July 2, 1957 H. E. McGOWEN, JR 2,797,700

BALANCED FLOW VALVE

Filed Aug. 7, 1953 2 Sheets-Sheet 1

Fig. 1

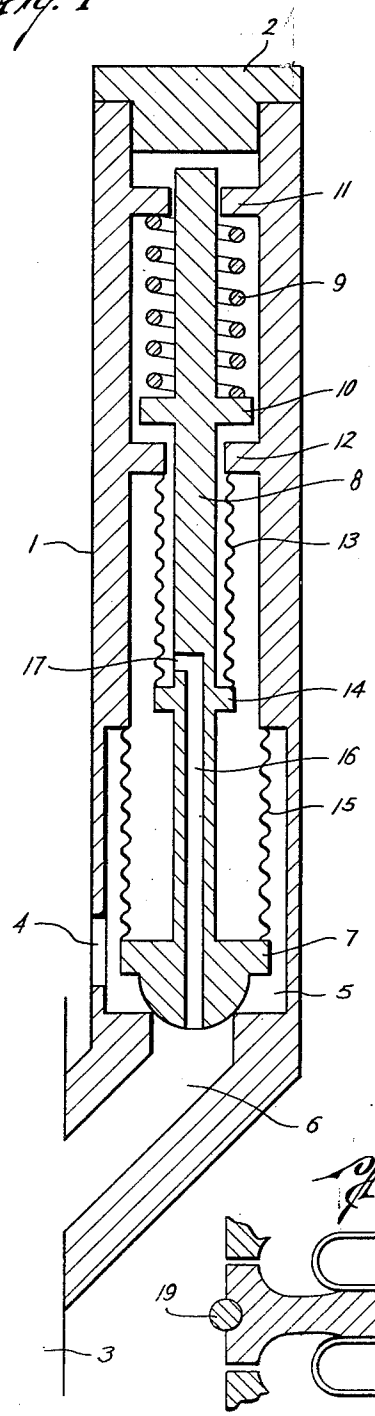


Fig. 4

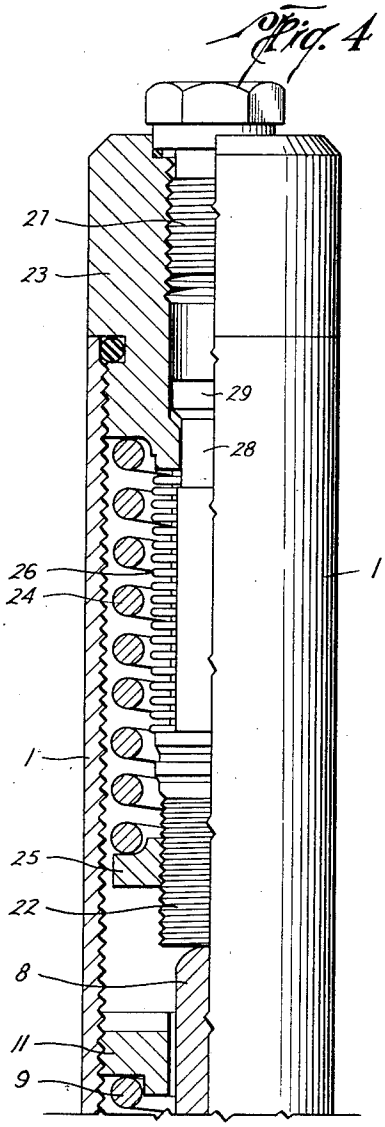


Fig. 3

Harold E. McGowen, Jr.
INVENTOR.

