On an Improved Safety Valve for Steam Engine Boilers

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ON AN IMPROVED SAFETY VALVE FOR STEAM ENGINE BOILERS.

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The subject of this paper is an improvement in the construction of the Safety Valves at present in use on locomotive marine and stationary engine boilers, for the purpose of preventing the pressure of the steam whilst blowing off through the safety valve from rising beyond the limit to which the valve is adjusted. This rise of pressure during blowing off is found to take place to a greater or less extent in all steam boilers with the ordinary safety valves, including locomotive marine and stationary boilers; but it occurs especially with locomotive boilers, where the safety valves are pressed down by levers with spring balances at the extremity, and the rising of the valve in blowing off causes a lifting of the lever and a considerable extra extension of the spring balance and consequent increase of pressure upon the valve.

From experiments made by the writer with locomotive boilers, he believes that a clear available opening of 7-10ths of a square inch will allow the steam to escape as fast as it can be generated in a large locomotive boiler at a pressure of 120 lbs. per square inch, when the engine is not consuming steam by running, and with the help of a steam jet in the chimney. Taking the theoretical velocity of steam at that pressure issuing into the atmosphere as 1900 feet per second, the practical velocity of the issuing steam, allowing for its friction in passing the safety valve and the resistance of the atmosphere into which it has to flow, may be assumed at 70 per cent. of this amount or 1330 feet per second. This velocity with the above-named opening of 7-10ths of a square inch gives a discharge of 11,172 cubic inches of steam passing off per second. Taking the relative volume of steam to water at that pressure as 203 times, this is equivalent to an evaporation of about 12 gallons of water per minute (11·94); or a consumption of about 8 cwts. (7·99) of coal per hour, taking the evaporative duty at 8 lbs. of water per lb. of coal. This extent of evaporation and consumption the writer believes to be the maximum that could be attained under extreme circumstances in locomotive boilers.

The present large locomotive boilers are made some with two safety valves of 3½ inches diameter, some with two valves of 4 inches diameter, some with two of 5 inches diameter, and some engines are working with four valves of 3 inches diameter; the valves being loaded by spring balances through levers, or in some cases by a spring acting direct, without the intervention of a lever. When the spring balance and lever are used, the proportions of the lever are generally arranged so that 1 lb. pressure of the balance is equal to 1 lb. per square inch on the valve; and then the perpendicular lift of the valve in opening multiplied by the number of square inches in its area gives the distance that the outer end of the lever has to move to allow the required opening of the valve; and this lift of the lever end multiplied by the number of lbs. to the inch in the graduations of the spring balance gives the number of lbs. per square inch of additional load put upon the valve by the act of lifting, and the corresponding increase of pressure necessitated in the steam to admit of its escape through the opening of the valve, in addition to that required for overcoming the friction of the steam in passing the valve and the resistance to it in flowing into the atmosphere.

Taking the case of two valves of 5 inches diameter, giving a combined circumference of 31·4 inches, and say 30 lbs. to the inch as the graduation of the spring balances, with a ratio of leverage (or area of valve) of 19·63 to 1, a total area of discharge of 7-10ths square inch would require a lift of the valves of $\frac{0 \cdot 7}{31 \cdot 4}$ or ·0223 inch; but as the bearing faces of the valve and seat are not horizontal but inclined at 45°, a vertical lift of the valve equivalent to 1 square inch (0·99) annular area is required for giving a discharging area of 7-10ths square inch; and the total lift will therefore be ·032 inch. This gives an extension of the spring balance of ·032 × 19·63 or ·628 inch, causing an extra load upon the valve of ·628 × 30 or 18·8 lbs. per square inch in order to get the required opening for discharge of the steam. The result is therefore that, in order to give a sufficient area of opening for the discharge of all the steam that the boiler is capable of generating, the pressure must rise in the boiler about 19 lbs. per square inch above the intended limit of the working pressure, or the point at which the safety valves are adjusted to begin blowing off; and this action of increasing the total pressure upon the valve as the valve rises is inseparable from all arrangements in which the valve is pressed down by a spring acting either through a constant lever or direct upon the valve.

The improved Safety Valve forming the subject of the present paper has been designed by the writer for the purpose of removing this defect, 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, diminishing in length as the valve rises in the same proportion that the tension of the spring is increased by the rising of the valve, so as to prevent any increase taking place in the total pressure upon the valve.

The improved valve is shown in Figs. 1 to 4, Plates 63 and 64, Fig. 1 being a vertical section, and Fig. 2 a sectional plan.

