

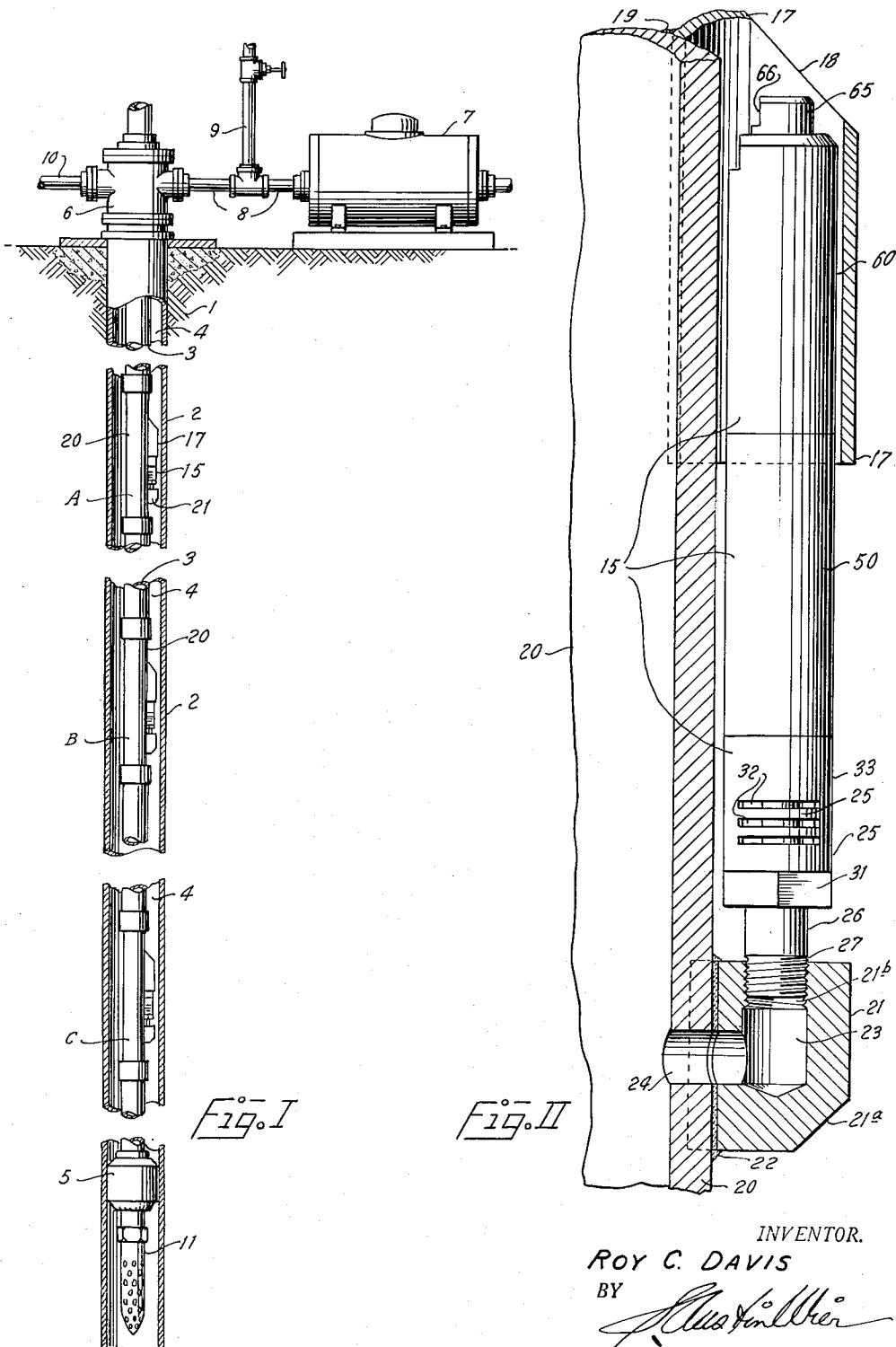
June 5, 1956

R. C. DAVIS
FLUID LIFT APPARATUS

2,748,792

Filed March 31, 1951

3 Sheets-Sheet 1



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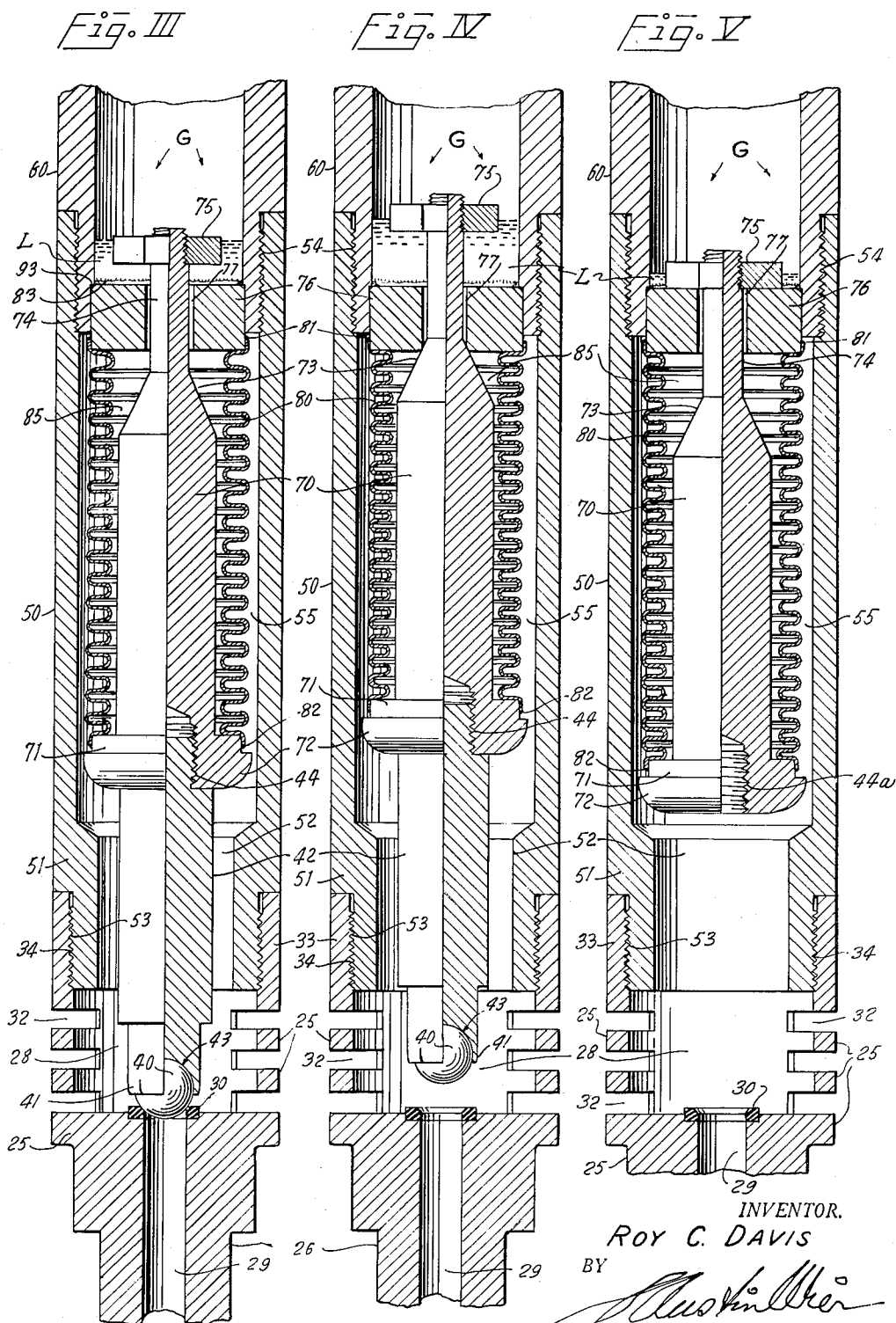
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FLUID LIFT APPARATUS

