Sept. 20, 1955 M. B. CONRAD 2,718,265

APPARATUS FOR AUTOMATICALLY FILLING WELL CASING

Filed Nov. 25, 1950 2 Sheets-Sheet 1

Fig. 1.

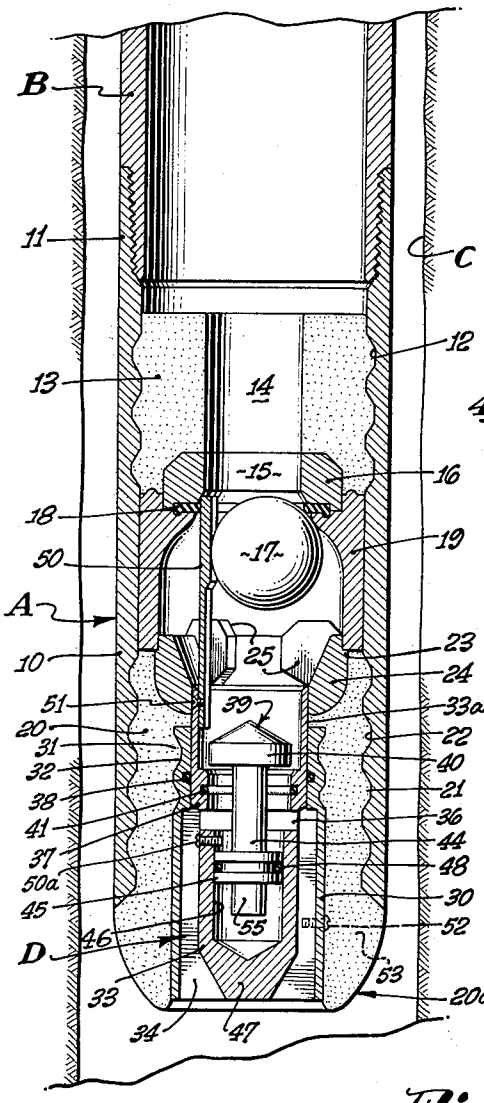


Fig. 2.

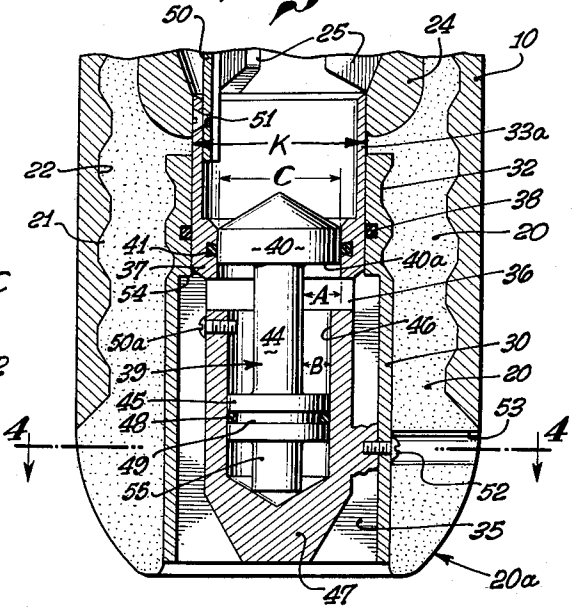


Fig. 6.

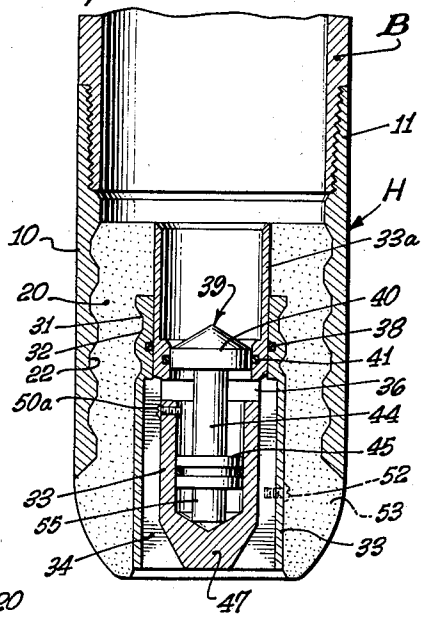


Fig. 8.

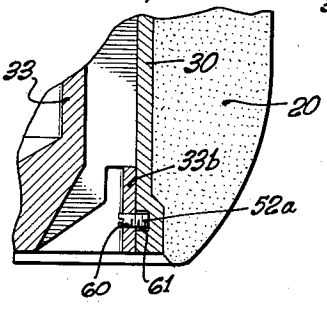
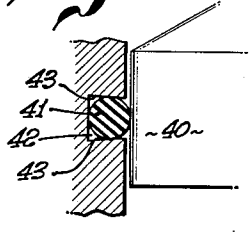


Fig. 5.



INVENTOR.
MARTIN B. CONRAD,
BY
Mellin and Hanscom
ATTORNEYS

Sept. 20, 1955 M. B. CONRAD 2,718,265

APPARATUS FOR AUTOMATICALLY FILLING WELL CASING

Filed Nov. 25, 1950 2 Sheets-Sheet 2

Fig. 3.

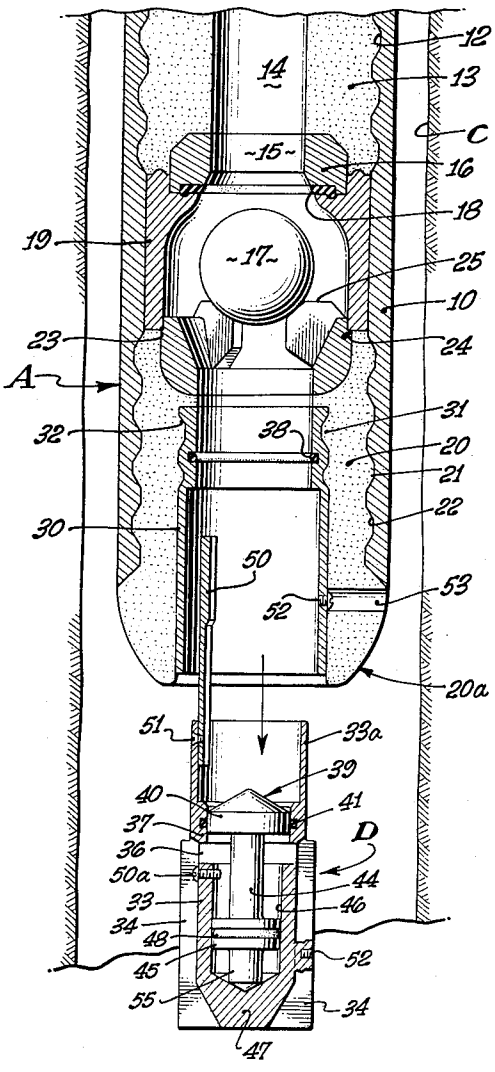


Fig. 7.

