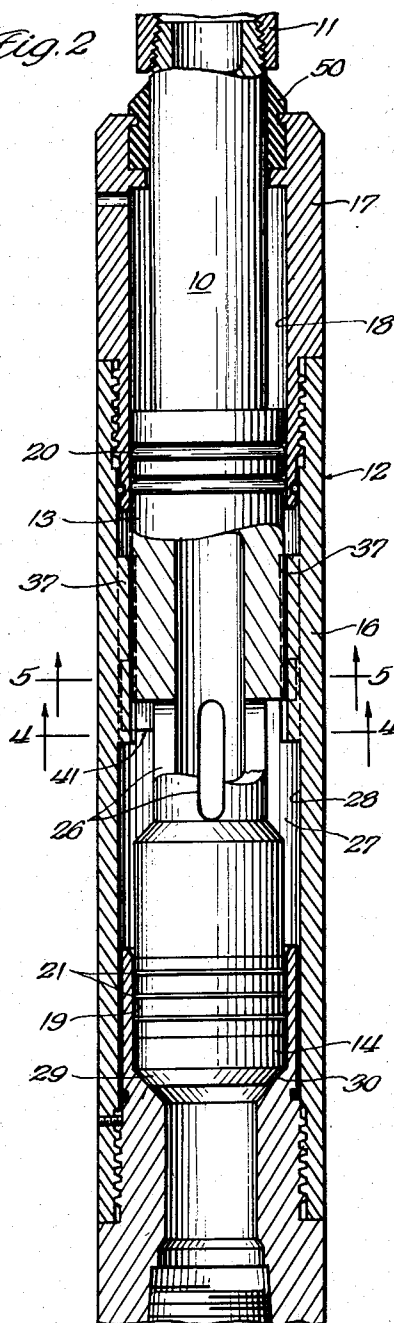


**R. C. BAKER**

TUBING TESTER AND CIRCULATING VALVE

2 Sheets-Sheet 1



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July 12, 1960

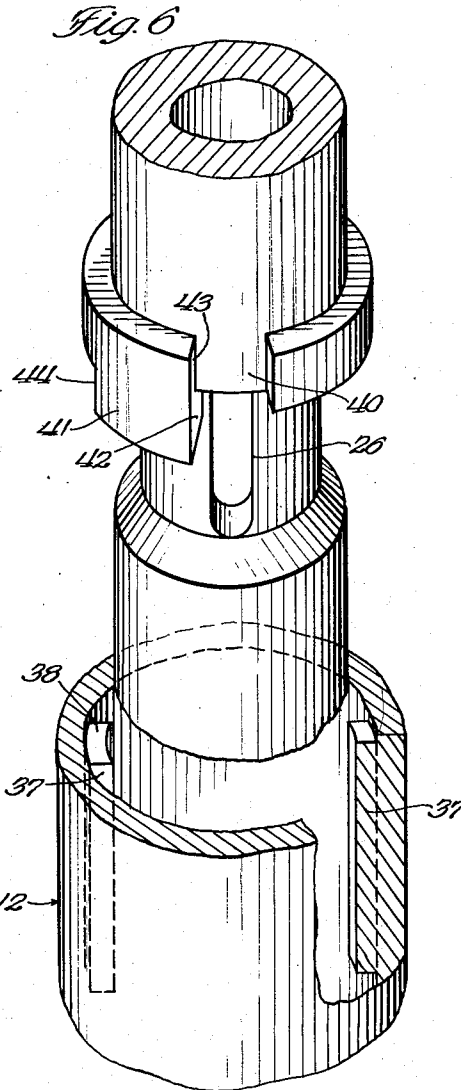
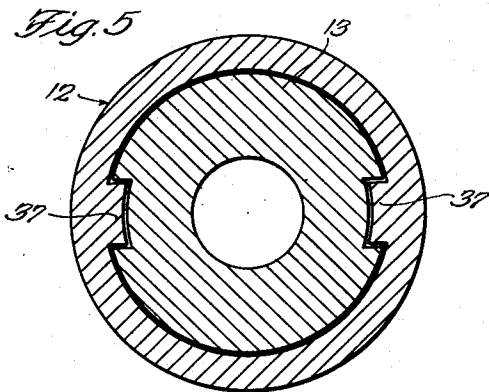
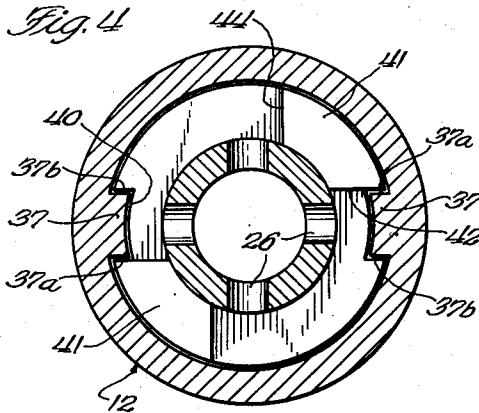
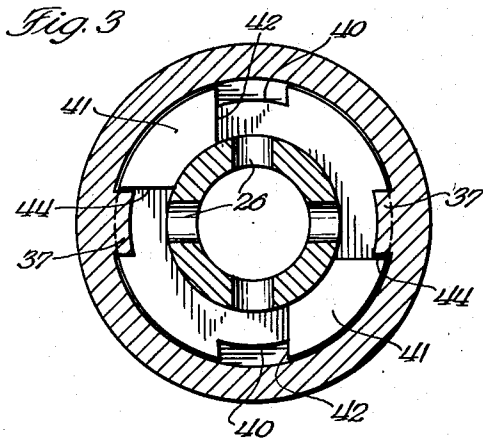
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2,944,607

