ON THE CONSTRUCTION OF SAFETY VALVES.

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Attention has been called to this subject by the occurrence of deplorable results from explosions of steam boilers caused by defective construction and working of the Safety Valves; and the object of the present paper is to consider the past construction of safety valves,—to illustrate and describe those valves which have hitherto been in most common use,—to indicate the principles upon which safety valves should be constructed,—and to illustrate and describe a valve which, by combining those principles, has proved itself practically successful.

Of those safety valves which have hitherto been in most common use, Figs. 1 and 2, Plate 22, represent the ordinary safety valve, which until recent years may be said to have been the only one in common use. It is the most primitive conception of a safety valve; consisting of a seating, with a plain moveable valve resting upon it, and a lever with a weight or spring attached to the end to give the required load on the valve for the purpose of counteracting the pressure of the steam underneath it. Two forms of the moveable part of this valve are shown: namely Fig. 1, guided in the seating with three wings, and Fig. 2, with a central spindle.

In this construction of safety valve the following points may be noted:—

1st.—The seating is of brass, let into a cast-iron cover. As both metals are subject to the same temperature in the working of the boiler, the brass metal will expand twice as much as the cast-iron, and an undue compression and possible distortion of the brass seating will ensue.

2nd.—The moveable part of the valve being guided in its motion by the brass seating, if undue compression or distortion of the seating should take place, this part of the valve—the critical part of it—may be either irregularly guided and therefore "jammed," or it may be "nipped" or held fast. It is clear, whatever the precise result may be, there is always in this construction a possibility of irregular agencies of this nature coming into play and disturbing the mechanical accuracy of the valve.

3rd.—When this valve rises, it is evident that it will cease to be subject to the same pressure as when it is closed; for the moment it rises, the mass of steam which had hitherto been quietly pressing against its under surface will commence to flow in a direction at right angles to that surface, and diminished pressure against it must necessarily ensue. This is a radical defect in this safety valve, that while blowing off it is not subjected to the full pressure of steam within the boiler.

4th.—The load on the lever of this valve being capable of being easily tampered with, it cannot be considered a reliable index of the pressure of steam within the boiler.

5th.—When a spring instead of a weight is attached to the end of the lever, the increasing tension of the spring as the lever rises tends to put an increasing load upon the valve; and this, coupled with the diminished pressure on the valve after it rises, as above alluded to, causes the opening for the escape of steam to be greatly restricted, and consequently the pressure in the boiler to become increased.

As will be observed in the drawings, the lever is shown constructed with knife edges, or in steelyard fashion, instead of with joints and pins. The knife edges are a great improvement, as there is no liability in them to stick fast, while there is much greater accuracy of leverage, and much less friction. The strut being made as shown, namely in the form of a simple pin with rounded end, ensures the load being put evenly on the valve at whatever angle the lever may be standing.

In Fig. 3, Plate 22, is shown the ordinary dead-weight safety valve, hitherto used chiefly for marine purposes. Two descriptions of the moveable part of this valve are shown, namely at A, having a central spindle to guide that part in the seating, and at B, having three wings. These forms of construction are subject to the same remarks as have been applied to the valves shown in Figs. 1 and 2. In this valve a dead weight W takes the place of the lever with its weight or spring in the ordinary valve, the advantage of this alteration being that the load on the valve cannot be so readily altered, and the load is applied direct; but this is manifestly a cumbrous valve, with the addition of another guiding point to the spindle; and in the case of its application to marine purposes the load on the valve must be altered as the weights are more or less inclined by the swinging of the vessel to and fro, or as the momentum of the dead weight may suddenly exert its force at the termination of each rising or falling motion of the vessel. It is necessary for a marine safety valve to have an escape steam pipe; and one point to be carefully attended to in regard to it is to arrange for the removal of any water that may tend to accumulate in the pipe, or in the casing round about the valve, for the momentum of a body of water accumulated there, when suddenly propelled forward by the steam escaping from the opened valve, has proved peculiarly destructive.

In Fig. 4, Plate 22, is shown the Cowburn dead-weight safety valve, its principal features being the suspension of the weights below the acting surface of the valve, instead of their being piled up above it as in the above-mentioned valve, thus lowering the centre of gravity of the load in relation to the acting surface of the valve, and rendering the action of the valve itself easier; also the moveable part of the valve has no wings or central pin to guide it in its seating, but is made convex, or the segment of a sphere, so as to swing easily over the seating. But after allowing for these improvements, this valve remains subject to nearly all the other defects of the ordinary dead-weight safety valve shown in Fig. 3.

In Fig. 5 is shown Naylor's improved safety valve, as designed for locomotive purposes. This invention was intended to correct one of the defects mentioned in describing the ordinary safety valve, namely to prevent the pressure of the steam whilst blowing off through the valve from rising beyond the limit to which the valve has been adjusted; especially in locomotive boilers, where the safety valves are pressed down by levers with spring balances at their extremities, and the rising of the lever in blowing off causes a constantly increasing tension of the spring in the spring balance and consequent increased pressure upon the valve. It operates by causing the spring that presses upon the valve to act not through a constant lever, but through one which varies in its effective length; this variation being so arranged that as the valve rises the lever diminishes in length in the same proportion as the tension of the spring is increased. This valve is further intended to make it impossible for the engine driver to tamper with the spring so as to increase the pressure beyond the intended limit. It is undoubtedly an ingenious mechanical invention for accomplishing both of these objects, but it is cumbrous and expensive.

In Fig. 8, Plate 23, is exhibited Ramsbottom's mode of weighting safety valves, applied however to a new valve. This arrangement has been in extensive use, especially for locomotive purposes. The points to be noted in connection with it are—great simplicity, great absence of means of tampering with the load, convenient funnels for the escape of the steam, and a ready means of ascertaining by a touch of the lever if the valves are working freely. But this invention has not touched the cardinal defect of the ordinary safety valve, namely the reduction of pressure upon it after rising from its seat, and the consequent restriction of its opening and increased pressure of steam within the boiler.

From the above and other considerations the following principles regulating the construction of safety valves are deduced:—

1st.—It is evident that the seating and the valve should be made of the same metal, for they are required to fit each other at varying temperatures, and this can only be accomplished when the metals are alike. *Safety* being the first consideration in a safety valve, any other—such as a small economy—which may tend to interfere with the certainty of the valve's action, ought to be disallowed.

2nd.—The seating should never be made in the form of a brass bush inserted into a cast-iron cover, for the important reason of the difference of expansion of the two metals, as previously named.

