March 22, 1932. J. W. TAYLOR ET AL 1,850,423

FLUID VOLUME CONTROL

Filed July 30, 1928 2 Sheets-Sheet 1

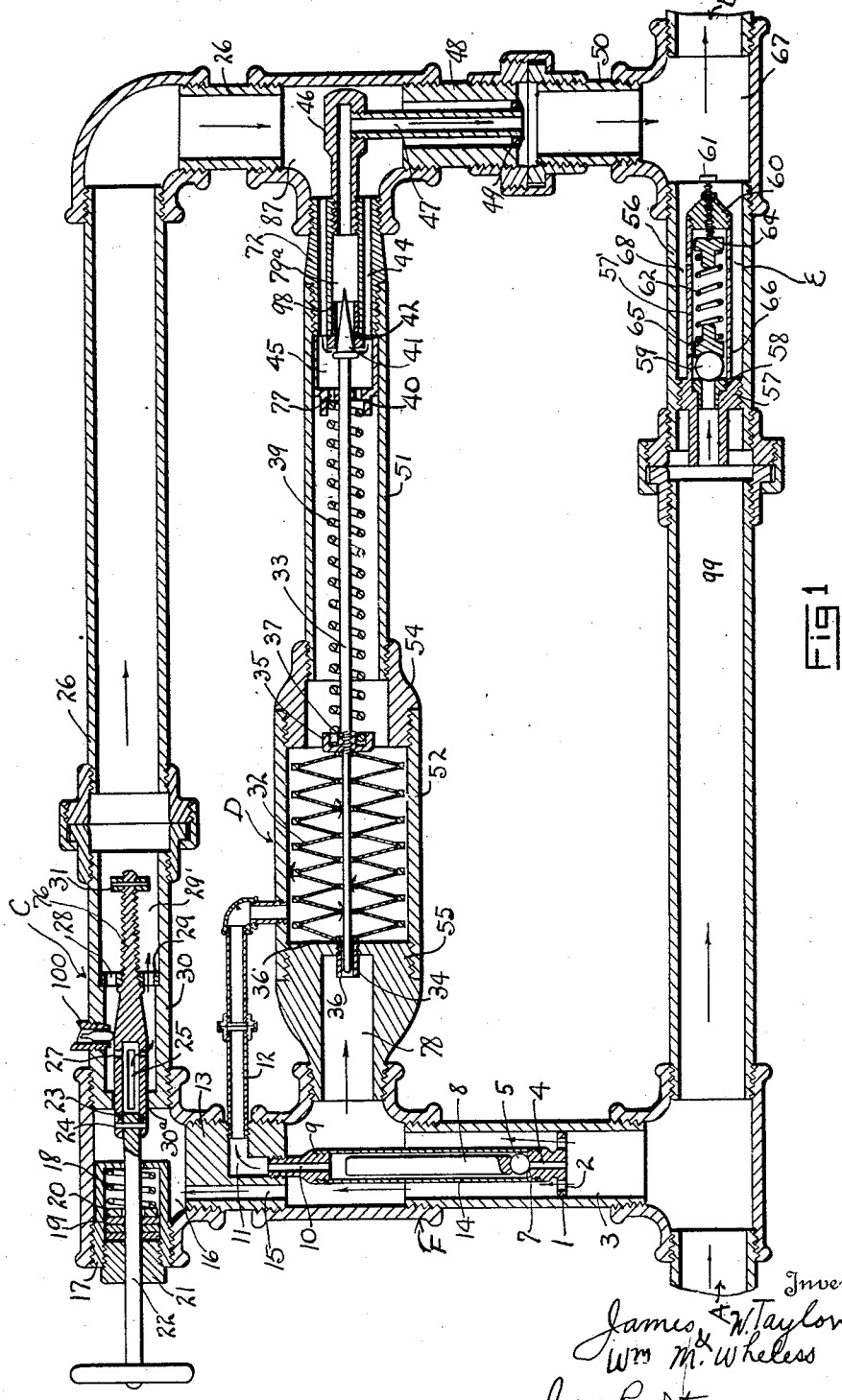


Fig 1

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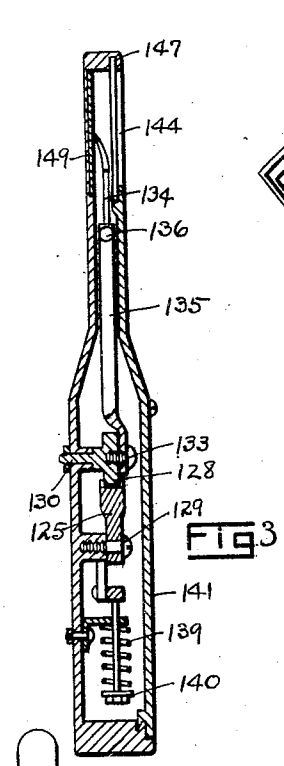


Fig 3

Fig 2

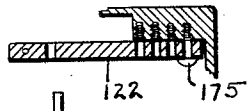


Fig 4

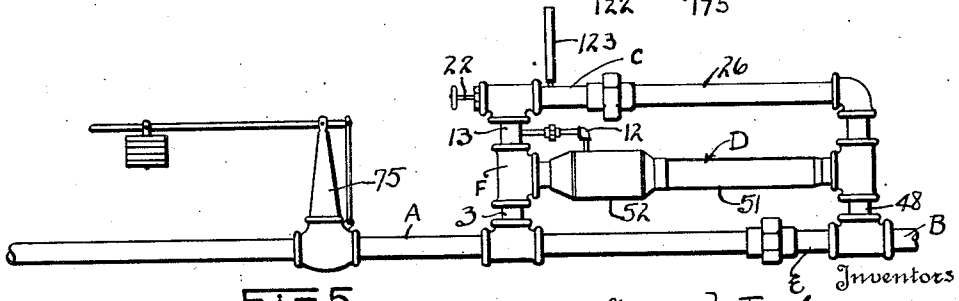


Fig 5

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UNITED STATES PATENT OFFICE

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FLUID VOLUME CONTROL

Application filed July 30, 1928. Serial No. 296,224.