The safety valve A is only 2 inches diameter inside the seating, and is pressed down by the inverted spiral spring B acting upon the opposite end of the bent lever C, the effective length of lever being $2\frac{1}{2}$ inches at the valve and $1\frac{3}{4}$ inches at the spring. When the valve rises, the bearing point of the spring at the end of the lever, being inclined downwards at an angle of 35° from the vertical line D in Fig. 3, is deflected nearer to this vertical line by the lifting of the valve end, as shown by the dotted position in Fig. 3; and the result is that the effective leverage at which the spring acts is reduced to the extent required to compensate for the increased tension of the spring caused by the motion of the lever, so that the total pressure upon the valve remains unaltered. The centre E on which the lever works is a knife-edge, so as to prevent its action from being interfered with by friction from the heavy pressure upon it, which is nearly double the pressure of the spring; and the connection of the spring to the lever at F is by a knife-edge also, Figs. 3 and 4, in order to give complete freedom of action to the whole. The spiral spring is made of $\frac{3}{8}$ inch round steel, and the pressure upon the valve is adjusted by screwing up the spring by the nut G, the highest pressure being limited by a solid collar upon the spindle. Any accident from failure of the spring is provided against by the lower end of the lever then coming in contact with the casing at H, Fig. 3, which prevents any risk of the valve becoming displaced.

This valve being only 2 inches diameter with a circumference of 6·28 inches, the height to which it must be lifted in order to give the same area of discharge as before, 7-10ths of a square inch, is $\frac{1}{6 \cdot 28}$ or ·159 inch; and the valve end of the lever being $2\frac{1}{2}$ inches long, this requires an angular movement of the lever of 3° 39′. The angle between the spring end of the lever and the vertical is consequently reduced from 35° to 31° 21′; and taking the horizontal distance $1\frac{3}{4}$ inches or 1·75 inches as the sine of the former angle, the sine of the latter angle will be 1·59 inches, making a shortening of ·16 inch in the leverage at which the spring acts. The difference between the cosines of these angles to the same radius, or ·106 inch, will be the extension of the spring produced by the same range of motion; and the area of the valve being 3·14 square inches, the total pressure of the spring to give a pressure upon the valve of 120 lbs. per inch will be 538 lbs. with the original leverage of 1·75 inches, and with the reduced leverage of 1·59 inches the total pressure required at the spring is then 593 lbs. Hence an increase of 55 lbs. in the total pressure of the spring has to be produced by the extension of ·106 inch in length caused by the motion of the lever, in order to maintain a constant pressure upon the valve; and this gives 519 lbs. per inch deflection for the strength of spring required for the purpose.

In practice the spring is adjusted so as to give a slightly reduced total pressure upon the valve when fully open, the pressure per square inch on the valve being made about 4 per cent. less when the valve is blowing off strongly than when the valve is shut; in order to compensate for the effect of the friction of the large quantity of steam passing in that case through the narrow opening of the valve. It has been found by careful trials with this valve that, when the steam is blowing off very strongly, the pressure within the boiler exceeds the load upon the valve by about 5 per cent.; and therefore by proportioning it as above with 4 per cent. less pressure of the spring upon the valve when open than when closed, the occurrence of any sensible increase of pressure within the boiler beyond the limit at which the valve is set is completely prevented. At the same time it is found that the valve closes again after blowing off strongly, without allowing any sensible fall in the boiler pressure below that limit.

This improved valve therefore effectually provides for the prevention of any increase of pressure occurring under any circumstances in the boiler beyond the intended limit of pressure; and the one valve, although only 2 inches diameter, gives the full area for discharge of the steam obtained with the two large valves ordinarily used. The one valve may consequently be considered as fully equivalent in safety to the two ordinary valves, although it may be preferred still to adopt the precaution of employing two valves.

In the case of the two ordinary safety valves of 4 inches diameter, having a combined circumference of 25·1 inches, and a ratio of leverage of 12·57 to 1, a total increase of pressure of 15·0 lbs. per square inch will be caused in giving the required full area of opening of 7-10ths square inch for discharge. And with two valves of 3 inches diameter, having a combined circumference of 18·8 inches, and a ratio of leverage of 7·07 to 1, the total increase of pressure will be 11·3 lbs. per square inch.