3rd.—The valve should be so constructed that the *full* pressure of the steam within the boiler is always operating on it, so as to cause it to rise to the utmost possible extent when the steam is being generated freely.

4th.—The bearing surface of the valve should form the smallest possible percentage of its area; and the valve should be at all times guided evenly upon its seat. The bearing surface should be of a conical form for the highest pressures, that being the most easily kept tight.

5th.—While the valve itself should be quite open and free for inspection and trial to ascertain if it is working properly, means should be adopted for preventing its load from being easily tampered with.

6th.—In constructing the lever form of valve, joints and pins should be discarded, and the steelyard fashion with knife edges should be substituted.

7th.—For marine purposes, the direct spring-loaded valve is to be preferred to the dead-weight; and the writer may here remark it is generally understood that this principle is now being fully adopted by the Board of Trade.

Having indicated the principles which ought to regulate the constructión of safety valves, the writer will now proceed to illustrate and describe a valve which, by combining those principles, has proved itself practically successful.

In Plates 23 to 25 is shown a safety valve first invented by Professor J. Klotz of Prague, and since then improved and manufactured by the Avonside Engine Co., Bristol. It consists, as will be observed in the section, Fig. 13, first, of a seating C that is not used to contain the moveable part of the valve, as in the ordinary safety valve, but merely to fix the valve in its place, and to form the base of its superstructure, and to supply a passage for the escaping steam. Secondly, of a hollow cylindrical part D, which is raised above this seating, and attached to it by feathers, and forms the guide to the moveable part of the valve. Thirdly, of a moveable part E, which instead of fitting within the seating C, as in the ordinary safety valve, fits outside of this cylindrical part D. The cylindrical part is closed in the centre to all except a pipe F; also the moveable part E is closed at the top as usual, and there receives its load. Here is a radical departure from all previous constructions of safety valves; and the moveable part E is not actuated by the escaping steam, but by the full pressure of steam within the boiler, specially conveyed to it by means of the pipe F screwed into the solid centre of the cylindrical part D. Thus the first three and the most important principles of construction which have been indicated are embodied in this valve.

The illustration in Figs. 6 and 7 shows this valve as arranged with a lever and weight for stationary boiler purposes; that in Fig. 8 with Ramsbottom's lever and spring for locomotive purposes. A specimen valve is exhibited on the table.

For marine purposes, a new adaptation of this valve is shown in Plate 24. The springs, as will be observed, are not subject to the action of the escaping steam; and means of easing the valve can be readily provided.

For locomotive purposes, the most improved adaptation of this valve is shown in Fig. 12, Plate 25; and a specimen pair of valves for a 16-inch cylinder locomotive engine is exhibited.

Professor Klotz states that experiments were made on a boiler having 272 sq. ft. of heating surface, with a $3\frac{1}{4}$ in. Klotz safety valve, so loaded as to allow the steam to escape at a pressure of 70 lb. per sq. in.; and that when the valve had been shut the steam began to escape at $69\frac{1}{2}$ lb., and it took 44 minutes of continued forced firing of the boiler, during which time the steam escaped violently from the safety valve, before the pressure was got up to 76 lb., after which it could not be made to rise any higher. Another ordinary safety valve of $2\frac{7}{8}$ in. diameter upon the same boiler was then allowed to be the only escape for the steam; it was loaded in the same way, steam began to escape at $68\frac{1}{2}$ lb., but after moderate firing during 7 minutes the steam rose to $76\frac{1}{2}$ lb., after which it rose so rapidly that to prevent danger the Klotz valve was put in operation. The correctness of the above statement has been tested at the Avonside Engine Works by a trial with two engines in the erecting shop. The two engines were similar, and had exactly the same Klotz safety valves, only the

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pressure pipes were taken away from one of them so as to change the action of the Klotz valve into that of an ordinary safety valve. When steam was up, and the firing continued, there was a very marked difference in the behaviour of the two boilers; the pressure in the one with the Klotz valve could not be increased more than a few lbs., whereas in the other the steam continued to rise until it was found advisable to stop the trial.

These valves have been largely applied by the Avonside Engine Co. to locomotive boilers; and Messrs. J. and E. Wood of Bolton have also applied them, as a precaution, to the intermediate receivers between the cylinders of compound engines.

In conclusion the writer would remark that he believes this to be a most important subject for discussion at this Institution in the interests of the public safety.

Mr. WILSON exhibited specimens of the Klotz safety valves, as applied to stationary, locomotive, and marine boilers.

Mr. F. W. WEBB observed that in the construction shown of the locomotive safety valve, having the valve enclosed within a brass casing made in two separate portions, if the upper portion of the casing were sufficiently loose for a man to lift it up against the top lever, then by putting a wedge between the two portions of the casing the valve could be hermetically sealed. Having had to deal with a large number of the Ramsbottom safety valves, he had seen the disadvantages of the men being able to tamper with them, as had been done by putting a clip on two or three coils of the spring; and he had endeavoured to get over the difficulty by putting the whole in a close box, so that no one could get at the spring at all. With regard to the valve now described, it appeared to him that, if the boiler primed or stood a long while without blowing off, the two surfaces of the valve and the seating which were in contact inside might be liable to corrode; and if any dirt or mud were to get in between them from the boiler it might set the valve fast, and so deceive a person as to what the real pressure in the boiler was. He should be glad to know how it was intended to get over these apparent objections in the valve.

Mr. LEWIS OLRICK thought the valve now described could hardly be regarded as "a radical departure from all previous constructions of safety valves," because a valve very similar to this had been invented at least 14 years ago by Mr. Bodmer, who however went a little too far. Instead of making, as in the Klotz valve, a very loose joint between the valve and its seating, so that there was no actual contact between the internal circumference of the valve and the external circumference of the cylindrical seating inside the valve, he made the valve a piston working in a cylinder, and the consequence of its acting as a piston was that there was a certain amount of friction, which prevented the valve from working freely, and in practice it suffered from the very defect which had been pointed out by Mr. Webb; and he believed there were now very few valves in use of that description.

There was one point with regard to safety valves which he thought should be added to the recommendations given in the paper, namely, not to put too large valves upon boilers—rather to put two or three smaller valves on a boiler than one large valve containing the same total area. As an illustration, a safety valve of ten sq. in. area would be about $3\frac{5}{8}$ in. diameter, with a circumference of 11·38 in.; whereas with ten valves of one sq. in. area each—he did not recommend that number and size, but merely used an extreme illustration — the diameter of each would be $1\frac{1}{8}$ in., and the circumference 3·53 in.; consequently ten safety valves of one sq. in. area each would have a total circumference of 35·3 in., or more than three times the area of outlet with the same height of lift as compared with a single safety valve of ten sq. in. area.

With regard to Naylor's safety valve, this was generally admitted to be a very ingenious one, and he could not concur in the opinion expressed in the paper that it was cumbrous and expensive; comparing it with the Ramsbottom safety valve, there was not sufficient difference he thought between the two to lead to one being called cumbrous as contrasted with the other. He had a favourable opinion of Naylor's safety valve, because of having had something to do with a valve similar to it, which was the joint invention of Mr. E. Field and himself, and was on the same principle as Naylor's. In the ordinary spring-balance valve, as pointed out in the paper, when the spring stretched an additional amount of pressure was put on the valve; and consequently when the valve was set to blow off at 100 lb. pressure, an ordinary spring-balance valve might easily allow the pressure in the boiler to rise considerably above the pressure at which the valve was set. The "Paragon" safety valve that he referred to, which was illustrated in Plate 26, was provided with a double-pointed pin to keep it in position; a compensating lever of bell-crank shape was placed at the top of the pin, and the spring frame stood on the top of the compensating lever, the frame being kept down by the tension of the spring. When it was wanted to set the valve to any pressure, the adjusting nut was screwed up, and consequently the indicating pin at the top rose to the pressure desired; the drawing showed the valve set to 100 lb. pressure. The moment the valve began to rise and blow off, the short arm of the compensating lever would remain practically of the same length, whereas the virtual length of the longer or acting arm of the lever was reduced exactly in proportion to the rise of the valve. Instead of the leverage remaining the same as at first, $2\frac{7}{8}$ to $2\frac{1}{2}$, it would be reduced to $2\frac{1}{8}$ to $2\frac{1}{2}$ when the valve rose to its highest lift; and thus, although the tension of the spring was increased by the rising of the valve, the acting leverage became reduced in equal proportion, and the valve was allowed to blow off freely. An experiment had been made by Mr. Naylor with two 5 in. ordinary spring-balance valves set to blow off at 100 lb., and when they were in full play the pressure rose from 100 lb. to 145 lb.; the same experiment was carried out with only one Naylor safety valve of 2 in. diameter, and the pressure under the same circumstances rose to 105 lb. only. The two 5 in. spring-balance valves had a circumference of 15·7 in. each, giving a total circumference of 31 in.: they did not lift more than about 1-32nd in., therefore there was only one sq. in. area of opening for the exit of steam. The 2 in. Naylor valve, having a circumference of 6·3 in., rose on account of the compensating arrangement about ½ in., giving an exit of three sq. in. as compared with only one sq. in. exit afforded by the two 5 in. spring-balance valves. Although this might not represent the comparison with absolute correctness, it was sufficient to prove clearly why one construction of valve was superior to the other. The valve which he had described was quite inaccessible to the firemen or engine drivers, and there was no means of inserting a wedge in any place so as to increase the pressure. A testing lever was provided for the purpose of testing the valve, to see that it did not stick; that was a point which had not been provided for in Naylor's safety valve, but which he himself had found to be necessary. A valve of that description had been applied to a locomotive, and the men used to put their hands on the testing lever, and thereby put on extra pressure; but he had got over the difficulty simply by making the pin of the fulcrum, upon which the compensating lever was fixed, a screw, and the head of the testing lever a nut, so that the moment it was attempted to put a pressure on, the result was simply that the lever became unscrewed, instead of putting increased pressure on the valve. He might state that the Indian Government had "Paragon" valves fitted to all their Field boilers, which worked at 180 lb. pressure; and Messrs. Merryweather and Sons had used several hundred of these valves for their steam fire-engine boilers; the reason being that, the Field boilers making steam so very fast, it was found necessary to use a safety valve that could discharge the surplus pressure equally fast.

Mr. H. Chapman observed that in the marine safety valve shown in Fig. 9 the springs were said not to be subject to the action of the escaping steam. But if the spindle bearing upon the valve was made so tight a fit in the hole through which it passed that the steam could not escape there, he should be glad to know whether an inconvenience had not been found from corrosion, not merely in setting the valve fast, but also in putting on more pressure than was intended.

Mr. E. A. COWPER did not quite agree that either of the so-called ordinary safety valves shown in Figs. 1 and 2 was of the commonest or best ordinary kind. One of them was shown with a flat seat, which was pretty generally given up now, and was very objectionable, owing to its tendency to keep down when blowing hard. A number of wings were objectionable for several reasons: they caused more friction, were more likely to jam from expansion when dirty from priming, and were much more liable to stick (owing to the guide being so short and large in diameter) than with a central pin as a guide to the valve, as such a guide was long and small in diameter, as usually made and indeed as he had made them himself for many years.

With regard to the experiments made with the Klotz valve, the statement given in the paper appeared to be that of Prof. Klotz. Of the two safety valves tried, the Klotz safety valve was $3\frac{1}{4}$ in. diameter, and the common safety valve $2\frac{7}{8}$ in., the Klotz valve being thus 1-5th larger in area than the other; but on looking at the pressure to which the steam rose while blowing off, it appeared that, when the valves were both loaded to 70 lb., by firing hard the Klotz safety valve was made to give a pressure of 76 lb., and with the other the pressure rose to $76\frac{1}{2}$ lb.; so that, as far as these figures went, the smaller common valve did the best; and he should like to know the rise of pressure that actually took place. If with the common safety valve the pressure ran up to 100 or 120 lb., it might be time to leave off the experiment; but there was no statement as to how much higher the pressure ran up with the common valve than with the Klotz in either experiment. He agreed with Mr. Webb that a valve of that sort ought not to be made too good a fit, for if the boiler primed the valve would be very likely to set fast.

Mr. W. HARTNELL agreed in the opinion with regard to the new valve, that if the bell was made nearly to fit the internal cylindrical guiding portion it would probably be in danger of sticking; but if it was not made a near fit, then there appeared to him to be another objection, that the steam would rapidly escape between the two cylindrical portions of the valve, and the pressure where the steam was escaping being less than it was inside the boiler, the value of the internal pipe would be almost lost. If a pressure gauge had been attached to the internal pipe, and the pressure noted at the moment when the valve began to blow off, and then the amount of variation noted, and the same thing done with the clearance made greater and greater between the valve and the seating, the effect of the amount of clearance would have been practically ascertained.

With regard to the pressure to which the ordinary construction of safety valve of good proportions and workmanship would allow the steam to rise in blowing off, he had tried many experiments on small boilers and a few on Lancashire boilers at about 60 lb. pressure, and had found the excess of pressure seldom exceeded 6 lb. He had also tried a Lancashire boiler 7 ft. diameter by about 28 ft. length with three pendant dead-weight hemispherical safety valves of $1\frac{1}{8}$ in. diameter and one of $2\frac{1}{2}$ in. diameter, and with hard firing the steam did not rise more than 6 or 7 lb. above the pressure to which the valves were set: that trial was made at the instance of a boiler inspector. He should be glad if Mr. Webb would give some information with reference to the rise of pressure in locomotives in blowing off, whether the steam was found to rise more than in the trial he had mentioned.

Mr. F. W. Webb replied that with the Ramsbottom system of two valves 3 in. diameter he had never found the steam rise in locomotive boilers more than 5 or 6 lb. above the pressure at which the valve was set to blow off. He had made a trial recently to ascertain what area of outlet would be sufficient to relieve a locomotive boiler hard fired: with a 1 in. pipe perfectly open he had managed to raise the steam to something like 10 lb. above the proper pressure; but on taking out the 1 in. pipe and putting in a $1\frac{1}{4}$ in. pipe he could not raise the steam pressure at all.

Mr. A. Paget observed that in this question of the safety valve it was a matter of great satisfaction to hear the very clear evidence given by members of such great experience, that with the ordinary safety valve, if suitably proportioned to the boiler and properly made, the steam pressure in blowing off would not rise to the great extent that had often been supposed. He wished this fact had been more generally made known before, as a great deal of misplaced ingenuity and invention had been exercised in trying to obviate a difficulty which was now proved to be almost imaginary; for he believed that the ordinary safety valve when properly constructed would not stick fast, and would not allow any rise of pressure that could cause any danger to a properly constructed boiler. If that fact had been as well established amongst mechanical engineers, and as thoroughly believed in as it was by himself after what he had now heard, he thought a great deal of misplaced ingenuity and invention might have been saved. He was glad that it would appear clearly in the records of this Institution that men of experience, like those who had now spoken, had established the fact beyond a doubt, that the ordinary safety valve which had been so much abused was not an unreliable instrument as some inventors appeared to wish it to be considered.

Mr. W. Richardson mentioned an incident that had come under his notice in using a safety valve something like that shown in Fig. 1, only that the valve was made a segment of a sphere, without any guides below the sphere. Such a valve was applicable to stationary boilers, where levers and weights could be used; but of course it would not do for locomotive or marine boilers, on account of the shaking motion. It was admitted that there was a condition of still water in steam boilers, in which the water would carry more caloric than was due to the pressure; and when it got disturbed there was a very quick ebullition and development of steam by this excess of caloric. In the case to which he was referring it happened that the lever of one of the safety valves, with a weight at the end to produce 80 lb. pressure per sq. in., was swung clear over, liberating the valve; fortunately the guard to the lever was only an open fork, and when the engine was started the lever and weight were swung over clear away, and the valve blew out, giving a free discharge for the boiler. If therefore that force were generated from the still water containing more caloric than was due to the pressure, he considered the boiler could not have relieved itself, had not the valve blown out as it did; and there must otherwise have been some great accumulation of pressure, perhaps so much that the boiler would have required to be very strong to carry it. This which had happened in his own experience, and which might happen in other places, was one of those things which ought to be provided for. It was known that a great number of boilers had exploded just when the engines had been started after a long stoppage; there were many such cases in the history of the boiler associations, and he attributed the occurrence to the stillness of the water enabling it to carry more caloric than was due to the pressure; then the moment the engine was started and the pressure relieved, the sudden ebullition and exit of steam increased the pressure as described.

Mr. G. D. HUGHES enquired whether the Klotz valve had ever been applied with the object of preventing accidents to boilers from deficiency of water. From statistics given by the Association for the Prevention of Steam Boiler Explosions and by boiler insurance companies, he found that a great proportion of the accidents to steam boilers arose from deficiency of water from some cause or other; and from his own experience he believed that in the case of every stationary boiler, if it was to have a safety valve deserving that name, it should also provide against that frequent source of accident. There were instances in the Institution Proceedings of safety valves which had provided both for excess of pressure and also for deficiency of water.

The objections that had been urged with regard to the liability to stick between the seating and the outside of the valve now described were in his opinion very cogent; and he should be glad to hear whether the author had any suggestion to make on that point; some short time ago an accident had occurred in Nottingham in consequence of a safety valve sticking, whereby a life had been lost. It was an ordinary three-winged valve, the seating being made of cast iron bushed with brass, into which the three-winged valve was fitted. There were two of these valves upon the boiler, which was 20 ft. long and 6 ft. diameter. During the dinner hour there was a heavy fire on, and all at once one of the valves rose so high in the seating and stuck fast there that steam and water escaped and scalded the attendant to death. On examining the valves he found that they fitted very tightly into the seating, more tightly he thought than they could have fitted when originally made. It then occurred to him to try the experiment that had been tried by their Past-President, Mr. Bramwell, in the case of the "Thunderer." The boiler was standing cold, and he got some water at a temperature of 212° and placed the valve in it; and upon then putting the valve into the seating it stuck quite fast in all positions; but when the valve was cooled down to about the same temperature as the boiler, it just managed to work freely. This showed the danger of making these surfaces fit so tightly that the slightest amount of priming would cause them to stick. Great care should be taken to give them sufficient liberty, seeing that the mere difference of expansion in the metals might cause the wings of the valve to stick fast.

Mr. T. ADAMS observed, with regard to the relative expansion of brass and cast iron, that a number of experiments had been made on this subject by the Board of Trade, and it had been found that the expansion of brass was not so much as double that of cast iron. The expansion of brass varied a little with its composition; the composition which he always used was 1 lb. of copper to $2\frac{1}{4}$ oz. of tin and $\frac{1}{2}$ oz. of spelter. The experiments were made with the metal at a temperature of 66° Fahr., at 212°, at a temperature represented by 50 lb. absolute steam pressure, and at a temperature represented by 100 lb. steam pressure; and from the results obtained could be deduced rules which would suit any temperature. At 212° the expansion of brass above cast iron was as 1·46 to 1, and at 100 lb. pressure it was as 1·60 to 1. The expansion of the seating was not simply as its diameter, but was nearly in the ratio of the difference between the inner and outer diameter; and in consequence of this relation he had made a 3 inch seating expand as much as a 6 inch seating by simply making the thickness of the metal greater in the 3 inch than in the 6 inch seating.

The ordinary safety valve he did not consider could be regarded as free from danger; there was sufficient proof that with the ordinary safety valve set to 60 lb. pressure, and with hard firing, the steam would rise to 120 lb.; and there was danger in that surely. Having just finished a calculation of the arrangement of the valve gear of the "Sidonia's" boiler (which burst a little while ago), he found that the action of the lever vanished at $1\frac{1}{2}$ in. rise of the valve, that is that the fulcrum of the lever and the joint of the stud bearing on the valve would then be in the same vertical line, so that the valve could not be made to lift higher with any amount of force. For the guiding of the ordinary safety valve he did not consider that a central pin was better than feathers. A given amount of clearance was necessary in each case; supposing, for example, the clearance was 1-32nd inch in the pin; then when the valve rose up from its seat, if it shifted from its central position the spindle would come against the guide at the bottom and against the pin of the lever at the top, and it acted with a leverage at that point, throwing the valve considerably further out of the central line. With feathers that was not the case, because the feathers guided close against the seating; therefore whatever was the clearance with the feathers, the valve could not go farther from the central line than that. In the paper now read it had been proposed to indicate the correct principles upon which safety valves should be constructed; but he did not consider that any of the safety valves shown in the diagrams were constructed upon the correct principle, which he believed to be that the force, the resistance, and the motion should all lie in the same straight line. With any system of levers the valve moved always in a straight line, while the levers moved in a curved line; consequently there was no correct principle in that mode of construction. The double conical spring shown in connection with the Klotz safety valve appeared to him a very objectionable form: the strength of a helical spring was as the diameter of its coils, and in the double conical spring here shown the central coils were double the diameter of those at the extremities; the proper method of constructing a helical spring was parallel, so as to be of equal strength throughout. It had been stated that the Klotz valve had been applied on board ship; but he was not aware of its having been passed by the Board of Trade, and he thought the internal pipe would prevent it from being passed, as also would the internal cup. The most beautiful point about Ramsbottom's valve had not been mentioned either in the paper or in the discussion, namely that, instead of the hole for the spring attachment being precisely in line with the points of the studs bearing upon the valves, it should be made slightly below that line, for enabling the lever to act properly; then if the action of the valves were not exactly true, and one valve happened to rise before the other, the spring attachment would be brought nearer to the valve which rose and further from the one which did not rise, thereby increasing the pressure upon the former and at the same time relieving the latter. In a large number of the valves which he had constructed on that principle, he had made the hole for the spring attachment 11-16ths inch below the level of the bearing points of the studs upon the valves. Naylor's valve, which was said to be the best arrangement for the liberation of steam from the boiler, had been surpassed at the present day, but was a very good one at the time of its introduction; the worst feature of it was, he thought, that the steam in escaping destroyed the spring by gradually cutting it away. As to dead-weight safety valves, the best construction of dead-weight safety valve that had passed through his hands had been found to allow 17 lb. increase of pressure in blowing off, when set to blow off at 60 lb. in accordance with the Board of Trade rule for that size of valve. That was the best type of ordinary valve that he had met with; but there were many ordinary safety valves that allowed much greater increase of pressure in blowing off.

In the construction of helical springs, whether for safety valves or for other purposes, the proportions that he had found most advantageous in all cases were $11\frac{5}{8}$ to 3 for the ratio of the length or height of the spring to its external diameter; the pitch of the coils 29 per cent. of the diameter of the coil; and the side of square steel or the diameter of round steel 1-6th of this diameter. The deflection of such a spring under 1-6th of its breaking load would amount to 1-3rd of its diameter, when made of square steel, and to about 1-8th less when made of round steel. These proportions held good for any range that might be required in the construction of helical springs: so that, in the case of one spring half the size of another, the small spring would be exactly half the diameter of the large one, exactly half the length, and exactly half the pitch, and it would be one-fourth of the section of metal; and the load upon this half-size spring would be one-fourth of that upon the full-size one. The Board of Trade formula for the strength of helical springs for safety valves, deduced from a series of experiments with 400 springs, was $\sqrt[3]{\frac{L \times D}{C}} = d$, where D was the helical diameter of the spring in inches, L the load in lbs., which was not to exceed 1-6th of the breaking weight, *d* the side of square steel or diameter of round steel in inches, and C a constant, which was taken to be 8,000 for round steel and 11,000 for square steel; this formula held good both for compression and for extension of the spring. Square steel was superior to round steel whether for strength or elasticity; it was 12 per cent. more elastic than round steel, and about as much superior in strength; it was in every respect the superior spring of the two.

Mr. E. B. Marten agreed with the previous remark that too large a safety valve was not good; and a larger valve than was necessary was a source of danger. He had some experience with large safety valves, and had seen safety valves of 2 ft. diameter: in that case however the weights were so large that when the valves did blow they caused jerks in rising and falling, and created more danger than that they were intended to provide against. He had more experience with the ordinary safety valves than with any other, and agreed that there was more safety in them than was generally supposed; otherwise there would have been many more explosions than had occurred. It was almost astonishing how well the ordinary safety valves did relieve the pressure, provided they were kept in anything like decent order. But they were frequently, even habitually, overloaded; when they were blowing off at the full pressure, it took a little more load to shut them: that was the reason why they were so often overloaded; yet as a rule they were what they were described to be, tolerably good safety valves.

Mr. WILSON explained, with regard to the specimen exhibited of the locomotive safety valve, that the two portions of the brass casing enclosing the valve were fastened together by two screws round the rim, so as to prevent any separation of the two portions from each other. They had originally been constructed with one half screwed into the other; but the objection to that plan was that a man might partially unscrew them and so jam the upper one against the lever; they were therefore now made to fit one within the other without any screwing. There was thus no possibility of getting a wedge in to separate them; and though he had once thought of bringing a flange from the casing a little over the valve, which would entirely prevent the chance of anything being put in, it seemed now unnecessary to do so.

With regard to the surfaces of the valve and seating sticking fast with priming of the boiler, it must be borne in mind that the valve and the seating were both made of the same metal, so that they both expanded alike; and the one was made an easy fit over the other. These were conditions which he thought were the best possible for preventing sticking or jamming of any kind.

With regard to priming, boilers ought not to prime if they were properly constructed; but the Klotz valve would act equally well if water went up the pressure pipe instead of steam; it was not a necessity that there should be steam up the pipe, and if the pipe were carried down into the water of the boiler, the results would be equally good. Moreover the rubbing surfaces of the valve and seating were vertical surfaces, which were the best possible form for letting away any water that might get in or any dirt or scum that might get between the two surfaces. If they had been horizontal rubbing surfaces it would have been very different.

He agreed that it was undesirable to put large safety valves upon boilers; in his own experience with locomotive engines he found that 3½ in. diameter was the largest size of valve required for the largest locomotive engine. Even that size he thought might be safely reduced; and the smaller the valve the more desirable it was. In this respect he thought the Klotz valve possessed a great advantage, the escape of steam from a valve of small size being so very free that a smaller valve might be put on of this construction than of the ordinary make. Naylor's valve was an indirect way of arriving at that which was so simply arrived at in the Klotz valve; the bent lever in the Naylor valve required to be very accurately made and adjusted, as did also the spring; and that arrangement was used for the purpose of obtaining what was effected in the simplest manner by means of the pressure pipe in the construction of the Klotz valve: in comparing these two valves therefore he thought one might certainly be spoken of as cumbrous and expensive, while the other was simple and economical.

In reference to the experiments with the Klotz valve, the statements in the paper were those of Prof. Klotz himself. In the experiments at the Avonside Engine Works the result was simply that with the Klotz valve the pressure could not be made to rise in the boiler more than 6 lb. above that at which the valve was set to blow off. In regard to the pressure with the ordinary valve rising to a dangerous extent, the boiler was being tested to 140 lb., and the pressure was running up so rapidly that it was thought wise to stop, as everything was getting very hot, and there might not have been sufficient control over the pressure. The Klotz valve had not been applied in connection with low-water regulating apparatus; it had been used hitherto simply as a steam-pressure safety valve for stationary and locomotive boilers, and for the application made by Messrs. Wood to the receivers of compound engines.

With regard to the centre pin being better than feathers for a safety valve, he thought they were both very bad, and that a construction like the Klotz valve was greatly preferable to either of them; it was a good mechanical construction, having the bearing point of the load at a low level, and a wide base to keep the valve steady and to guide it properly. With a centre pin, only the smallest possible space could be allowed for the rising of the valve. With reference to the enquiry about the corrosion of the central spindle bearing upon the valve, where it passed through a hole in a guide plate above, he had never found any objection on that score; it had never yet been brought under his notice in practice.

As to the construction of the spring for the safety valves exhibited, the proper mechanical construction in the case of a helical spring would undoubtedly be a cylindrical outline, like that employed for the Ramsbottom valves; but it was found more convenient in the present case to shape the spring in the double conical form shown in the drawings. The proper way of constructing it would certainly be to taper the material, so as to have a smaller diameter of steel at the small ends of the spring. That was a point in the manufacture, and the diameter of steel could be so tapered from the centre to the ends that each coil of the spring would take its proper share of the load. At present it would be expensive to get springs so manufactured, but there were means of doing it economically in that way; practically it was found that the double conical form of spring served every purpose, though a greater proportion of the load was certainly taken by the centre coils.

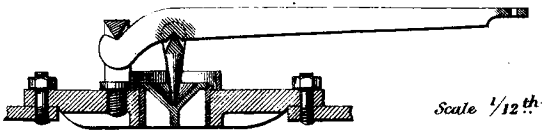
The PRESIDENT was sure the meeting would be very glad to accord a vote of thanks to Mr. Wilson for having brought this important subject before them in his paper, which had been the means of eliciting such an exceedingly useful discussion.

The vote of thanks was passed.

The following paper was then read:—

SAFETY VALVES.

Fig. 1. *Ordinary Safety Valve.*



Scale 1/12th

Fig. 2.

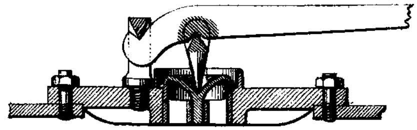
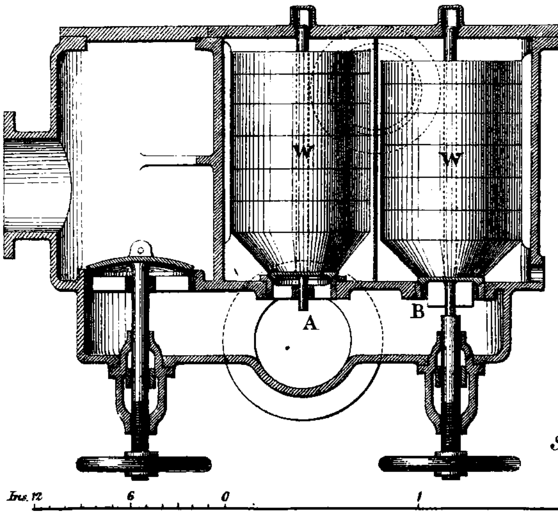


Fig. 3. *Ordinary Dead-Weight Valve.*



Scale 1/12th

Fig. 4. *Cowburn Valve.*

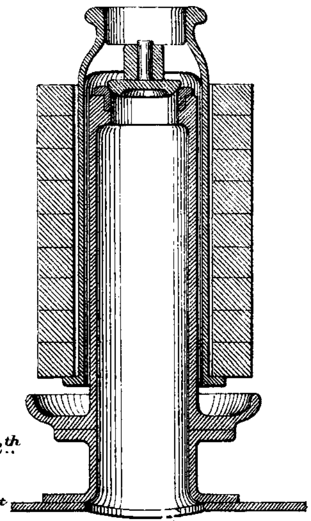
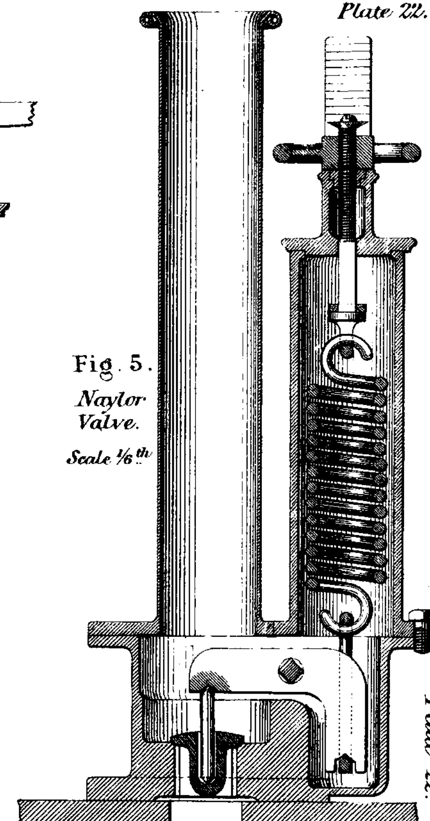


Fig. 5. *Naylor Valve.*

Scale 1/6th



(Proceedings Inst. M. E. 1877.)