BY R C Helmig
Wm E Ford
ATTORNEYS

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Fig. 2

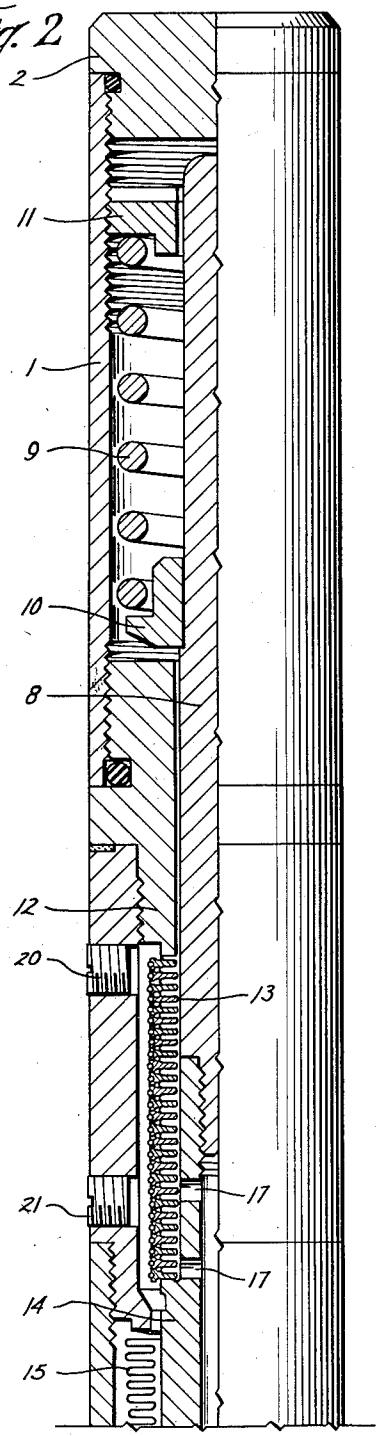
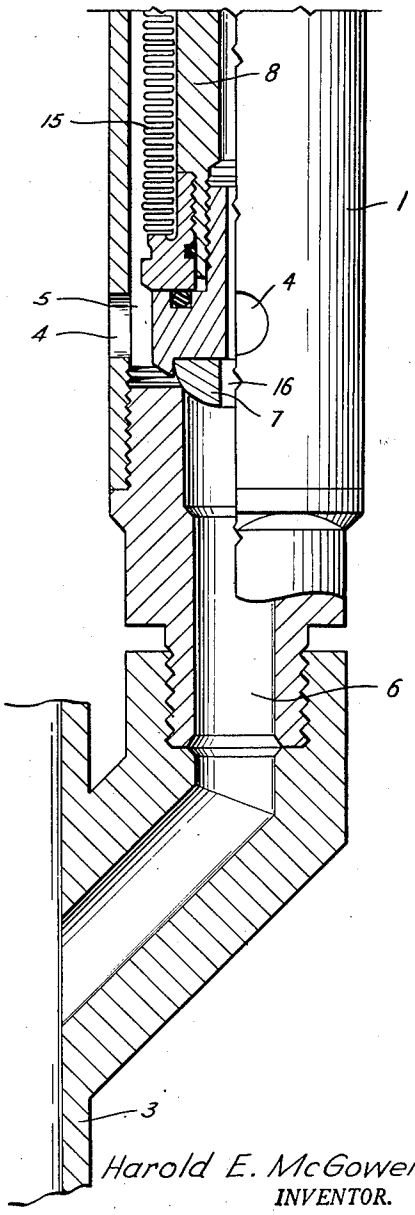


Fig. 2A



Harold E. McGowen, Jr.
INVENTOR.

BY G C Helming
Wm E Ford
ATTORNEYS

United States Patent Office

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BALANCED FLOW VALVE

Harold E. McGowen, Jr., Houston, Tex., assignor to Camco, Incorporated, Houston, Tex., a corporation of Texas

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14 Claims. (Cl. 137—155)

This invention relates to the application of fluid pressure to accelerate liquid movement such as raising toward the surface of underground oil through a well bore and more particularly to an improved gas lift or flow valve. An oil well bore is usually fitted with a large diameter casing within which is positioned a smaller diameter tubing, whose wall is a circular partition between an inner passage within the tubing and an outer passage surrounding the tubing. To assist oil flow to the surface it has been common practice to direct gas under pressure through one of these passages for introduction at one or more points into the other passage below the oil level so that the pressure gas supplements available well pressure in lifting the oil column.