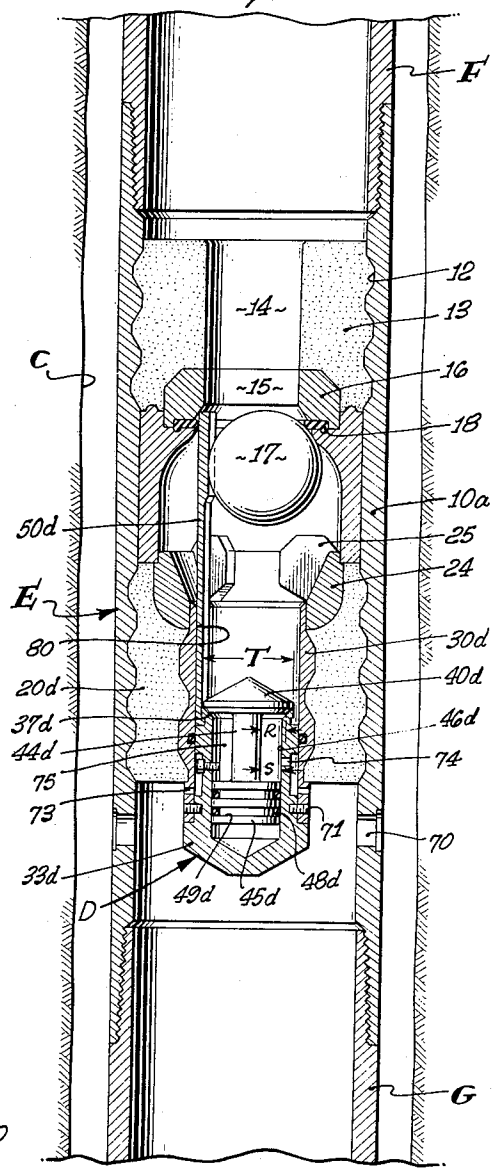
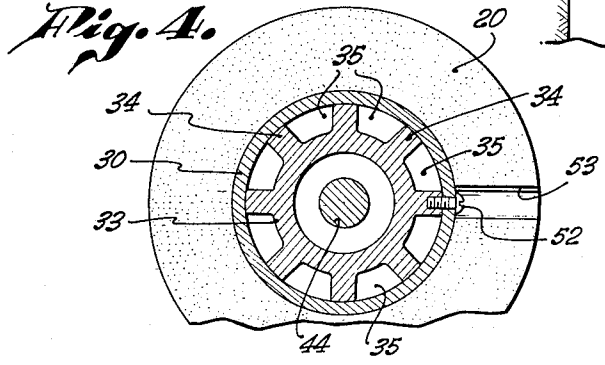


Fig. 4.



INVENTOR.
MARTIN B. CONRAD,
BY
Mellin and Hanscom
ATTORNEYS

United States Patent Office 2,718,265
Patented Sept. 20, 1955

2,718,265

APPARATUS FOR AUTOMATICALLY FILLING WELL CASING

Martin B. Conrad, Downey, Calif., assignor to Baker Oil Tools, Inc., Vernon, Calif., a corporation of California

Application November 25, 1950, Serial No. 197,542

26 Claims. (Cl. 166—225)

The present invention relates to subsurface well apparatus, and more particularly to apparatus for controllably filling a string of well casing, or the like, as it is lowered through the fluid in the well bore.

In running a string of well casing in a well bore, it has been usual practice to cause the well fluid to sustain a portion of the weight of the casing string by floating the string in the well fluid, through the expedient of maintaining its interior in a substantially empty state. The well fluid is ordinarily prevented from entering the casing string by an upwardly closing check valve, which later accomplishes the purpose of preventing cementitious material, such as cement slurry, pumped down and around the casing string, from reentering the latter.

In running comparatively long strings of casing in the well bore, the hydrostatic head of fluid acting on the lower portion of the casing may be very high and may collapse the casing. To offset this possibility, it is usual practice to place the same type of drilling fluid that may be present in the well bore inside the casing string up to a desired elevation, lower than the level of fluid in the well bore. This decreases the differential hydrostatic head on the casing, while still maintaining a large degree of buoyancy in the casing string, to continue its floating in the well bore during lowering to its final position.

An object of the present invention is to automatically fill the casing string to predetermined elevations below the level of the well fluid surrounding the casing string as the latter is lowered in the well bore.

Another object of the invention is to cause the well fluid itself to effect automatic filling of the casing string to predetermined levels as it is lowered in the well bore.

A further object of the invention is to provide a float shoe or float collar that can form part of a well casing string, which is effective to automatically fill the casing string to particular levels as it is lowered in the well bore, and in which the back pressure valve of the shoe or collar is still effective to prevent return flow of cement slurry, or other fluids, into the well casing after the latter has been landed in the well bore.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of several forms in which it may be embodied. Such forms are shown in the drawings accompanying and forming part of the present specification. These forms will now be described in detail, illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a longitudinal section through an embodiment of the invention, with the parts in the position they occupy while lowering the equipment through the fluid in the well bore;

Fig. 2 is an enlarged longitudinal section illustrating the automatic casing fill-up device in closed position;

Fig. 3 is a view similar to Fig. 1, disclosing the automatic casing filling portion of the device ejected from the casing shoe;

Fig. 4 is a cross-section taken along the line 4—4 on Fig. 2;

Fig. 5 is a fragmentary longitudinal section illustrating the casing filling valve sealing arrangement;

Fig. 6 is a longitudinal section through a modified form of apparatus;

Fig. 7 is a longitudinal section through another embodiment of the invention;

Fig. 8 is a fragmentary longitudinal section showing another manner of attaching the valve body to the valve housing.

The apparatus disclosed in Figs. 1 to 5, inclusive, is a casing shoe A adapted to be threaded, or otherwise suitably attached, to a casing section B thereabove; so as to form the terminal end of a casing string to be lowered in a well bore C. If the apparatus A is placed in an intermediate portion of the casing string, it would operate in the same manner, but would then be considered as a casing collar.