Klotz Valve for stationary boiler.

Fig. 6. Fig. 7.

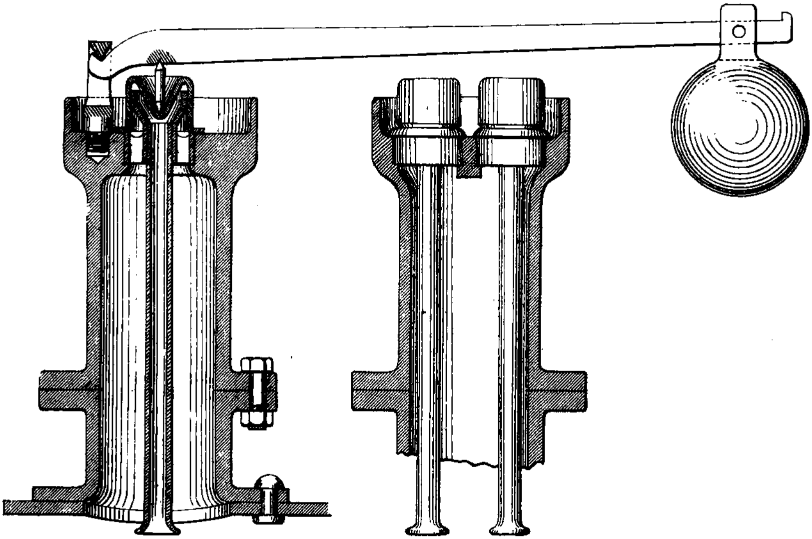
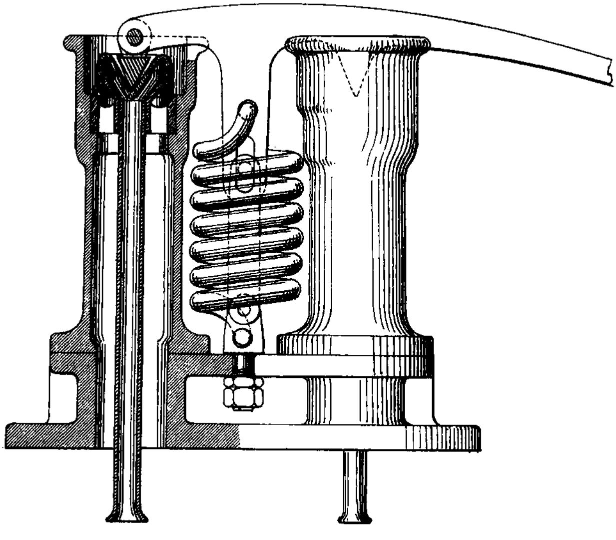


Fig. 8. *Klotz Valve with Ramsbottom lever.*



(Proceedings Inst. M. E. 1877.) *Scale 1/8th.*

Klotz Valve for marine boiler.

Fig. 9.

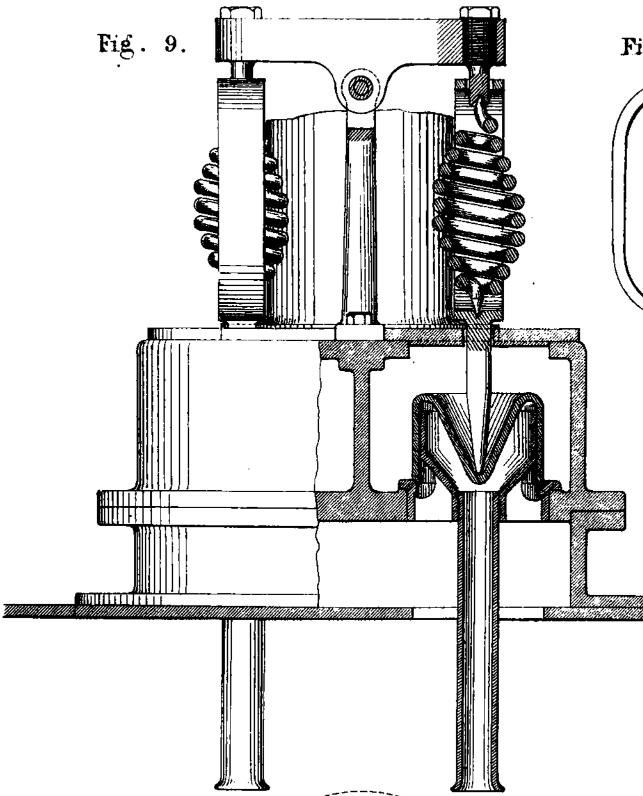
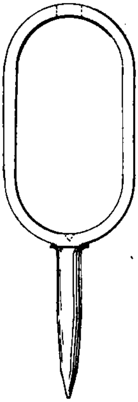


Fig. 10.



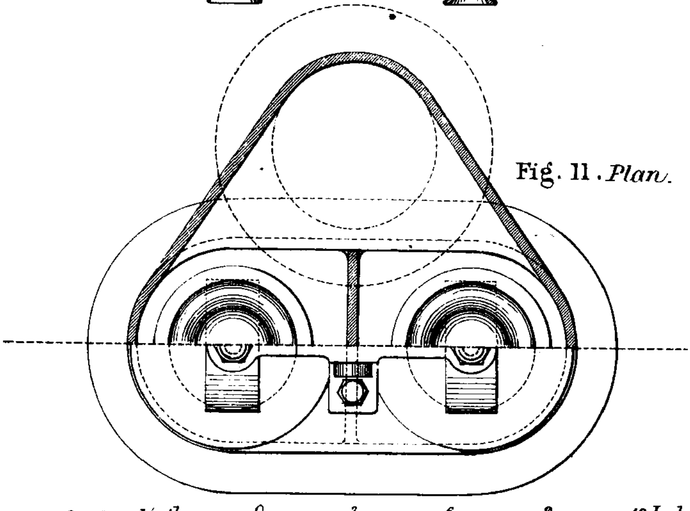
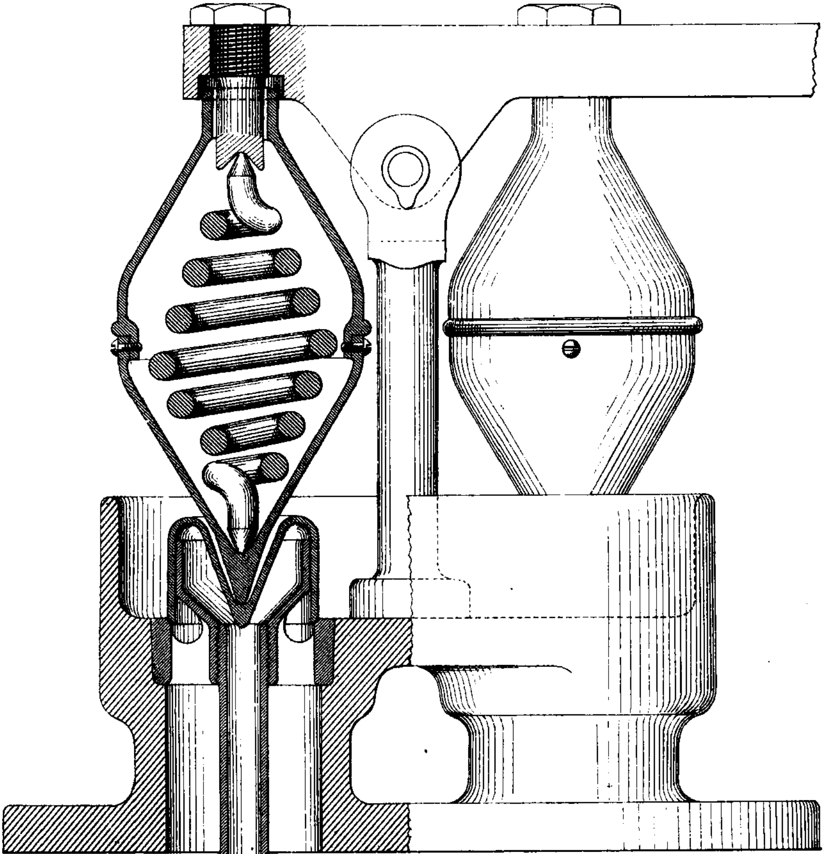


Fig. 11. *Plan.*

Scale 1/6th 0 3 6 9 12 *Inches.*

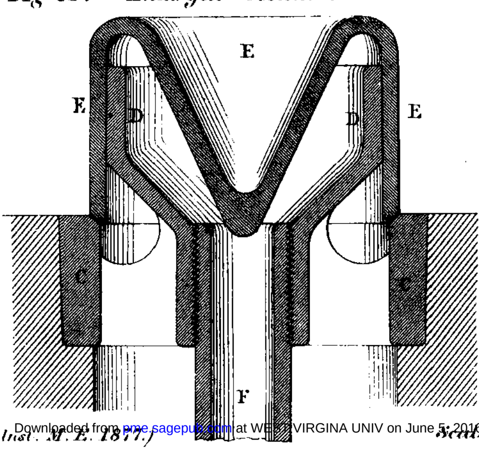
(*Proceedings Inst. M. E. 1877.*)

Fig. 12. *Klotz Valve for locomotive boiler.*



Scale ¼th 0 1 2 3 4 5 6 7 8 9 10 Ins.

Fig 13. *Enlarged Section of Valve.*



(Proceedings Inst. M. E. 1877.) *Scale ½.*

SAFETY VALVES.

"Paragon" Safety Valve.

Fig. 14.

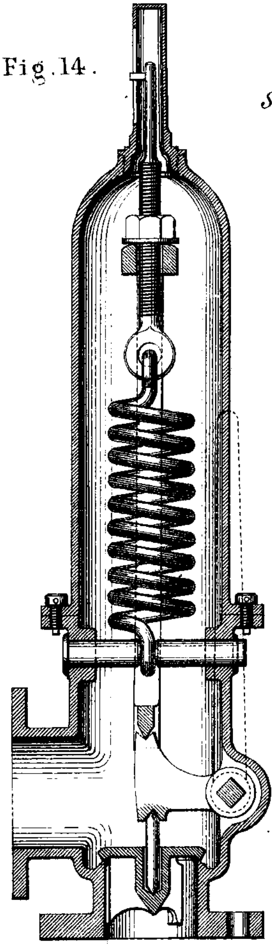


Fig. 15.

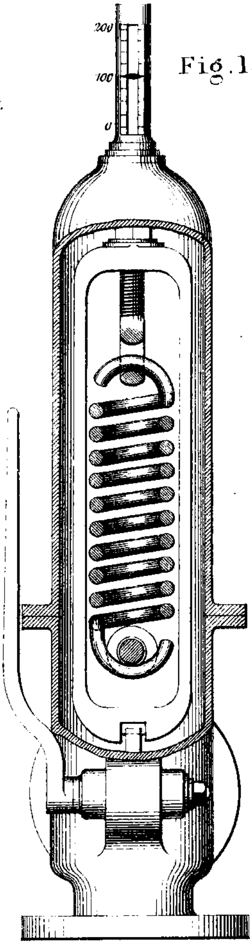
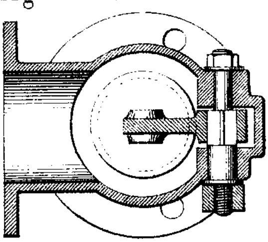
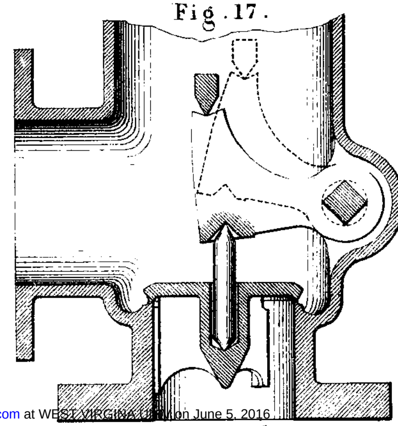


Fig. 16. Sectional Plan.



Scale 1/6th.

Fig. 17.



Scale 1/4th.

(Proceedings Inst. M. E. 1877.)

0 3 6 9 12 Ins.