Either passage may be for oil flow, and for convenience, this specification will treat the tubing as for oil and the casing for gas, it being understood that as regards the invention the terms may be considered as interchangeable and not as limitations.

It is an object of the present invention to provide an improved pressure responsive valve assembly for controlling flow of pressure gas or fluid from the lift gas supply passage to the oil column passage and which operates under surface control of gas delivered pressure without regard to oil well pressure fluctuation. To this end the valve in one embodiment is balanced or has opposed surfaces of equal area exposed to tubing or well pressure and is spring loaded on its seat in opposition to application thereon of casing gas pressure whereby the valve will open each time at the same given gas lift pressure as determined by the preset spring load to be overcome.

While precise balancing of valve opposed surfaces presented to well pressure is a theoretical optimum for certain installations, it has been found that for most purposes the expense of extreme manufacturing accuracy is not always essential and satisfactory operation will result if the balancing surfaces are more or less equal. Furthermore, desirable effects can be obtained with a selected or intentional slight unbalance, as for example one which favors unseating of the valve by having the total surface area active in opposition to the valve seating spring greater by given amounts as large as eight percent than the total surface area active in valve closing direction. The beneficial result obtained is that well pressure is available to condition the parts for a quick response to surface controlled gas pressure and a more instantaneous or snap action in the valve opening operation. Accordingly the balance referred to is one having a slight latitude.

A further object of the invention is to provide an improved flexible wall seal arrangement between the valve and its housing through the use of a pair of spaced bellows, sealing one against casing pressure and another against tubing pressure, with the space or chamber between the bellows containing liquid of a volume substantially filling the bellows chamber when the valve is unseated, whereby the incompressibility of the liquid stablized the flexible walls of both bellows and acts as a force transmitting medium between the two bellows walls

and solidly resists or bucks pressure forces imposed on their remote faces exposed respectively to the pressures existing within the tubing and the casing annulus. The casing annulus and tubing interior are in communication whenever the valve is unseated and their pressures will be equalized or approach equalization, wherefore the confined liquid exerts an equal opposing pressure within the bellows chamber formed between the walls of the bellows and these walls are thus freed from fluid pressure deflection stress. In this fashion the bellows walls are protected against casing or gas pressure such as is in excess of valve unseating pressure. They are also protected by another expedient against high tubing or well pressure when the valve is seated and which pressure of itself can never unseat the valve because the pressure force has presented to it opposed surface areas in balanced relation. This latter protective feature is afforded by incorporating solid rings in the convolution spaces on the side of the bellows wall opposite that exposed to tubing or well pressure, and these rings buck the tubing pressure to resist excess wall deflection laterally without interference to bellows action axially.

Another object of the invention is to provide a gas lift unit whose valve can be unseated only in response to controlled gas pressure and without modification, but by the addition of a supplemental unit, will afford a variable pressure operation in which unseating of the valve will still be dependent on surface controlled gas lift pressure but a pressure whose value differs according to a predetermined adjustment, and is either lower or higher depending on whether well pressure is above or below a given value. Thus a factor of differential pressures may be introduced for certain installations when desirable, with the primary valve structure being of universal application. Among other things there will be gained the economical advantage of larger production with lower unit manufacturing, inventory, and service costs.

Other objects and advantages become apparent during the course of the following specification having reference to the accompanying drawing illustrating a preferred embodiment and wherein: Fig. 1 is a vertical sectional view of the improved valve assembly illustrated for ease or understanding in a somewhat diagrammatic and simplified form; Figs. 2 and 2A are half sectional views of the upper and lower portions of the valve assembly as designed for production usage; Fig. 3 is a fragmentary section illustrating a detail of one of the bellows units, and Fig. 4 is a vertical section of the upper portion of a valve having a supplemental spring seating force.