The device A includes an outer tubular member **10**, usually made of steel, having an upper threaded box **11** for attachment to the adjacent casing section B. This tubular member is provided with a series of upper internal grooves **12** for securing an upper cementitious plug **13** to it, as a result of casting the plug directly in the tubular member. This plug has a central passage **14** in alignment with a passage **15** through a valve seat **16** disposed in the lower portion of the plug **13**.

A back pressure valve element **17**, that may be in the form of a ball buoyant in cement slurry, is disposed in the shoe below the seat **16**, being movable upwardly into engagement with the latter to prevent upward flow of fluid into the well casing B. For the purpose of preventing leakage around the ball, when seated, it engages a suitable seal ring **18** clamped between the valve seat **16** and a spacer sleeve **19** extending from the upper plug **13** to a lower plug **20** of cementitious material, which is anchored to the tubular member **10** by means of its external ribs **21** cast into internal grooves **22** in the tubular member.

The lower end of the spacer sleeve **19** engages a shoulder **23** on a stop member **24** seating in the lower cementitious plug **20**, this member having a plurality of lugs or fingers **25** on which the ball valve element **17** can rest when fluid is being pumped downwardly through the casing string B and its casing shoe A. The valve seat **16**, spacer sleeve **19** and stop member **24**, in effect, form a valve cage containing the ball valve element **17**.

The lower cementitious plug **20** may have a lower rounded nose **20***a* for guiding the casing string past any obstructions or restrictions in the well bore.

Apparatus of the general type so far described is known. During lowering of the casing string B in the well bore C, the drilling fluid, or other liquid, in the well bore would be prevented from entering the interior of the casing string, in view of the upward engagement of the valve element **17** against its companion seat **16** and seal **18**. As a result, the interior of the casing string does not contain any fluid. As the casing string is lowered to greater depths in the well bore, the hydrostatic head of liquid acting on the exterior of the shoe and the lower portions of the casing string B increases. In deep wells, this hydrostatic head may be so extensive as to tend to collapse the casing string. To forestall this action, the casing string has heretofore been filled with fluid from the top of the well bore, creating a hydrostatic back pressure offsetting the external hydrostatic head and reducing to a safe value the differential pressure tending to collapse the lower portion of the casing string inwardly.

By means of the devices disclosed in this application,

the well fluid itself is instrumental in allowing its entry into the well casing, to provide a column of liquid within the casing string that rises to a lesser elevation than the height of the liquid in the well bore surrounding the casing. In this manner, the differential hydrostatic head tending to collapse the casing is decreased, but the casing itself can be maintained empty to a large degree; to assist in floating it in the well bore while it is being lowered to its ultimate position.

As disclosed in the drawings, fluid can enter the well casing B through the casing shoe A whenever permitted to do so by a differential valve device D, which is opened or closed in dependence upon the proportionate hydrostatic heads of fluid within and outside of the casing string. This valve device includes a tubular valve housing **30** disposed in the lower cementing plug **20** coaxial of the central passage **14** through the upper plug, being secured to the plug **20** by inner ribs **31** in the latter cast within external grooves **32** in the housing. A valve body **33** is disposed in this housing, including a lower series of circumferentially spaced longitudinally extending ribs **34** engaging the inner wall of the sleeve **30**, the spaces **35** between the ribs providing passages for fluid to flow from the exterior of the shoe A upwardly into its interior. From these passages **35**, the fluid can flow to the interior of the body **33** through a plurality of body ports **36**, the fluid then passing upwardly through a generally cylindrical valve seat **37** in the body, and into the upper cylindrical portion **33***a* of the body that may project within the stop member **24**. Leakage between the housing and exterior of the upper body portion **33***a* is prevented by a suitable side seal **38** in the housing **30** engaging the exterior of the upper body portion.

The ability of the external well fluid to flow upwardly into the shoe, in the manner just described, is dependent upon the open or closed position of a valve member **39**, which open or closed position is governed automatically by the differential pressure existing between the hydrostatic head of fluid externally of the casing B and the hydrostatic head of fluid internally of the casing. The valve member **39** itself includes a valve head **40** having a cylindrical periphery adapted to be disposed within the cylindrical body seat **37**, for the purpose of preventing upward passage of fluid into the casing shoe. When in this position, leakage around the valve head **40** is prevented by engagement of its periphery with a seal ring **41** disposed in a groove **42** in the valve seat **37**. The ring is preferably of round cross-section, being received within the groove **42** having opposed side walls **43** that may be parallel to one another, or which may converge toward each other in a direction toward the axis of the device (Fig. 5); to insure retention of the seal ring **41** in the groove **42**.

The valve head **40** is secured to, or is made integral with, a depending rod **44** attached to, or integral with, a lower piston **45** slidable within a cylinder **46** in the valve body having a closed lower end **47**. Leakage around the periphery of the piston **45** is prevented by a suitable seal ring **48** disposed in a piston groove **49** and slidably engaging the wall of the cylinder **46**. Between the piston **45** and the lower cylinder head **47** no fluid is present, this space originally being occupied by air at substantially atmospheric pressure. A stem **55** depends from the piston **45**, for the purpose of limiting downward movement of the valve member **39** to a position in which the head **40** is in fully closed position within the seat **37** and its seal **41**. Upward movement of the valve member is limited by engagement of the piston **45** with a stop screw **50***a* threaded into the body **33** and extending into the cylinder **46**.

The fluid passing upwardly through the longitudinal passages **35** in the valve body **33** flows through the ports **36**, and under certain conditions will act on the underside **40***a* of the valve head **40**, for the purpose of elevating it above its seat **37** to open position, in which the well fluid can continue flowing through the upper portion **33***a* of the body, around the ball valve element **17** and through the upper plug passage **14** into the casing sections B above the shoe A. To allow such flow to occur around the ball valve element **17**, the latter is initially prevented from moving upwardly into engagement with its seat **16** by a retainer arm **50** secured to the valve body **33**, as by a screw **51**, and holding the ball to one side of the valve seat axis, in the manner illustrated in Fig. 1. It is only when this retainer arm **50** is removed that the ball valve element **17** is allowed to move upwardly into engagement with its seat **16**.

