plate had little or nothing to do with it, but the spacing of the tubes, length and depth of firebox, and the width of water ways around the firebox were mainly responsible.

As the evaporation of steam took place around the firebox more rapidly than anywhere else in the boiler, the flow of steam upwards in the water spaces was so great that there was little downward flow of water, therefore the water that got into the water spaces must come from the front through the spaces between the tubes and at the sides of the boilers.

The increased length and decreased depth of fireboxes introduced three or four years ago, as compared with the G.W.R. 3001 class and the first lot of Belpaire boilers, had increased the demand for water in the spaces and decreased the space through which it was assumed to flow. The heat creating this flow had not increased the circulation, consequently over-heated sides and leaky tubes and stays would be the result ; hence periodical and practical examinations were required.

The introduction and erection of water softening plant at various points on the line ought to be a considerable advantage to highly pressed boilers, and the effect of using soft water instead of hard ought to outweigh the cost of laying down the plant, whatever the expense may be.

The advantages gained through being able to obtain pure soft water were too well known to need enumeration. It was, however, only of late years that steam users had been giving the subject the attention which it undoubtedly deserved. Formerly, no matter how much they suffered pecuniarily from incrustation of their boilers, they had usually been satisfied with the use of " Boiler Fluids," which, more often than not, were of a corrosive nature. But an awakening of interest in the subject of hard water had resulted in the demand for efficient water softening appliances.

The " Albion " class of boiler (Fig. 2) was one of the best boilers made by the G.W.R., and had given the best results, having throughout the journey from Paddington to Exeter maintained full pressure under a heavy load. It was a well designed scientific boiler, and appeared to comprise every essential that went to the making of a good boiler. It was open at the throat, had a good circulation, free from sharp bends which impeded the flow of water, proper spacing of the tubes, a large heating surface, complete combustion and equal expansion. Its strength and reliability were guaranteed by good material and workmanship.

In the manufacture of a modern boiler in the G.W.R. Works, the first operation was to thoroughly examine and test every plate before it was put into the boilermaker's hands. The plates were then worked out in full size, or by using templates for the purpose, then shaped, and sent to the hydraulic press and rolls, to be bent into the various shapes necessary. They were then marked off (every hole being drilled), and after being trimmed at the edges by circular and band saws, planing and milling machines, were annealed and set to gauge ready for the platers to put together.

The plates were rivetted together by a powerful hydraulic rivetting machine, with a pressure of 1,500 lbs. per square inch, or about 43 tons on the rivet. After the firebox was placed into the casing shell and rivetted there, the drilling, tapping and staying was done, and the whole shell was put together for the last time, the rivetting being finished by hydraulic means, and the caulking by pneumatic hammers.

The last operation of tubing, etc., was of great importance, and men were specially trained for this work. After the tubes had been carefully examined for defects, cut to length and ground at the ends, they were put into the boiler, expanded, and beaded by tools driven either by compressed air or electricity. The boiler mountings were then fixed and the finished boiler sent to the Testing House.

With regard to the staying of the boiler, the bars from which the stays were cut were delivered in lengths of about 14 feet. These were thoroughly examined for flaws or laminations, then tested, and after receiving a certificate of good quality, were cut up into suitable lengths with small circular saws. After being straightened in rolls they were then centred and the middle part cut out and the ends chased in lathes. The thread was gauged, the ends drilled, and the stays were stamped with numbers to identify the makers in case of failure.

The tapping of the holes and the fit of the stays were carefully checked by a responsible man, the rivetting being done by pneumatic revolving tools specially designed for the purpose.

Recently a boiler of this class was steamed and tested, and not one stay out of about 1,100 was leaking. It was probable hand work would soon cease and the plant employed for up-to-date boilermaking would by electrical, pneumatic and hydraulic power automatically perform the operations of cutting, shaping and preparing the material, conveying it to its place and placing it into boilers in course of construction.