Referring to the simplified illustration in Fig. 1 the reference character 1 indicates a hollow tubular valve housing closed at its upper end by a plug 2 and mounted at its lower end on the outside of a mandrel or tubing section 3 for communication through the tube wall with the interior of the well tubing. The location of the valve housing on the outside of the tube is for use of the tube interior for oil flow. When oil is to be lifted in the outer casing by supplemental gas pressure supplied by way of the inner tube, the location of the valve housing will be interiorly of the tubing wall. In either event the communication is from one side to the other of the tube wall. In the tube exterior valve arrangement shown, the communicating passage includes one or more wall openings 4 from the annular casing space surrounding the tubing 3, a valve chamber 5 and a passageway 6 leading from the valve chamber to the interior of the tubing mandrel. Located within the valve chamber and seated on an annular shoulder between the chamber 5 and passage 6, is an enlarged head 7 on the lower end of a valve stem 8 slidably mounted within the housing 1 and urged downwardly by a coiled compression spring 9 which bears at opposite ends on a stem abutment 10 and a housing abutment 11,

Below the spring engaging bearing abutment **10** on the stem, the housing has an internal flange or annular rib **12** to the underside of which the upper end of an annular spring metal bellows **13** is secured and sealed with its lower end secured and sealed to an annular collar **14** on the valve stem surrounded by the bellows. For a balanced valve the internal diameter of the bellows **13** should correspond substantially with the internal diameter of the valve seat at the passage **6**. A similar and larger flexible wall or annular bellows **15** is located within the valve chamber **5** and has its upper end secured and sealed to the housing and its lower end secured and sealed to the rim of the valve head **7** so that the unbalance of valve area exposed to casing fluid favors valve unseating. The annular chamber sealed off between the two bellows is substantially filled with a liquid of such volume that when the valve **7** is unseated the liquid completely fills the bellows chamber and forms in effect a solid strut to resist flexing of the bellows walls inwardly of each other. As a limit stop to preclude excess valve unseating travel, the terminal of the stem **8** is arranged for co-operative abutment with the end plug **2**. Permissible valve travel should be less than that which would impose strain on the bellows seals, including forces which in the absence of a positive stop, would be transmitted through the trapped liquid body.

An open passage **16** extends upwardly through the valve stem **8** from its lower end to a point above the collar **14** and has one or more side passages or lateral ports **17** leading to the interior of the housing **1** around the upper end of the stem **8** within and above the bellows seal **13**. By reason of the passage **16**, the interior of the bellows **13** and the upper portion of the housing **1** are in open communication at all times with the tubing interior and will be at a pressure substantially corresponding with tubing or well pressure. Optionally, the passage communicating opposite sides of the valve may be provided through the valve housing wall or by a separate tube, but the formation of the passage **16** in the valve stem is both convenient and economical. In any event, its size can be sufficient to afford free passage and an absence of throttling for a better balancing action during pressure variations. Well pressure will act upwardly against the bottom of valve head **7** exposed to the passage **6** inside the boundary of its receiving seat and also against the uppermost surface of the lateral port **17**. Likewise it will act downwardly against the lower surface of the port **17** and against the surface of the collar **14** exposed within the bellows **13** and the top end of the stem **8**. These oppositely directed surface areas in the aggregate equal or balance one another so that tubing fluid pressure has no effect to move the valve in either direction. By selection of diameter of the port **6** at the valve seat, the valve head area exposed to well pressure can be governed for a desired degree of balance as before indicated.

Operation of the balanced or near balanced valve is independent of variations in well pressure and, even with a slight unbalance, is controlled primarily by the force of the spring **9** in opposition to surface regulated gas lift pressure. The latter acts against the under side of the valve head **7** throughout the exposed surface area beyond the valve seat to the rim of the valve head, with the bellows **15** sealed at its lower end to the top of the valve head **7** limiting the extent of surface exposure to gas lift pressure. Casing pressure is preferably controlled at the surface by suitable valving and when it is desired to implement well pressure for lifting liquid within the tubing, the casing or gas lift pressure is increased to the desired degree and when its force on the valve head overcomes the valve seating force the valve will open. Thereupon and co-incident with well pressure increases, pressure acting on inside face of the bellows **13** and in the passages **6** and **16** approximates that on the outside of the bellows **15** in the valve chamber **5**. So long as the valve remains

open the casing and well pressure will be the same and the liquid contained within the bellows chamber protects both bellows and serves as a force transmitting medium between the flexible walls and solidly resists the fluid pressure acting with the same force on the outer face of the bellows **15** and on the inner face of the bellows **13**. With equalization of pressure on their opposite faces neither of the flexible wall seals will be under strain.