The valve body **33** and retainer arm **50** are held initially in an upward position by a shear screw **52** attaching the body **33** to the valve housing **30** (see Fig. 2). This screw may be inserted through a lateral hole **53** in the lower guiding portion of the lower plug **20** and threaded into a valve body rib **34**. When in this position, the upper ends of the ribs **34** engage a shoulder **54** on the valve housing **30**, and the retainer arm **50** holds the ball valve element **17** displaced to one side of a coaxial position with the seat **16**.

By referring to Fig. 2 particularly, it is to be noted that the fluid externally of the well casing B can pass upwardly through the longitudinal passages **35** and through the ports **36**, entering the cylinder **46** and acting downwardly on the lower piston **45** across the annular area B between the wall of the cylinder and the piston rod **44**. This same fluid is acting upwardly on the valve head **40** over the annular area A between the valve rod **44** and the cylindrical seat **37**. Any fluid in the interior of the well casing B acts downwardly on the valve head **40** over its entire cross-sectional area C.

The area A is greater than the area B, so that the hydrostatic head of fluid on the exterior of the casing string acts on a differential area of A minus B, and tends to lift the valve head **40** off its seat **37**, to shift it to open position. As stated before, the hydrostatic head of fluid inside the casing acts downwardly over the valve head area C, and tends to shift the valve head **40** downwardly to closed position and maintain it in this closed position. Opening or closing of the valve, neglecting friction, is therefore dependent upon the following relationship:

$$P_1(A-B)=P_2C$$

or

$$P_2=\frac{P_1(A-B)}{C}$$

in which P_1 is the hydrostatic head externally of the casing string, and P_2 is the hydrostatic head internally of the casing string B. When the hydrostatic head P_1 externally of the casing string increases in a certain proportion above the hydrostatic head internally of the casing string, the valve **39** will elevate to open position, allowing the well fluid to pass upwardly through the shoe A and into the casing string B, to increase the height of liquid inside the casing string, and thereby increase its head P_2. When this latter head reaches a certain value, it will exert a total downward force on the valve member **39**, overbalancing the force of the greater external hydrostatic head P_1 on the valve member **39**, and the latter will be shifted downwardly to closed position within its cylindrical seat **37**.

As an example, let it be assumed that the area A is 2.3194 sq. in., the area B is 1.3990 sq. in., and the area C is 2.7612 sq. in. Substituting these constant values in the above equation, it is found that P_2 equals $\frac{1}{3}$ P_1. In other words, under the assumed condition, when the pressure P_1 externally of the casing string is three times the pressure P_2 internally of the casing string, the valve **39** will open and allow the internal casing string pressure or hydrostatic head to increase. When this latter hydrostatic head P_2 is more than one-third of the external hydrostatic head P_1, it will reclose the valve automatically.

Accordingly, from the above relationship, and since

for any particular design the several areas A, B, C are constant, the valve mechanism **39** will allow the well fluid to flow automatically into the casing string B and maintain a direct straight-line proportion between the internal pressure P_2 and the external pressure P_1. Under the assumed example, the hydrostatic head P_2 inside of the well casing will be maintained at one-third the hydrostatic head P_1 externally of the casing.

The apparatus A is secured to the lower end of the casing string B, as shown in Fig. 1, with the ball valve **17** prevented from engaging its seat **16**. As the casing string B is lowered through the fluid in the well bore C, the external hydrostatic head P_1 elevates the valve **39** to open position, and allows the fluid to flow through the shoe A and into the casing string B. Assuming that descent of the casing string is stopped (as occurs when another section of casing is to be attached to the top of the well bore), the external hydrostatic head P_1 will hold the valve **39** open until the fluid level inside the casing string reaches a predetermined point, which is preferably a fraction of the external level of fluid in the well casing; so that the well casing is kept substantially empty for the purpose of having the well fluid sustain a large portion of its weight. At this time, the internal pressure P_2 acting over the larger area C of the valve head **40** will shift the latter downwardly to closed position, such as disclosed in Fig. 2. Upon continuance in the descent of the string of casing in the well bore, a greater external hydrostatic head P_1 will be imposed on the valve **39**, causing it to again elevate to open position and allowing the hydrostatic head P_2 in the interior of the casing string to increase.

After the casing string has been lowered in the well bore to the desired location and extent, the ball valve element **17** is to be freed; to permit its upward engagement with its valve seat **16**. At this time, the casing string B can be filled with fluid, as from the surface of the well bore, until it is completely full, whereupon pressure can be imposed on the fluid inside the casing. With the valve head **40** closed, such downward pressure cannot shift the valve **39** to any lower position, inasmuch as the stem **55** depending from the piston **45** engages the cylinder head **47**. The pressure internally of the casing string is then operative over the entire area K across the upper portion **33***a* of the valve body, the hydraulic force acting on the frangible screw **52** to shear the latter and pump the entire automatic fill valve mechanism D downwardly out of the casing B, in the manner disclosed in Fig. 3. This ejection carries the retaining arm **50** downwardly with the valve body **33**, and removes it from the casing shoe, freeing the ball valve element **17** for upward movement into engagement with its companion seat **16**.

The well casing B may now be cemented in place, as by pumping cement slurry down the casing string, the ball valve element **17** resting on the supporting lugs **25** while the cement slurry is passing around it and out through the lower end of the shoe A for upward passage around the exterior of the casing string B. When the pressure inside the casing is relieved, the tendency for the cement slurry to flow back into the casing is prevented by upward movement of the ball valve element **17** into engagement with its seat **16**.

Accordingly, it is apparent that the device D allows the casing string B to fill automatically with fluid as it is lowered with the well bore, while maintaining a definite ratio between the hydrostatic head or pressure P_1 externally of the casing string and the head P_2 internally of the casing string, the latter head preferably being only a fraction of the external head P_1. In this manner, the pressure differential on the lower portion of the casing string is prevented from becoming excessive, thereby precluding the possibility of collapsing of the casing. Despite the permitting of the fluid to flow upwardly into the casing string, the back pressure valve **17** is still later effective to prevent return flow of cement slurry, or other fluent substances, into the casing string B after having been ejected therefrom.

In Fig. 8, a modified form of release for securing the valve body **33** to the valve housing **30** is disclosed. Instead of inserting the shear screw **52** through a hole **53** in the cementitious plug **20**, the valve body **33** may have an arcuate lower sleeve-like portion **33***b* engaging the wall of the housing **30**. This sleeve-like portion has a threaded hole **60** in alignment with a threaded bore **61** in the lower end of the housing **30**. A shear screw **52***a* can readily be inserted from the interior of the housing into these threaded holes **60**, **61** for the purpose of detachably securing the body **33** to the housing **30**. By virtue of this arrangement, assembly of the body **33** to the housing **30** is facilitated.