The Author, in conclusion, acknowledged the courtesy of the Manager of the G.W.R Works in sending some specimens of work, as well as some modern pneumatic machinery for drilling, rivetting, and caulking for inspection at the meeting.

DISCUSSION.

Mr. G. H. Burrows, Chairman, said that with the present state of efficiency and the future development the Author had pointed to, there appeared to be a good time coming for the boilermaker. He was glad to hear what the Author had said about G.W.R. No. 1 Standard Boiler, but this boiler could not be very well compared with Nos. 2 and 3. No. 1 was the best for one class of engine, while the other two classes were better suited to different types of engines. The Author had not said much about iron stays in the place of copper. Iron stays had been found unsatisfactory, but he believed some had been tried recently, and would like to know the result. Copper stays were the reverse of iron, in that the ductility of the latter increased with the life of the boiler.

The Author replied that a few iron stays had been put in some time ago, but their use had been discontinued. Iron and copper stays had been used alternately, but the result was not satisfactory.

Mr. W. A. Stanier said he had had a good deal to do with the upkeeping of boilers, and from that point of view related a few practical difficulties in connection with the steaming and circulation in boilers. G.W.R. No. 1 Boiler was a good boiler, but so was the boiler of G.W.R. Locomotive No. 98, which gave good results last year. He instanced a case where that engine, in taking a train from Paddington to Bristol in two hours, with a load of fourteen eight-wheel carriages, maintained her full steam, in fact was blowing off the whole distance. There had been trouble with the bottom corners of the fireboxes, this part of the boiler leaking sometimes very considerably. Was this due to the square foundation ring ? He hoped the Author would have said something about the flanged ring, and asked the Author's opinion as to which was the better and cheaper in the long run. The use of soft water for boiler purposes was of great importance. Since the adoption of a small water softening plant at Paddington the boilers of the G.W.R. " Kruger" Class (2601) engines had given no trouble, whereas previously they were a source of great inconvenience. After running for eight months, the boilers showed no scale and not a single stay had given trouble.

The Author replied that most of the leaking at the corners of the firebox was due to the unequal expansion which existed in the working of a boiler. The flanged ring referred to was an old idea, and every now and then was tried as something new. Where this ring was used the grooving in the plate was so excessive, and the difficulty in repairing so great, that it was not economical. He had not known one to last more than about two years.

Mr. Stanier remarked that the ring to which he had alluded was of a different section at the corners, being deeper at these points. The lower portion was reduced in thickness, being flush on the outside ; whereupon the Author said that that was the best ring it was possible to use. It was carried down at the corners, as described, to get the proper number of rivets in without difficulty.

Mr. W. H. Pearce asked the Author to give some information as to the result of the combined copper and iron stay, in which the copper stay was drilled to receive a Taylor iron stay through the centre ; but the

Author could not inform him on the point, as there was not as yet a boiler on the G.W.R. fitted with that particular stay.

Mr. E. G. Wainwright said that the steel firebox had not made much headway in England, but was used entirely in America. With reference to bronze stays, he thought they were unsatisfactory. The boiler of G.W.R. Locomotive No. 10 was fitted with bronze stays, but the results were not good.

The Author stated that steel fireboxes were unsatisfactory ; two had been obtained from America, Philadelphia and Baldwin's ; also one had been made with Bolton steel, which went to Tondü, and did very well for a time, but soon gave trouble. He was sent to Tondü owing to a long report of leakages ; these were stopped, and he remained there for a day before returning to Swindon to report on the boiler. On reaching home he was informed that since he left Tondü the Bolton steel box had split down one side for a length of 4′ 6″, the crack being $\frac{1}{16}$″ wide. The American steel was not good, for the plates would rip up in a most peculiar manner. Ten boilers had been recently made at Swindon with steel fireboxes and had been worked very hard. The thickness of the plates when put in was $\frac{3}{8}$″, and in less than nine months was reduced to $\frac{5}{16}$″. Consequently new sides had to be put in. The steel plates would not stand the fire like the copper. Bronze stays, although stronger in tensile strength than copper when first put in, would not stand the fire, and became brittle. If bronze stays were to be used they must be kept out of the fire.

