April 28, 1942. A. BOYNTON 2,280,787

DIFFERENTIAL STAGE LIFT FLOW DEVICE

Filed Dec. 8, 1939 2 Sheets-Sheet 1

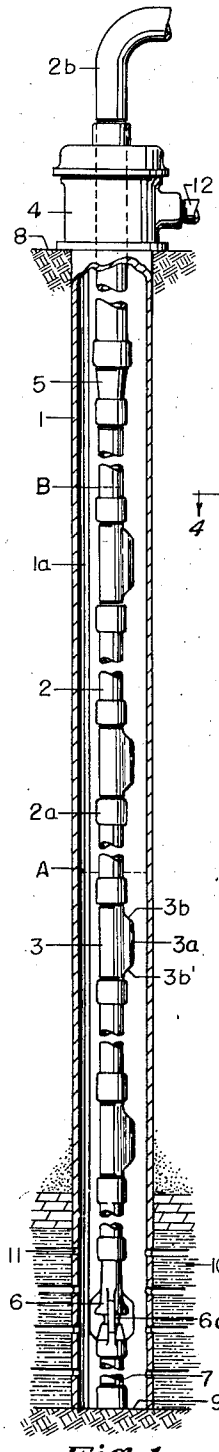


Fig. 1.

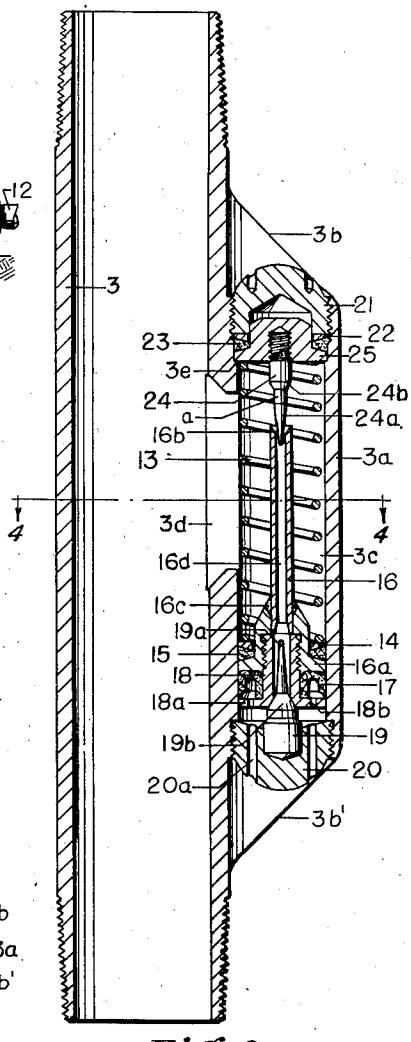


Fig. 2.

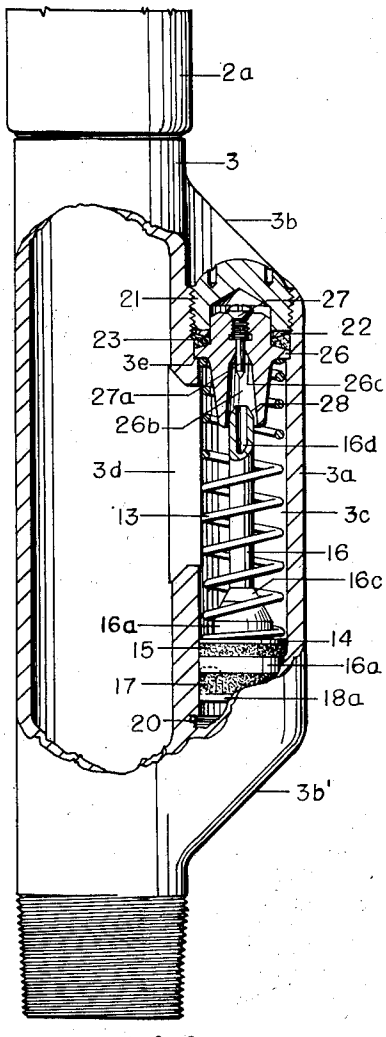


Fig. 3.