TUBING TESTER AND CIRCULATING VALVE

Filed Nov. 24, 1953

2 Sheets-Sheet 2



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2,944,607

## TUBING TESTER AND CIRCULATING VALVE

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5 Claims. (Cl. 166—226)

The present invention relates to subsurface well apparatus, and more particularly to apparatus for enabling a string of tubing or drill pipe to be tested and for controlling the circulation or passage of fluid therethrough.

An object of the present invention is to provide an improved apparatus for pressure testing a tubular string disposed in a well bore, or to allow fluid to circulate through the tubular string, which apparatus is relatively easy to manipulate between testing and circulating positions, and which can be locked in a circulating position, if desired.

Another object of the invention is to provide an apparatus that can be closed for the purpose of pressure testing a tubular string disposed in a well bore, or opened to allow fluid circulation through the tubular string, and in which fluids are permitted to pass upwardly only through the apparatus when it is in a closed position, thereby allowing the tubular string to fill automatically with the well bore fluid while being lowered therein, and also to permit reverse circulation of fluid upwardly through the apparatus and the tubular string when the tester is 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 a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of 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 a tubular tester and circulation valve, with the valve in open position;

Fig. 2 is a view similar to Fig. 1, with parts shown in elevation, of the tester in closed position;

Fig. 3 is a cross-section taken generally along the line 3—3 on Fig. 1;

Fig. 4 is a view taken generally along the line 4—4 on Fig. 2;

Fig. 5 is a cross-section taken along the line 5—5 on Fig. 2;

Fig. 6 is a fragmentary exploded isometric projection of a portion of the apparatus disclosed in Figs. 1 to 5 inclusive.

The apparatus disclosed in the drawings is specifically intended for use in a tubular string, such as a string of tubing or drill pipe, disposed in a well bore and extending to the top of the latter. The upper portion of the apparatus is connectible to the lower end of the string of tubing (not shown), whereas the lower end is adapted to be secured to a suitable well tool therebelow, such as to the body A of a well packer, which may be of the retrievable type.

The tester and circulation valve includes an inner man-

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drel 10 whose upper end 11 is connectible to the lower end of the tubing string. This mandrel is telescopically disposed within a cylinder 12, the lower end of which is connected to the body A of the lower tool. More specifically, the mandrel 10 includes an upper section 13 threaded onto a lower section 14, whereas the cylinder 12 includes a lower section 15 threaded onto the body A of the lower tool, which in turn, is threadedly secured within an intermediate cylinder section 16 whose upper end is threaded onto an upper cylinder section or head 17.

The upper and lower cylinder sections 17, 15 have upper and lower cylindrical walls or seating surfaces 18, 19 that are engageable by upper and lower seals 20, 21 respectively, mounted on the mandrel 10. Thus, the upper section 13 of the mandrel carries one or a plurality of side seals 20, in appropriate mandrel grooves 22 that are adapted to slidably seal along the upper cylindrical seat or wall 18. The lower seals 21 may be of any suitable type. As disclosed, they are longitudinally spaced chevron type of sealing members facing in an upward direction and separated by intervening spacers 23, the seal ring 21 and spacer 23 combination surrounding the lower mandrel section 14 and resting upon a lower shoulder 24 on the latter, being held in appropriate position by the lower end 25 of the upper mandrel section 13.

The mandrel 10 is tubular, being provided with a plurality of side ports 26 therethrough establishing communication between the interior of the mandrel and an annular chamber 27 defined between the exterior of the mandrel 10 and the surrounding cylinder 12, the inner wall 28 of the cylinder section 16 having a substantially greater diameter than the diameter of the mandrel 10, to provide the annular space 27 through which fluid can circulate freely when the apparatus is in an open position. The mandrel 10 can be lowered with respect to the cylinder 12 to dispose its lower seals 21 completely within the lower cylindrical valve seat 19, as determined by engagement of the lower end 29 of the mandrel with a stop shoulder 30 formed on the lower cylindrical body section 15. When the lower seals 21 are in this position, the upper seals 20 are still in sealing engagement with the upper cylinder seat 18.

The lower portion 14 of the mandrel is closed against downward passage of fluid, as by means of a downwardly seating ball valve 31, or similar element, adapted to engage a companion valve seat 32, which surrounds a lower passage 33 through the lower portion of the mandrel. The ball 31, however, can move upwardly from its seat 32 when upward flow of fluid tends to occur in the apparatus, the internal diameter of the lower mandrel section 14 above the seat 32 being much greater than the ball diameter, to allow fluid to by-pass around the ball 31 in an upward direction, and continue on upwardly through the mandrel 10 and into the tubing string thereabove. The upward travel of the ball valve element 31 is limited by its engagement with a retaining pin 34 secured to the lower mandrel section 14 and extending across the passage through this section.

As stated above, when the mandrel 10 has been shifted downwardly with respect to the cylinder 12, to place the lower seals 21 in engagement with the lower cylindrical seat 19, the upper side seals 20 still engage the upper cylindrical seat 18. Fluid pumped downwardly through the mandrel 10 cannot pass down through the lower cylinder section 15 and into the body A of the lower tool, in view of the downward movement of the ball valve member 31 into engagement with the valve seat 32. Similarly, any fluid in the mandrel 10 passing out through the ports 26 and into the cylinder 12 cannot pass upwardly between the mandrel and cylinder in view of the upper seals 20. It also is incapable of passing

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downwardly into the lower portion 15 of the cylinder because of the sealing engagement of the lower seal rings 21 against the lower cylindrical valve seat 19. However, when the mandrel 10 is elevated with respect to the cylinder 12, as determined by engagement of a flange 35 on the mandrel with the lower end 36 of the upper cylinder section 17, the lower seals 21 are disposed a substantial distance above the lower cylindrical valve seat 19. When in this position, fluid can then pass down the inside of the mandrel 10 and out through the side ports 26 into the annular space 27 between the mandrel 10 and cylinder 12, continuing around the lower seals 21 and through the lower cylinder section 15 into the body A of the lower tool. The upper seals 20 are still in engagement with the upper cylindrical wall or seat 18, to prevent fluid from passing in an upward direction between the mandrel 10 and the upper cylinder head.