Mr. W. Russell observed that expanding tubes caused the crown of the box to rise $\frac{1}{2}$″ from end to end ; he would like to know what effect this had on the side stays.

The Author replied that the stays sometimes were found broken at the top, but they would break elsewhere. The expansion of the tubes was bound to raise the crown slightly, but this was never more than $\frac{1}{4}$″. When a boiler was being " tubed," two rows of stays were always left out until after the crown stays had been fixed. In reply to another question by Mr. Russell, the Author said it was necessary to take out side stays when re-tubing.

Mr. C. B. Collett, referring to the drawing of G.W.R. No. 1. Standard Boiler (Fig. 2) said it appeared to be a most difficult undertaking for the boilermaker to mark off and cut the plates to suit so many different curves and bends. No doubt it gave the draughtsman much trouble to get out the plates for that boiler, but he thought the work in the plates themselves was far more difficult. The construction of this boiler could only be carried out in a modern shop and with good workmanship. Bad water was a source of trouble in boilers, but in this respect much had been done of late to overcome the difficulty. Faulty material was sometimes to blame in the failure of a boiler ; and of course the design was not always blameless. Some time ago he was showing an American gentleman round the Boiler Shop at Swindon, who was astonished to learn that copper boxes were being used, and was surprised to see so much repairs. He asked the American how he repaired the steel firebox, and was told that a new box had to be put in, as a boiler was never patched. He (Mr. Collett) agreed with the Author as to the use of copper stays where they came in contact with the fire, but approved of the upper stays being of bronze. The boiler of " La France " (No 102) was fitted in this manner, and the new boilers which were on order would be similarly fitted. French engineers had copied our idea for their boilers in this respect. Flexible stays were numerous, but not successful. Experiments were being made with what appeared to be a good stay, " The Broughton," which was made in four pieces. The cup stays for the crown had been discontinued. Taylor iron stays were being tried again, and he had noticed a curious effect with these iron stays, for if, after having been used for some time, and when the copper firebox was removed, the stay was not rigidly fixed in the casing, it could be bent double, whereas, if firmly held, it would break off like a carrot upon being knocked.

The Author stated that Americans used steel $\frac{5}{16}''$ thick for their fireboxes ; the boilers were larger and the stays were closer together. The fuel used in America being chiefly wood, had a different effect on the plates.

Mr. J. H. Shepherd said the fact of stays being sometimes knocked off with a hammer, as mentioned by Mr. Collett, was due to the thickness of the plates. The Americans, as was stated, used thinner plates ($\frac{5}{16}''$). The Americans also were able to knock off stays, and this occurred in the region of the bottom of the throat and foundation ring. The stays used in America were of Taylor iron, the plates were steel of their own rolling, and expansion stays were made of iron. As to throwing away boilers, he thought they only threw away the wrapper. With regard to the reference which had been made to the water in use at Reading, he was pleased to say that a softening plant was to be fixed for that district.

The members were then invited to inspect various samples of boiler-making and modern boilermaking tools, kindly lent by Mr. H. C. King (Vice-President).