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3 Sheets-Sheet 2



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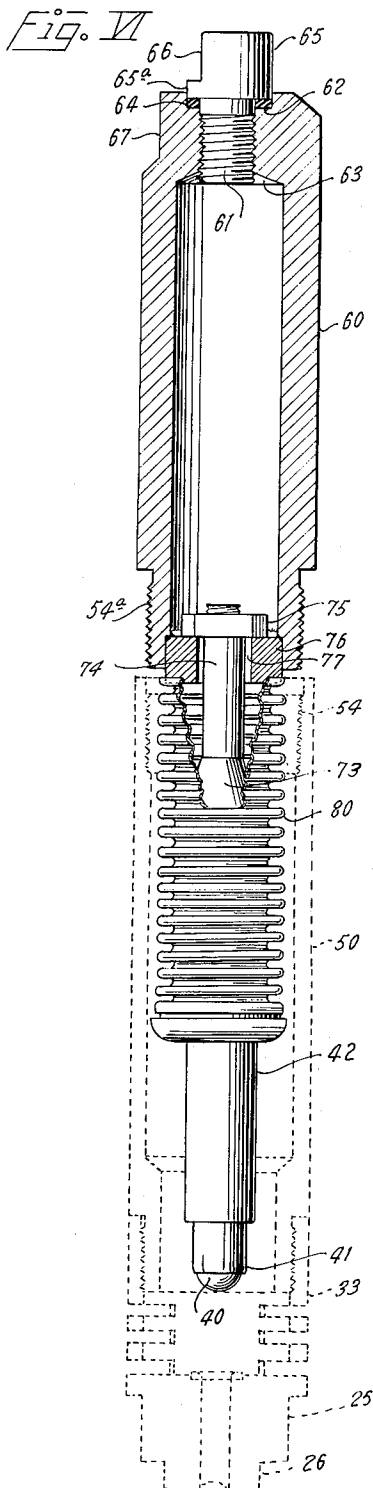
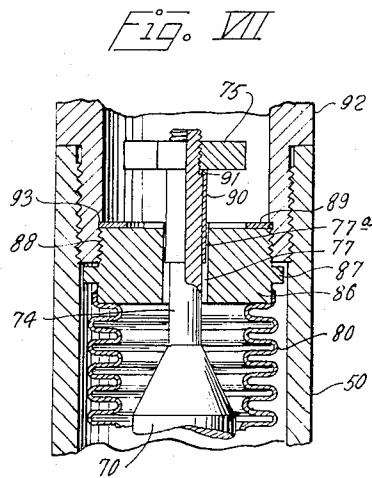
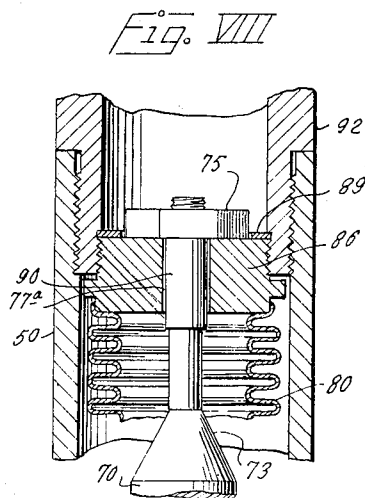
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FLUID LIFT APPARATUS

