

1,222,071.

G. H. CLARK.
SAFETY VALVE.

APPLICATION FILED FEB. 9, 1916.

Patented Apr. 10, 1917.

4 SHEETS—SHEET 1.

Fig. 1.

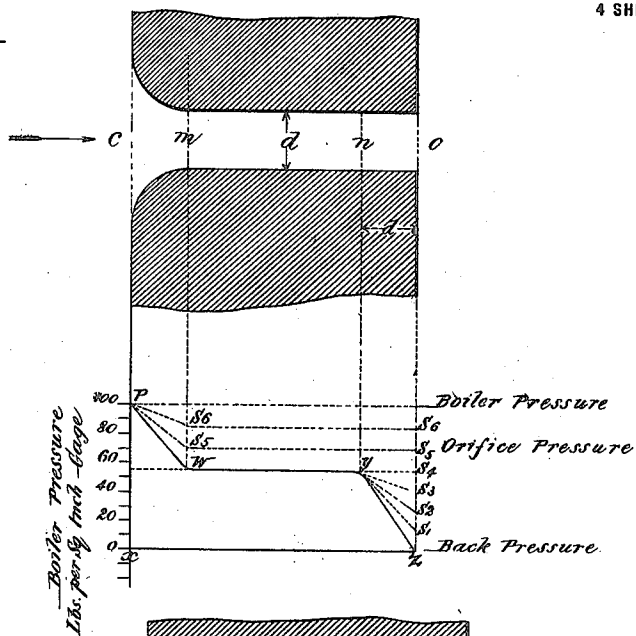


Fig. 2.

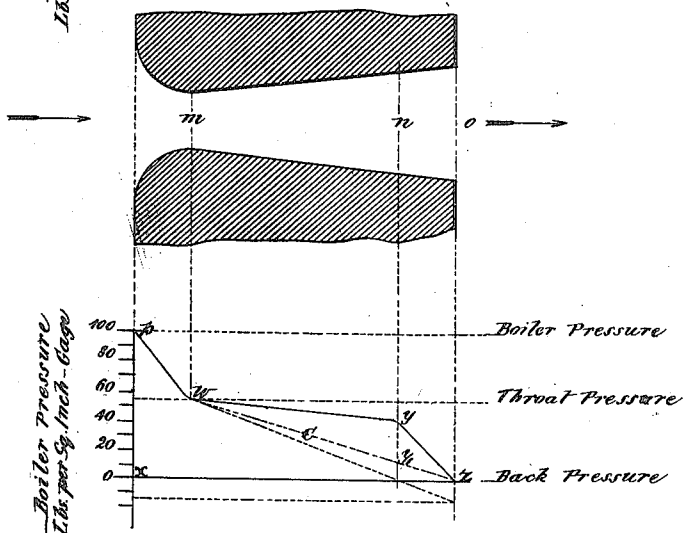
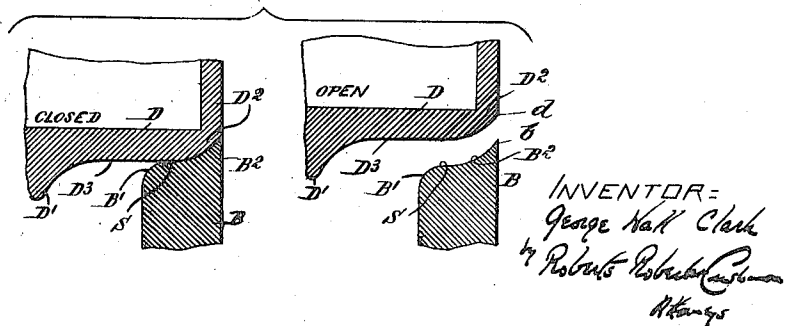


Fig. 3.



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4 SHEETS—SHEET 2.

Fig. 4.

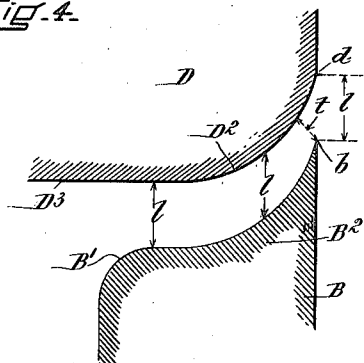


Fig. 5.

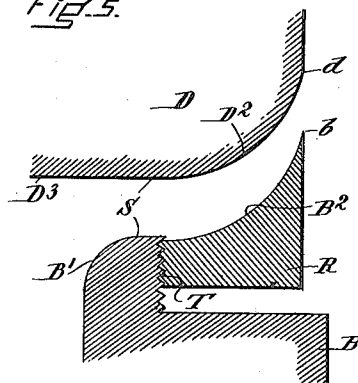


Fig. 6.

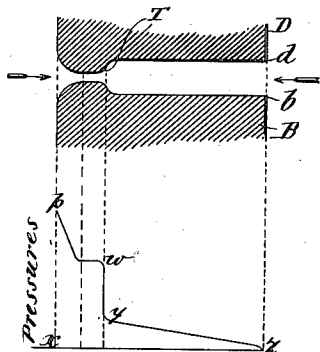


Fig. 7.