This invention relates to the control of the flow of fluid and has for its purpose the control of the volume of compressed fluid flowing through a conduit. It is intended primarily to be used in flowing oil wells by pneumatic means, but may be used in various other ways wherever the same purposes are sought. It has been designed with a view to overcoming the objectionable features usually found in devices of this kind.

Heretofore the plan employed in the construction of devices of this character has involved the use of a diaphragm with the fluid pressure on its inner area while its outer area was exposed to the atmosphere, thus necessitating a powerful spring under high tension to actuate the diaphragm as the pressure fluctuated on its inner area. This permitted of little movement of the valve mechanism controlling the flow of fluid, the result being a locking or closing of the valve under slight variation of the fluid pressure.

For instance, devices of this character are in demand for use in the fluid lines when wells are flowed by what is commonly known as "heading." This consists in restricting the flow of gas or air within the annular space between two strings of pipe in such manner as to allow the well to accumulate a head of oil in the lower part of the hole. When the oil has risen to a certain height in the bottom of the well it will begin to meet with the increasing gas pressure, and this will continue until the pressure of the gas has become greater than the liquid pressure in the well, when the oil will be forced down and around the bottom of the inner string of pipe by the rising gas pressure. When the gas pressure has forced all of the oil out of the well casing into the inner string of pipe, it will then follow in behind the oil, the result being that the head of oil is discharged from the well.

This method is employed where the well is not producing sufficient oil to maintain steady flow. This being true, it will be readily seen that there is a heavy loss of gas after each head, which is due to the absence of oil in the bottom of the well to prevent its escape. The result is that there is a sudden drop of gas pressure in the well after each head, this often being as great as 75% of the pressure required to discharge the head of oil. It is at this point that the need to control the flow of gas arises, and it also becomes evident that any device used to control the flow must be adapted to wide variations in pressure.

It has been ascertained by experimentation what the flow of a compressed fluid through any given sized orifice will be under a fixed and unvarying pressure. For instance, it is found by maintaining an absolute pressure of 5 lbs., i. e., a pressure of 5 lbs. per sq. inch above atmospheric pressure, and allowing the gas to flow into the atmosphere, that 247 cu. ft. of free gas will flow through a 1″ orifice each minute. By "free gas" is meant gas at atmospheric pressure. It has also been found that the rate of flow through an orifice increases or decreases in almost direct proportion to the increase or decrease in the size of the orifice.

It is an easy matter to gauge or control the flow of fluid through any given sized orifice, so long as there is no fluctuation of pressure on either side of the orifice. If the pressure on the "upstream" side of the orifice, i. e., the side from which the flow is coming, be 100 lbs. per sq. in. and the pressure on the opposite "downstream" side be 90 pounds, then there will be a pressure differential of ten pounds, and the flow will remain the same as long as there is no change in pressures.

However, in a case as just outlined, if the pressure on either side of the orifice fluctuates, the flow of fluid will change accordingly. If the pressure on the upstream side of the orifice drops to 90 pounds, then the flow will cease entirely. Or if the pressure on the upstream side remains at 100 lbs., and the pressure on the downstream side drops to 80 lbs., then there will be a difference of 20 lbs., in pressure and the flow will, of course, be much greater than under the 10 lb. differential.

In view of the foregoing, it is plain that the pressure on the upstream side of the orifice must be held fixed; and that provision must be made for a widely varying pressure on the opposite side, if the volume of gas flow-

ing through the orifice is to be controlled under actual working conditions.

Assuming that the available gas or air pressure is greater than that with which it is desired to flow the well, any pressure regulator, of which there are numerous makes on the market, may be used in the pipe line supplying gas to the apparatus herein contemplated to maintain a fixed pressure in the line between the pressure regulator and the control. The capacity of the pressure regulator will always be sufficient to assure an adequate supply of fluid to the control, although the latter may be operating to capacity. The pressure regulator may be omitted where the gas pressure is maintained steady by the compressor.

With a fixed and unvarying pressure assured on the upstream side of the orifice, the next step is to provide an orifice the size of which will, in effect, increase or decrease in accordance with the variation of pressure on its opposite or downstream side, or the side adjacent to the well; and also provide against closing or locking of the control mechanism, regardless of the extent to which the pressure may drop when the well heads. It is an object of the invention to embody these new and desirable features in an apparatus.

Since it is desirable that the volume of gas flowing through the control be known at all times, it is an object to provide visible means also for indicating with a reasonable degree of accuracy the rate of flow, regardless of the pressure being carried in the gas or air lines. This consists, broadly, of a mechanism that indicates at all times the size of an adjustable orifice, the latter being placed at an appropriate point in the device.