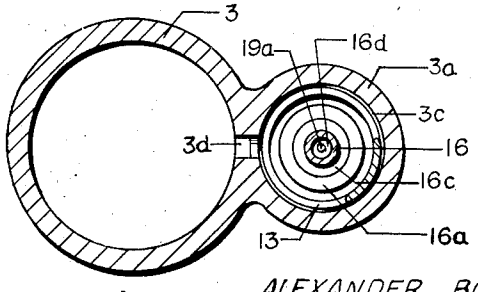


Fig. 4.

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Filed Dec. 8, 1939 2 Sheets-Sheet 2

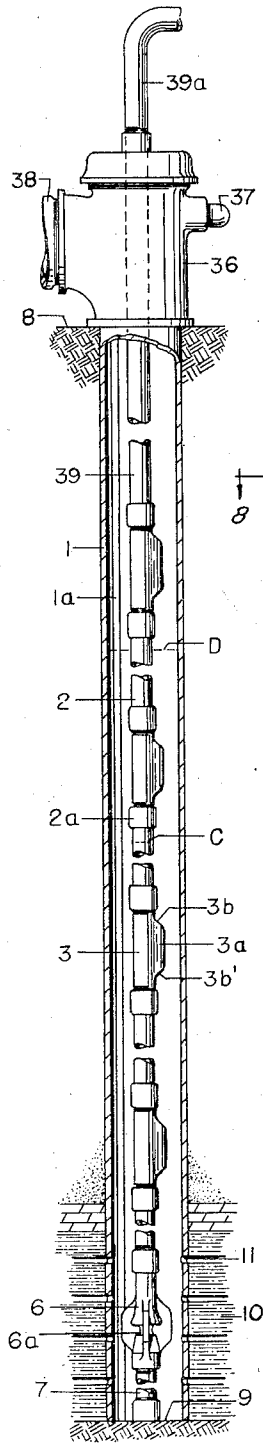


Fig. 5.

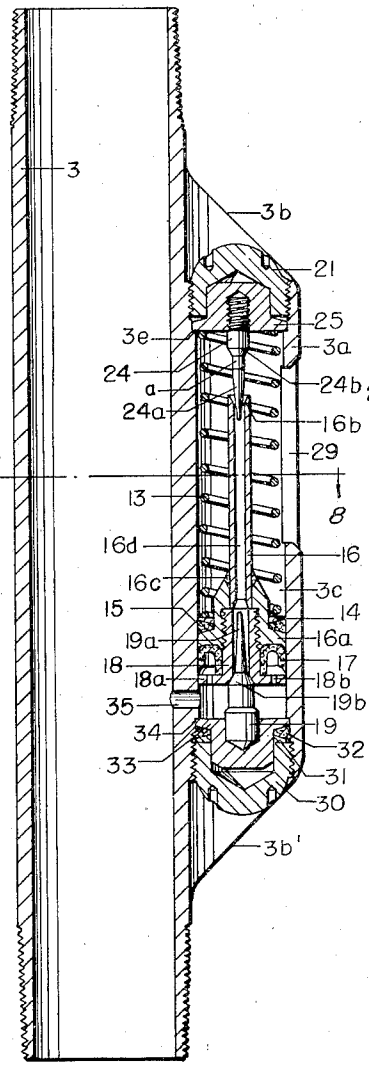


Fig. 6.

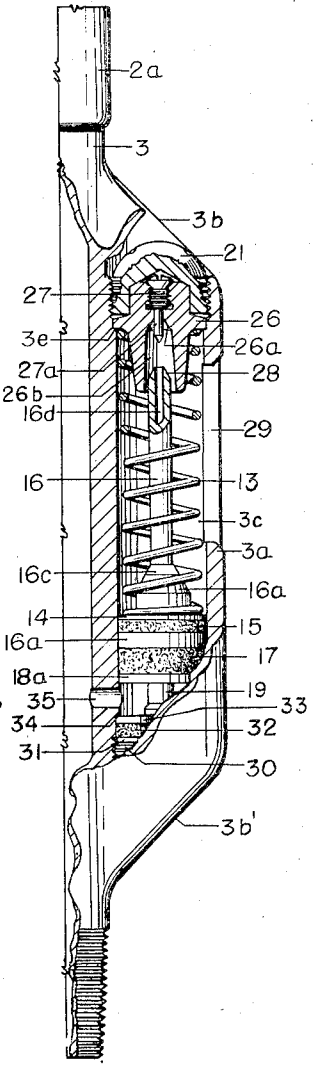


Fig. 7.

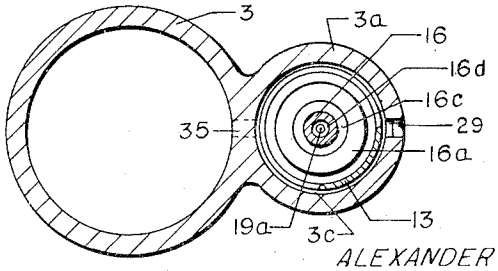


Fig. 8.

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UNITED STATES PATENT OFFICE

2,280,787

DIFFERENTIAL STAGE LIFT FLOW DEVICE

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Application December 8, 1939, Serial No. 308,306

5 Claims. (Cl. 137—111)

My invention relates to flowing devices for wells, compressed air or gas being employed as the lifting force.

An object is to provide a larger area than that of the valve, upon which larger area force is employed to actuate the valve.

Another object is to so construct the valve that it will not chatter, flutter, or fly open when slugs of well liquid in the eduction tube pass the devices.

Another object is to provide a means for flowing wells through the tubing which means can be readily adapted for flowing wells through the casing.

A further object is to provide a flowing device with an extremely sensitive valve which will not be apt to leak in service.

Another object is to regulate and control the flow of the lifting medium through the devices so as to obtain great efficiency in the use of the lifting force.

A still further object is to provide means for protecting the valve and valve seat from being damaged by abrasive substances in the pressure fluid.

In accomplishing the foregoing objects, I employ a series of devices spaced at intervals in the tubing, each device having a movable valve slidable in a chamber interposed between the eduction tube and the pressure fluid. The valve is normally urged open by the yieldable force of a coiled spring. An axial opening through the valve admits pressure fluid into the well liquid where the resistance of the well liquid is less, within predetermined limits, than the force employed to lift the liquid. This opening is adapted to be closed by a valve wherever the resistance of the well liquid is less than the minimum value of such predetermined resistance. A combination sleeve and tapered valve is employed to prevent the improper admission of lifting force during momentary fluctuations of the differential.

I attain the foregoing objects by mechanism explained in this specification and illustrated in the accompanying drawings in which:

Fig. 1 is an installation plan of the device in a well adapted to be flowed through the tubing.

Fig. 2 is a longitudinal section of the preferred embodiment of the invention for tubing flow.

Fig. 3 is mainly a longitudinal section of a modified form of the valve mechanism in Fig. 2.

Fig. 4 is a cross section on the line 4—4, Fig. 2.

Fig. 5 is an installation plan of the device shown in Fig. 6, for flowing the well through the casing.

Fig. 6 is a longitudinal section of a modified form of the device shown in Fig. 2, adapted for casing flow.

Fig. 7 is mainly a longitudinal section of the device shown in Fig. 3 adapted for casing flow.

Fig. 8 is a cross section on the line 8—8, Fig. 6.

Similar characters of reference are employed to designate similar parts throughout the several views.

In Fig. 2, the tubular nipple portion 3 of the device may be cast or otherwise formed integrally with the tubular shell 3a, the intervening wall being slotted at 3d.

Within the upper end of the shell 3a, the base plate 25 is engaged upon the slight internal annular shoulder 3e. The packing 23 is engaged between the upper side of the plate 25 and the gland ring 22 by the top plug 21, having threaded engagement within the upper end of shell 3a. The upper end of the bore 3c thus is closed hermetically.

The upper pin base 24, having the depending tapered pin 24a, has central threaded engagement within the plate 25.

The bottom plug 20, having threaded engagement within the lower end of the shell 3a, has the passages 20a. The lower pin base 19, having the upstanding tapered pin 19a, may be pressed into or otherwise secured within and central of the plug 20.

The valve seat 19b is adapted to engage a mating valve within the lower end of the assembly nipple 18. The valve 16b is adapted to engage the seat 24b, from which it is urged resiliently by the spring 13.

The valve member 16 may be pressed into the base 16a and secured there by the weld 16c. The valve assembly nipple 18 is engaged threadedly within and central of the lower end of the base 16a. The U cup 17, which may be of leather or any other tough yieldable substance, in any other suitable form, is secured between the member 16a and the flange 18a by the threaded engagement between the members 16a and 18. Obviously, metallic rings, which preferably should be staggered, may be employed in place of the U cup or packing 17. The openings 18b admit pressure fluid to contact the nether side of the cup 17 and expand it against the wall of the bore 3c. The packing 15 is engaged between the upper side of the member 16a and the gland ring 14 by the expansive force of the coiled spring 13, which is installed under some compression between the ring 14 and the plate 25.

The parts 14 to 18, both inclusive, will be referred to as the movable assembly. This assem-

bly is closely slidable below the slot 3d within the polished surface of the bore 3c, which may have a diameter such as one to one and one-half inches.

The column of well liquid standing up in either the tubing or the casing above the level of the well liquid in the other conduit, due to the presence of pressure fluid therein, will be referred to as the upstanding column.

The difference in pressures obtaining above and below the movable assembly will be referred to as the differential, which is the difference between the value of the pressure fluid and the varying force exerted by the upstanding column at different levels thereof.

It will be noted, in all forms of the invention, that the valve controlling the flow of pressure fluid into the upstanding column of liquid is normally open until closed by the pre-determined differential.

The valve in the lower end of the member 16a is normally lightly closed upon the seat 19b by the expansive force of the spring 13, which spring also resists the closing of the valve 16b and normally positions it away from its seat 24b, as appears in Fig. 2. The circular pin 19a, somewhat longer than the distance of the valve travel, may have a top end diameter of approximately ⅛ inch, while the base diameter of this pin immediately above the seat 19b may vary from approximately ¼ to 7/16 inch. The central opening through the member 16a, continuous with the opening 16d through the movable assembly, may have a diameter of one to five thousandths inch greater than the base diameter of the pin 19a. The diameter of this opening, like the diameter of the pin 19a, should vary in proportion to the volume of well liquid to be discharged and other well conditions.

The upper pin 24a tapers arcuately in reverse direction from the lower pin 19a to the straight portion a. The size of the passage between this pin and the central opening 16d should be approximately the same as the opening between the lower pin 19a and the member 16a when the movable assembly is midway of its travel between valve seats 19b and 24b.

Since the pins 19a and 24a are arcuately tapered and have their smaller ends facing toward each other, and since the openings within which these pins are positioned are not tapered, it is evident that the clearance between the pin 19a and the opening 16d through the member 16a will increase as the movable assembly rises, and that, at the same time, the clearance between the pin 24a and the opening 16d will diminish.

The pins 19a and 24a, as shown in Fig. 2, will admit the greatest volume of pressure fluid into the upstanding liquid column in the tubing when the movable assembly is mid-way of its travel. If it is desired to pass a greater volume of pressure fluid through the devices at low differentials, the pin 19a may be made smaller, or entirely eliminated in rare instances. If the pin be so eliminated, the maximum volume of pressure fluid will pass through the devices at low differentials. Whenever the governor pins are employed, as in Figs. 2 and 6, if a straight portion a, having a close slide valve fit within the opening 16d, be employed, then each device thereby will be prevented from opening its valve when slugs of well liquid at high velocities pass through the eduction tube opposite or above the valve.

In Fig. 1, a series of devices are shown spaced at intervals in the tubing 2 within the casing 1 by means of the couplings 2a, the sloping ends 3b and 3b' of the shell 3a being to guide the device through the casing. The tubing is shown to be of somewhat larger diameter in the upper regions of the well than below, the different sizes being joined together by the swaged nipple 5. Such expansion of the tubing in the upper portion affords greater efficiency in flowing through this conduit.

The anchor string 7, which may be employed to support part of the weight of the tubing upon the bottom of the well 9, is joined to the tubing by means of the intake nipple 6 provided with the openings 6a to admit well liquid into the tubing.

The perforations 11 serve to admit the contents of the producing formation 10 into the well.

The casing head 4 proximately above the ground surface 8 is employed to effect a hermetical seal between the casing 1 and the tubing 2, it being understood that the flow line 2b connects the tubing 2 with a flow tank not shown.

The line 12 may be employed to convey pressure fluid to the well or to convey surplus gas from the well.

The devices, for illustration, may be spaced 150 to 300 feet apart in the tubing string.

The spring 13 should be of such strength as to resist the closing of valve 16b upon its seat 24b by a force somewhat greater than the force exerted by the weight per square inch of the column of well liquid between adjacent devices, in order that the next upper valve will remain open until the next lower valve is uncovered by the receding liquid.

The movable valve assembly forms a barrier between the space interior of the tubing and the annular space 1a, between which spaces the openings 20a, 16d, and the slot 3d afford the only path of communication above the liquid intake nipple 6.

Before the flowing operation, it will be assumed that the flow line 2b is closed by a valve, not shown, and that pressure fluid of proper value is within the annular space 1a.

The per square inch value of the pressure fluid employed to flow the well preferably should be approximately two or three times the per square inch force required to seat the valve 16b, and it may be much greater.

Now, to flow the well through the tubing, open the unshown valve in the line 2b. This bleeds off the pressure fluid within the tubing and causes the well liquid to be depressed within the space 1a to the level indicated at A and to upstand within the tubing 2 to a level indicated at B. This upstanding column from A to B will balance against the pressure fluid in the casing. All valves above the upstanding liquid column in the tubing will be closed on their seats 24b, and the valve above the depressed liquid level in the casing nearest the base of the upstanding column will be open. Pressure fluid, therefore, will pass into the tubing from the annular space 1a through the openings 20a, 16d, and the slot 3d. The upstanding liquid column, therefore, will be stretched by the expanding globules of pressure fluid so admitted until the well will flow through the tubing 2 and line 2b.

When the liquid level in the space 1a is lowered sufficiently by flowing the well, the next lower device will be uncovered. The next valve above then will be approaching its seat. This operation continues, valve by valve or stage by stage, until the depressed well liquid uncovers the

openings 6a in the nipple 6, whereupon the entire upstanding column will be lifted and expelled as a slug. The well is then "pumped off" and the flowing operation may be suspended long enough for the well to build up another "head."

However, if the production of the well is great enough, a level will be found somewhere above the nipple 6, where the well liquid will hold steady against the output of the devices.

Increasing the value of the pressure fluid, of course, will increase the rate of flow, and vice versa.

Attention is directed to the fact that pressure fluid entering through the openings 18b will expand the cups 17 into sealing engagement with the polished wall of the bore 3c, whenever there is less pressure above than below the cups; also, that the packing 14 is adapted to sweep clean the wall of bore 3c ahead of cup 17 during the upward travel of the movable assembly.

Fig. 3 illustrates a modified form of valve in which the valve 28 formed upon the upper end of the member 16 is adapted to slidably engage over the pin 27a and have engagement upon the seat 26a. The screw portion of the member 27 is integral with the pin 27a and has threaded engagement within the member 26, thereby positioning the pin centrally of the valve seat 26a and in line with the central opening 16d through the member 16.

The tapered bore 26b in the member 26, having the seat 26a at its upper end, is smallest at the seat and largest at the lower end. The tubular member 16 being of uniform diameter, it is apparent that the flow of pressure fluid between the member 16 and the tapered bore 26b will diminish as the differential increases while the valve 28 is approaching its seat 26a.

The pin 27a, shown in Figs. 3 and 7, is adapted to have a slide valve fit within the upper end of the passage 16d. This valve will completely cut off the flow of pressure fluid through the passage 16d before the valve 28 seats, and maintain the shutoff until the valve has opened far enough to disengage the pin.

This construction protects the seat 26a from being damaged by abrasives in the pressure fluid, and also prevents the valve from opening when heavy slugs of well liquid go by at great velocities.

The clearance between the valve member 16 and the bore 26b, when the valve is open as in Fig. 3, may be the approximate equivalent of a circular opening having a diameter of 1/8 to 1/4 inch, depending upon the velocity and volume of well liquid to be discharged. When the valve is seated, the clearance around the member 16 in the bore 26b may be one to five thousandths of an inch.

Otherwise than as stated, the construction, operation and installation of the mechanism illustrated in Fig. 3 is the same as was illustrated and explained in connection with Fig. 2.

In both Figs. 2 and 3, illustrating means for flowing through the tubing, the movable assembly will close on the valve seat 19b after each flowing operation and prevent the well liquid left in the tubing from settling back into the well providing a check valve is provided in the tubing somewhere between the nipple 6 and the lowest flow device.

Fig. 6 illustrates a modified form of the device shown in Fig. 2 adapted to flow the well through the casing.

The adaptation is accomplished by closing the slot 3d between the shell and nipple in Fig. 2, and opening the slot 29 on the outside of the shell in Fig. 6 above the travel of the movable assembly, and by closing the passages 20a in Fig. 2 by employing the plug 30 and associated parts to hermetically close the lower end of the bore 3c, and by providing the lateral passage 35. The pin base 19 may be pressed into its support plate 33. This plate is landed upon the slight internal annular shoulder 34 by the force of the bottom plug 30, having threaded engagement within the lower end of shell 3a, and engaging upon gland ring 31 which urges the packing 32 outwardly and against the plate 33. The gland ring 22 and packing 23 employed in Figs. 2 and 3 are omitted from Figs. 6 and 7.

Fig. 7 illustrates the adaptation of the construction shown in Fig. 3 to accomplish flow through the casing. The slot 3d, between the nipple and the shell in Fig. 3 is closed, and the slot 29 is provided exterior of the shell 3a. The valve and movable assembly is the same as shown in Fig. 3. The lower end members 30 to 33, both inclusive, are the same as in Fig. 6.

All reference characters shown in connection with Figs. 6 and 7, and not otherwise referred to, will be understood to designate parts of similar construction and purpose to those designated by the same reference characters in Figs. 2 and 3.

In Fig. 5, either the device shown in Fig. 6 or the one shown in Fig. 7 may be spaced at the stated intervals in the tubing 39.

This installation plan for casing flow is identical with the one shown in Fig. 1, except for the casing head and tubing.

The casing head 36 accomplishes a seal between the casing 1 and the tubing 39. One side of the casing head is closed by the bull plug 37 and the other side is open into flow line 38. The tubing 39, preferably all of a uniform diameter, has an extension 39a through which pressure fluid is supplied to flow the well.

Before beginning the operation of flowing the well through the casing, a valve (not shown) in the flow line 38 will be closed until pressure fluid of proper value is built up within the tubing and the annular space 1a. This is assumed to be done.

Now, to flow the well through the casing, open the unshown valve in the flow line 38. The well liquid will be depressed within the tubing to a level indicated at C and will upstand in the casing to a level indicated at D where it will balance against the pressure in the tubing. All valves above the upstanding liquid in the casing will be closed, and the valve in the device next to the base of this column will be open, due to the slight differential there.

Above the lateral openings 6a in the nipple 6, the only path of the pressure fluid out of the tubing and into the well liquid in the casing is through the passages 35, 16d, and the slot 29. The seat 19b in Fig. 6 is provided to arrest the movable assembly above the passage 35.

The operation of the valves in flowing through the casing is so similar to that previously described for flowing through the tubing that it is thought unnecessary to more than call attention to the difference in the manner of applying pressure fluid resulting in a different position of the upstanding column, and to the different paths of the pressure fluid through the devices. The action of the movable assembly and of the valves as well as the adjustment and spacing of the devices, may be the same, whether the well be flowed through the tubing or the casing.

In all forms of the invention, it will be noted

that the force of the pressure fluid is constantly tending to seat the valve on its upper seat; while the force of spring 13, plus the weight of the upstanding column, are the forces constantly tending to unseat the upper valve. Pre-determined increasing differences between these opposing forces will first regulate and then shut off the flow of pressure fluid into the upstanding column by valve action controlled by the movement of the piston assembly. Likewise, pre-determined decreasing differentials will gradually open the valves first to regulate, and then to allow the maximum flow of pressure fluid through the devices.

Manifestly, the force of the pressure fluid and of the spring 13 are constant at all levels; while the force exerted by the upstanding column is different at different levels.

The differential at which the valves controlling the flow of pressure fluid close may be constant for all the valves, or it may vary according to well conditions and the spacing of the devices for either the tubing or casing flow. It is also apparent that the volume of pressure fluid admitted through the devices may be varied as well conditions may require, by increasing the size of the passages for this fluid.

The diameter of the piston being many times greater than the diameter of the valve that it controls, as shown, it is evident that the valve will be actuated in its movement and seated by a much greater force than can be employed to actuate and seat the usual valve which has the same seating area as that employed to contact the seating force.

The invention as herein illustrated and described is manifestly subject to many changes in construction and arrangement of parts which will remain within the scope and purpose of the stated objects and appended claims.

The invention claimed is:

1. In a stage lift flowing device, a tubular nipple, a valve chamber in the wall of said nipple, said chamber having an inlet at one end for admitting fluid from a pressure fluid chamber to the valve chamber and an outlet in the wall of the chamber and in spaced relation with the inlet for passage of the pressure fluid to a chamber within which liquid is to be lifted by the pressure fluid, a valve assembly within the valve chamber, said assembly including a tubular piston slidable within the chamber, an annular valve seat at the lower end of the chamber, a tapered pin extending upwardly from within said valve seat and adapted to enter the bore in said piston, means resiliently urging the valve assembly downwardly into engagement with said valve seat, a seating surface at the upper end of the bore in the piston, and a downwardly facing valve seat at the upper end of the chamber adapted to close the passage through the valve assembly when the piston rises a predetermined distance.

2. In a device of the character described, a tubular nipple, a valve chamber in the wall of said nipple, spaced inlet and outlet openings in the walls of said chamber, a tubular piston sealably engaging the walls of the chamber and movable longitudinally of the chamber intermediate said openings, an upwardly facing seating surface at the upper end of the bore in the piston, a downwardly facing valve seat in alignment with said seating surface and bore, and a metering pin extending downwardly from said valve seat and adapted to meter the flow of fluid through the piston as the piston moves upwardly toward seating engagement with the valve seat.

3. In a device of the character described, a tubular nipple, a valve chamber in the wall of said nipple, spaced inlet and outlet openings in the walls of said chamber, a tubular piston sealably engaging the walls of the chamber and movable longitudinally of the chamber intermediate said openings, an upwardly facing seating surface at the upper end of the bore in the piston, an annular downwardly facing valve seat in alignment with said seating surface and bore, and a tapered metering pin extending downwardly from within said valve seat and extending into said bore.

4. In a device of the character described, a tubular nipple, a valve chamber in the wall of said nipple, spaced inlet and outlet openings in the walls of said chamber, a tubular piston sealably engaging the walls of the chamber and movable longitudinally of the chamber intermediate said openings, an upwardly facing seating surface at the upper end of the bore in the piston, an annular downwardly facing valve seat in alignment with said seating surface and bore, and a tapered metering pin extending outwardly from within said valve seat and extending into said bore, said metering pin having a cylindrical portion adjacent the valve seat adapted to close the bore as the piston approaches terminal position.

5. In a device of the character described, a tubular nipple, a valve chamber in the wall of said nipple, a piston in said chamber, a tubular valve member extending upwardly from the piston, and having a seating surface on the upper end thereof, a valve seat member in the upper end of the chamber, said member having a tapered bore surrounding the upper end of said valve member and terminating in a valve seat adapted to engage said seating surface.

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