Filed March 31, 1951

3 Sheets-Sheet 3



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2,748,792

FLUID LIFT APPARATUS

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Application March 31, 1951, Serial No. 218,625

9 Claims. (Cl. 137—155)

This invention has to do with apparatus employed in the lifting of fluids and especially liquids in a well by the use of other fluids and especially gas. Suitable apparatus is provided for the compression, entrapment and valved release of gas, which may be natural gas, air or other. The release is effected below the surface of the liquid to be elevated, and this liquid may be oil, well fluids, water et cetera. The release may be such as to provide a continuous stream of gas for effecting liquid lift, or such gas may be provided intermittently and at timed periods as desired.

This invention is sometimes referred to as gas lift equipment, and at other times it is called flow valve equipment, and both terms are well known to oil field trade.

The apparatus comprehends equipment sufficient to provide a number of gas operated flow valves and allows the placement thereof at different depths within the well to give elevating impulse to the liquid therein at different levels.

The flow valves employed in plural or multiple installations along a single string of pipe are set to be actuated at predetermined pressures. This allows the selection of the valve to be initially operated, and permits the determination of the time order in which other valves in the multiple installation may be caused to operate.

However, any valve singly installed and all valves of a multiple installation may be caused to operate simultaneously, if desired; and any one or more may be caused to operate continuously, if desired, rather than intermittently.

Usually a typical valve, which is part of the apparatus made the subject of this invention, is carried by and outwardly of a special mandrel, or hollow tube, which mandrel becomes a part or section of a string of tubing; and the tubing string is set to operate within the casing string.

The annulus between tubing and casing is closed at the earth's surface and also below the lowermost valve installation. Gas under pressure is then fed into the annulus at ground level, forcing downward any liquid therein; and the gas pressure is built up in the annulus until it is sufficient to open one or more valves and release a volume of gas into the tubing, in which oil is standing. This released gas elevates a quantity of oil in the tubing. Further gas releases from the same valve, and/or other valves at other depths, deliver additional and continuing lifting impulses into the column of oil, until it flows from the tubing at ground level.

Certain objects of this invention may be understood by contrasting it with conventional apparatuses of the same general character.

Gas lift valves and apparatus heretofore employed have been deficient and unsatisfactory in several respects. They usually employed valving apparatus installed in the annulus space between casing and tubing, and such apparatus has been very bulky in character, requiring unnecessarily large annulus space. Such requirement is obviated by this invention. It employs a small and narrow elongated valve assembly easily fitted in a limited annulus.

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Some prior conventional valves have employed pressure charged vessels having an elastic element in the wall thereof, such as an elastic diaphragm or bellows, and/or a spring. Such apparatus has usually proved to be short lived because of the early destruction of the elastic member. The diaphragm frequently became permanently distorted and/or ruptured (whether made of plastic or rubberized material or of flexible metal). The same early failure has been found in apparatus employing a conventional bellows, especially when the latter was made of metal.

These failures in the elastic element, operating in conjunction with a gas pressure charged vessel, were due to several reasons. Some are noted below, thus:

(a) Expansion of the gas within the chamber, incident to the increase of temperature therein, subjected the elastic element to excessive and damaging pressures. Distortion resulted beyond recovery, and rupture was not uncommon.

In several ways, to be hereafter explained, the instant invention protects the pressure operated elastic medium, employed in the valve assembly, from any undesirable change in shape, volume or movement, laterally, vertically or otherwise.

(b) Many old fashioned valves came to an early failure because of the almost incessant movement of their elastic element, operated in conjunction with a gas charged chamber. Such undesired movement may be characterized as "chattering," and it produced early fatigue in the elastic element, regardless of the material from which it was made. In elastic elements of metallic character such fatigue was accompanied by crystallization. In all such old and unprotected elastic members there soon resulted loss of elasticity, permanent distortion and eventual rupture.

The undesirable chattering and the resulting fatigue and failure heretofore found in old devices has been entirely eliminated by this invention, in which hydraulic fluid flow is "metered" and other protection is afforded.

(c) Earlier devices of the general character of this invention usually required the confinement of the elastic element, particularly the bellows, within a cage or housing under such circumstances that the cage could not be removed once the pressure chamber and bellows were charged with fluid under pressure, else the bellows would instantly expand abnormally and/or rupture. They often literally blow up. Considering the high pressures with which such chambers are frequently charged, any attempted removal of such cage was highly dangerous to the operator, as well as damaging to the apparatus. The result was that no visual inspection could be made of the bellows (after charging) in such old valve apparatus. This highly objectionable result has been entirely eliminated and corrected in the instant invention. Visual inspection of a loaded bellows is now made both easy and safe.

(d) Valve heads and seats were quickly cut away in old apparatus, which chattered incessantly in continuous and countless opening and closing operations. Fluid velocity increased through the narrow and constantly changing spaces between valve closing elements, carrying seat-destroying abrasives, sand, scale, etc.

Valve heads and valve seats of uncommonly long life have been achieved in this invention.

(e) Old apparatus has been found quite vulnerable to breakage from external forces, as when striking couplings and pipe walls while being lowered into casing. In this invention a single flow valve assembly is so shielded, mounted and carried on the side wall of a special flow mandrel as to be fully protected from external damage and unwanted forces and shocks, notwithstanding that such assembly is capable of quick and easy removal.

Other objects of the invention will become apparent upon further reading of the specification and an examination of the accompanying drawings.

The accompanying drawings present views as follows:

Fig. I—Schematic elevational view of typical installation of apparatus, with casing partly cut away.

Fig. II—Typical flow valve assembly in elevation, with supporting wall of mandrel and valve shield in section.

Fig. III—Partially sectionalized elevational view of midsection of typical valve assembly, with valve closed.

Fig. IV—View as in Fig. III with valve open.

Fig. V—Partially sectionalized elevational view of midsection of typical valve assembly, with valve stem removed showing depending bellows at maximum extension supported by bellows core.

Fig. VI—Elevational view of typical valve assembly showing charged pressure chamber in section with depending bellows and valve stem, the bellows casing and valve housing being removed, as indicated in dotted lines.

Fig. VII—Partially sectionalized elevational view of modified form of base of pressure chamber and sleeve for adjusting hydraulic passage.

Fig. VIII—View as in Fig. VII except that bellows is at maximum extension.

In the accompanying drawings, the various parts, elements and adjuncts of apparatus presenting a typical embodiment of this invention have been designated by numerals, and like parts have been given like numerals in the various figures of the drawings.

The numeral 1 indicates the earth formations through which a well has been drilled; and the drilled hole has been fitted with conventional well casing which is indicated by the numeral 2. Within the well casing is arranged a string of tubing pipe 3. The annular space 4 is therefore provided between the tubing and the casing.

Even though the annulus be relatively small, applicant's typical valve assembly 15 may be safely carried within such annulus.

At some point down in the casing, substantially below the level of oil or well fluid standing in casing and tubing, the annulus 4 should be sealed off with a conventional packer 5. Such packer may be conveniently carried by, and about, the tubing string, and expanded into sealing contact with the walls of the casing.

At the ground surface there is provided conventional casing head closure apparatus 6. Through the use of such apparatus the annulus 4 is closed at its upper end.

Usually oil and well fluids stand in the annulus 4. The level of this standing fluid may be somewhat lowered, before the packer is set, by pumping into the upper part of the casing a quantity of gas under pressure. All the fluid in the casing, standing above the set packer, may be forced out of the annulus into the tubing through the operation of a series of valve assemblies 15, indicated schematically as at A, B and C in Fig. I.

Before the fluid lifting apparatus is installed and put into operation, it is proper to determine the liquid level in the casing, the normal casing pressure, the normal tubing pressure and the average weight per foot of the fluid column.

Knowing these factors, and the static fluid level measured from the surface of the earth, and the available outside gas pressure which may be used to operate the valves to lift liquid in the tubing, then a determination is made of the proper settings, in pounds per square inch, of the several valve assemblies to be employed, where multiple valve installation is desired; and the spacing of the valves is determined together with their respective depths in the well.

Such valves may be set to operate at any desired pressure, such as 100 p. s. i. or 500 p. s. i. or whatever is desired.

One valves installation may be employed, if multiple

valve installation is not desired. Where several valve assemblies are employed in a tubing string they may be set to operate at any pressure desired, and even the same pressure.

A typical (though simplified) installation is shown in Fig. I, in which three valve installations are placed at spaced intervals along a tubing string. The uppermost installation is shown at A. The next lower installation is shown at B. The lowermost installation is shown at C.

For purposes of illustration, it may be assumed that the valve in assembly A is set to open at 500 p. s. i.; and that the valve in assembly B is set to open at 450 p. s. i.; and that the valve in assembly C is set to open at 400 p. s. i.

As gas pressure is built up in the annulus 4 it will first cause the opening of valve C, and the release of liquid from the annulus through said valve into the tubing. Valve B will open next, as the pressure increases, and it will unload a quantity of liquid from the annulus into the tubing. Further increased pressure will open valve A, and allow liquid to be emptied from the annulus into the tubing. The liquid entering the tubing through the valves is lifted up through the tubing by the force of expanding gas charges, which are intermittently thrown into the tubing under successive heads of liquid therein. In this way, the casing is unloaded and freed of liquid between casing head and packer.

Assuming that valve C is chosen as the operating valve, then after the unloading process is completed, valve C will intermittently open and discharge a volume of gas from the annulus into the tubing underneath a head of liquid therein.

The gas control device 7, arranged on the earth's surface, includes equipment for regulating and maintaining gas pressure, timing its release, and intermittently releasing it into the annulus. All of the apparatus indicated at 7 is conventional.

Intermitter apparatus 7 is so set to operate that when a predetermined head of oil shall have risen in tubing 3, above the operating valve C, then gas pressure in the annulus 4 will be increased until valve C opens and throws a charge of gas underneath such predetermined head of oil in the tubing, thus elevating the oil in the tubing.

If the natural flow of oil into the tubing has sufficient inherent pressure, then valve C may be held open by an increase in annulus pressure. Thereafter, the valve will regularly feed a flow of gas under pressure into the rising stream of oil in the tubing. The oil will be elevated with the assistance of the added and expanding gas therein supplied through the valve.

Usually the lowermost valve in the series of valves is the operating valve, and all those thereabove are used only to unload the annulus. Thereafter they are not required in the lifting of the oil in the tubing.

However, by reason of changed conditions, some operators may prefer to have one or more valves arranged below the operating valve. This will also allow the unloading of the annulus at a point below the operating valve, whenever such is desired. In a deep well as many as a dozen separate valve assemblies, each placed at successive depths and properly spaced apart and loaded to operate at different pressures, may be employed. However, the principle of operation is the same as heretofore indicated. Gas under pressure flows from control apparatus 7, through conduit 8, into casing head 6, and thence into the annulus 4, where it opens the valves at predetermined pressures.

The operation of the valves in the annulus causes the elevation of oil in the tubing 3. Then such oil is forced outwardly through flow line 10 to storage tanks. By such process oil is lifted from the well through use of this apparatus.

Incidentally, where desired, a direct pipe 9 may be provided from the main gas supply or pump, so as to maintain constant pressure in the annulus 4, by-passing the

intermitter. This is advised in operating continuous flow valves.

Below the packer 5 there may be arranged the tail pipe 11, which may simply be a length of tubing, or several lengths of tubing, or a perforated member, or any other desired apparatus, conventional or otherwise. Oil to be lifted enters the tube through the tail pipe 11.

A typical valve assembly is shown at 15. It includes a pressure chamber 60, a bellows casing 50 and a valve housing 25. The delivery tube 26 may be a part of the valve housing, or it may be simply connected thereto.

Valve assembly 15 is protected at its upper part by valve shield 17, which may best be arranged as an arcuate shield, open at top and bottom, and rigidly attached, as with welding 19, to the side walls of mandrel 20.

Spaced below the shield 17 is lug 21, which is rigidly attached to the outer wall of mandrel 20, as with the use of welding 22.

Lug 21 should be provided with a beveled heel 21a, to prevent such lug from hanging up on any objects, such as pipe joints, as the valve assembly is raised or lowered in the casing. Also it is proper to provide the beveled shoulder 18 on the valve shield 17 for the same purpose.

Mandrel 20 is a hollow tubular member which really constitutes a section of the tubing string. It may be secured therein through the use of conventional pipe couplings, threaded internally.

Through the lug 21 there is provided gas delivery conduit 23. An aligned opening 24 is made through the mandrel wall to connect conduit 23 with the bore of the mandrel. The conduit 23 is opened and closed by the operation of the main valve arranged thereabove.

Male threads 27 may be provided about the end of delivery tube 26, and companion female threads arranged internally of conduit 23, thus providing means for attaching valve base 25 to lug 21. The member 25 provides more than a valve base, in that it affords a hollow valve housing and constitutes a valve seat element.

The upper part of valve base housing 25 is provided with an enlarged bore 28. Thus is provided the hollow section 33 of the valve base or housing.

Through the lower part of member 25 there is arranged channel 29, which is provided with valve seat 30. This seat may be made removable and replaceable.

Around the base of the valve housing 25 there should be provided flat faces 31 to receive a wrench for screwing the valve into the channel 23 in lug 21, and removing it therefrom.

The side wall of valve housing 25, and preferably the lower part of hollow section 33 of such housing, is provided with a series of ports 32, through which fluid may flow freely whenever the channel 29 is opened by the lifting of the valve head 40, which normally closes the channel.

Female threads 34 are provided within section 33 of housing 25 to receive and make up with companion male threads 53 which are provided on the thickened foot section 51 of bellows casing 50.

The valve head 40 may simply be a rounded or tapered or pointed end of valve stem 42, or it may be provided through the use of ball 40, as shown. This ball is preferred, and when used it may be carried within socket 43 provided in the free end of valve stem 42. Such socket may be made slightly deeper than the radius of ball 40, and along the lower edges of this socket there may be slots so made as to provide therebetween retaining fingers 41. When the ball 40 is placed in socket 43, then the fingers 41 are simply peened inward slightly to retain the ball, and prevent it from falling out. Nevertheless, this arrangement and construction will allow the ball to turn freely within socket 43, and thereby expose a multitude of faces successively to seat upon valve seat 30. This will greatly lengthen the lift of both the valve head 40 and its seat.

Obviously, if desired, ball 40 may be rigidly secured

in socket 43 as by welding. In such case fingers 41 need not be employed.

Valve stem 42 is provided with male threads 44 on its fixed end, which may be made up with companion female threads 44a in the base of bellows core 70, or in the supporting base or shoe 71, which is arranged at the lower end of the core.

Within the foot section 51 of the bellows casing 50 there is provided a reduced bore 52, through which the valve stem 42 operates.

The larger or normal bore 55 of casing 50 surrounds the bellows 80. It is in the bore 55 that the bellows normally extends and contracts. It operates within a very definite and limited range, limited as is herein elsewhere explained. The upper end of casing 50 is provided with internal threads 54 to receive companion threads 54a arranged externally of the lower end of chamber 60, by use of which these members may be firmly yet removably held together.

Pressure chamber 60 is an elongated hollow vessel, provided with a partition or base 76 at its lower end and having a filling opening 63 in its upper end, arranged for charging the chamber with fluid under pressure. This opening is internally threaded to receive the externally threaded section 61 of sealing plug 65.

Opening 63 has arranged about its upper end the gasket recess 64 which is provided to receive resilient gasket 62. This gasket is preferably made of soft annealed copper. It is to be noted that rubber and rubber-like materials are not indicated for gasket use, as they simply do not last as well and are not as dependable as the soft metal gasket. Plug 65 has an enlarged midsection 65a, circular in contour, which presses down upon the gasket 62 as the plug is made up in the threaded opening, thus effectively sealing the chamber against the escape of gas therefrom.

It is well to provide a flat face 66 on plug 65 to receive a wrench. And it is well to provide a wrench face 67 on the side wall of chamber 60.

Within bellows 80 there is arranged the protecting core 70, which constitutes a supporting body. At the lower end of this body there may be attached (or made integrally therewith) the shoe 71, on which the lower end of the bellows rests and to which it is sealingly attached, or fused, as with induction brazing, indicated as at 82.

Any suitable means for sealingly attaching the lower end of the bellows to the supporting shoe, or to the lower end of the bellows core may be employed. The same may be said with respect to effecting sealing attachment of the upper end of the bellows, shown as at 81, to the partition 76, which partition constitutes the base of pressure chamber 60.

Guide 72 is recommended to be provided so as to extend outwardly slightly farther than the bellows wall. This guide may be made as a rounded lip. However, it may be provided as a spider or other member having three or more fingers outwardly disposed. In any event, the guide should be caused to extend slightly further outwardly than the outermost region of the bellows wall. The outwardly extending guide will prevent the bellows from effecting frictional and abrasive engagement with the inner face of bellows casing 50.

The core 70 may be provided with a removable plug head 73; or such member may be made integral with the core. It constitutes a safety valve head which will close passage 77, under circumstances to be explained later.

Supporting rod 74 rigidly connects with and carries core 70. Such rod may be removable or made integral with the core (or the plug 73). Such construction is optional.

Supporting rod 74 is arranged to movably extend through the passage 77, such passage being provided through the base or partition member 76 of pressure chamber 60.

The size of rod 74 is so related to the size of passage

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77 as to leave about the rod an annular space of predetermined width. It is through this annular space that hydraulic fluid flows back and forth between the pressure chamber 60 and the hollow annular cavity 85 within bellows 80.

In normal operation of the apparatus the cavity 85 within the bellows 80 is filled with liquid, shown as at L. Sufficient amount of liquid is provided in the cavity 85 and the pressure chamber 60 so that the level of the liquid will be above the partition 76 when the bellows is at the limit of its extension. Above the level of this liquid the pressure chamber is filled with compressed gas, indicated as at G.

A cap 75 is removably attached to the upper end of supporting rod 74. This cap may be of any desired structure or shape. It is only required that it be larger than the passage 77, so that it may not pass therethrough. The under side of cap 75 should be smoothly finished so that it may intimately contact the upper face of partition 76 when the bellows 80 is in extreme extension (as shown in Fig. V).

Partition or base member 76 may be fixedly attached to chamber 60, as with welding 83; or it may be removably attached to such chamber, as indicated in Fig. VII, where threads are used. In the lower end of chamber 60 there should be provided shoulder 93 against which the base or partition member 76 may be forced and made to rest.

The core member 70 substantially fills the bellows cavity, and prevents undue lateral movement of the bellows and prevents the bellows from collapsing inwardly if subjected to undue outside pressure.

The core 70 carries and supports the lower end of the bellows, and the supporting rod 74 extends upwardly therefrom through the passage 77 in the partition 76, leaving an annular space about the rod through which fluid may flow at a metered rate between the bellows cavity 85 and the pressure chamber 60.

The cap 75, arranged on the outer end of the rod 74, limits the downward movement of the core and thereby the extension of the bellows.

By the above described arrangement it may be seen that the entire core element (including the rod 74, the core 70 and the shoe 72) is dependingly carried by the base or partition 76 when the cap 75 contacts the partition, and such construction allows only a limited longitudinal extension of the bellows.

The conical head 73 on the core 70 is arranged to enter the passage 77 in the partition 76 upon contraction of the bellows and thereby close the passage and limit the contraction of the bellows. Thus an inner safety valve is provided to protect the bellows against undue contraction.

This safety valve entraps within the bellows a sufficient quantity of liquid to fill it at the time of the closure of the safety valve, by the upward thrust of the core.

This liquid L is non-compressible and non-corrosive, clean and always free of foreign substances; and it affords an excellent lubricant which fills the small annulus space 85 between the core and the inner surface of the bellows walls.

Therefore, no amount of excessive fluid pressure within the annulus 4, between the well casing and well tubing, can cause any damage to the bellows or effect collapse of the bellows.

This same construction provides a regulated fluid flow around the supporting rod 74 and through the chamber base passage 77 which results in a "damping effect" on the movement of the bellows 80 and of the main valve head 40. Such main valve is free to open to the full extent of the working stroke on the proper range of pressures, but it remains "damped" sufficiently to maintain the metering effect regardless of pressure variations in the annulus 4.

This "damping" arises directly from the metering of the

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flow of fluids through passage 77; and it prevents the unbalancing of the equilibrium necessary for continuous flow through the main valve and through channel 29. Minor variations in pressure in either the casing or the tubing are all smoothed out, and there is no interruption of fluid flow through the main valve and flow channel 29.

Such construction and operation is of great importance in that it allows this flow valve to operate as a continuous flow valve, whenever desired. Increase of gas pressure in annulus 4 sufficiently to open and keep open the main valve will result in continuous flow through the valve without any "chattering" and without any damage to the bellows 80, or to main valve seat 30 or to valve head 40.

Considerable modification may be made in the apparatus here disclosed, and still the objects of the invention may be properly carried out. Modified forms of certain elements of the device are shown in Figs. VII and VIII. The changes in such structure have to do with the provision of a removable base 86 in the pressure chamber; and such base may be provided with a passage 77 therethrough having a slightly different diameter than such passage may be given in other forms of the device, in other removable bases, or in the preferred form with a fixed base as shown in Fig. VI.

The modification indicated in Fig. VII also presents a sleeve element 90 for adjusting and changing the size of the annular orifice 77 which permits the passage of hydraulic fluid around supporting rod 74.

The special or modified chamber base 86 may be provided with lugs or wrench shoulders or other elements for receiving a wrench, such as shown at 87. The upper part of the base is provided with male threads 88 which are arranged for fitting and making up with companion female threads arranged internally of the lower end of modified pressure chamber 92.

Chamber 92 is provided with the usual shoulder 93, against which gasket 89 may find rest when the base is screwed up and made tight. Such gasket is preferably made of soft metal, so that it will have a longer life, yet seal effectively against the leak of hydraulic fluid.

The standard supporting rod 74 may be made of such size as to leave thereabout the standard sized annular passage 77. Or such passage may be made of greater diameter and thereafter adjusted as to the annular space remaining for the passage of fluid. Such adjustment may be provided by sleeve 90, which is arranged to fit tightly around the rod 74 and be suspended by an inwardly turned shelf 91 at the head of such sleeve. This shelf rests upon the slight shoulder provided near the upper end of the rod.

Whatever form of cap 75, or ferrule or other member, may be affixed to the upper end of rod 74, whether by threads or otherwise, it should be so affixed as to hold the sleeve 90 and its inturned flange 91 secure and tight, so that the sleeve will always move with the rod.

Obviously, by such arrangement, sleeves of different wall thickness may be provided which will have the effect of adjusting and changing the size of passage 77 through which hydraulic fluid may flow. The passage 77 may be so adjusted to be made smaller, as indicated at 77a.

Such passage is to be originally made of proper size, or adjusted to proper size, in contemplation of several physical factors and certain properties of the hydraulic fluid employed. For instance, viscosity of such fluid is a factor. The temperature thereof is another factor. The pressure thereof is also to be considered. Also to be taken into consideration is the gas charge within the chamber 60, or 92, as the case may be.

Properly arranged, the hydraulic fluid passage will have the "leveling" effect on the movement of valve stem 42 which is so very much desired to make the opening and closing of the valve a smooth and easy operation. It will prevent the fluttering of the valve or the "cracking" of the valve, in response to variations of fluid pressure within the well annulus, or in the tubing itself.

I claim:

1. In a device of the character described, a pressure chamber; a bellows casing; a partition arranged between the chamber and the casing; a passage provided through the partition; a bellows suspended from the partition within the casing and being closed at its free end, the interior of the bellows being in communication with the pressure chamber through the passage; a core arranged in the bellows and attached to the free end of the bellows; a rod attached to the core and having a free end movably extending through the passage into the pressure chamber, such rod being smaller in diameter than the passage; means carried by the core engageable with the lower side of the partition to limit the contraction of the bellows and close the passage; means carried by the free end of the rod and engageable with the upper side of the partition to limit the movement of the core upon extension of the bellows; and disengageable fastening means connecting the chamber and the casing to permit the removal of the casing and allow inspection of the bellows while pressure charged.

2. In a device of the character described, a pressure chamber; a bellows casing; a partition arranged between the chamber and the casing; a passage provided through the partition; a bellows suspended from the partition within the casing and being closed at its free end, the interior of the bellows being in communication with the pressure chamber through the passage; a core arranged in the bellows and attached to the free end of the bellows; a rod attached to the core and having a free end movably extending through the passage into the pressure chamber, such rod being smaller in diameter than the passage; the core being so enlarged within the bellows as to limit the lateral movement of the latter; a beveled shoulder arranged on the core below the partition to close the passage upon the contraction of the bellows; and means carried by the free end of the rod and engageable with the upper side of the partition to limit the movement of the core upon extension of the bellows and thereby limit the extension of the bellows without sealing the passage.

3. In a device of the character described, a pressure chamber; a bellows casing; a partition arranged between the chamber and the casing; a passage provided through the partition; a bellows suspended from the partition within the casing and being closed at its free end, the interior of the bellows being in communication with the pressure chamber through the passage; a core arranged in the bellows and attached to the free end of the bellows; a rod attached to the core and having a free end movably extending through the passage into the pressure chamber, such rod being smaller in diameter than the passage; means carried by the core below the partition and engageable with the partition to limit the contraction of the bellows and close the passage; means carried by the free end of the rod and arranged to engage the upper side of the partition to limit the movement of the core upon extension of the bellows without sealing the passage; liquid in the bellows of sufficient quantity to fill the bellows at the limit of its extension; and gas under pressure in the chamber sufficient to urge the bellows to extended position.

4. In a device of the character described, a pressure chamber; a bellows casing; a partition arranged between the chamber and the casing; a passage provided through the partition; a bellows suspended from the partition within the casing and being closed at its free end, the interior of the bellows being in communication with the pressure chamber through the passage; a core arranged in the bellows and attached to the free end of the bellows; a rod attached to the core and having a free end movably extending through the passage into the pressure chamber, such rod being smaller in diameter than the passage; means carried by the core below the partition and engageable with the partition to limit the con-

traction of the bellows and close the passage; means carried by the free end of the rod and arranged to engage the upper side of the partition to limit the movement of the core upon extension of the bellows without sealing the passage; liquid in the bellows of sufficient quantity to fill the bellows at the limit of its extension; gas under pressure in the chamber sufficient to urge the bellows to extended position; a valve housing communicating with the bellows casing, and having ports through the housing wall and a channel through the housing base; a valve seat in the channel; a valve element carried by the bellows and arranged to be normally urged against the valve seat to close the channel.

5. In a device of the character described, a pressure chamber; a bellows casing; a partition arranged between the chamber and the casing; a passage provided through the partition; a bellows suspended from the partition within the casing and being closed at its free end, the interior of the bellows being in communication with the pressure chamber through the passage; a core arranged in the bellows and attached to the free end of the bellows; a rod attached to the core and having a free end movably extending through the passage into the pressure chamber, such rod being smaller in diameter than the passage thereby providing an annular space about the rod; means carried by the core below the partition to limit the contraction of the bellows and close the passage; means carried by the free end of the rod and engageable with the upper side of the partition to limit the movement of the core upon extension of the bellows without sealing the passage; and means to vary the diameter of the annular space.

6. In a device of the character described, a pressure chamber; a bellows casing; a partition arranged between the chamber and the casing; a passage provided through the partition; a bellows suspended from the partition within the casing and being closed at its free end, the interior of the bellows being in communication with the pressure chamber through the passage; a core arranged in the bellows and attached to the free end of the bellows; a rod attached to the core and having a free end movably extending through the passage into the pressure chamber, such rod being smaller in diameter than the passage; means carried by the core below the partition and engageable with the lower side of the partition to limit the contraction of the bellows and close the passage; means carried by the free end of the rod and engageable with the upper side of the partition to limit the movement of the core upon extension of the bellows without sealing the passage; and a shoe arranged on the lower end of the bellows, the diameter of such shoe being slightly less than the inner diameter of the casing and substantially greater than the outside diameter of the bellows.

7. In apparatus of the character described, a pressure chamber having an hydraulic passage arranged through its base; a rod having a free end movably extending through the passage into the pressure chamber; a cap carried within the chamber and attached to the free end of the rod, said cap being engageable with the base to limit the extension of the bellows; an elongated bellows core rigidly depending from the rod below the base, the core being provided with a conical top arranged to engage the edge of the passage to limit the contraction of the bellows and close the passage; a supporting shoe carried by the lower end of the core; a valve stem extending downwardly from the shoe; a valve head terminating the lower end of the stem; a hollow valve housing provided with a plurality of ports through its side walls and having a reduced bore constituting a fluid channel; a valve seat arranged in the channel to accommodate the valve head; a bellows arranged about the core and having its upper end attached to the base of the pressure chamber and its lower end attached to the shoe; and a

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casing surrounding the bellows and removably attached to the chamber and to the valve housing.

8. In apparatus of the character described, a pressure chamber having an hydraulic passage arranged through its base; a rod having a free end movably extending through the passage into the pressure chamber; a cap carried within the chamber and attached to the free end of the rod, said cap being engageable with the base to limit the extension of the bellows; an elongated bellows core rigidly depending from the rod below the base, the core being provided with a conical top arranged to engage the edge of the passage to limit the contraction of the bellows and close the passage; a supporting shoe carried by the lower end of the core; a valve stem extending downwardly from the shoe; a valve head terminating the lower end of the stem; a hollow valve housing provided with a plurality of ports through its side walls and having a reduced bore constituting a fluid channel; a valve seat arranged in the channel to accommodate the valve head; a bellows arranged about the core and having its upper end attached to the base of the pressure chamber and its lower end attached to the shoe, the shoe being provided with a laterally extending guide of greater diameter than the bellows; and a casing surrounding the bellows and removably attached to the chamber and to the valve housing.

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9. In an apparatus of the character described, a pressure chamber having a passage through its base; an elongated body having a free end portion movably extending through the passage and having a portion depending below said base; a cap arranged within the chamber and attached to the free end of the body, the cap being larger than the passage; the depending portion of the body having an enlarged section below the base wider than the passage; a valve seat element provided with an aperture therethrough; a valve stem depending from the body and normally maintaining closure of the aperture; a removable casing attached to both the chamber and the seat element; and a bellows arranged within the casing and about the enlarged section of the body and united to the lower ends of both the body and the chamber, the interior of the bellows being in communication with the pressure chamber through the passage.

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