At times when the valve is seated and gas lift pressure is low or not needed, there will be occasions when the well pressure acting outwardly on the bellows **13** will rise excessively or surge to a value which might cause breakage of the thin flexible bellows wall if some precaution is not taken to stiffen the bellows wall against the high internal force. Thickening of the thin spring metal wall is not feasible, but a satisfactory form of stiffener is shown in Fig. 2 and in the enlarged fragmentary section of Fig. 3. In each of the outer spaces between convolutions there is fitted a solid filler ring **18** of metal or other suitable material, which may be formed in segments for convenience of assembly with the segments either fused together as by welding or held against separation by a circumferential wire or snap band **19** seated in a peripheral groove in the ring segments. The arrangement enables normal axial deflection but excess well pressure will crowd the inner bends of the convolutions and expand the outer bends with the radial walls bearing firmly against and restricted from further distention by the fillers **18**. By reason of the backing, rupture of the bellows thin wall is unlikely and an effective bucking of high well pressures is provided.

Since it would not be practical to build the housing and the stem each in one piece, after the fashion diagramed in Fig. 1, a production embodiment will involve an assembly of parts joined together as in Figs. 2 and 2A. Here it will be seen that both the housing and valve stems are shown as threaded together parts and the joints are sealed against leakage by either solder or suitable packing rings or both.

The housing spring seat **11** is an externally threaded ring adjustably mounted in the upper sleeve portion of the housing **1**. Upon removal of the end plug **2**, the ring **11** may be threaded in or out in order to preset the elastic force of the spring **9** for the response to a calculated value of gas pressure. Usually a number of flow valves will be employed at different levels on the well tubing and each can be individually set at a different pressure unseating value so that surface control will enable selective introduction at several levels of lift force to the fluid to be lifted, which for example may consist of oil or a mixture of oil and gas.

Fig. 2 also shows a pair of closure plugs **20** and **21** in the housing side wall for closing vent and filler openings leading through the wall to the chamber formed between the bellows. For some purposes a single opening may constitute a combined filler and vent port. After assembly of the embodiment shown, liquid is introduced through the port in which the plug **21** is later fitted and venting occurs through the opening later closed by the plug **20**. In the filling operation the chamber space is substantially filled with the liquid and at least to the extent that a slight collapse of the bellows incident to the unseating of the valve will fill a void intentionally provided. Should an increase in volume be necessary within the bellows to allow valve opening, it will be at the expense of space within the valve chamber **5** by bulging of the wall of the bellows **15**. However, the latter is expected to be negligible, since the filling operation can be so controlled that the liquid body volume allows opening of the valve before the entrapped liquid stops valve travel and is conditioned to neutralize pressures acting outwardly on the bellows **13** and inwardly on the bellows **15**.

Inasmuch as deep well temperatures often exceed by several times earth surface temperatures, it will be preferable to employ a high boiling point bellows entrapped

liquid having a relatively low co-efficient of expansion for the heat encountered and thus minimize disturbances to the pre-selected valve opening pressure.