In the form of invention illustrated in Fig. 6, a guide shoe H is attached to the lower end of the casing string B. This shoe does not have a float valve, but in all other respects the differential valve D is the same as disclosed in the Fig. 1 to Fig. 5 device. The valve mechanism D is effective to control the flow of the well fluid into the casing string B until the predetermined ratio between the internal and external hydrostatic heads of fluid exists. After the casing string has been landed in the well bore, it is only necessary to fill the casing string and impose an internal pressure on the fluid therewithin, which will shear the screw **52** and eject the valve body **33** and the movable valve element **39** itself from the shoe housing **30**, opening the passage through the latter so that fluent substances can be pumped downwardly and out through the casing shoe.

In the form of invention shown in Fig. 7, a differential valve device is illustrated as forming part a float collar E threadedly secured to upper and lower casing sections F, G to hold them in spaced relation. The parts are essentially the same as in the other form of invention, except that the head of fluid externally of the casing can enter the collar through the lateral ports **70** in the tubular collar member **10***a*. The valve body **33***d* is initially secured to the valve housing **30***d*, that is anchored in the lower cementitious plug **20***d*, by one or more shears screws **71** extending between a depending portion of the housing and the valve body. The valve body **33***d* itself is provided with a cylinder portion **46***d* and with an upper tapered valve seat **37***d* engageable by a tapered valve head **40***d*. A stem **44***d* depends from this head, the lower end of which is secured to a piston **45***d* slidable in the cylinder **46***d* and carrying one or more seal rings **48***d* in ring grooves **49***d*. The cylinder space below the piston **45***d* is preferably occupied by air originally at atmospheric pressure.

An arm **50***d* is secured to the valve body **33***d* and extends upwardly into engagement with the ball valve element **17** to hold it off its seat **16**. As in the other form of invention, the area R between the valve stem and the sealing point of the valve head **40***d* against the seat **37***d* is greater than the annular area S across the piston. The area T across the valve head **40***d* corresponds to the area C in the other forms of the invention.

The same relationship exists as was specified in connection with the other form of the invention, and which may be expressed in the following equation:

$$P_2=\frac{P_1(R-S)}{T}$$

Since R, S and T are constants, there is a direct and straight-line proportion between the hydrostatic head internally of the casing string, P_2, and the hydrostatic head of fluid externally of the casing string, P_1.

As the casing is lowered through the fluid in the well bore, the fluid can enter the valve mechanism through the housing ports **73** and through the body ports **74** into the annular space **75** between the wall of the cylinder **46***d* and valve stem **44***d*. This pressure will elevate the valve head **40***d* from its seat and allow the fluid to flow upwardly

into the casing string. When the fluid level inside the casing string rises to a point in which an equalized condition is obtained under the above equation, the valve **40***d* will be shifted downwardly by the internal pressure to closed position.

After the casing has been lowered to its final position in the well bore, it may be completely filled with fluid and pressure applied to the latter sufficient to overcome the shear strength of the screws **71**, releasing the valve body **33***d* and blowing the differential valve mechanism D and arm **50***d* downwardly out of the collar E, opening the central passage **80** through the valve housing **30***d* to allow downward flow of fluid therethrough. At the same time, the restraint on the ball valve element **17** is released, which will allow the latter to move upwardly into engagement with its seat **16**, in the event back flow of fluid into the well casing tends to occur.

The inventor claims:

1. In well apparatus: a tubular member having a fluid passage therein and having means thereon for securing said member in a conduit string to be lowered in a well bore; said passage having an outlet adapted to communicate with the conduit string above said member and an inlet below said outlet; a valve member between said inlet and outlet for closing said passage, said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid above and on the outlet side of said valve member to urge said valve member downwardly to passage closing position, said valve member having a second resultant fluid pressure actuatable surface, when said valve member is in open position, which is subject to the pressure of fluid below and on the inlet side of said valve member to urge said valve member upwardly to passage opening position; the area of said first surface being substantially greater than the resultant area of said second surface.

2. In well apparatus: a tubular member having means thereon for securing said member in a conduit string to be lowered in a well bore; means securing a valve body in said member; a valve seat on said body; a valve member movable into and out of engagement with said seat; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular member to urge said valve member into engagement with said seat, said valve member having a second fluid pressure actutatable surface subject to the pressure of fluid externally of said tubular member to urge said valve member out of engagement with said seat when said valve member is disengaged from said seat, the area of said first surface being substantially greater than the area of said second surface when said valve member is disengaged from said seat.

3. In well apparatus: a tubular member having means thereon for securing said member in a casing string, said member having a fluid passage; valve means coacting with said passage for determining the flow of fluid through said passage between the exterior and interior of said tubular member; said valve means having a first fluid pressure actuatable surface subject to the pressure of fluid in the casing string above said tubular member to urge said valve means to passage closing position, said valve means having a second fluid pressure actuatable surface subject to the pressure of fluid externally of the casing string to urge said valve means to passage opening position; the area of said first surface being substantially greater than the area of said second surface acted on by fluid externally of the casing string with the valve means in open position.

4. In well apparatus: a tubular member having means thereon for securing said member in a casing string, said member having a fluid passage; valve means coacting with said passage for determining the flow of fluid through said passage between the exterior and interior of said tubular member, said valve means being movable longitudinally of said tubular member between open and closed positions; said valve means having an upwardly facing fluid pressure actuatable surface subject to the pressure of fluid in the casing string above said tubular member to urge said valve means downwardly to passage closing position; said valve means having a downwardly facing fluid pressure actuatable surface subject to the pressure of fluid externally of said casing string to urge and maintain said valve means upwardly in passage opening position, the pressure actuatable area of said upwardly facing surface being substantially greater than the pressure actuatable area of said downwardly facing surface when said valve means is in passage opening position.