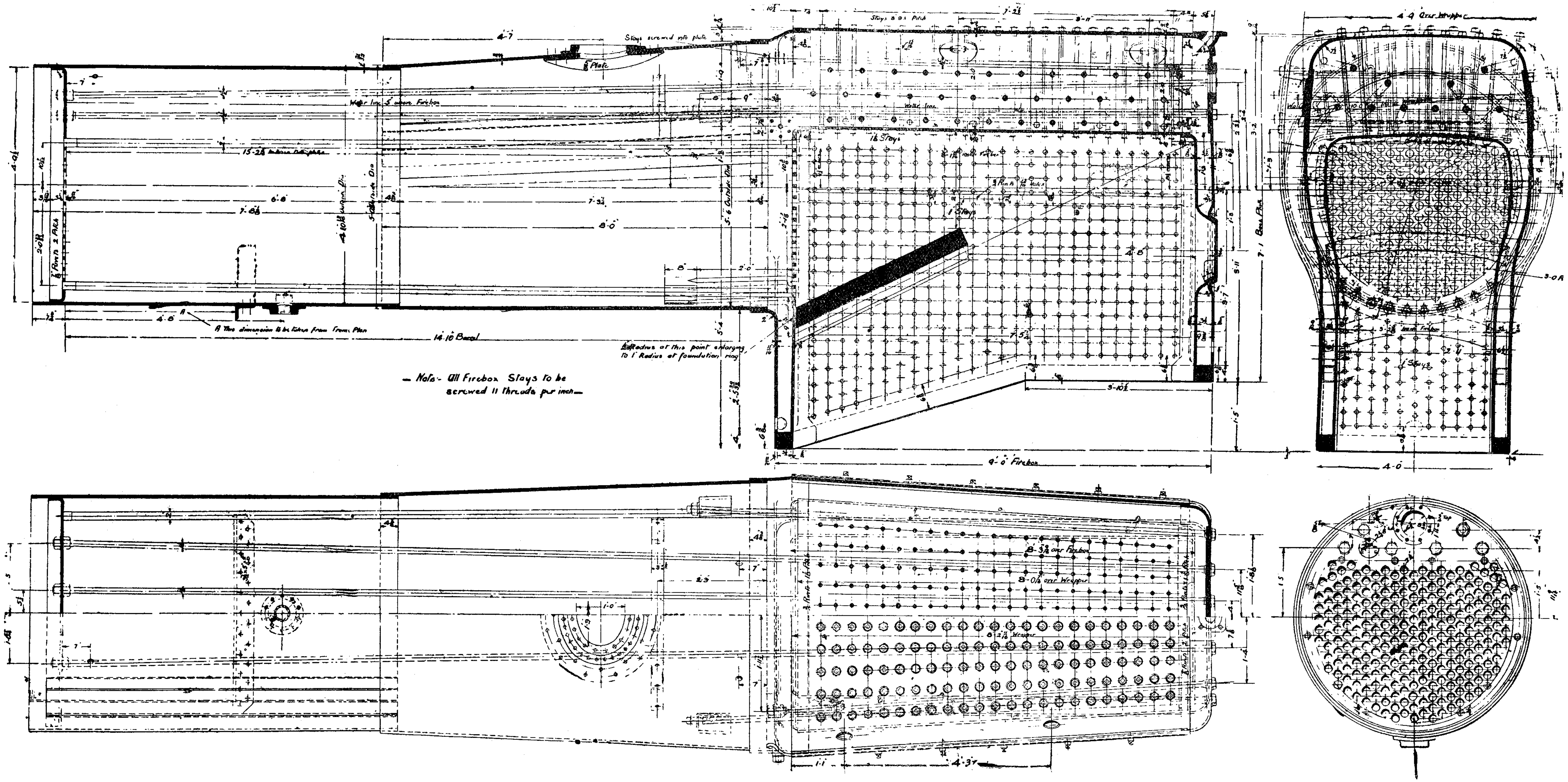

Fig. 2.

"Albion" Class or Standard No. 1. Boiler.

Heating Surface—250 Tubes 2" dia.	..	1988·65 square ft.
Firebox ..	..	154·26 ,,
Total	..	2142·91 ,,
Firegrate Area ..	..	27·07 square ft.
Area at Water Line ..	..	102·25 ,,
Steam Space ..	..	97·68 cubic ft.
Flue Area ..	..	4·37 square ft.
Working Pressure ..		225lbs. per square in.