When it is desired to supplement the force of the main spring 9 and modify operation of the valve in accordance with well pressure values, the end plug 2 is removed and the upper end of the housing 1 is extended as in Fig. 4 to inclose a retractible plunger 22 arranged to bear at its lower end on the upper terminal of the valve stem 8 and to be slidably mounted at its upper end in a closure plug 23. A coil spring 24 bears at opposite ends on the plug 23 and a collar 25 adjustably threaded on the lower end of the plunger 22. The adjustable mounting of the spring seating collar 25 enables any desired given loading for the spring 24. A sealing bellows 26 surrounds the plunger and is sealed at opposite ends to the cap plug 23 and to a collar or shoulder on the plunger 22. Thus the bellows 26 limits plunger area exposed to well pressure to cause plunger retraction when the fluid presure reaches the value of the force exerted by the spring 24. Such fluid pressure will tend to take the spring 24 out of action in proportion to the value of the fluid pressure and when the well pressure is high the main valve will open at a relatively lower lift gas pressure than is required when well pressure is low.

A plug 27 closes the end of a central opening in the cap 23 which slidably receives the upper terminal of plunger 22 as a sub-assembly with the cap. Throughout its major extent the opening is circular and at its lower end is oblong or elliptical, providing diametrically opposite inwardly extending lands for slidable bearing with a reduced neck 28 on the plunger. Beyond the neck, the plunger has an enlarged head 29 also of oblong shape to afford a T-shaped terminal which may be alined with, and passed through the oblong opening or key hole slot and then turned ninety degrees for retention. The shoulders at opposite ends of the reduced lower portion of the central opening afford limit stops for the head at one end of the reduced plunger neck and a shoulder at the other end, the axial length of the neck being greater than that of the reduced diameter passage in accord with the desired range of travel.

While but one embodiment of the invention is herein disclosed, it will be understood that various modifications may be made as come within the scope of the appended claims.

What is claimed is:

1. In a gas lift valve, a housing having an inlet and an outlet and a passage for communicating the inlet and the outlet, a spring seated pressure actuated valve controlling pressure fluid flow through said passage, a pair of spaced flexible wall seals between the housing and the movable valve, said seals being joined to the valve to present substantially balanced opposed valve areas to the outlet pressure and unbalanced valve areas favoring valve unseating to the inlet pressure, one of the wall seals sealing the valve and housing with respect to inlet pressure and the other wall seal sealing the valve and housing with respect to outlet pressure and a substantially incompressible liquid contained in the space between said walls and of a volume conforming to the volume of said space when the valve is open to serve as a force transmitting medium in equalizing forces on opposite faces of each flexible wall.

2. In a gas lift valve, a housing having a fluid flow passage, a spring seated valve in the housing, a bellows sealing the valve to the said passage and co-operating with the valve to define an area exposed to fluid pressure on one side of the valve for adding a valve seating force in counteracting balance in relation to other valve area exposed to said fluid pressure in opposition to the valve seating spring and a second bellows sealing the valve to the housing so that a valve area is exposed to fluid pressure on the other side of the valve for unseating the valve.

3. In a gas lift valve assembly of the character described, a housing and a spring seated valve therein, opposed surfaces on the valve exposed to one source of fluid pressure in substantially balanced relation, a bellows sealing the valve and housing with respect to said pressure source, a valve area exposed to a second source of fluid pressure for unseating the valve and a bellows sealing the valve to the housing with respect to said second pressure source.

4. In a gas lift valve assembly of the character described, a housing and a spring seated valve therein, approximately equal opposed surface areas on the valve exposed to fluid pressure on one side of the valve, a bellows seal between the valve and the housing against escape of said pressure, a valve area exposed to fluid pressure on the opposite side of the valve for unseating the valve, a bellows seal between the valve and the housing against blow by of the last mentioned fluid pressure, and a body of liquid of a volume filling the space between said bellows seals when the valve is unseated.

5. In a well flow valve primarily responsive to surface controlled fluid pressure on the inlet side of the valve without major regard to fluctuations in pressure on the outlet side of the valve, a spring seated valve having approximately balanced opposed areas exposed to the last mentioned pressure and a differential area exposed to the inlet fluid pressure to open the valve, double bellows seals for the valve and a body of liquid confined between the seals and of a volume to afford a stiff strut between the seals when the valve is open.