It appears therefore that, with the ordinary construction of safety valves, the larger size of valves, instead of giving increased freedom to the discharge of the steam, are actually inferior in this respect to the smaller valves, the two 5 inch valves allowing an increase of pressure of 18·8 lbs. per inch during the escape of the steam, whilst the two 3 inch valves allow only 11·3 lbs. per inch increase with the same discharge. This arises from the circumstance that the pressure required to hold down the valve increases as its area or as the square of its diameter, whilst its area for discharge increases only as its circumference or directly as its diameter. This result is also not altered in the cases where, instead of using a lever with a spring balance at the end, a large spiral spring is employed pressing direct upon the valve, or between two valves, the pressure of the spring and its motion being then the same as those of the valve, instead of the pressure of the spring being diminished and its motion increased both in the same ratio by the action of the lever.

The improved valve possesses an important advantage over most forms of the ordinary valves, from the circumstance that it is quite impossible for the valve to be tampered with by the enginedriver so as to increase the pressure beyond the intended limit; and in the writer's personal knowledge the frequency of this occurrence with ordinary valves is much greater than is generally supposed.

One cause of extra pressure in locomotive boilers occurs when an engine is proceeding with a train, with the steam well up and a good fire, and it is suddenly checked by a danger signal being exhibited, and the engine has to be reversed. In such a case, whilst the fire is generating steam vigorously, the cylinders instead of using it are converted into air pumps, pumping air into the boiler at every stroke. The steam generated must all pass off by the safety valves, and the pressure often rises considerably above the limit at which they are adjusted.

When an engine is taking a heavy load up an incline slowly, the steam blowing off strongly, as much as 40 lbs. excess of pressure has occurred within the writer's experience, without the safety valves being interfered with. The writer has also known the case occur of a large goods engine coming to a stand on an incline from want of power, although the steam was blowing off very strongly; and the driver being afraid to go back from fear of a collision, has secured the valves against blowing off, by pegging down the levers in the slots through which they passed in the weatherboard. The regular working pressure was 120 lbs., but the steam got up to 180 lbs. per inch by the pressure gauge, and the engine was then able to take the train to the top of the incline.

Another source of risk of extra pressure is when an engine is having the steam got up in the engine shed, and to hasten it the steam jet has been put on and left on while the fire-lighter is gone to look after other engines. From a number of experiments the author has ascertained that, if the jet be left full on for six minutes after the steam begins to blow off, there will be an excess of pressure in the boiler of at least 30 lbs. per square inch over what the safety valves on the ordinary construction are loaded at.

In the case of marine boilers it is required by the government regulations that there shall be at least one safety valve upon each boiler loaded direct by weights, and that the area of this valve shall be one circular inch for every horse power nominal; so that a boiler supplying steam equal to 100 horse power requires a safety valve 10 inches diameter. But although these valves are loaded by direct weights, the pressure in the boiler will necessarily exceed the load on the valve when the steam is blowing off in great force, which is liable to occur occasionally when the engines are stopped, from neglect in not easing the pressure at that time. There is however a serious defect in this mode of loading safety valves on marine boilers, from the circumstance that when the vessel rolls the pressure of the weight is diminished; and if it rolls to the extent of 45° there will not be more than 70 per cent. of the full load upon the valves at that moment, and consequently there will be a loss of power when the greatest power may be required. Moreover the water in the boiler is subjected to violent commotion by the repeated starts of ebullition from the pressure being suddenly reduced by the lifting of the safety valve; and this commotion is not at all times stopped by the closing of the valve, but produces priming in the cylinders. With the improved valve however the full pressure would be preserved steadily in the boilers, with any extent of rolling of the vessel.

On the boiler of a stationary engine a comparative trial has been made of one of these valves of only $1\frac{9}{16}$ inch diameter, and two other ordinary valves of $3\frac{5}{8}$ inches diameter, loaded one with dead weights and the other with a lever and spring balance, all the valves being adjusted so as to begin blowing off at the same pressure. The engine was stopped and the firing of the boiler continued, and the steam generated had all to escape through the safety valves. The valve loaded by a lever and spring balance did not appear to increase in the amount of steam passing by it, and the valve loaded by dead weights increased in extent slightly; but the improved valve increased to a perfect roar, thereby telling its own tale as to which valve was carrying away the steam. When the damper was closed and the firedoor opened, all the valves ceased blowing off at the same time.

The number of boiler explosions that have occurred from over pressure show the necessity of some effective means being adopted to prevent that occurrence; and if a boiler be at all defective in construction or have become so after long use it is the more necessary that it should be provided with safety valves which will render it safe against any excess of pressure occurring beyond the amount required for working the engine. All surplus pressure put upon a boiler through the defect of the safety valves not being able to carry away the steam as fast as generated is tending to positive destruction without any advantage; and if the boiler has a sufficient margin of strength to resist such surplus pressure as it is subjected to with the ordinary arrangement of safety valve, the use of a valve that will maintain a uniform pressure would have the advantage of allowing an increased pressure to be regularly used in the engines.

Mr. Naylor exhibited specimens of the safety valve, and explained that in the case of valves constructed for marine boilers an india-rubber diaphragm was fixed across the bottom of the chamber containing the spring, as at II in the 5 inch marine safety valve shown in Figs. 5 and 6, Plate 65, so as to protect the spring from the corrosive action of any salt water thrown out from the boiler with the steam in blowing off, in consequence of the rolling of the vessel. This provision was not necessary in the valves for locomotive or stationary boilers, because in these cases the steam blowing off from the valve passed direct up the funnel placed over the valve, and any water carried off along with the steam by priming was blown out through the funnel in the same way, so that neither steam nor water was found to get to the spring.

The CHAIRMAN enquired how many of the new valves were now in use, and where they were at work.

Mr. NAYLOR replied that there were now about forty of the valves in use, most of which were on locomotive boilers, principally upon the Great Northern Railway. In the first adoption of the new valve upon that line, the size of the valve seemed so extremely small, in comparison with the safety valves previously employed, that a special trial was made to test the sufficiency of the new valve. One of the new valves of 2 inches diameter was fixed on a locomotive boiler, and the two ordinary valves of 4 inches diameter previously used were removed: the engine had a large firebox, and in order to increase the generation of steam an additional length of funnel was attached above the chimney, and a steam jet was added in the smokebox. By this means a very rapid generation of steam was obtained, producing a great blow-off at the valve; but it was found that even under these extreme circumstances the pressure in the boiler could not be raised to as much as 10 lbs. above the limit at which the valve was set to blow off. In a trial made with one of the new valves of $1\frac{1}{8}$ inch diameter, the result had not been satisfactory, because the valve had not been made with lift enough in that particular case; but from experiments subsequently made he was satisfied that a valve of only that size was amply sufficient in practice for a locomotive boiler, when arranged so as to allow the full lift required to give the necessary area of opening for blowing off; and the principle of the bent lever afforded the means of obtaining any amount of lift, without increasing the pressure upon the valve by the extension of the spring.

Mr. F. J. Bramwell thought the new safety valve was a very ingenious practical contrivance for getting over the defects of the ordinary construction of safety valves, and allowing the steam to blow off in any quantity with complete freedom at the intended limit of pressure. The defects in the principle of ordinary safety valves acted on by spring balances arose from two causes, the first being the extra pressure put upon the valve in blowing off, owing to the extension of the spring and the additional force consequently exerted by it; and although theoretically this extra pressure might be reduced to any extent by using a spring of greater length and consequently greater elasticity so as to give less increase of pressure with the same extent of stretching, yet in practice very little improvement could be effected in this way, as the total length of spring that could be employed was limited by practical considerations of convenience; and in the case of locomotive boilers it was not practicable to employ springs having much more elasticity than those at present generally used, which gave a force of not less than 20 lbs. per inch of extension. The second defect attendant upon ordinary safety valves arose from the circumstance that, at the time of blowing off, the pressure of the steam in the immediate neighbourhood of the aperture of the valve was reduced by the rapidity of the motion of the escaping steam; and consequently, in order that the valve might be held open for blowing off at the intended limit of pressure, it was necessary that the steam pressure within the rest of the boiler should have risen considerably above that limit, in order to keep the reduced pressure at the aperture of the valve up to that limit. Both of these defects in ordinary safety valves were completely met by the principle of construction of the new valve, in which the adoption of the bent lever not only allowed of the valve being lifted to the full extent without any increase of pressure being put upon it by the extension of the spring, but also afforded the means of actually diminishing the load upon the valve in lifting, to any extent that might be found necessary to compensate for the diminished pressure of steam at the aperture in blowing off. The principle of the bent lever thus caused the safety valve to blow off with certainty at the intended limit of pressure, without allowing the steam in the boiler under any circumstances to rise beyond that limit by more than the small fixed percentage determined by the original adjustment in the proportions of the lever and strength of the spring.

Mr. NAYLOR remarked that the rise of pressure in blowing off with ordinary safety valves was also partly due to the resistance offered by the atmosphere to the escape of the issuing steam; and he thought the amount of this resistance was considerably greater than it was generally believed to be. For it was evident that in the case of a safety valve loaded by a dead weight instead of by a spring, if there were no resistance offered by the atmosphere to the escape of the steam, the steam would blow off with perfect freedom and the pressure would never rise above the intended limit, since the valve would lift to any required extent without the load upon it being thereby increased. But in practice it was found that this was not the case; for with an ordinary safety valve of 5 inches diameter loaded by a dead weight upon a boiler 25 feet long he had found that there was as much as 8 to 10 per cent. increase of pressure beyond the limit at which the valve was set to blow off; and he believed this was due to the resistance met with by the steam in issuing into the atmosphere.

Mr. F. J. BRAMWELL did not think the resistance offered by the atmosphere to the issuing steam was by any means so great as to account for an increase of pressure of 8 to 10 per cent. beyond the intended limit; but he considered this increase of pressure in blowing off was almost entirely due to the circumstance which he had previously mentioned, the velocity of the escaping steam causing the pressure to be so much reduced in the immediate neighbourhood of the valve, that in order to maintain the pressure at the valve up to the intended limit it was necessary for the pressure in the rest of the boiler to rise considerably above that limit. In accordance with this view of the question a construction of safety valve had been employed upon some boilers, having a slide valve worked by a piston; and the piston being acted upon by the steam pressure inside the boiler, at some distance from the aperture of the slide valve, opened the slide at the intended limit of pressure and kept it open, without requiring the pressure to exceed the limit.

The CHAIRMAN enquired what was the cost of the new safety valves, in comparison with ordinary safety valves having levers and spring balances.

Mr. NAYLOR replied that the difference of cost of the new safety valves as compared with the ordinary valves was very little. The two new valves exhibited were each $2\frac{1}{2}$ inches diameter and were intended for locomotive boilers: the one with brass funnel and brass chamber for containing the spring cost £10 10*s*., and the other made of iron with gunmetal valve and valve-seat cost £9. The new valves were much lighter than the ordinary valves of larger size, used for the same situations, with their levers and spring balances.

Mr. F. J. CANNELL thought the new safety valve was of very great advantage for boilers in ironworks heated by the puddling furnaces, where it constantly occurred that the steam was suddenly shut off from the engine while the furnaces required to be kept in full work; and in such cases it was of the utmost importance to have the means of blowing off through the safety valve the whole of the steam that the boiler could generate. At the Old Park Iron Works, Wednesbury, they had had one of the new safety valves of 2 inches diameter at work for six months on one of the locomotives working at 85 lbs. pressure, and it had given complete satisfaction; the engine had often stood still for $\frac{3}{4}$ hour with a full fire, and the steam had been so effectually carried off by the safety valve that the pressure in the boiler had not risen 1 lb. above the limit of 85 lbs. at which the valve was fixed to blow off; whereas in other boilers having ordinary safety valves with levers and spring balances the pressure rose 15 or 16 lbs. above that limit under similar circumstances. He had paid great attention to the working of the new valve, and was satisfied that it effectually prevented any rise of pressure in the boiler above the fixed limit.

Mr. W. FORD SMITH remarked that, on one occasion of taking to pieces for repairs an ordinary locomotive safety valve with lever and spring balance, he had found that the centre pin of the lever, having been carefully fitted in the first instance, had become rusted so tightly in the eye that it required an additional force of probably 60 to 80 lbs. at the end of the lever to lift it; and he was therefore glad to see that pins were done away with in the new safety valve, a simple knife-edge bearing alone being employed as the fulcrum for the bent lever. He enquired whether the valve was guided in lifting by a centre spindle inside the boiler, because he had found that mode of guiding was also liable to the objection of the spindle becoming corroded in the guide, and he had seen safety valve spindles so encrusted in the guides that it was impossible for the valve to lift at all.

Mr. NAYLOR explained that in the new safety valve the valve itself was guided by three wings cast upon it, and not by a spindle; it was then not liable to become stuck by corrosion, and the only objection experienced in guiding by wings was when the valve seating was composed of a brass bush let into an iron seat, in which case the brass bush being unable to expand freely outwards became tightened upon the valve and caused the wings to bind in the seating, so that the valve could not lift. In the new valves however the seating was always made entirely of brass, so that there was no tendency to nip the wings of the valve in expanding.

In reference to the knife-edge bearing of the bent lever, the use of the knife-edge was very advantageous in reducing the extent of the bearing surface and thereby getting rid of the friction inevitably attending a round pin. The square centre pin forming the knife-edge bearing was fixed in the valve casing, so that it could not turn in its place; and the width of the bent lever was sufficient to ensure the knife-edge bearing holding it steady from any lateral twist in working.

A point of great practical importance in the new safety valve was the impossibility of tampering with the valve, as there was no external projecting lever which could be pegged down in its slot holes or loaded with additional weight; but the valve was entirely boxed up, and could not be got at by the enginedriver in any way.

Mr. J. TOMLINSON observed that it could only be owing to bad management if the levers of ordinary safety valves became rusted in their bearings, and he had found it necessary to have all locomotive safety valves taken to pieces regularly once every three months for examination and cleaning; and if the same plan were carried out in other cases there would be no danger of the valve becoming corroded fast. In the new safety valve he thought there appeared a possibility of dirt getting into the closed part of the valve casing in which the bent lever worked, and so causing it to stick fast; and he enquired whether any difficulty had been experienced with the new valve in this respect. He asked also whether the fact of slightly relieving the load upon the valve in blowing off did not cause the steam pressure in the boiler to fall below the intended limit before the valve could be closed again by the spring. In the case of a locomotive boiler working with 120 lbs. steam, he should expect that the pressure would have to fall 6 or 7 lbs. below the limit before the valve would close again after blowing off.

Mr. NAYLOR replied that the pressure of steam in the boiler did not fall below the limit in blowing off, because as the violence of the blowing off subsided the valve gradually closed; and the spring and bent lever were so adjusted that the valve shut again exactly at the fixed limit of pressure. It was of course possible by altering the adjustment of the bent lever to relieve the load off the valve to such an extent when lifted, that it should not close again until the pressure had fallen to a given percentage below the limit; but in practice this had not been found desirable.

In regard to the lever becoming obstructed by dirt getting into the valve, this had not been found to occur with any of the valves yet in use; and he thought any dirt getting in at the funnel of the valve would be blown out again by the steam in blowing off. There was no reason to apprehend that the knife-edge bearing could become stuck fast by dirt, as it could not be made a tight fit like a centre pin; and the extent of bearing surface was so small that there was no room for particles of dust or dirt to collect in sufficient quantity to obstruct the free action of the valve.

Mr. F. W. WEBB remarked that the only way in which there appeared any possibility of tampering with the new valve was by driving a plug in at the top of the funnel over the valve, to interfere with its opening; or by dropping in a heavy weight upon the valve to increase the load upon it; and so much ingenuity had been displayed by enginedrivers in tampering with previous safety valves, that it was very desirable to provide against any such attempts with the new valve.

Mr. NAYLOR said it was proposed to fix a cover of strong wire gauze at the top of the funnel over the valve, to prevent the possibility of tampering with it in any such manner as had been suggested.

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

The following paper was then read :—

SAFETY VALVE.

Plate 63.

Naylor's Safety Valve.

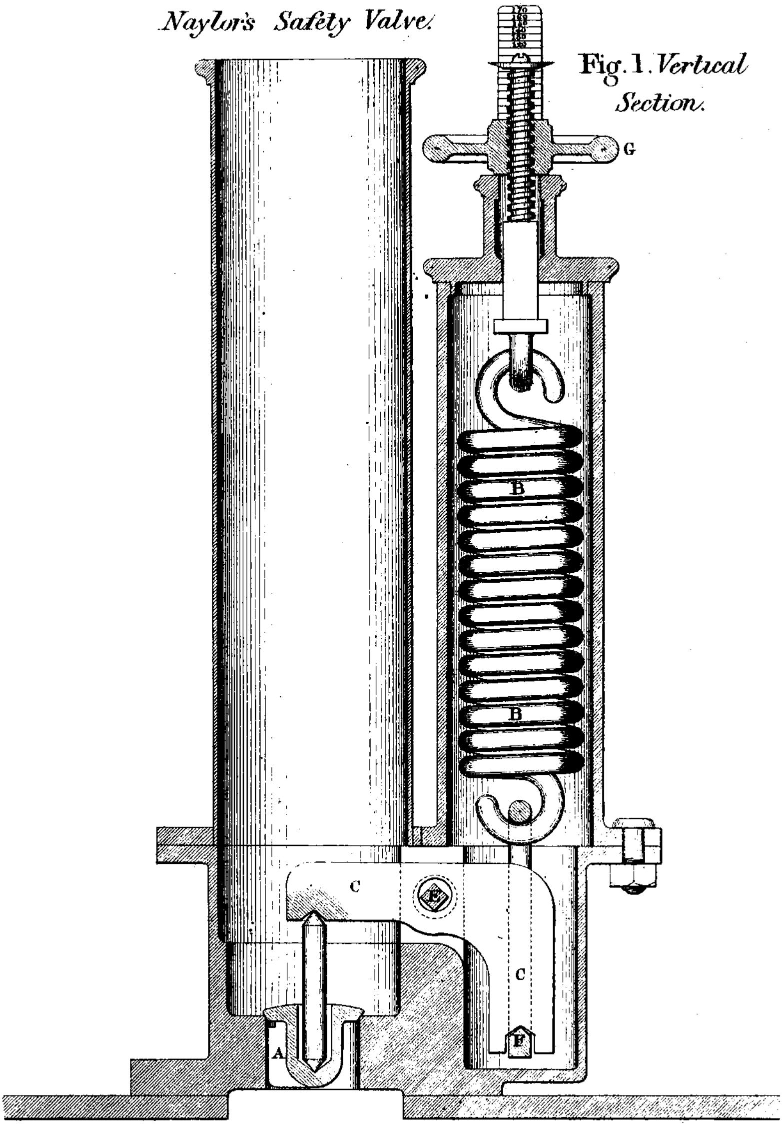


Fig. 1. *Vertical Section.*

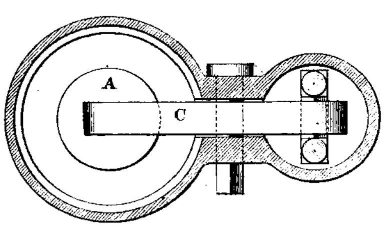
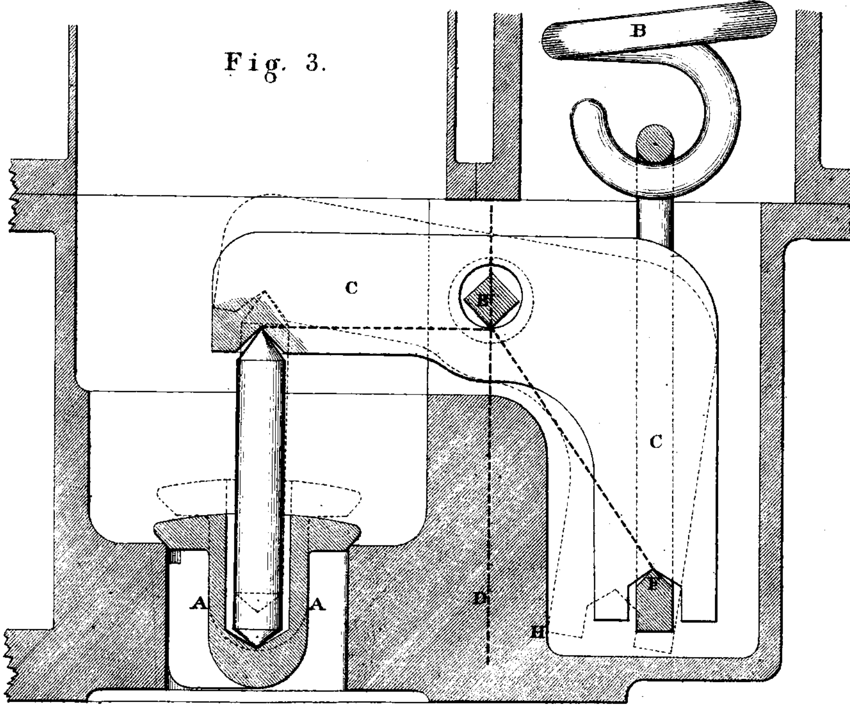


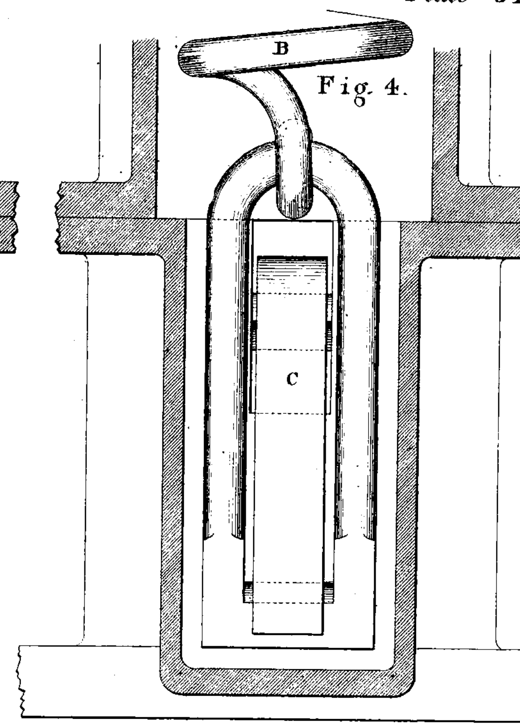
Fig. 2. *Sectional Plan.*

(Proceedings Inst. M. E. 1865. Page 330.) *Scale 1/4 th.*

SAFETY VALVE.

Plate 64.





(Proceedings Inst. M.E. 1865. Page 220.)

Scale half full size.

SAFETY VALVE.

Safety Valve for marine boilers.

Fig. 5

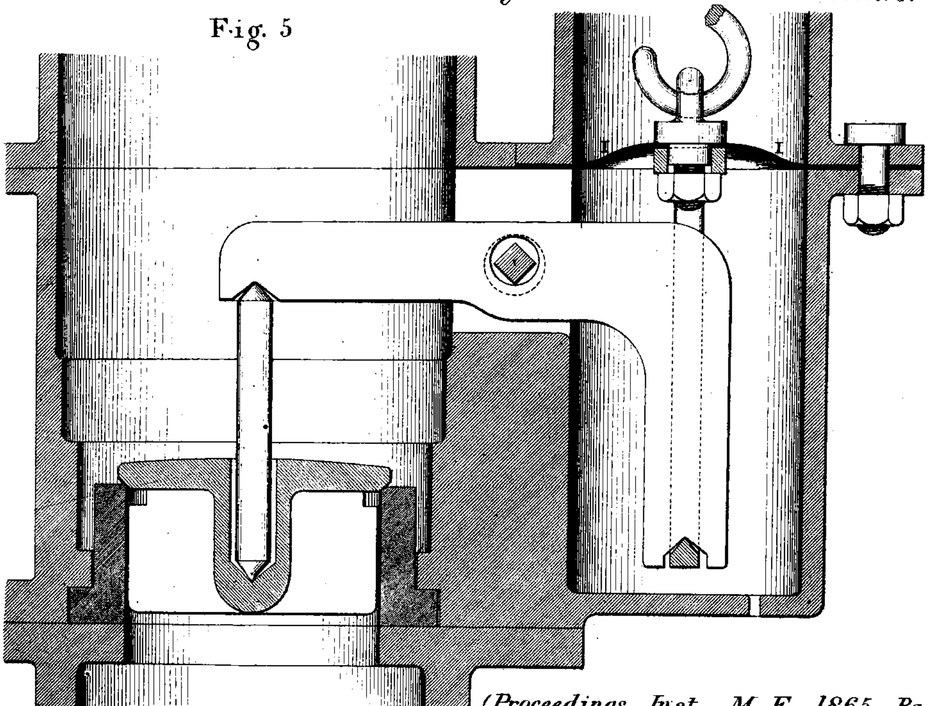
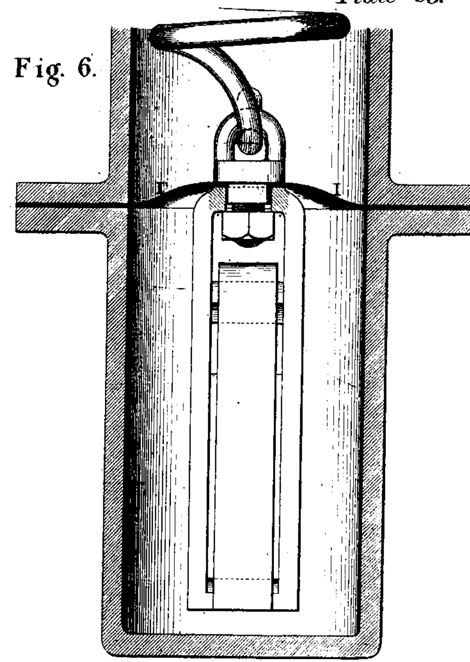


Fig. 6.



(Proceedings Inst. M. E. 1865. Page 220.)

Scale 1/4 th.