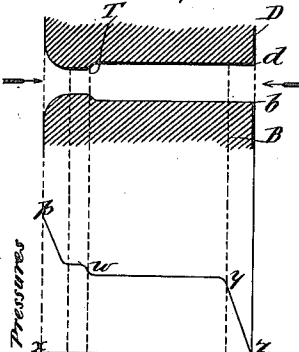


Fig. 8.

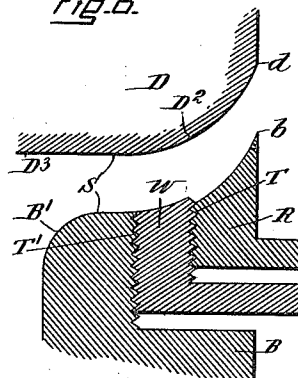


Fig. 9.

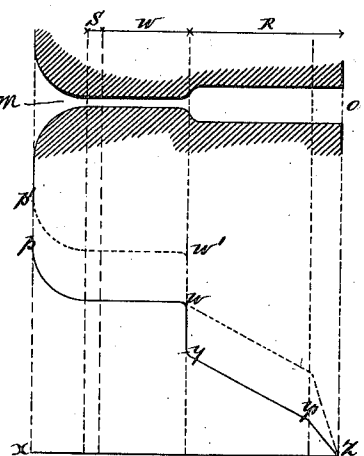
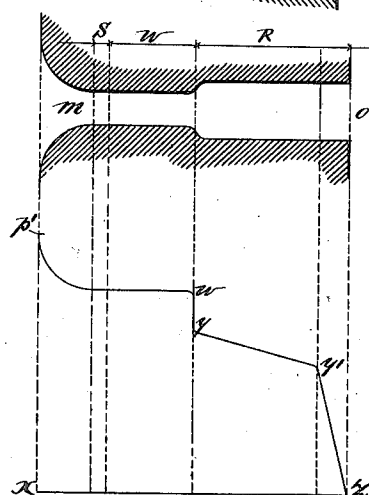


Fig. 10.



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4 SHEETS—SHEET 3.

Fig. 11.

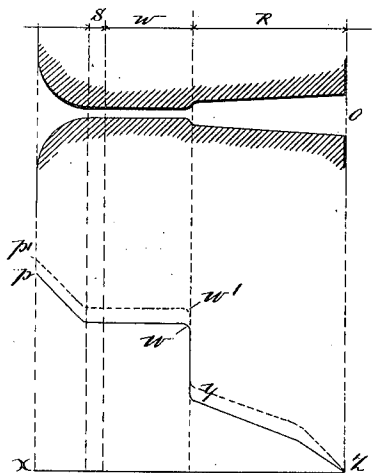
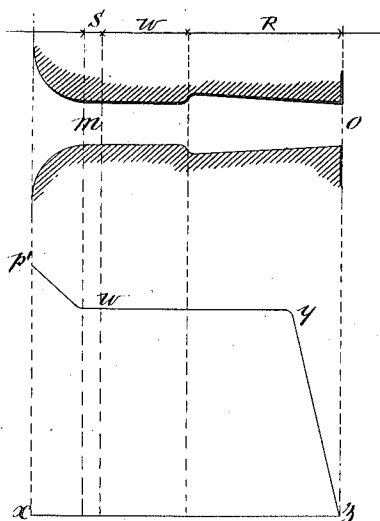


Fig. 12.



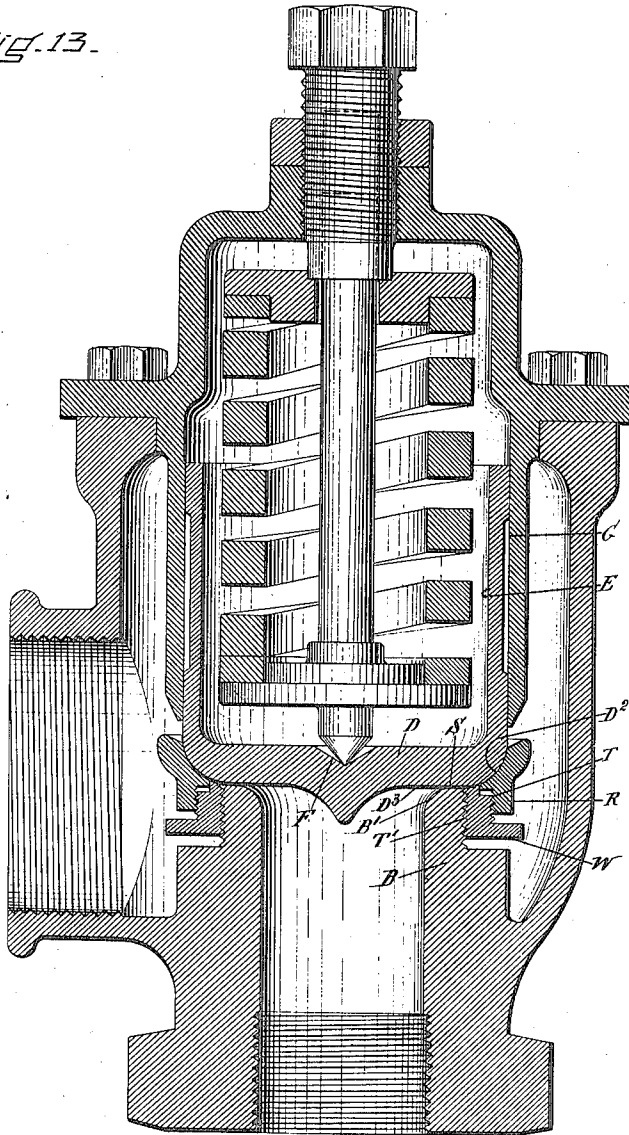
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4 SHEETS—SHEET 4.

Fig. 13.



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UNITED STATES PATENT OFFICE.

GEORGE HALL CLARK, OF CAMBRIDGE, MASSACHUSETTS, ASSIGNOR TO CROSBY STEAM GAGE & VALVE COMPANY, OF BOSTON, MASSACHUSETTS, A CORPORATION OF MASSACHUSETTS.

SAFETY-VALVE.

1,222,071.

Specification of Letters Patent.

Patented Apr. 10, 1917.

Application filed February 9, 1916. Serial No. 77,318.

To all whom it may concern:

Be it known that I, GEORGE HALL CLARK, a citizen of the United States, and resident of Cambridge, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Safety-Valves of which the following is a specification.

My invention relates to safety valves, and is addressed to the following main objects:
First: Increase in efficiency and capacity of delivery of steam or other elastic fluid under pressure.

Second: Maintenance of discharge-efficiency and capacity independently of variations in back pressure within wide limits;

Third: Confinement of "blow down" within permissible limits;

Fourth: Control, by adjustment, of the "warning" of a safety valve;

Fifth: Freedom from shock at re-seating, notwithstanding high valve-lift;

Sixth: Double or cumulative "pop" with resulting sustained lift and consequent capacity to respond to accumulating pressure.

In the drawings hereto annexed, which illustrate my invention,—

Figure 1 is a diagram showing a "standard orifice," and graphically indicating pressure conditions in such an orifice;

Fig. 2 is a diagram showing a modification of a standard orifice, and graphically indicating pressure conditions in such an orifice;

Fig. 3 is a diagram showing the manner in which a valve disk and its base may be shaped to provide a "standard orifice;"

Fig. 4 is a fragmentary sectional view, showing the relation of lift to delivery capacity, in a valve such as illustrated in Fig. 3;

Fig. 5 is a fragmentary sectional view of a "standard orifice" valve disk and base, with an adjustable "blow down" ring incorporated in the base;

Fig. 6 is a diagram illustrating a cylindrical "standard orifice" corresponding in respect to cross-sectional areas to that producible by the annular orifice shown in Fig. 5, and graphically indicating pressure conditions therein at low or initial valve lift;

Fig. 7 is a diagram illustrating the same "standard orifice" and graphically indicating pressure conditions therein at high, or final, lift;

Fig. 8 is a fragmentary sectional view of

a "standard orifice" valve disk and base, with two concentric adjusting rings incorporated in the base;

Fig. 9 is a diagram approximately illustrating by an equivalent cylindrical orifice, the conditions subsisting in a valve such as shown in Fig. 8, and graphically indicating the distribution of pressures at low, or initial lift;

Fig. 10 is a similar diagram, indicating approximately the conditions and distribution of pressures at high, or final, lift;

Fig. 11 is a diagram indicating more exactly than Fig. 9, the conditions subsisting in a valve such as shown in Fig. 8, at low or initial lift;

Fig. 12 is a similar diagram, illustrating the conditions subsisting at full lift; and

Fig. 13 is a vertical central section of a complete safety valve, which embodies the features illustrated by the preceding figures.

The cardinal feature of my invention is the provision, and substantial retention, notwithstanding the employment of sundry factors of modification, of what I shall designate as the "standard orifice" in a safety valve.

A "standard orifice," illustrated in Fig. 1, is one in which elastic fluid escapes under pressure at maximum delivery for the minimum cross section of the orifice, entirely fills all parts of the orifice, and exerts maximum aggregate pressure on the sides of the orifice throughout its length,—pressure which is substantially uniform throughout the length of the orifice—save for reduction at and near the discharge end.

It is well known, that if the curve of approach into an otherwise cylindrical orifice, has a radius substantially and preferably not less than the diameter of the orifice itself, the discharge of fluid under pressure through the orifice will be a maximum; and that the pressure at the throat of the orifice, *i. e.* where the curved surface of approach tangentially joins the cylindrical orifice itself, is approximately 60% of the absolute pressure of the fluid in the space from which it flows, and that this pressure at the throat is maintained on all parts of the orifice except near to the delivery end thereof. Thus, assuming a boiler pressure (by gage) of 100 lbs. per square inch, at *c* (Fig. 1), steam will enter the orifice, with progressive reduction in pressure due to expansion, until at the throat *m* the pressure becomes 60% of the

absolute boiler pressure, or, 54.1 lbs. gage pressure.

$$[(100+14.7) \times 0.6 = 68.8; 68.8 - 14.7 = 54.1.]$$

5 The gradual fall in pressure from c to m is indicated in Fig. 1 by the pressure curve $p w$.

10 Assuming that the orifice is a true standard orifice, with a diameter d at all points equal to the throat diameter at m , the pressure on the sides of the orifice at all points will equal that at the throat, until a point n is reached, about one diameter (d) distant from the outlet o ; from n outward the pressure drops until at o it reaches the back pressure which exists outside the outlet o . The pressure conditions from m to o , (assuming atmospheric pressure at o) are indicated in Fig. 1 by the line $w y z$.

20 If the back pressure beyond and at the outlet o be raised, as to values indicated by $s', s^2, s^3, s^4, s^5, s^6$, the pressure and therefore the flow in the standard orifice behind the point n will not be affected, until the back pressure is raised to a value in excess of the throat pressure under conditions of free flow, when the pressure conditions in the orifice will be as indicated by the dotted lines $p s^5 s^5$ or $p s^6 s^6$, according to the back pressure value.

30 Should the orifice be flared or enlarged from the throat m , as indicated in Fig. 2, the pressure at m will be, as before, 60% of the absolute boiler pressure, but the pressures at points between m and n will progressively diminish. The distribution of pressures in such an orifice is indicated by the curve $p w y z$ of Fig. 2. Thus: for an orifice having any given minimum cross section, the maximum aggregate pressure will be exerted in the orifice if it be a "standard" orifice, of uniform cross section throughout, save for the curved entrance.

40 As the delivery capacity of a given safety valve depends on the height at which it sustains its lift, the maximum lift-sustaining effect due to static pressure will be obtained by a valve of which the disk and base are shaped to provide a standard orifice of uniform cross section. Maximum lifting force and maximum delivery capacity at all lifts, will thereby be secured, and will be conserved independently of variations in back pressure up to a value equal to the throat-pressure in the standard orifice.

55 In Fig. 3 there are shown, sectionally, parts of a disk and base, shaped to provide a standard orifice. The disk D makes seating contact with the base B at the narrow annular region S . The surfaces of approach to the seat S are, in effect, curved to secure flow of steam in uninterrupted contact with these surfaces. These curved surfaces of approach are equivalent to those shown in Figs. 1 and 2 in relation to a cylindrical

orifice. A safety valve, provided with curved surfaces of approach substantially like those shown in Fig. 3, is shown and described in Edward F. Miller's Patent No. 1,020,921, dated March 19, 1912. The curve at B' on the base B of the valve should have a radius approximately equal to the predetermined normal full lift of the valve, so that the orifice between the disk D and base B will always fill, and the escaping steam exert maximum lifting pressure on the lower surface of the disk D .

The effective seat of the valve, when the disk D and base B make steam tight contact, should be close to the throat of the orifice, as at S . Though the surfaces B^2 and D^2 are shown as if they actually made contact with each other at all points when the valve is closed, in practice these surfaces should not make such complete contact, but should have a clearance space between them sufficient to insure that the steam tight seat shall always be close to the throat of the valve orifice. If, when the disk D lifts from the base B , the orifice is to be a "standard orifice" as above defined, the cross-sectional area of the passage from the throat (at S) to the lips b and d at the outlet, must be kept constant. If the meeting surfaces of the disk and base were to continue outward from the seat in planes at right angles to the direction of lift, the orifice would in effect be an expanding orifice, like that shown in Fig. 2, and while the curves of approach B' and D' would insure maximum delivery through the minimum cross section of the orifice at the throat (near S) the increase of the cross-sectional areas, progressively toward the outlet, would reduce the total lifting pressure on the disk. In order to preserve substantial uniformity of cross-sectional area of orifice, I shape the surfaces B^2 and D^2 so that the effective minimum sectional area between them shall be constant (or substantially so) at all points between the throat and lips of the orifice. This may be arranged as shown in Figs. 3 and 4, by shaping the disk and base so that the minimum section of orifice at the throat shall be equal to the lift multiplied by the circumference, the mid-plane of the orifice at that point being perpendicular to the direction of lift, and thence curving the surfaces B^2 and D^2 at a progressively increasing angle to the said mid-plane. Thus (Fig. 4) the lift l being the same distance at all points of the disk, the orifice area at the throat will be l multiplied by the orifice-circumference at that radial distance, and at the lip b will be the distance t multiplied by the disk-circumference at that radial distance. Strictly speaking, the circumference taken as the factor will be a mean between the inner and outer circumferences of the imaginary conical cross-sectional surface at t .

The shortest distances between the curved surfaces B^2 and D^2 , will progressively diminish from the throat to the lips of the valve orifice at any degree of lift. If l be the maximum working lift of the valve pre-determined by calculation, subject to empirical correction, the curves of the surfaces B^2 and D^2 should be so shaped that the orifice sections on minimum distances shall be equal at all points; thus the increase of radius from the disk-axis is compensated for by decrease in minimum distance between the curved surfaces and the orifice becomes a true "standard orifice" at the lift l pre-determined as aforesaid. Under these conditions, the orifice is one of maximum delivery efficiency, and the lifting pressure on the disk is a maximum, being the same at all points between the throat and the point near the lips where the pressure declines toward the outside back-pressure value. And, unless back pressure in the region beyond the lips b and d rises to a value higher than 60% of the absolute fluid pressure below the disk, back pressure will have no diminishing effect on the delivery capacity of the valve.

The condition of true standard orifice can be absolutely secured, with a disk and base construction as above described, only at one value of lift l ; but the approximation to true standard orifice is so close at smaller values of lift that practically the efficiencies of standard orifice are secured at all lifts. Stated accurately, the progression of condition is this: At initial lift, the value represented by throat-area divided by lip area is less than unity, and this value approaches unity as the disk approaches the lift l .

But, while high efficiency of delivery, maintenance of maximum lifting effect, and indifference to back pressure values up to 60% of the absolute boiler pressure, are secured by a valve constructed as shown in Figs. 3 and 4, such a valve would in practice have a seriously large "blow-down."

In order to correct the valve design to meet this important practical consideration, I modify it in the manner indicated in Fig. 5.

I provide a "blow-down" ring R, which, while it forms part of the base B, is adjustably mounted on the base by a thread-connection T. The curve B^2 is formed on the ring R, and corresponds to the same curve, as shown in Fig. 4; but, for a purpose presently to be explained, this curve, and the corresponding curve D^2 on the disk, is carried farther than before, so that both curves, at the lips b and d approach more nearly than before to parallelism to the direction of lift.

Suppose the predetermined or calculated maximum lift be l as before. The ring R is backed away from the disk D, to such a distance that when the disk D reaches the lift l the orifice area at the lips will be equal to

the orifice area at the throat. There will then be a slight increase in orifice area at the step or shoulder formed at the threaded part T by the aforesaid adjustment of the blow down ring R. Nevertheless, at the lift l the condition of standard orifice will be substantially produced, and the valve efficiency both as to delivery and maintenance of lifting pressure, will be secured, as with the design shown in Fig. 4.

But, it will be perceived, at initial lift, the orifice area at the throat will be less than the sectional area at any point from the step or shoulder at T outward to the lips b, d . The value represented by throat-area divided by lip-area will be less than unity at initial lift of the disk D, and as the lift approaches the predetermined maximum value l , this ratio will approach unity, and attain it when lift l is reached. Substantially, therefore, the progression of condition, with a valve as shown in Fig. 5, is the same as with a valve as shown in Fig. 4. The pressure conditions in the valve orifice at initial lift and full lift, are indicated in Figs. 6 and 7. In these figures, an orifice, of cylindrical character corresponding substantially with the orifice of the valve shown in Fig. 5, is diagrammatically illustrated, the diagrams being uniform in scheme with Figs. 1 and 2.

Fig. 6 represents the condition at initial lift. The shoulder or enlargement at T (corresponding to T in Fig. 5) has the effect of bringing the outlet near to the throat of the orifice at low lifts and thus reducing the extent of true "standard orifice." The area at b, d , is appreciably greater than the throat area. The pressure in such an orifice is indicated by the curve $p w y z$, p being the boiler pressure and w being 60% of p . The total pressure exerted on the sides of the orifice is represented by the area $x p w y z$.

As the lift increases, the condition illustrated in similar manner in Fig. 7 is progressively approached and finally assumed. Here the entire extent of valve-orifice has progressively approached and finally reached a close approximation to the condition of true standard orifice; the ratio between throat area and lip area approximates to unity, and the pressure curve becomes $p w y z$ (Fig. 7) and the total lifting pressure $x p w y z$; a value materially greater than the total for initial lift, shown in Fig. 6.

In the valve designed as indicated in Fig. 5, the ratio between throat area and lip area becomes unity at a finite value of lift, and the conditions of true standard orifice at the predetermined or calculated lift-value are obtained.

With a valve thus constructed, and with the blow down ring R adjusted as described, when the boiler pressure is reduced in slight degree by escape of steam, the valve disk D descends a short distance. This descent, or

reduction of lift immediately reduces the total lifting pressure on the disk, inducing immediate further reduction, and so on, until the condition indicated by Fig. 6 is resumed, with this modification,—that the boiler pressure p has by this time diminished, so that the area represented by $w p w y z$ (Fig. 6), is less than it was at the moment of initial lift. Therefore the valve disk D, under the pressure of its spring, closes on the base B.

By moving the blow down ring up or down, the sectional areas of the valve orifice, from the throat outward, can be varied, and the aggregate effective pressure acting on the disk at the progressive stages of lift can be altered. With the blow down ring backed away from the disk to a decided extent (relatively speaking) the blow down can be reduced to a small value.

But, if the shoulder at T be close to the throat at S, with the blow down ring adjusted to give a small blow down to the valve, the valve will not develop enough lifting pressure at initial lift to raise it promptly to greater lift-values, consequently the "warning" of the valve will be unduly prolonged, and the valve will not "pop" to full lift until steam pressure has accumulated more than may be desirable.

For many situations, the extent of "warning" may be predetermined by so proportioning the valve base B that the distance from the throat at S, to the threaded shoulder T shall be great enough to afford the essential characteristics of a true standard orifice of such extent that the aggregate pressure therein at initial stages of lift shall suffice to carry the disk D promptly toward its predetermined full lift in response to a permissibly small accumulation of boiler pressure. The annular area between the seat S and shoulder T may, therefore, be termed the "warning annulus", since its extent will determine the extent of warning given by the valve. To insure retention of the actual seat at S, where the throat of the orifice is located, the warning annulus should be given a slight clearance, so as not actually to touch the disk surface when the valve is closed.

I prefer, however, to construct the valve so that the extent of warning may be adjustably determined, and therefore to correct the "standard orifice" design for the purpose of reducing and adjustably controlling the "warning" of the valve, I provide the modification of design illustrated in Fig. 8.

Between the blow down ring R and the seat S, I mount an adjustable "warning" ring W. The blow down ring R is threaded at T to the warning ring W, and the warning ring W threaded to the base B at T'. By adjusting the warning ring W so that it is nearly flush with the seat S, the seat-

contact at S is preserved, and the condition of true standard orifice produced at low lifts, from the throat to the outer rim of the warning ring W, so that maximum aggregate lifting effect is obtained on the surface of the disk D, out to the rim of the ring W. The blow down ring R may be backed well away from the disk D, its adjustment having no appreciable effect on the "warning", while the adjustment of the warning ring W has, reciprocally, no appreciable effect on the blow down, provided the blow down ring is adjusted to produce a properly small blow down with the warning ring flush with the seat.

The pressure conditions produced at initial and full lift of a valve such as indicated in Fig. 8, are diagrammatically shown in Figs. 9 and 10, which represent cylindrical orifices drawn to the same scheme as Figs. 1 and 2. In Fig. 9, which shows the conditions at low lift, the distribution of lifting pressure is expressed by the curve $p w y y' z$, p being the pressure at which the valve is set to open. The orifice divisions corresponding to the seat S, warning annulus or ring W and blow down ring R are designated by S, W and R, respectively. The clearance produced by the adjustment of the blow down ring R produces a condition in which, at initial lift, the ratio expressed by area at m divided by area at o is a fraction considerably less than unity; there is consequently a marked drop in pressure at w . Thus, if we assume that the aggregate pressure represented by the area $p w y y' z$ just suffices to hold the disk lifted a slight distance from the base, the valve will stand in the "warning" position until accumulation of pressure reaches—say—the value p' (Fig. 9) when the total aggregate pressure, represented by the area $p' w' y y' z x$, suffices to lift the disk to full predetermined opening; this condition being diagrammatically represented in Fig. 10. Here the area ratio

$$\frac{\text{area at } m}{\text{area at } o}$$

approaches more nearly to unity than under the conditions represented by Fig. 9, and the condition of true standard orifice is to that extent approached.

In order to represent the action of a valve provided with a blow down ring such as shown in Fig. 5, however, the effect of continuing the curved surfaces D^2 and B^2 to a nearer approach to parallelism to the direction of lift, should be taken into account. If the surfaces are designed and proportioned as in Fig. 4, the area ration

$$\frac{\text{area at } m}{\text{area at } o}$$

is less than unity at initial lift (because of the difference in radius at m and o respec-

tively) but becomes unity at the predetermined lift-value l (because of the inclination of the surfaces D^2 and B^2 to the direction of lift at the orifice-section t). If the curved surfaces D^2 and B^2 , in a valve provided with a blow down ring, (Fig. 5) were the same in design and proportion as in Fig. 4, and the blow down ring were then backed away from the surface D^2 , the area ratio

$$\frac{\text{area at } m}{\text{area at } o}$$

at the lift-value l , would still be less than unity. Therefore, in a valve provided with a blow down ring, the curved surfaces D^2 and B^2 are continued a little farther than in the case represented by Fig. 4, so that the further inclination of the curved surfaces will compensate for the initial clearance produced by backing off the ring R. By this means the valve will, at the predetermined lift-value l , produce an area-ratio

$$\frac{\text{area at } m}{\text{area at } o}$$

equal to unity, and thus attain the condition of true standard orifice.

The diagrams, Figs. 11 and 12, illustrate the progressive pressure conditions produced by a valve, such as is shown in Fig. 8, more accurately than Figs. 9 and 10.

In Fig. 11, the condition of "warning" at boiler pressure p , is indicated. The area-ratio

$$\frac{\text{area at } m}{\text{area at } o}$$

is here much less than unity—because of the joint effect of greater radius at o and the backing off of the ring R. Accumulation of pressure to p' , let us assume, increases the aggregate pressure to a value sufficient to carry the disk to greater lifts. As the disk rises, the proportions and inclination of the surfaces D^2 , B^2 at the lips of the orifice compensate progressively for the initial excess of orifice at o (due to the backing off of the blow down ring R) and the area-ratio

$$\frac{\text{area at } m}{\text{area at } o}$$

approaches and finally reaches unity when the predetermined lift value l is obtained.

This condition is diagrammatically indicated in Fig. 12; the pressure diagram discloses a curve of the same character as that of Fig. 1.

Fig. 13 shows in vertical section an arrangement of valve disk and base in which the above described principles of construction are incorporated. The disk D is provided with a cylindrical extension, E, which slides loosely in a cylindrical guide G. A central depression F in the disk D, provides

a suitable bearing-seat for the the valve spring.

According to the requirements of the users, valves exemplifying the invention and improvements above described may be proportioned and adjusted to afford either of two specific modes of operation, in both of which the characteristics of standard orifice are conserved.

Under some conditions, it is desirable to have a safety valve which will attain maximum lift under accumulating pressure, by means of a second "pop"; under other conditions, a valve may be demanded which will have a high sustained lift on the initial "pop" opening, and high discharge capacity at the popping pressure. In valves proportioned to afford the latter specific peculiarities in service, there will be no second "pop," the lift increasing slowly under accumulation of pressure.

Within the principles of construction hereinabove described there are three variable factors; first: the angle of inclination of the opposed surfaces of the disk and base, at the lips; second: the relative width of the two rings, and third: the initial clearance of the two rings.

If it be desired to have the valve-disk settle back to a reduced lift after the initial pop, and afford high sustained lift under accumulation of pressure after a second pop, or quick rise from the original point of reduced lift, the warning ring should be relatively wide, and adjusted to give a very small clearance when the disk is seated. The blow down ring should be backed off to give a more pronounced clearance, and its curved surface (together with the curved surface of the opposed member) should be developed to a steeper angle than in the case of a valve designed to give a single pop. When so proportioned and adjusted, the valve will pop, with little or no warning, and immediately after attaining the initial pop-lift, will settle back to a relatively lower lift, at which the disk-sustaining pressure is effective over a surface substantially limited to the area of the warning ring, because the blow down ring is practically out of action by reason of its large initial clearance. If then the boiler pressure accumulates so as to lift the disk farther, the disk will rise slowly until the conditions of standard orifice progressively extend to the zone occupied by the blow down ring, and, when the condition of standard orifice is more nearly approximated in the blow down ring zone, the effective lifting pressure on the disk will increase and the valve will take a second pop to higher lift, when the standard orifice condition, being fully assumed over the entire orifice-surface, will cause the valve disk to be sustained at the high lift assumed. When the specific pressure in the boiler is relieved

by discharge, the disk will settle gradually at first, then with a progressively increasing rapidity, as the blow down ring goes out of action; the standard-orifice condition will then be confined to the warning ring zone; but, as the specific boiler pressure is now reduced, the disk will continue to settle until the slight clearance of the warning ring removes that ring from lift-sustaining action, when the disk will descend abruptly to its seat. This final closing drop of the disk does not take place until the more gradual descent of the disk has brought it very close to the seat; thus there will be no injurious hammering impact of the disk on its seat.

If, on the other hand, the conditions of use require a valve which will assume and sustain high lift at and after the initial pop, without subsidence of the disk (until discharge has reduced the boiler pressure) the warning ring should be made narrower than for a double-pop valve, and should also be adjusted to a larger clearance; the blow down ring will here have an initial clearance less than in a double pop valve, both absolutely and relatively to the warning ring clearance. The width of the blow down ring will be greater in relation to the warning ring, and the angle of exit at the lips need not be so steep, as in the double pop valve. The sustaining power of the orificial pressure is afforded by both rings after the first pop, and the disk will not subside to the point where the warning ring alone is effective, except when the boiler pressure has been reduced and the valve disk is on its way to final closure. In such a single-pop valve, accumulation of pressure, while it will increase the lift, will not do so by any sudden increase or second pop.

If accumulating pressure should demand greater relief than the designed full lift of the valve affords, the disk will rise still further, producing a ratio

$$\frac{\text{area at } m}{\text{area at } o}$$

which is greater than unity, and thus causing the orifice to depart proportionately from the true standard orifice. The efficiency of the valve will, under such conditions, be diminished, but the available discharge area will be increased, so that absolutely more weight of steam per time-unit will be discharged, though at lower efficiency, than when the normal maximum discharge was being delivered at maximum standard-orifice efficiency. Intelligent selection of dimensions of a valve, with due regard for the maximum generative capacity of the boiler, will render such an abnormal condition of excessive lift quite improbable. The ability to sustain high lift makes it feasible to employ a valve, designed according to the principles herein explained, of

dimensions materially smaller than those of an old-style valve of the same calculated delivery-capacity.

It should be observed that in a safety valve constructed according to the principles herein set forth, the fluid pressure acts upon the valve disk in two distinct modes. Variation of the boiler pressure, as in all safety valves, produces movement of the valve disk, but the total sustaining or lifting pressure effective on the disk is determined by the form and proportions of the orifice, independently of variations in the specific fluid pressure in the boiler. When the specific fluid pressure of the boiler has attained a value sufficient to start the disk from its seat, if that pressure then remains constant, the effect of the "standard orifice" is to increase the total lifting force exerted on the disk, and, as the rise of the disk from the base produces a progressively closer approximation to perfect standard orifice condition, this total lifting force increases; so that with constant pressure at the inlet end of the orifice, the lifting effect increases in absolute value as the orificial area increases, and the discharge efficiency also progressively approaches the maximum at the predetermined full lift at which the standard orifice condition becomes perfected.

Also, when the valve disk, in response to diminution of boiler pressure, begins to descend, the total sustaining force becomes progressively depleted by reason of the departure from the condition of true standard orifice which characterized the position of the disk at the predetermined or calculated full lift, so that the pressure condition which initiates subsidence of the valve disk is favorable to continuance of subsidence and final reseating of the disk.

I claim:

1. In a safety valve, the combination of a disk and a base shaped to provide a standard orifice.
2. In a safety valve, the combination of a disk and a base shaped to provide a standard orifice of substantially equal orificial area at throat and lips when the disk is at its predetermined full lift.
3. In a safety valve, the combination of a disk and a base shaped to provide a standard orifice of substantially equal orificial area at throat and lips when the disk is at its predetermined full lift, said orifice modified by an enlargement extending toward the lips from a region between throat and lips.
4. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice, said disk and base provided with a seat of mutual engagement close to the throat of said standard orifice.
5. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice of substantially equal orificial

area at throat and lips when the disk is at its predetermined full lift, said disk and base provided with a seat of mutual engagement close to the throat of said standard orifice.

6. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice of substantially equal official area at throat and lips, said disk and base provided with a seat of mutual engagement close to the throat of said standard orifice, the standard orifice modified by an enlargement extending toward the lips from a region outside the seat.

7. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice, one of the members (disk or base) comprising a ring adapted to be backed away from the opposing surface of the other member, one of the lips of the valve orifice being on said ring.

8. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice, one of the members (disk or base) comprising a ring adapted to be backed away from the opposing surface of the other member, one of the lips of the valve orifice being on said ring, and one of the members (disk or base) comprising another ring, adjacent to the throat of said standard orifice, and adapted to be backed away from the opposing surface of the other member.

9. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice of substantially equal official area at throat and lips when the disk is at predetermined full lift, one of the members (disk or base) comprising a ring adapted to be backed away from the opposing surface of the other member, one of the lips of the valve orifice being on said ring.

10. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice of substantially equal official area at throat and lips when the disk is at predetermined full lift, one of the members (disk or base) comprising a ring adapted to be backed away from the opposing surface of the other member, one of the lips of the valve orifice being on said ring, and one of the members (disk or base) comprising another ring adjacent to the throat of said standard orifice, and adapted to be backed away from the opposing surface of the other member.

11. In a safety valve, the combination of a disk and a base, and means to vary progressively the ratio between throat official area and lip official area from a value less than unity toward unity as the valve opens.

12. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice, and means to vary progressively the ratio between throat official area and

lip official area from a value less than unity toward unity as the valve opens.

13. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice, the opposed surfaces of said disk and base in the region of the lips thereof inclined to the plane of the seat, to equalize the official area at throat and lips.

14. In a safety valve, the combination of a disk and a base, shaped to provide a standard orifice, the opposed surfaces of said disk and base in the region of the lips thereof inclined to the plane of the seat to equalize the official area at throat and lips at a predetermined value of lift, said surfaces when the valve is closed being spaced apart from the lips inward toward the throat, to provide initial excess of official area at the lips over that at the throat.

15. In a safety valve, the combination of a disk and a base, provided with a seat of mutual engagement, an adjustable ring adjacent to and surrounding the seat, a second adjustable ring outside the first ring, said rings constituting parts of the said members (disk or base), the opposed surfaces of the disk and base shaped to form a standard orifice.

16. In a safety valve, the combination of a disk and a base, shaped to form a standard orifice, a seat of mutual engagement of said disk and base adjacent to the throat of said orifice, the opposed surfaces of the disk and base spaced apart in an annular region adjacent to the seat, and still farther spaced apart outside of said annular region.

17. In a safety valve, the combination of a disk and a base, shaped to provide an orifice of substantially equal official area at throat and lips when the disk is at a predetermined full lift.

18. In a safety valve, the combination of a disk and a base shaped to provide an orifice of substantially equal official area at throat and lips when the disk is at its predetermined full lift, said orifice modified by an enlargement extending toward the lips from a region between throat and lips.

19. In a safety valve, the combination of a disk and a base, shaped to provide an orifice of substantially equal official area at throat and lips when the disk is at its predetermined full lift, said disk and base provided with a seat of mutual engagement close to the throat of said standard orifice.

20. In a safety valve, the combination of a disk and a base, shaped to provide an orifice of substantially equal official area at throat and lips, said disk and base provided with a seat of mutual engagement close to the throat of said standard orifice, the standard orifice modified by an enlargement extending toward the lips from a region outside the seat.

21. In a safety valve, the combination of

a disk and a base, shaped to provide an orifice of substantially equal orificial area at throat and lips when the disk is at predetermined full lift, one of the members (disk or base) comprising a ring adapted to be backed away from the opposing surface of the other member, one of the lips of the valve orifice being on said ring.

22. In a safety valve, the combination of a disk and a base, shaped to provide an orifice of substantially equal orificial area at throat and lips when the disk is at predetermined full lift, one of the members (disk

or base) comprising a ring adapted to be backed away from the opposing surface of the other member, one of the lips of the valve orifice being on said ring, and one of the members (disk or base) comprising another ring adjacent to the throat of said standard orifice, and adapted to be backed away from the opposing surface of the other member.

Signed by me at Boston, Massachusetts, this eighth day of February, 1916.

GEORGE HALL CLARK.