6. The structure of claim 5 together with solid rings in the spaces between the convolutions on the liquid side of the bellows which seals against the said last mentioned pressure.

7. In a well flow valve assembly, a spring seated valve having a surface exposed to fluid pressure on the upstream side of the valve in unseating the valve, a bellows seal to exclude said pressure from action on an opposing valve surface, a second bellows seal effecting an approximate balance of opposed surfaces exposed to fluid pressure on the downstream side of said valve and solid fillers in the spaces between convolutions of the second bellows on the side opposite to that subject to the last mentioned pressure.

8. In a well flow valve assembly responsive to pressure of the fluid whose flow is to be controlled, a spring seated valve presenting more or less balanced opposing surfaces to fluid pressure on the downstream side of the valve and unbalanced surfaces to fluid pressure upstream of the valve, a pair of spaced sealing bellows respectively sealing against pressure fluid upstream of the valve and pressure fluid downstream of the valve, solid fillers between outer convolutions of the bellows seal against pressure on the downstream side of the valve to resist outward pressure force on said bellows convolutions, and a liquid body between the bellows which fills the intervening space when the valve is open to resist bellows wall deflection under fluid pressure on the upstream side of the valve.

9. In a well gas lift valve assembly for imposing supplemental pressure on existing well pressure, a housing having a lift gas passage therethrough, a spring seated valve controlling said passage, a surface area exposed to the pressure of incoming lift gas in the housing upstream of the valve for unseating the valve, a secondary spring exerting a seating force on the valve and a bearing for the secondary spring having unbalanced surfaces exposed to fluid pressure on the downstream side of the valve to control the force exerted by said second spring in proportion to increase in the last mentioned fluid pressure.

10. In a gas lift valve of the character described, a housing having a fluid flow passage and a valve seat in the passage, a valve engageable with the seat, a pair of springs separately exerting forces to seat the valve, a bellows seal between the valve and the housing serving to confine the valve surface area exposed to fluid pressure

ahead of the valve in favor of unseating the valve and a movable abutment for one of said springs, in separable engagement with said valve and subject to fluid pressure beyond said valve in opposing spring force thereon and tending to move said abutment away from engagement with the valve.

11. In a gas lift valve of the character described, a housing having a passage, a valve seat in the passage, a valve engageable with said seat, a pair of springs exerting forces to seat the valve, a bellows seal between the valve and the housing, there being a valve surface area exposed to pressure in advance of the valve for unseating the valve, a plunger retractably mounted in said housing in response to fluid pressure beyond the valve, a bellows seal between the plunger and the housing and an abutment on the plunger to act on one of said springs and decrease the force exerted thereby upon plunger retraction.

12. A one way valve assembly including a passage to communicate two sources of pressure fluid, a valve seat in said passage, a valve slidably mounted to engage said seat, a bellows seal co-operating with the valve, yieldable force exerting means urging the valve toward its seat, a surface on the valve exposed on one side of said bellows seal to one of said pressure fluid sources for unseating the valve when the pressure on said surface overcomes said yieldable force exerting means and opposed surfaces of equivalent effective area on the valve fully exposed on the other side of said bellows wall and without restriction at all times to the other source of fluid pressure.

13. In a valve assembly of the character described, a housing, a movable pressure responsive valve in the housing, a flexible wall sealing the movable valve to the housing against pressure fluid ahead of the valve a second flexible wall spaced from the first wall to seal the valve and housing against pressure fluid behind the valve, and an incompressible liquid confined in the space between said walls and of a volume to fill the space when the pressure responsive valve is lifted from its seat.

14. The structure of claim 13 wherein said flexible walls are of the bellows type and solid rings are disposed within the convolution spaces on the liquid side of one of the bellows to resist bellows lateral deflection under fluid pressure thereon in excess of fluid pressure on the other bellows.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,797,700 July 2, 1957

Harold E. McGowen, Jr.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 66, for "the housing" read --the said passage--; line 67, for "said passage" read --housing--.

Signed and sealed this 20th day of August 1957.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents