July 15, 1941. A. BOYNTON 2,248,950

DIFFERENTIAL STAGE LIFT FLOW DEVICE

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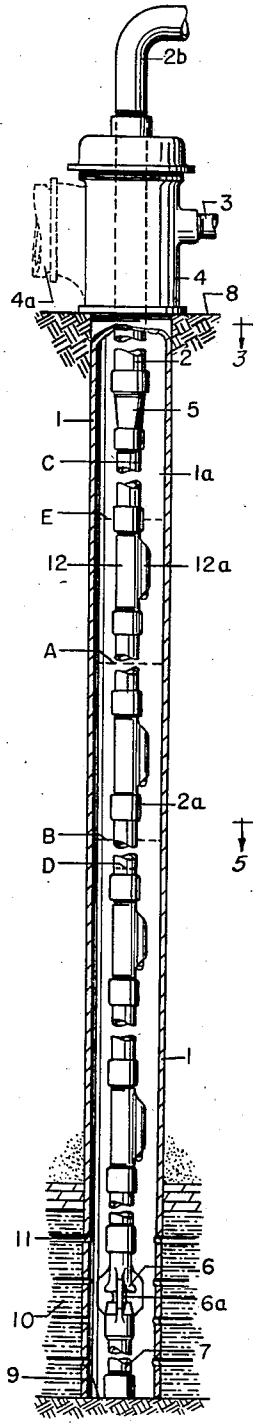


Fig. 1.

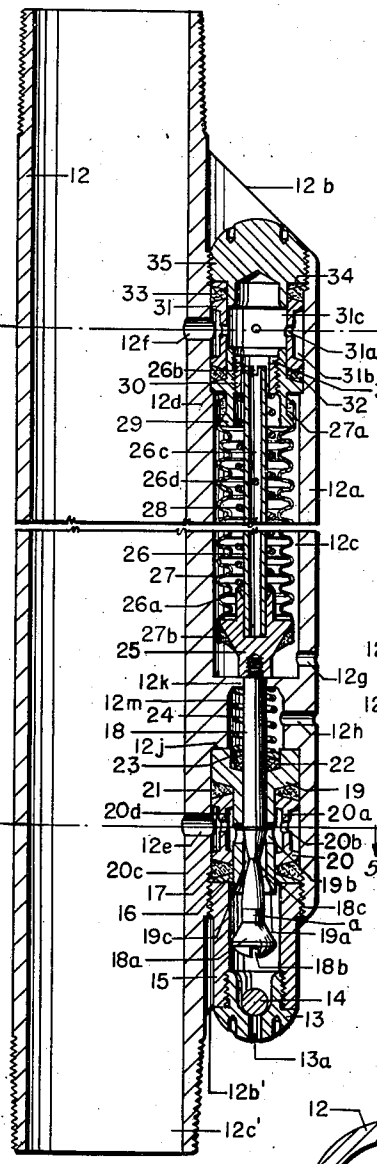


Fig. 2.

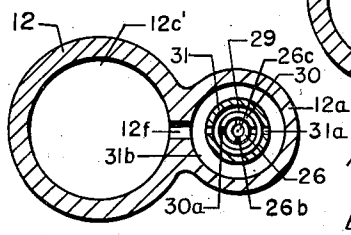


Fig. 3.

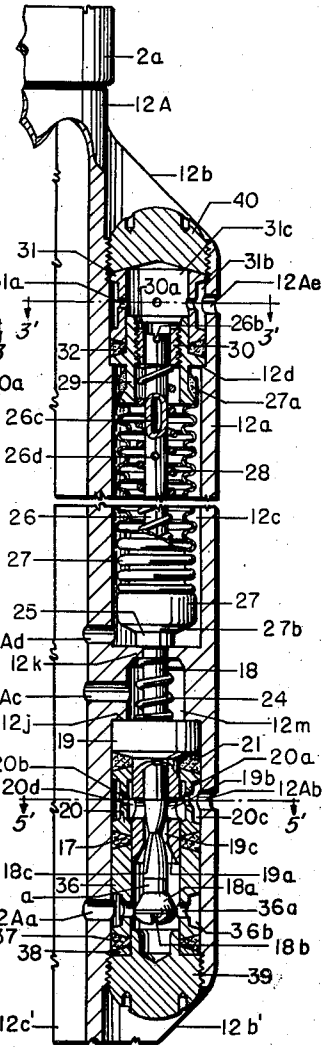


Fig. 4.

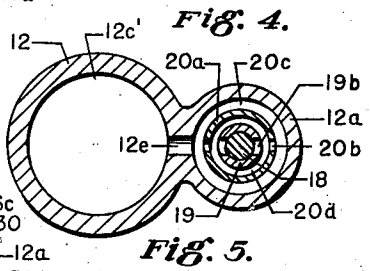


Fig. 5.

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DIFFERENTIAL STAGE LIFT FLOW DEVICE

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7 Claims. (Cl. 137—111)

My invention relates to flowing devices for wells, especially oil wells, the flow being accomplished by aeration.

The principal object is to accomplish the flow of well liquid by employing relatively low pressure for starting and flowing and to obtain relatively low gas-oil ratios in the flowing operation.

In accomplishing this object, other objects are: 1, to cause the valve employed to admit and cut off the flow of pressure fluid to be actuated by a larger area than that of the valve being exposed to the valve actuating force in order to make the valve action more positive; 2, to minimize friction in the valve actuating means by employing a pressure-responsive element to actuate an attached valve; 3, to provide means that will automatically regulate the flow of pressure fluid in proportion to the energy required to accomplish flow of well liquid at economical gas-oil ratios; 4, to prevent the valve from being opened by slugs of well liquid flowing through the devices; and 5, to provide mechanism for flowing a well through either the tubing or the casing by slightly changing either construction to accomplish the other purpose.

In attaining these objects, I interpose a chamber between the induction and the eduction tubes and within this chamber I place a pressure-responsive bellows secured at one end and free at the other end, the free end being attached to a combination sleeve and poppet valve adapted to close when the bellows is compressed and thereby cut off the supply of pressure fluid into the well liquid; the bellows being adapted to be compressed by pressure fluid contacting its exterior surface.

I attain the foregoing objects by mechanism illustrated in the accompanying drawing, in which—

Fig. 1 is a side view partly in section showing the installation of the devices in a well.

Fig. 2 is a longitudinal section through the preferred embodiment of the invention.

Fig. 3 is a cross section on the line 3—3, Figs. 2 and 4.

Fig. 4 is mainly a longitudinal section of a modified form of the invention shown in Fig. 2.

Fig. 5 is a cross section on the line 5—5 of Fig. 2, or 5'—5' of Fig. 4.

Similar reference characters designate similar parts throughout the several views.

The difference in pressures obtaining at the same time within the tubing and exterior of it at any level will be referred to as the differential. Pressure fluid in the annular space 1*a*, Fig. 1, and none in the tubing, will cause the well liquid to upstand in the tubing and balance against the pressure fluid. If pressure fluid be placed in the tubing, and none in the annular space 1*a*, the well liquid will upstand in the casing. Either column will be referred to as the upstanding column.

Pressure of the upstanding column will be designated as back pressure.

In Fig. 2, the body nipple portion 12, having the central longitudinal opening 12*c'*, may be cast or otherwise fabricated integrally with the shell portion or valve housing 12*a*, having upper sloping end 12*b* and lower sloping end 12*b'* for tubing guides.

The bellows 27, which may have a diameter such as one to one and one-half inches, is secured to its upper connection 29 by the solder or weld 27*a* and to its lower connection 25 by the solder or weld 27*b*. A minimum clearance such as $\frac{1}{32}$ to $\frac{1}{16}$ inch should be provided between the bellows and the wall of the bore 12*c*. A low pressure tube 26 is supported at its lower end in the lower connection 25 and may have its lower end pressed into a central upstanding flange of said member where it may be secured by the weld 26*a*. The upper end of the tube 26 is slidable within the central opening through a sleeve 30 which has threaded engagement within the upper bellows connecting member 29, the slots 30*a* being for an assembling tool. A coiled spring 28, preferably installed under some compression, is mounted within the bellows member and slides freely over the tube 26, its ends being engaged between the members 25 and 30. Said valve tube has openings 26*d* therein from the inner passage 26*c*.

The member 29 has an annular enlargement which is supported upon the slight internal annular shoulder 12*d* against which it is held by the packing 32. Said packing is urged downward by the plug 35 acting, in turn, upon the gland ring 34, the packing 33, and the sleeve 31, the latter member being slidable over the proximate annular ends of members 29 and 35. A hermetic seal thus is effected proximately above and below the annular space 31*b*.

The annular space 31*b* provides that fluid will always find free passage between the opening 12*f* and the openings 31*a*.

The valve rod 18, slidable through a central opening in the partition 12*k* and likewise slidable in a central opening through the member 19, has threaded connection within a tubular depend-

ing extension of the member 25. The packing 22, preventing leakage between the members 18 and 19, is compressed by the gland ring 23 urged downward by the spring 24, installed under some compression between the ring 23 slidable within the central opening in the upper end of the member 19 and the partition 12k, said spring being free over the rod 18 and having clearance within the chamber 12m.

The packing 21 is engaged upon the nether side of the upper enlarged portion of member 19 by the sleeve 20, the ends of this sleeve being slidable over the lower central depending extension of the member 19. The packing 17 is engaged upon the lower end of the sleeve 20 by the gland ring 16 slidable over the lower extension of the member 19 and urged upon the packing 17 by the valve housing nipple 15, having threaded engagement within the lower end of the shell or valve housing 12a. The upper end of the valve seat member 19 is engaged upon the annular internal shoulder 12j by the nipple 15 screwed within the lower end of the housing and transmitting pressure through the ring 16, the packing 17, the sleeve 20, and the packing 21. The annular chambers 20c and 20d are formed on either side of the tubular shell 20a in order to provide passage way for the pressure fluid between the openings 12e and 19b, regardless of the exact position rotatably of the sleeve 20. The packings 17 and 21 serve to prevent ingress to the tubing passage 12c' of pressure fluid, except through the annular space 19c.

A valve 18a is formed upon the lower end of the valve rod or stem 18 and is normally spaced away from its seat 19a which is formed centrally within the lower end of the lower central extension of the member 19, by the landing of the member 25 upon the partition 12k, as appears in Figs. 2 and 4.

The lower portion of the rod 18 has two oppositely tapered portions providing the place of smallest diameter at 18c, approximately midway between the upper end of the seat 19a and the openings 19b, in the lower extension of the member 19. This serves to regulate the flow of pressure fluid through the device. These tapers may be so changed as to move the place of smallest diameter upward or downward. If moved upward, the peak volume of pressure fluid while passing through the device, will be at a higher differential, and vice versa.

The straight portion a of the valve shank has a close sleeve valve fit within the passage 19c, which fit will prevent pressure fluid from passing while the valve 18a is in the proximity of its seat 19a. Slugs of well liquid passing through the device at high velocity during the flowing operation are thereby prevented from opening the valve. The same construction may be employed in Figure 4.

The plug 13, having threaded connection within the nipple 15, has a central opening 13a over the upper end of which opening the ball check valve 14 is adapted to seat.

Manifestly, the members 18 and 25 will have to be assembled from above and below the partition 12k, because neither the member 25 nor the valve 18a will pass through the opening in this partition, the slots 18b and 26b being for convenience in assembling these parts.

The port 12h, formed in the wall of chamber 12m, admits pressure fluid to contact the upper side of gland ring 23, thus aiding the spring 24 to compress the packing 22 for the purpose of preventing leakage between the rod 18 and the member 19.

The bellows 27 and spring 28 should offer such resistance to compression that the valve 18a will close upon its seat 19a at a differential force per square inch equal to the pressure per square inch of the well liquid in an upstanding column thereof somewhat longer than the distance between adjacent devices as they are spaced in the tubing.

The valve 18a is normally open, in all devices, as shown in Figs. 2 and 4, until closed by the differential.

The pressure fluid exerts the only force tending to seat the valve 18a. This fluid enters the bore 12c through the opening 12g and contacts the outside of the bellows. This force, at all devices above the depressed liquid level in the space 1a, is the value of the pressure fluid employed to flow the well.

The force tending to unseat the valve 18a in each device is the expansive force of the bellows and the spring 28, plus the back pressure of the upstanding liquid column in the tubing above the device.

The unseating force of the back pressure is exerted interior of the bellows. The path of this force is out of the tubing passage 12c', through the opening 12f, the annular space 31b, the openings 31a, the chamber 31c, the opening 26c, and against the interior of the bellows via the openings 26d.

Manifestly, the force of the pressure fluid, at any given value thereof, is constant. The opposing force of the spring and bellows is, likewise, constant and pre-determined. The differential is the only force that varies in each device according to its position with reference to the upstanding column.

Preferably, the devices may be spaced 150 to 300 feet apart in the tubing. If, for example, the devices are spaced 200 feet apart and a column of well liquid 200 feet high will exert a back pressure of 70 pounds per square inch, the devices should be adjusted so that somewhat more than 70 pounds per square inch will be required to compress the bellows and spring 28 far enough to seat the valve 18a.

The value of the pressure fluid employed to flow the well, preferably, should be not less than two or three times the differential required to close the valve, and may be much greater. Increasing this pressure will, of course, increase the rate of liquid flow from the well.

In flowing through the tubing, the pressure fluid enters the device through the opening 13a, lifting the check valve 14, passes through the annular space 19c, the openings 19b, the annular space 20d, the openings 26b, the annular space 26c, and into the tubing through the opening 12e.

The upstanding liquid column in the tubing is elongated by expansion of the globules of pressure fluid which thereby produce the flow in a manner well known to the art.

The devices illustrated in Fig. 2 may be connected into the tubing 2, Fig. 1, by means of the couplings 2a. The upper portion of the tubing may be larger than the lower portion, the different sizes being joined together by the swaged nipple 5. The anchor string 7 below the intake nipple 6, having lateral openings 6a for admitting well liquid into the tubing, may extend to the bottom 9 of the well. The casing head 4 accomplishes a hermetic seal between the tubing

2 and the casing 1 proximately above the ground surface 8.

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

The pipe line 3 may be employed to convey pressure fluid into the annular space 1a if the well does not produce enough gas to flow it or that line may be used to convey surplus gas from the well.

In flowing through the tubing, the dotted-in discharge line 4a will be disregarded as if not shown.

Before beginning the flowing operation, it will be assumed that the liquid level in the well is at A in both the casing and the tubing, that pressure fluid of proper value is in the annular space 1a, and that an unshown valve in the line 2b is closed.

It will be understood that eduction of the well liquid will be caused by the expansion of pressure fluid introduced through the devices into the upstanding column.

Now, to flow the well through the tubing, open the unshown valve in the line 2b. The rapid discharge of the pressure fluid through the open line 2b will close the valve in each device and cause the liquid in the tubing to quickly rise to the level indicated at C; while the liquid in the annular space 1a will be depressed to the level indicated at B. The valve in the upper device will be barely closed or opening due to the considerable differential there, while the valve next above the level B will be wide open, due to the slight differential there.

If the well is caused to flow at a more rapid rate than the production comes in, the level B will be depressed until the next lower device will be uncovered and so on, until finally the openings 6a in the nipple 6 will be uncovered, at which time the upstanding column in the tubing will be blown out as a slug.

The input pressure fluid line 3 may then be closed, if pressure fluid is supplied from that source, and the unshown valve in the flow line 2b may also be closed until it is desired to repeat the flowing operation.

The check valve 14 will prevent any liquid left in the tubing at conclusion of any flowing operation from draining back through the devices. In some installations wherein it is never necessary to reverse the pressure for well cleaning purposes, a check valve may be placed in the tubing proximately above the nipple 6.

The device illustrated in Fig. 4 is an adaptation for casing flow of the tubing flow device illustrated in Fig. 2.

The body 12A integral with the shell portion 12a, having the sloping ends 12b and 12b' as tubing guides, is similar to the device in Fig. 2, but has the openings 12Ac and 12Ad communicating with the opening 12c' interior of the tubing, instead of with the annular space 1a, as in Fig. 2. These openings allow pressure fluid to contact the same members and for the same purpose as in Fig. 2. The opening 12Aa conveys pressure fluid into the device in the same manner as the opening 13a in the previous embodiment. The opening 12Ab takes the place of the opening 12e in Fig. 2. The opening 12Ac serves to replace the opening 12h in Fig. 2. The opening 12Ad serves the purpose of the opening 12g in the same figure. The opening 12Ae replaces the opening 12f in Fig. 2.

The packing sleeve 36 engaging between the packing 17 and the packing 37 corresponds to the valve housing nipple 15 in Fig. 2, and causes these packings to prevent the passage of pressure fluid between the intake opening 12Aa and the discharge opening 12Ab, except through the annular opening 19c controlled by the valve 18a.

The gland ring 38 is urged upon the packing 37 by the plug 39 in order to close hermetically the lower end of the shell or housing 12a. The plug 40 has direct contact with the sleeve 31, the gland ring and packing employed between the similar members in Fig. 2 being omitted in this construction.

In flowing the well through the casing, the path of the pressure fluid through the device is through the opening 12Aa, the annular space 36b, the openings 36a, the annular space 19c, the openings 19b, the annular space 20d, the openings 20b, the annular space 20c, and out into the annular space 1a through the opening 12Ab. The path of the back pressure force contacting the interior of the bellows from the annular space 1a is through the opening 12Ae, the annular space 31b, the openings 31a, the chamber 31c, the opening 26c, and the openings 26d.

All other parts not mentioned as different are the same as in Fig. 2. The bellows and the spring 28 will be understood as ordinarily requiring approximately the same force to seat the valve 18a in Figs. 2 and 4. Likewise, the spring 24 may be of the same force in both constructions.

The installation will be the same as in Fig. 1, except as follows: The pipe line 3 will be replaced by a plug in the casing head; and the tubing, preferably all of the smaller diameter, will become the induction conduit for the pressure fluid, and the liquid flow will, of course, be through the casing, discharging through the flow line indicated at 4a.

Now, to flow the well through the casing, it will be understood that the well liquid is standing at A in both the casing and the tubing. Pressure fluid is turned into the tubing 2 through the line 2b with the pipe line 4a open. The valves 18a in the flow devices will be closed quickly above the level A. The liquid level in the tubing is depressed to D while the liquid level in the annular space 1a rises to the place indicated at E. The device next above the level D will open wide, while the one above it will remain closed or be opening. The path of pressure fluid after the well has been pumped off will be, of course, out of the tubing via the openings 6a into the annular space 1a.

Flow will result through the casing, one valve after another being uncovered until the well will be pumped off by stages, in a manner so similar to the previously described tubing flow as to be readily understood without further discussion.

Since the flow device valve 18a will be open always to admit pressure fluid above the base of the upstanding column for either tubing or casing flow, it is evident that much less pressure will be required to start a well equipped with these devices than would be required to start one by forcing the non-aerated upstanding column out through the tubing.

In deep wells, it is sometimes conducive to lower gas-liquid ratios if the devices have their valves controlling the admission of pressure fluid adjusted to close at progressively less differential with increasing depth. Such adjustment sometimes will require that the valves be further adjusted to intake progressively less pressure fluid

and that they also be spaced progressively closer together as the depth increases.

For flowing through the tubing, the upper portion of the tubing may be larger than that below in order to provide for more efficient expansion of the pressure fluid. For flowing through the casing, the tubing, which then becomes the induction conduit, may be preferably all of one size, and smaller than that employed for the tubing flow method.

It is apparent that various minor changes may be made in the constructions set forth in the specification and drawing, within the scope and purpose of this invention; and I reserve the right to make such changes in carrying out the objects thereof pursuant to the appended claims.