5. In well apparatus: a tubular member having means thereon for securing said member in a conduit string to be lowered in a well bore; a valve body in said member; a valve seat on said body; a valve member movable into and out of engagement with said seat; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular member to urge said valve member into engagement with said seat, said valve member having a second fluid pressure actuatable surface subject to the pressure of fluid externally of said tubular member to urge said valve member out of engagement with said seat, the area of said first surface being substantially greater than the area of said second surface; and means, releasable by hydraulic pressure within said tubular member imposed upon said valve member and body when said valve member engages said seat, for securing said valve body to said tubular member, release of said means enabling said valve body and valve member to be shifted within said tubular member to a position in which said valve body and valve member are ineffective to control passage of fluid in said tubular member thereby allowing fluid to flow in both directions in said tubular member.

6. In well apparatus: a tubular member having means thereon for securing said member in a conduit string to be lowered in a well bore; a valve body in said member; a valve seat on said body; a valve member movable into and out of engagement with said seat; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular member to urge said valve member into engagement with said seat, said valve member having a second fluid pressure actuatable surface subject to the pressure of fluid externally of said tubular member to urge said valve member out of engagement with said seat, the area of said first surface being substantially greater than the area of said second surface; and frangible means securing said valve body to said tubular member, disruption of said frangible means enabling said valve body to be shifted within said tubular member to a position in which said valve body and valve member are ineffective to control passage of fluid in said tubular member thereby allowing fluid to flow in both directions in said tubular member.

7. In well apparatus: a tubular member; a valve body in said member; a valve seat on said body; a valve member movable into and out of engagement with said seat; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular member to urge said valve member into engagement with said seat, said valve member having a second fluid pressure actuatable surface subject to the pressure of fluid externally of said tubular member to urge said valve member out of engagement with said seat, the area of said first surface being substantially greater than the area of said second surface; means, releasable by hydraulic pressure within said tubular member imposed upon said valve member and body when said valve member engages said seat, for securing said valve body to said tubular member, release of said means enabling said valve body and valve

member to be shifted within said tubular member to a position in which said valve body and valve member are ineffective to control passage of fluid in said tubular member; back pressure valve means in said tubular member; and means interconnecting said valve body and back pressure valve means to prevent closing of said back pressure valve means, said interconnecting means being rendered ineffective to prevent closing of said back pressure valve means upon release of said securing means and shifting of said valve body within said tubular member.

8. In well apparatus: a tubular member; a valve body in said member; a valve seat on said body; a valve member movable into and out of engagement with said seat; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular member to urge said valve member into engagement with said seat, said valve member having a second fluid pressure actuatable surface subject to the pressure of fluid externally of said tubular member to urge said valve member out of engagement with said seat, the area of said first surface being substantially greater than the area of said second surface; means, releasable by hydraulic pressure within said tubular member imposed upon said valve member and body when said valve member engages said seat, for securing said valve body to said tubular member, release of said means enabling said valve body and valve member to be shifted within said tubular member to a position in which said valve body and valve member are ineffective to control passage of fluid in said tubular member; a second valve seat above said body; a valve element movable upwardly into engagement with said second seat; and means interconnecting said body and element to prevent engagement of said element with said second valve seat, said interconnecting means being rendered ineffective to prevent engagement of said element with said second valve seat upon release of said securing means and shifting of said valve body within said tubular member.

9. In well apparatus: a tubular member adapted to form part of a casing string positionable in a well bore; a valve body in said tubular member having a passage surrounded by a valve seat, said passage having an inlet below said seat; a valve head in said body movable downwardly into engagement with said seat; said body providing a cylinder below said seat communicating with said passage inlet when said valve head engages said seat; a piston secured to said head and slidable in said cylinder; said cylinder being closed below said piston to prevent entry of fluid thereinto while said apparatus is in the well bore; said head having an upwardly facing fluid pressure actuatable surface subject to the pressure of the casing fluid above said head and said head and piston having a resultant downwardly facing fluid pressure actuatable surface subject to the pressure of the well fluid externally of said tubular member when said valve head engages said seat; said upwardly facing surface having a substantially greater area than said resultant downwardly facing surface; and means releasable by fluid pressure acting downwardly on said head for securing said body to said tubular member.

10. In well apparatus: a tubular member adapted to form part of a casing string positionable in a well bore; a valve body in said tubular member having a passage surrounded by a valve seat, said passage having an inlet below said seat; a valve head in said body movable downwardly into engagement with said seat; said body providing a cylinder below said seat communicating with said passage inlet when said valve head engages said seat; a piston secured to said head and slidable in said cylinder; said cylinder being closed below said piston to prevent entry of fluid thereinto while said apparatus is in the well bore; said head having an upwardly facing fluid pressure actuatable surface subject to the pressure of the casing fluid above said head and said head and piston having a resultant downwardly facing fluid pressure actuatable surface subject to the pressure of the well fluid externally of said tubular member when said valve head engages said seat; said upwardly facing surface having a substantially greater area than said resultant downwardly facing surface.

11. In well apparatus: a tubular member adapted to form part of a casing string positionable in a well bore; a valve body in said tubular member having a passage surrounded by a valve seat and a cylinder to one side of said passage, said passage having an inlet between said seat and cylinder; a valve head in said body movable downwardly into engagement with said seat; a piston slidable in said cylinder; a rod interconnecting said head and piston and spaced from the wall of said cylinder to provide an annular space communicating with said passage; the cross-sectional area of said annular space being less than the cross-sectional area of the underside of said head between said rod and the point of engagement of said head with said seat; said cylinder having a confined space below said piston into which fluid in the well bore cannot enter.

12. In well apparatus: a tubular member adapted to form part of a casing string positionable in a well bore; a valve body in said tubular member having a passage surrounded by a valve seat and a cylinder to one side of said passage, said passage having an inlet between said seat and cylinder; a valve head in said body movable downwardly into engagement with said seat; a piston slidable in said cylinder; a rod interconnecting said head and piston and spaced from the wall of said cylinder to provide an annular space communicating with said passage; the cross-sectional area of said annular space being less than the cross-sectional area of the underside of said head between said rod and the point of engagement of said head with said seat; said cylinder having a confined space below said piston into which fluid in the well bore cannot enter; and means releasable by fluid pressure acting downwardly on said head for securing said body to said tubular member.

13. In well apparatus: a tubular member adapted to form part of a casing string positionable in a well bore; a valve body in said tubular member having a passage surrounded by a valve seat and a cylinder to one side of said passage; a valve head in said body movable downwardly into engagement with said seat; a piston slidable in said cylinder; a rod interconnecting said head and piston and spaced from the wall of said cylinder to provide an annular space communicating with said passage; the cross-sectional area of said annular space being less than the cross-sectional area of the underside of said head between said rod and the point of engagement of said head with said seat; said cylinder having a confined space below said piston into which fluid in the well bore cannot enter; means, releasable by hydraulic pressure within said tubular member imposed upon said valve member and body when said valve member engages said seat, for securing said valve body to said tubular member, release of said means enabling said valve body and valve member to be shifted within said tubular member to a position in which said valve body and valve member are ineffective to control passage of fluid in said tubular member; a second valve seat above said body; a valve element movable upwardly into engagement with said second seat; and means interconnecting said body and element to prevent engagement of said element with said second valve seat, said interconnecting means being rendered ineffective to prevent engagement of said element with said second valve seat upon release of said securing means and shifting of said valve body within said tubular member.

14. In well apparatus: a tubular member having means at its upper end for attaching said member to an adjacent casing section forming part of a casing string;

a cementitious plug secured in said member; a housing secured in said plug; a valve body in said housing having a valve seat; a valve member in said body movable downwardly into engagement with said seat, said member having an upwardly facing surface subject to the pressure of fluid in the tubular member above said seat to urge said member into engagement with said seat, said valve member having a downwardly facing surface subject to the pressure of fluid in said tubular member below said valve member to urge said valve member upwardly out of engagement from said seat; and means releasably securing said body to said housing to enable said body and valve member to be ejected hydraulically downward from said housing.

15. In well apparatus: a tubular member having means at its upper end for attaching said member to an adjacent casing section forming part of a casing string; a cementitious plug secured in said member; a housing secured in said plug; a valve body in said housing having a valve seat; a valve member in said body movable downwardly into engagement with said seat, said member having an upwardly facing surface subject to the pressure of fluid in the tubular member above said seat to urge said member into engagement with said seat, said valve member having a downwardly facing surface subject to the pressure of fluid in said tubular member below said valve member to urge said valve member upwardly out of engagement from said seat; means releasably securing said body to said housing to enable said body and valve member to be ejected hydraulically downward from said housing; a second valve seat above said body; a valve element movable upwardly into engagement with said second seat; and means interconnecting said body and said element to prevent engagement of said element with said second valve seat, said interconnecting means being rendered ineffective to prevent engagement of said element with said second valve seat upon release of said securing means and shifting of said valve body within said tubular member.

16. In well apparatus: a tubular member having means at its upper end for attaching said member to an adjacent casing section forming part of a casing string; a cementitious plug secured in said member; a housing secured in said plug; a valve body in said housing having a passage surrounded by a valve seat and a cylinder to one side of said passage; a valve head in said body movable downwardly into engagement with said seat; a piston slidable in said cylinder; a rod interconnecting said head and piston and spaced from the wall of said cylinder to provide an annular space communicating with said passage; the cross-sectional area of said annular space being less than the cross-sectional area of the underside of said head between said rod and the point of engagement of said head with said seat; said cylinder having a confined space below said piston into which fluid in the well bore cannot enter; and means releasably securing said body to said housing to enable said body and valve member to be ejected hydraulically downward from said housing.

17. In well apparatus: a tubular member having means at its upper end for attaching said member to an adjacent casing section forming part of a casing string; a cementitious plug secured in said member; a housing secured in said plug; a valve body in said housing having a passage surrounded by a valve seat and a cylinder to one side of said passage; a valve head in said body movable downwardly into engagement with said seat; a piston slidable in said cylinder; a rod interconnecting said head and piston and spaced from the wall of said cylinder to provide an annular space communicating with said passage; the cross-sectional area of said annular space being less than the cross-sectional area of the underside of said head between said rod and the point of engagement of said head with said seat; said cylinder having a confined space below said piston into which fluid in the well bore cannot enter; and frangible means securing said valve body to said housing to enable said body and valve member to be ejected hydraulically downward from said housing.

18. In well apparatus: a tubular member having means at its upper end for attaching said member to an adjacent casing section forming part of a casing string; a cementitious plug secured in said member; a housing secured in said plug; a valve body in said housing having a passage surrounded by a valve seat and a cylinder to one side of said passage; a valve head in said body movable downwardly into engagement with said seat; a piston slidable in said cylinder; a rod interconnecting said head and piston and spaced from the wall of said cylinder to provide an annular space communicating with said passage; the cross-sectional area of said annular space being less than the cross-sectional area of the underside of said head between said rod and the point of engagement of said head with said seat; said cylinder having a confined space below said piston into which fluid in the well bore cannot enter; frangible means securing said valve body to said housing to enable said body and valve member to be ejected hydraulically downward from said housing; a second valve seat above said body; a valve element movable upwardly into engagement with said second seat; and means interconnecting said body and said element to prevent engagement of said element with said second valve seat, said interconnecting means being rendered ineffective to prevent engagement of said element with said second valve seat upon release of said securing means and shifting of said valve body within said tubular member.

19. In well apparatus: a tubular member having a fluid passage therein and having means thereon for securing said member in a conduit string to be lowered in a well bore; said passage having an outlet and an inlet below said outlet; a valve member between said inlet and outlet for closing said passage and movable longitudinally of said tubular member between open and closed positions, said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid above said valve member to urge said valve member downwardly to passage closing position, said valve member having a second resultant fluid pressure actuatable surface, when said valve member is in open position, which is subject to the pressure of fluid below said valve member to urge said valve member upwardly to passage opening position; the projected area of said first surface normal to the axis of said valve member being substantially greater than the projected area of said second resultant surface normal to the axis of said valve member.

20. In well apparatus: tubular means having a fluid passage and having means thereon for securing said tubular means in a conduit string to be lowered in a well bore; means providing a valve seat in said passage; a valve member slidable along said tubular means into and out of engagement with said seat to close and open said passage; said tubular means having a cylinder along which said valve member is slidable; said valve member and cylinder defining a cylinder space therebetween; means providing a slidable seal between said valve member and cylinder to prevent passage of well fluid on both sides of said valve member into said cylinder space; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular means to urge said valve member into engagement with said seat, said valve member having a second resultant fluid pressure actuatable surface subject to the pressure of the fluid externally of said tubular means to urge said valve member out of engagement from said seat; the projected area of said first surface normal to the axis of said valve member being substantially greater than the projected area of said second surface normal to the axis of said valve member.

21. In well apparatus: tubular means having a fluid passage and having means thereon for securing said tubular means in a conduit string to be lowered in a well bore; means providing a valve seat in said passage; a valve member slidable downwardly along said tubular means into engagement with said seat and upwardly along said tubular means out of engagement from said seat; said tubular means having a cylinder portion along which said valve member is slidable; said valve member and cylinder portion defining a cylinder space therebetween; means providing a slidable seal between said valve member and cylinder portion to prevent passage of well fluid on both sides of said valve member into said cylinder space; said valve member having an upwardly facing pressure actuatable resultant surface subject to the pressure of fluid above said valve member to urge said valve member downwardly into engagement with said seat, said valve member having a downwardly facing pressure actuatable resultant surface subject to the pressure of fluid below said valve member to urge said valve member upwardly out of engagement from said seat; the projected area of said upwardly facing surface normal to the axis of said valve member being substantially greater than the projected area of said downwardly facing surface normal to the axis of said valve member.

22. In well apparatus: a tubular member having a fluid passage therein and having means thereon for securing said member in a conduit string to be lowered in a well bore; a valve member for closing said passage and movable longitudinally of said tubular member between open and closed positions; said passage having an inlet within said tubular member disposed below said valve member when said valve member is in passage closing position and an outlet above said valve member; said valve member having a first fluid pressure actuatable surface subject to the pressure of fluid above and on the outlet side of said valve member to urge said valve member downwardly to passage closing position, said valve member having a second resultant fluid pressure actuatable surface, when said valve member is in open position, which is subject to the pressure of fluid below and on the outlet side of said valve member to urge said valve member upwardly to passage opening position; the area of said first surface being substantially greater than the resultant area of said second surface.

23. In well apparatus: a tubular structure having a means thereon for securing said structure in a conduit string to be lowered in a well bore; said structure having a fluid inlet and outlet; means securing a first valve member in said structure; a valve seat on said first valve member between said inlet and outlet; a second valve member movable into and out of engagement with said seat; said second valve member having a first fluid pressure actuatable surface subject to the pressure of fluid on the outlet side of said seat to urge said second valve member into engagement with said seat, said second valve member having a second fluid pressure actuatable surface subject to the pressure of fluid on the inlet side of said seat to urge said second valve member out of engagement from said seat, the area of said first surface being substantially greater than the area of said second surface; means releasably securing said first valve member to said tubular structure; back pressure valve means in said tubular structure; and means interconnecting one of said valve members and back pressure valve means to prevent closing of said back pressure valve means, said interconnecting means being rendered ineffective to prevent closing of said back pressure valve means upon release of said securing means and shifting of said first valve member within said tubular structure.

24. In well apparatus: tubular means having a fluid passage and having means thereon for securing said tubular means in a conduit string to be lowered in a well bore; a first valve member providing a valve seat in said passage; a second valve member slidable along said tubular means into and out of engagement with said seat to close and open said passage; said tubular means having a cylinder along which said valve member is slidable; said second valve member and cylinder defining a cylinder space therebetween; means providing a slidable seal between said second valve member and cylinder to prevent passage of well fluid on both sides of said valve member into said cylinder space; said second valve member having a first fluid pressure actuatable surface subject to the pressure of fluid internally of said tubular means to urge said second valve member into engagement with said seat, said second valve member having a second resultant fluid pressure actuatable surface subject to the pressure of fluid externally of said tubular means to urge said second valve member out of engagement from said seat; the projected area of said first surface normal to the axis of said second valve member being substantially greater than the projected area of said second surface normal to the axis of said second valve member; means releasably securing said first valve member to said tubular means; back pressure valve means in said tubular means; and means interconnecting one of said valve members and back pressure valve means to prevent closing of said back pressure valve means, said interconnecting means being rendered ineffective to prevent closing of said back pressure valve means upon release of said securing means and shifting of said first valve member within said tubular means.

25. In well apparatus: a cylindrical tubular member having a fluid passage therein and having means thereon for securing said member in a conduit string to be lowered in a well bore; said passage having a central outlet coaxial of said member adapted to communicate with the conduit string above said member and an inlet below said outlet; means providing a valve seat in said passage above said inlet and between said inlet and outlet and coaxial of said tubular member; a valve member coaxial of said tubular member movable downwardly into engagement with said seat and upwardly out of engagement therefrom; said valve member having a resultant upwardly facing fluid pressure actuatable surface subject to the pressure of fluid in the outlet and conduit string thereabove to urge said valve member downwardly into engagement with said seat; said valve member having a resultant downwardly facing fluid pressure actuatable surface subject to the pressure of fluid in said inlet to urge said valve member upwardly out of engagement from said seat; the pressure actuatable area of said upwardly facing surface being substantially greater than the pressure actuatable area of said downwardly facing surface when said valve member is disengaged from said seat.

26. In well apparatus: a cylindrical tubular member having a fluid passage therein and having means thereon for securing said member in a conduit string to be lowered in a well bore; said passage having a central outlet coaxial of said member adapted to communicate with the conduit string above said member and an inlet below said outlet; means providing a valve seat in said passage above said inlet and between said inlet and outlet and coaxial of said tubular member; a valve member coaxial of said tubular member movable downwardly into engagement with said seat and upwardly out of engagement therefrom; said tubular member having a cylinder coaxial therewith and along which said valve member is slidable; said valve member and cylinder defining a cylinder space therebetween; means providing a slidable seal between said valve member and cylinder to prevent passage of well fluid on both sides of said valve member into said cylinder space; said valve member having a resultant upwardly facing fluid pressure actuatable surface subject to the pressure of fluid in the outlet and conduit string thereabove to urge said valve member downwardly into engagement with said seat; said valve member having a resultant downwardly facing fluid pressure actuatable sur-

face subject to the pressure of fluid in said inlet to urge said valve member upwardly out of engagement from said seat; the pressure actuatable area of said upwardly facing surface being substantially greater than the pressure actuatable area of said downwardly facing surface when said valve member is disengaged from said seat.

References Cited in the file of this patent

UNITED STATES PATENTS

1,153,373	Deemer	Sept. 14, 1915
1,216,872	Sowden	Feb. 20, 1917
2,179,226	Bryan	Nov. 7, 1939
2,204,658	Burt	June 18, 1940
2,211,846	Brown	Aug. 20, 1940
2,326,462	Johnson	Aug. 10, 1943
2,330,267	Burt et al.	Sept. 28, 1943
2,644,527	Baker	July 7, 1953