With these and other objects in view, as will appear as the description proceeds, the invention consists in the novel features of construction and combination of elements and parts hereinafter to be fully described and pointed out in the claims.

In the accompanying drawings:

Fig. 1 is a vertical sectional view through an installation embodying the component parts of the control apparatus.

Fig. 2 is a view mostly in section showing the indicator.

Fig. 3 is a section on the plane 3—3 of Fig. 2.

Fig. 4 is a sectional view on the plane 4—4 of Fig. 2.

Fig. 5 is an assembly view showing the device connected within a fluid pressure line.

The device is intended for inserting within a flow line for the pressure fluid and between the pump or compressor and the pipe leading into the well or at any other place where fluid pressure is desired. In Fig. 1 is shown an assembly the use of which is contemplated, a pipe A being understood as leading from the source of fluid under pressure. The port B at the opposite side is adapted to be connected to the well where the pressure fluid is to be employed. The fluid is intended to pass from the port A by way of a safety valve indicated at F and a regulating valve C to the control D and from there to the outlet port B. Directly between the two ports A and B a relief valve E may be employed.

The safety valve adjacent the port A comprises a sleeve 14 extending longitudinally of a pipe 3 and having at its lower end a flange 1 fitting closely against the inner walls of the pipe 3 and having the passages 2 therethrough for the pressure fluid. There is a central passage 4 from the lower end of the tube 14, leading to a valve seat 7 closed by a ball valve 5. Said valve is held normally seated by means of a weight 8 resting thereon and it is to be understood that this weight may be regulated to hold the valve 5 closed with a predetermined pressure. The upper end of the tube 14 is connected by a nipple 9 to a plug 13. Said plug 13 has an L shaped passage 11 thereto into which the nipple 9 is screwed. A passage 10 through the nipple connects with the L shaped passage 11 into which an outlet conduit 12 is connected. The said conduit makes connection with the control mechanism D as will be later described.

The plug 13 has a plurality of passages 15 extending longitudinally thereof and connecting with a chamber 16 within the regulator C. Said regulator includes a tubular member having at one side thereof a threaded opening in which is screwed a stuffing box 17 within which a stem 22 is rotatable. There is a packing 19 about said stem and a spring 18 within the box bearing against a washer 20 and acting to compress the packing about the rotatable stem. A gland 21 on the outer side of the stuffing box may be employed to adjust the pressure upon the packing. The spring 18 normally holds the packing under pressure, tending to take up ordinary wear.

The stem 22 is connected at its inner end with a valve member 23. Said valve member has a socket in which the stem 22 is connected, said stem being held therein by a transverse pin 24. Adjacent the stem 22 the valve member is provided with a chamber extending longitudinally of the valve and having a lateral orifice 25 therein, from which ports 27 lead to the interior of a chamber in the valve housing 30. Within said chamber is a transverse disc 29, having openings 28 therein and a central threaded opening within which the threaded end 76 of the valve is screwed. The said threaded end extends beyond the disc a material distance and is held at its end by a nut 31 which may be fixed upon the valve stem and sleeves to limit the motion of the valve in one direction.

The end of the valve housing 30 adjacent the valve stem 22 is extended inwardly about the valve forming an approximately fluid-

tight enclosure 30*a*, through which no appreciable amount of fluid may pass. This flange serves to close the space between the chamber 16 and the chamber 29′ within which the valve is movable and when the valve is screwed into the sleeve 30 as shown in Fig. 1 the orifice 25 will be closed. When, however, the valve is unscrewed by means of the stem 22, the orifice will be gradually advanced into the chamber 16, allowing the fluid to pass from said chamber into the chamber 29′ in an obvious manner.

The dial chamber 29′ is connected by a coupling with a pipe 26 which leads by way of the pressure control to the outlet passing to the well. The pressure control comprises a fitting connected with a pipe 26, having therein a chamber 87. The lateral opening in this chamber provides a connection with a special coupling 72, threaded at its inner end within a tube 51. The coupling 72 has a plurality of longitudinal channels 44 therein, away from the central axis of the coupling, these channels leading to a chamber 45. The coupling 72 has an axial passage therein with a central chamber 79*a*. The inlet end leading to this chamber is provided with a valve seat 42 which has a driving fit at 98 within the end of the coupling, this seat being adapted to receive a tapered head 41 of a valve member. The upper end of the chamber 45 is closed by a flange 40 except for the plurality of openings 77 leading from the chamber 45 to the interior of the pipe 51.

The valve 41 has a stem 33 thereon, extending through the pipe 51 and through a housing 52 for an expansible pressure member 32. Said housing 52 is connected at its inner side to a nipple 55 which is screwed within an opening in the pipe 3, as will be seen from Fig. 1. A passage 78 in said nipple is closed on the side adjacent the housing 52, except for a central opening in which a bushing 36 is screwed. This bushing has a passage through which the valve stem 33 may pass, acting as a guide for said valve stem and also allowing a passage for the pressure fluid from the pipe 3 into the interior of the diaphragm 32.