I claim:

1. In a stage lift flow device, a valve body, a tubular valve housing thereon, a lower valve chamber in said housing having an inlet, a valve in said inlet, a tubular valve seat member projecting downwardly in said chamber, lateral ports therein connecting with the interior of said body, a valve stem extending downwardly through said seat member, an oppositely flaring area on said stem adjacent said ports, a valve at the lower end of said stem formed to engage the lower end of said seat member, and means responsive to differential fluid pressure between the interior and exterior of said body for controlling the flow of pressure fluid through the housing.

2. In a stage lift flow device, a valve body, a tubular valve housing thereon, a lower valve chamber in said housing having an inlet, a valve in said inlet, a tubular valve seat member projecting downwardly in said chamber, said seat member closing across said housing except for an axial passage, ports in said seat member connecting with the interior of said body, a valve stem projecting downwardly through said passage, an oppositely flaring area on said stem in the tubular portion thereof, a valve at the lower end of said stem formed to engage the lower end of said seat member, and means responsive to differential fluid pressure between the interior and exterior of said body for controlling the flow of pressure fluid through the housing.

3. In a stage lift flow device, a valve body, a valve housing thereon, a valve chamber at the lower end of said housing, an upper chamber, a bellows diaphragm in said upper chamber, a tubular seat member in said valve chamber, a stem on said diaphragm extending downwardly through said seat member, a valve seat at the lower end of said seat member, a valve on said stem, lateral ports in said seat member communicating with the interior of said body, a reduced tapered area on said stem adjacent said ports, said upper chamber having openings therein to the interior and exterior of said body whereby differential fluid pressure may move said diaphragm and said valve.

4. A valve body, a tubular housing thereon, a valve chamber in one end of said housing having passages leading to the interior and exterior of the body, a second chamber having passages leading to the interior and exterior of the body, a bellows diaphragm in the second chamber, a partition separating said chambers, a valve stem on said diaphragm having a sealing fit through said partition, a tubular seat member through which said stem projects, lateral ports in said seat member opening to one of the passages in the valve chamber, a seat on the projecting end of said seat member, a valve on said stem, a reduced metering area on said stem adjacent said ports, a cylindrical area on said stem between said metering area and said valve, said diaphragm being exposed on one area to pressure from within said body and on its opposite area to fluid pressure from outside said body.

5. A valve body, a tubular housing thereon, a valve chamber in one end of said housing having passages leading to the interior and exterior of the body, a second chamber, a bellows diaphragm in the second chamber, a partition separating said chambers, a valve stem on said diaphragm having a sealing fit through said partition, a tubular seat member through which said stem projects, lateral ports in said seat member opening through the wall of said housing to one of said passages, a seat on the projecting end of said seat member, a valve on said stem below said seat tapered to engage therein, an oppositely flaring area on said stem movable with said stem relative to said ports, and fluid ports in said diaphragm chamber exposing said diaphragm to pressures of fluid from within and from the outside of said body.

6. In a stage lift flow device, a valve body, a tubular housing thereon, a partition therein dividing said housing into an upper bellows diaphragm chamber and a lower valve chamber, a bellows diaphragm member in the first mentioned chamber, a seat member below said partition, a tubular reduced portion on said seat member projecting downwardly in said valve chamber, a sleeve on said reduced portion, inner and outer annular grooves in said sleeve, ports in said seat member, said sleeve and said housing communicating with the interior of said body, means above and below said sleeve to seal said seat member with said housing, a valve stem on said bellows member projecting through said partition and said seat member, a valve on the lower end of said stem, a restricted metering area on said stem adjacent said ports, and an inlet for pressure fluid to said valve chamber.

7. A flow valve housing having an upper chamber and a lower chamber, a valve seat member in one of said chambers, a tubular projection on said member extending axially of said valve chamber, a valve stem slidable longitudinally in said tubular projection, means in the other of said chambers responsive to differential pressures between the ends of the chamber to move said valve stem, a seat on the end of said projection, a valve on said stem to engage said seat, lateral outlet ports from said projection, an inlet port to said chamber beyond said valve, and metering means on said stem to vary the amount of fluid flowing past said valve as said stem is moved in said tubular projection.

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