Within the housing 52 the pressure member 32 previously referred to is located. It is made up of a series of discs connected together in pairs at their outer margins and having a central opening through each set of discs to which the discs are welded. Thus there is a passage centrally through the discs for the valve stem and the valve stem is slidably free therein. A bellows arrangement, which allows maximum movement of the stem 33, is thus provided into which the pressure fluid may find access. The inner one of the bellows sections is connected at 36′ with the bushing 36. The opposite end of the bellows is connected to a stop member 35 screwed upon the valve stem at 37 and serving not only to close the pressure member 32 at that end, but also as a stop for a spring 39 surrounding the valve stem and pressing at its other end against a flange 40. This spring is under a predetermined pressure and tends to prevent the head 41 from closing the orifice 42.

The outlet end of the chamber 79*a* is connected with a member 46 which serves as a fitting connecting the interior thereof with a laterally extending tube 47, the end of which is welded at 49 with the forward end of a connecting member 48. The fluid passing through the connecting member 47 will pass into the pipe 50 and from there to the port B.

The relief member E acts as a by-pass directly from the port A to the port B and serves the purpose of allowing a passage directly to the port B; when the pressure within the assembly exceeds a predetermined amount it acts to eliminate the possibility of rupturing and bursting any part of the diaphragm 32 should a volume of gas under extraordinarily high pressure be suddenly applied to the control device and for other purposes as will be later seen. There is a bushing 57 screwed within one end of the housing 56 for this member, said bushing having a central passage leading from the connecting pipe 99 to a valve chamber, said valve chamber is an extension 57′ upon the bushing 57 and it is closed at its forward end by a plug 60. A valve seat 58 is fitted within the inlet end of the valve chamber to accommodate a ball valve 59, said valve is held within the seat by means of a spring 62, having at each end thereof a bearing member 65 or 64. Said spring may be adjusted as to tension by means of a threaded shaft 61, extending axially through a plug 60 and bearing upon the member 64. There are lateral openings 66 in the valve chamber leading to a passage 68 through which the fluid may pass to the chamber 67 adjacent the outlet port B.

Referring to Fig. 1 and disregarding the spring 39, it will be noted that if the internal area of the diaphragm 32 be four sq. in., and the gas pressure be 100 lbs., the total pressure tending to force the valve-head 41 forward will be 400 lbs. This will of course force the valve 41 into the orifice 42 and close the chamber 45 to the escape of gas through said orifice 42. Assuming further that the area of the orifice 42 is 1 sq. in., it will be seen that if 100 lbs. pressure now be applied to the exterior of the diaphragm 32 through the chamber 45, that the total force tending to move the valve-head 41 out of the orifice 42 will only be 300 lbs.; for the reason that the effective outer area of the diaphragm 32 is reduced to the extent of the orifice 42. In other words, with 100 lbs. of gas pressure on either side of the diaphragm 32, the total force tending to close will be greater by 100 lbs. than the total force tending to open.

Under these conditions the valve would, of course, remain in closed position. This is due to the fact that by reason of the area of the orifice 42 being 25% of the area of the interior of the diaphragm 32, the total effective area tending to open the valve 41 is less by 25% than the total effective area tending to hold it in closed position; for the area tending to close will be 4 sq. in., whereas that tending to open will be 3 sq. in.

If now, 100 lbs. tension be placed on the spring 39, the valve 41 would still remain closed for the reason that the spring pressure of 100 pounds plus a total of 300 pounds gas pressure on the external side of the diaphragm, would just equal the 400 pounds pressing against the interior of the diaphragm, from the entry 78.

But should the tension on the spring now be increased to 115 pounds, the total force tending to open the valve will be 415 pounds, whereas the total force tending to hold it in closed position will still be 400 pounds. Under these conditions the valve-head 41 will move out of the orifice 42 far enough to permit the escape of 5 lbs. per sq. in. of gas pressure from the chamber 45 via the orifice 42; and since the exterior of the diaphragm 32 communicates with the chamber 45, through the orifices 77, this pressure will also have been removed from its exterior, thus restoring an equilibrium between the forces tending to open and those tending to close.

It will be observed that when the tension on the spring 39 was raised from 100 pounds to 115 pounds an "excess" pressure of 15 pounds was added to the force tending to open the valve 41; the effect of this was as though 5 lbs. per sq. in. more gas pressure had been added to the exterior of the diaphragm than was being exerted on its interior; and the result of this was that the valve 41 released 5 lbs. per sq. in. gas pressure, or a total pressure of 15 lbs. from the exterior of the diaphragm to restore a balance of the two forces controlling its movement. This means that the pressure in the chamber 45 has now dropped to 95 lbs, per sq. in., and that this pressure will remain constant in the chamber thereof. Thus it will be seen that the difference in pressures as between the pipes 3 and the chamber 45 will be determined at all times by the "excess" tension on the spring 39. If the total tension on the spring be 130 lbs., and the gas pressure remain at 100 lbs., then there will be an excess pressure of 30 lbs. tending to open the valve. This in turn will mean that 10 lbs per sq. in. in gas pressure will be released by the valve 41, or a total of 30 lbs., and that the pressure in the chamber 45 will drop to 90 lbs. per sq. in. instead of 95 lbs.

With 115 lbs. tension on the spring 39, when the valve-head 41 has been forced out of the orifice 42, it will have moved only far enough away from the orifice 42 to permit the escape of 5 lbs. per sq. in. of gas pressure from the chamber 41 and will stop in this position until there is a change in gas pressure. If 5 lbs. of gas pressure per sq. in. escaped when the valve 41 opened, then there would remain 95 lbs. per sq. in. gas pressure in the chamber 45; for 5 lbs. pressure from 3 sq. ins. totals 15 lbs.; and 15 lbs. from 415 lbs. equals 400 lbs.; so that when the valve reaches this position the force tending to close will equal the force tending to open and the valve will, as said before, stop at this point as long as there be no fluctuations in gas pressure.

Should the gas pressure in the chamber 45 tend to drop below 95 lbs. the valve-head 41 will move back into the orifice 42 and check the flow of gas to a point where 95 lbs. pressure would be restored to the chamber 45; for if the pressure in the chamber 45 drop to 90 lbs. per sq. in., then the total force tending to hold the valve in open position would be less by 15 lbs. than the force tending to close; for 90 lbs. gas pressure times 3 sq. in. equals 270 lbs. gas pressure plus 115 lbs. spring tension equals 385 lbs.; but the effective closing pressure would still be 100 lbs, gas pressure times 4 sq. in., or a total force of 400 lbs. tending to close. Thus it is seen that the valve 41 will move back and forth to reduce or increase the area opened to gas flow through the orifice 42 in direct proportion to the rise and fall of pressure in the chamber 45; and even though the gas flowing through orifice 42 be into the atmosphere, under the conditions just outlined, the pressure would always remain at 95 lbs. per sq. in. in the chamber 45; and further, that a difference of 5 lbs. per sq. in. will remain constant as between the entry 78 and the chamber 45.

From this it will be seen that the difference in pressure as between the entry 78 and the chamber 45 will be determined by the tension on the spring 39. This tension will be predetermined by the relative areas of the diaphragm 32 and the orifice 41, and will be placed on the spring when the apparatus is assembled. Further, the spring will be long enough and resilient enough so as to prevent any appreciable increase of its tension when the diaphragm 32 expands to move the valve stem 33 forward.

Referring to Fig. 1, it will require 10 lbs. per sq. in., against the ball valve 5 to lift the weight 8 and pass the gas pressure through the conduit 12 to the housing over the diaphragm 32. However, it has been seen that the difference in pressure as between the chamber 45 and the entry 78 will at no time be in excess of 5 lbs., per sq. in., under operating conditions. And, since there is communication between the chamber 45 and the housing over the diaphragm 32, it will be obvious that there would be no gas flow through the

safety valve to the housing over the diaphragm 32 when the apparatus is properly functioning. If, however, the orifice 25 be closed and, through leakage at the valve 41 or other causes, the gas pressure in the housing over the diaphragm 32 should drop to a point where there was danger of bursting the diaphragm, the gas will then begin entering through the conduit 12 via the safety valve 5 to maintain pressure on the opposite side of the diaphragm 32. This is the only function of the safety valve.

From the foregoing it is noted that with 100 lbs. gas pressure on either side of the diaphragm 32 and 100 lbs. tension on the spring 39, and with atmospheric pressure in the outlet 79*a*, that the valve 41 would tend to close as shown in the drawing.

But, if operating the device with 110 lbs. pressure and 100 lbs. tension on the spring, it is assumed that the gas will be flowing into a well casing or other receptacle and that pressure is being carried on the opposite side of the valve 41 in the outlet 79*a*. This being true, the automatic by-pass valve 59 will be set to open at 95 lbs. per sq. in., thus passing gas pressure to the outlet 79*a* through the pipe connection 67. So it will be seen that before the valve 41 could close, the by-pass will open and admit gas pressure to the opposite side of valve 41 at 79*a* through the conduit 47; for it has already been seen that the difference in pressures as between the chamber 45 and the outlet 79*a*, must be 100 lbs. or more per sq. in. before the valve 41 will close. This being true, with gas pressure at 110 lbs., the valve 41 would never close, although the pressure as between the outlet 79*a* and the chamber 45 may vary as much as 95 lbs. per sq. in. For, if the pressure in the outlet 79*a* drops below 15 lbs. the by-pass begins admitting gas to the opposite side of the valve at 79*a*. The pressure is in turn exerted back against the outer area of the diaphragm 32 through the orifices 77, thus causing the diaphragm to collapse and the valve 41 to assume an open position.

It will further be seen that by varying the areas and dimensions of the parts comprising the apparatus, that even greater differentials may be obtained. But, with the device constructed as herein described, the gas pressure may be raised to any point without readjusting any of the parts, and still preserve the differential of 95 lbs. For if the pressure on the inner side of the diaphragm be 300 lbs. per sq. in., this pressure will also be transmitted to the outer side of the diaphragm 32 through the chamber 45 and the orifices 77.

In operation, Fig. 1, the gas enters through the pipe 3, thence through the perforations 2—2 and the passages 15—15 to the orifice 25.

The stem 22 will then be rotated and the orifice 25 opened to any desired point, by being forced out of the bearing 30*a* in the manner already described. Thus the operator may increase or decrease the size of the orifice 25 at will, by merely rotating the stem 22.

It has already been seen that, with the device constructed to the dimensions given herein, there will be a constant difference of 5 lbs. pressure per sq. in. as between the pipe 3 and the chamber 45 when in operation, and, since there will be no restriction between chamber 45 and orifice 25, the gas pressure will be 5 lbs. less in the pipe 26 than in the pipe 3; for the orifice 25 will be the restricting agency as between pipe 3 and pipe 26.

Thus it is seen that with gas pressure at 100 lbs. there will be a difference of 5 lbs. pressure per sq. in. as between the upstream and the downstream side of orifice 25; and that even though the gas flow be into the atmosphere at 79*a*, with the pressure at 100 lbs. in pipe 3, 95 lbs., per sq. in. pressure will be constantly maintained in the pipe 26. This means that while in operation there will at all times be a pressure greater by 5 lbs. per sq. in. in pipe 3 than in pipe 26; for the pipe 26 and the chamber 45 have now become one, and the same forces will control the rise and fall of pressure in the pipe 26 as in the chamber 45.

Assuming that the pressure being carried in the apparatus is 100 lbs. and that the gas is discharging into the atmosphere at 79*a*, the pressure will then be 95 lbs. in the pipe 26, for the orifice 25 will be restricting gas flow to the extent of 5 lbs. per sq. in. If the size of the orifice 25 be reduced then the pressure in pipe 26 will tend to drop by reason of lesser flow. The pressure in pipe 3 would not rise, however, as the regulator 1 will hold this constant, and will shut off flow to the pipe 3, should the pressure rise above 100 lbs.

Should the pressure tend to drop below 95 lbs. in the pipe 26, the valve 41 will move into the orifice 42 and arrest gas flow to a point where 95 lbs. per sq. in. would be maintained in the pipe 26.

If the size of orifice 25 be increased to admit more gas from pipe 3 to pipe 26, the pressure will tend to drop in pipe 3, but the pressure regulator will open to supply the increased flow. With the increased flow the pressure will tend to rise in the pipe 26, but then again the valve 41 will move out of the orifice 42 and permit the gas to escape to a point where only 95 lbs. per sq. in. will be held in the chamber 45.

It has been found that under a 5 lb. differential, that is, a pressure greater by 5 lbs. per sq. in. on the upstream side than on the downstream side, that approximately 60 cu. ft. of gas will flow through a ½″ orifice each minute. If then the orifice 25 be ½ in. in diameter, it will be seen that with the pressure in pipe 3 at 100 lbs. and the pressure in pipe

26 at 95 lbs., that approximately 60 cu. ft. will be flowing through orifice 25 each minute. But bearing in mind that there is 95 lbs. pressure in pipe 26, and that the gas is flowing into the atmosphere from the chamber 45, it is plain that the area open to gas flow at valve 41 will have to be much smaller than the equivalent of an orifice ½ in. in diameter; for it is found that approximately 8 times as much gas will flow through a ½ in. orifice under a 95 lb. differential as will under a 5 lb. differential. This being true, it will be seen that the valve 41 will automatically move in and out of the orifice 42 to increase or decrease the area open to gas flow from chamber 45 to correspond to the open area of orifice 25. With the pressure as just outlined, the area open to gas flow at 42 would be approximately ⅛ the area of the orifice 25, since as much gas will flow through the smaller size into the atmosphere under a 95 lb. differential as will through the larger under a 5 lb. differential.

If now pressure in 79*a*, Fig. 1, begins to build up, it would not diminish the flow of gas through the orifice 25; for the valve 41 would recede into the chamber 45 and increase the open area of orifice 42 in exact ratio to the increase of pressure in the outlet 79*a*, thus assuring that the same volume would be moving through the orifice 25 as when flowing into the atmosphere at 79*a*. If, for instance, the pressure in 79*a* increases to 45 lbs., this pressure would be exerted back against valve head 41, thus reducing to that extent the force tending to close it. This would mean, of course, that the valve 41 would recede into the chamber 45; thus, as said before, increasing the area open to flow at 42 in exact ratio to the increased resistance offered at 79*a*. Until there was pressure in 79*a*, valve 41 had reduced the outlet at 42 to a point where 95 lbs. pressure was maintained against the downstream side of orifice 25; but with 45 lbs. at 79*a*, it will only be restricted to the extent of 50 lbs. as between the chamber 45 and the outlet 79*a*, and the area open to gas flow at 42 will be approximately twice that as without pressure in 79*a*. From this it will be seen that, while the pressure may vary as between the outlet 79*a* and the orifice 25, the volume of gas moving through the pipe 26 will remain the same as long as the pressure in 79*a* remains below 95 lbs. Should the pressure in 79*a* rise above 95 lbs., the flow will, of course, then be retarded in the pipe 26, and the volume of gas moving through 26 will diminish, for valve 41 will have ceased to function, due to an equalizing of the forces by which it is actuated.

From the foregoing it will be seen that the orifice 25 is the restricting agency as between pipe 3 and pipe 26; and the valve 41, by gauging the volume, and maintaining a constant density of fluid on the downstream side of the orifice is the factor that makes it practical to indicate the volume of fluid flowing thru the device.

It will be seen that, by changing the connections on the apparatus, the housing enclosing the diaphragm 32 may be used in a vertical position and that a weight may be substituted for the spring 39 and still obtain the same results as claimed herein.

Manually operated means are also provided to indicate the volume of gas flowing through the apparatus so that one may know at any time the pressure and the volume of the gas flowing through the control mechanism. In Figs. 2, 3 and 4 the details of this indicator are shown. The indicator is connected directly to the chamber 30, Fig. 2, for the valve 23 previously described. Within one side of the chamber 30 and adjacent the tapered part 102 of the said valve there is provided a bushing 112 which is screwed within the wall of the chamber 30 and extends laterally away from the chamber, providing a housing for a stem 111. Said stem is guided in its movement within the bushing 112, the inner end of the stem passing through a plug 116 which acts as a gland upon the packing 114 which is held in position by means of a spring 113. This packing prevents the escape of pressure fluid past the stem 111 into the indicating mechanism. The bushing 112 is mounted within the lower wall 118 of the indicator housing 123. The upper end of the stem 111 passes through a plug 116 and fits within the cupped lower end of a member 120 the upper tapered end of which fits within a recess 121 of the lever 122. Said lever 122 is pivoted upon a threaded pin 175 which is adjustable within a plurality of openings within the housing to vary the effect of the length of the lever 122 and the free end of said lever is connected by a link 124 with the arm 125 of a bell-crank lever, the other arm of which is formed into a rack or gear 125′ which meshes with a segmental gear 128 pivoted upon a pin 130. The free end of the lever 122 is held resiliently downward by means of a spring 139 pressing at its upper end against a stationary bracket in a housing and at its lower end upon a nut and washer 140 at the lower end of a rod extended through the end of the lever 122.

The gear 128 has secured frictionally thereto an arm 131 held upon the gear 128 by means of a screw 132. The arm 131 has a socket 135 therein to receive the pointer 134 secured adjustably in said socket by means of a set screw 136.

The pointer 134 will be carried in the slot 135 and held in position by the thumb-screw 136. The coil spring 137 will at all times prevent lost motion in the pointer 134 in a manner easily understood. It will be seen that the interior of the head 120 is an inverted cone, rounded at its smaller end; this permits a

rocking motion of the head 120 which in turn permits the stem 111 to travel in a direct line, although the notch 121 may tend to describe a circle in its upward and downward movement. In operation, there will be gas pressure in the member 30, which will tend to force the stem 111 upward; the spring 139 will counteract this force, and may be set to correspond to any pressure in 30 by the nut 140.

Numeral 141, Fig. 3, is a shutter that encloses the mechanism and is clamped to the housing by thumb screws as shown at 143 in Fig. 2.

Numeral 144, Fig. 3, represents a glass portion of the housing. The upper edge of the glass 144 will be circular and will fit into the circular portion of the housing as shown at 146, Fig. 2; the upper and circular edge of the glass will fit loosely in the housing 146 as shown at 147, Fig. 3, and will be supported by its ends resting in the housing. The member 149, Fig. 3, is the bracketed dial shown at 150 in Fig. 2. The dial carries the printed numerals and is made of any suitable material. A recess in the housing receives and holds the dial in position as shown at 149, Fig. 3.

The travel of the pointer 134 may be increased or decreased by changing the position of the screw 175, Fig. 2, relative to the openings in the arm 122. The packing 114 may be renewed by removing the screw 175, which in turn permits removal of the head 120, when the gland 116 is screwed out of the member 117. Gas will not escape while the packing is being replaced; for the beveled portion 176 on the member 111 will move into and seal the space 177 to the escape of gas in a manner easily understood.

Assuming now, that the pressure being carried is 150 lbs., and that the stem 22, Fig. 2, has been rotated to the right to a point where orifice 25 has been drawn into the housing 30. Orifice 25 will then be closed to the flow of gas through the member 30; and the stem 111 will have traveled up the beveled face of 102 until it is in position on the cylindrical portion of 23. This upward travel of the stem 111 will have imparted a left hand movement to the pointer 134, causing the latter to swing around to the pressure column P on the dial 150, thus indicating that orifice 25 is closed to gas entry to the chamber 30.

In computing the rates of flow herein, an orifice $\frac{1}{8}''$ in diameter is taken as a unit of measurement, and 1000 cu. ft. of free gas flowing through the orifice as the unit of volume.

If, for instance, the threads at 107 be 16 per linear in., it will mean that for each complete turn of the stem 22 the member 23 would move in or out of orifice 30*a* $\frac{1}{16}$ linear in.; and if the width of orifice 25 be $\frac{1}{4}''$, it will be seen that each turn of the stem 22 will increase or decrease the size of orifice 25 by what is approximately the equivalent of an orifice $\frac{1}{8}''$ diameter.

The mechanism actuating the pointer 134 will be coordinated with the horizontal movement of member 23 in such a manner as to cause the pointer to move from the center of one column to the center of another, on the dial 150, with each complete turn of the member 22. If the member 22 be rotated one complete turn to the right, it would cause the stem 111 to travel upward along the bevel face 102; this would mean, of course, that stem 111 had traveled a given distance in an upward direction. This upward movement of stem 111 will, as said before, be transmitted to the pointer 134 in such a manner as to cause the latter to move from the center of one column to the center of another on the dial 150. From this it will be seen that the pointer will at all times indicate the open area of orifice 25.

In the following, the number 15 is arbitrarily selected to represent one atmosphere as the unit of compression, and the exact figure (14.7, 60° F.), disregarded.

In operation, it is assumed, as pointed out and described in preceding pages, that the apparatus is operating under a 5 lb. differential; that is, there is a difference in pressure of 5 lbs. per sq. in. as between the upstream and the downstream side of the orifice 25.

It is found that under a 5 lb. differential, 3.86 cu. ft. of free gas will flow into the atmosphere through a $\frac{1}{8}''$ orifice each minute, or a total of approximately 5,500 cu. ft. per 24 hours.

However, if free gas be compressed to 10 atmospheres, or 150 lbs. per sq. in. it will have been reduced to $\frac{1}{10}$ of its volume at atmospheric pressure. If, then under a 5 lb. differential, and flowing into atmosphere, 5,500 cu. ft. of free gas moves through a $\frac{1}{8}''$ orifice in each 24 hours, when compressed to 150 lbs. and flowing against a pressure 5 lbs. less, or 145 lbs., it will be seen that 10 times the volume of free gas will be moving.

If compressed to 20 atmospheres, or 300 lbs. per sq. in., the volume moving would be approximately twice that moving under 150 lbs. pressure, assuming always that the differential of 5 lbs. as between the upstream and downstream sides of the orifice is maintained. For it is found that for each unit of compression added, the volume of air confined is increased by the capacity of the receiver at atmospheric pressure; if the receiver holds 100 cu. ft. of free gas or air then another 100 cu. ft. added would raise the compression one atmosphere or 15 lbs. per sq. in. Thus a pressure gauge reading of 150 lbs. will indicate that there is 10 times the capacity of the receiver at atmospheric pressure confined, plus the 100 cu. ft. it held when compression started.

Thus it will be seen that the higher the degree of compression, the greater will be

the volume of "free" gas moving through the orifice.

If operating the device under 150 lbs. pressure, then the member 22 will be rotated in a manner already described until the pointer 134 moves to the pressure column P. This will indicate that the orifice 25 is closed. The pointer 134 will then be moved out of the slot 135 until it is in the position with the pointer resting in the pressure column P and pointing to the first or lowest pressure bracket, that is "150", the pressure with which the apparatus is to be operated.

If now the member 22 be rotated one turn to the left, the pointer 134 will move to the position in the next adjacent column, and will rest in column I with its point at "55"; this will indicate that the orifice 25 has been opened to the equivalent of an orifice 1/8" in diameter, and that gas is flowing through at the rate of 55,000 cu. ft. of free gas each 24 hours. If it be desired to double the flow of gas, another left hand turn of member 22 sends the pointer to column II, which indicates that there is the equivalent of two 1/8" orifices open to gas flow, and that the volume moving through orifice 25 is now 111,000 cu. ft. per 24 hours. If the member 22 be rotated until the pointer rests in column IX, then it will indicate that there is the equivalent of nine 1/8" orifices open to gas flow at 25, and that the volume passing through is 500,000 cu. ft. per 24 hours.

If the pressure now be raised to 325 lbs. the pointer 134 will be set to rest on the 325 lbs. bracket in column P, and the stem rotated until the pointer indicates the desired flow. If the pointer rests as shown in the drawing, Fig. 2, then it will indicate that 509,000 cu. ft. of free gas is flowing through the orifice 25 each 24 hours and that the pressure being carried is 275 lbs.

The diaphragm 32, Fig. 2, is only one form of pressure operated means separating the pressure fluid chamber 78 from the chamber 45 and it is to be understood that other equivalent devices are contemplated at this point.

By the use of this control the volume of air or gaseous fluid delivered to the well or other receptacle may be automatically controlled so that the operator is assured of a uniform rate of discharge of fluid to the well no matter what the back pressure in the well may be.

What we claim as new is:

1. In a device of the character described, a flow line, a valve chamber therein, a valve adapted to fit an orifice therein, means to deliver a predetermined flow of air to the upstream side of said orifice, and means to control said valve to pass a predetermined volume of fluid through said orifice regardless of the amount of fluid pressure on the downstream side of said orifice, means to automatically pass pressure fluid to the downstream side of said valve when there is a predetermined difference of pressure on the opposite sides of said orifice.

2. A pressure fluid regulator device arranged to maintain a constant flow of fluid at varying pressures comprising a valve, a discharge orifice, means between said valve and said orifice to vary the size of orifice in proportion to the back pressure at said orifice.

3. A pressure fluid regulator including a regulator valve, a discharge orifice, a control valve for said orifice, and means to balance said control valve whereby an equal quantity of fluid by weight will pass both said regulator valve and said control valve at varying pressures.

4. A pressure fluid control system including a regulator valve subjected to a constant pressure on its upstream side, a discharge orifice, a control valve to vary the size of said orifice, and balanced means operable by variations in back pressure on said control valve to vary the size of said orifice so that equal quantities of pressure fluid will pass said regulator valve and said control valve.

5. In a pressure fluid regulator, a regulator valve and a control valve, means to subject said regulator valve to a constant differential pressure whereby a known quantity of fluid will pass therethru, means to subject said control valve to the downstream pressure of said regulator valve and to a variable back pressure, and additional balanced means to operate said control valve to release a quantity of fluid equal to that passing said regulator valve regardless of the back pressure on said control valve.

6. In combination with a pressure fluid flow regulator apparatus, means to measure the flow of fluid therethru at a constant predetermined pressure, and means subject to a variable back pressure to control the discharge of fluid from said apparatus at a rate equal to that of the measured flow.

7. In combination with a fluid pressure flow line, a regulator valve subjected to a constant differential pressure, a control valve subjected to a variable differential pressure, and means to actuate said control valve in response to changes in its differential pressure whereby the rate of flow of fluid thru both of said valves will be equal.

In testimony whereof we hereunto affix our signatures this 20th day of July, A. D. 1928.

JAMES W. TAYLOR.
W. M. WHELESS.