The mandrel 10 can be locked in its upper position with respect to the cylinder 12, or it can be shifted to a released position, which will enable it to be lowered with respect to the cylinder 12, to place it in a valve closing position. Thus, the intermediate cylinder section 16 is provided with a pair of diametrically opposed and elongate keys 37 extending inwardly from its side wall to a partial extent. The upper ends 38 of these keys are engageable by the lower surface 39 of the flange 35. When this occurs, the mandrel 10 cannot move downwardly with respect to the cylinder 12 from the position shown in Fig. 1. However, the flange 35 has a pair of diametrically opposite longitudinal slots or grooves 40 formed therein having a width slightly greater than the width of the keys 37. When the mandrel 10 has been turned relative to the cylinder 12, to place these slots 40 in alignment with the keys 37, the mandrel can be lowered with respect to the cylinder to dispose its lower seal elements 21 in engagement with the lower valve seat 19, thereby closing the valve apparatus against downward passage of fluid therethrough.

In order to determine the position of alignment or disalignment of the longitudinal slots 40 with the keys 37, a pair of diametrically opposite locating and driving lugs 41 depend from the stop or lock flange 35 to one side of the slots 40. Each lug, as disclosed in the drawings, and more particularly in Fig. 6, is disposed in a clockwise direction with respect to its associated slot 40, one face 42 of the lug preferably constituting a continuation of a side 43 of the slot. The other face 44 of the lug forms a stop surface adapted to engage a key 37 to insure the disalignment of the slots 40 with respect to the keys and causing the stop flange 35 to engage the upper ends 38 of the keys, as explained hereinbelow. When the upper end of the stop flange 35 is engaging the lower end 36 of the upper cylinder section or head 17, the locating and drive lugs 41 extend below the upper ends 38 of the keys 37, in order that rotation of the mandrel 10 in one direction or the other with respect to the cylinder 12 will cause one face 42 or the other face 44 of each lug 41 to engage one side or the other side of each key 37.

In the specific device disclosed in the drawings the rotation of the mandrel 10 in a counter-clockwise direction, or to the left, with respect to the cylinder 12, will engage the sides 42 of the lugs 41 in alignment with the sides 43 of the slots 40 with one face 37a of the keys 37. This is the position disclosed in Fig. 4, in which one face 42 of each lug is engaging a key 37, thereby placing each key in alignment with an associated slot 40 in the flange. This is the unlocked or released position of the device, which then allows the mandrel 10 to be lowered relative to the cylinder 12, to place the lower seals 21 in firm sealing engagement with the lower cylindrical valve seat 19, closing the valve device to downward flow of fluid therethrough.

With the mandrel 10 in its elevated position with respect to the cylinder 12, as determined by engagement of the flange 35, with the lower end 36 of the upper cyl-

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inder section 17, the rotation of the mandrel in a clockwise direction, or to the right, as seen in Fig. 6, will cause the other face 44 of each lug 41 to engage the other face 37b of a cylinder key 37, in which position the keys 37 are out of alignment with respect to the slots 40, which position is shown in Figs. 1 and 3. Accordingly, if the mandrel 10 is now lowered, the lower surface 39 of the flange 35 will engage the upper ends 38 of the keys 37, precluding downward shifting of the mandrel 10 within the cylinder 12, and insuring that the lower seals 21 will be disposed in a position well above the lower cylindrical valve seat 19, allowing fluid pumped down the mandrel 10 to pass out through the ports 26 and into the annulus 27 between the cylinder 12 and mandrel 10, thence continuing down through the lower cylindrical section 15 into the body A of the lower tool.

As stated above, rotation of the mandrel 10 in a counterclockwise direction, or to the left, will cause the lugs 41 to engage the other sides 37a of the keys 37, placing the slots 40 in alignment with the keys and allowing the mandrel 10 to be lowered to its fullest extent within the cylinder 12 to a closed position. When in this position, which is shown in Figs. 2 and 4, the lugs 41 and the sides of the slots 40 are still in engagement with the longitudinal keys 37. If it is again desired to open the device, an upward pull is taken on the mandrel 10, the latter being moved upwardly until the upper surface of its flange 35 engages the lower end 36 of the upper cylinder section 17, whereupon the mandrel is turned to the right, or to the position shown in Figs. 1 and 3, to relock the mandrel 10 with respect to the cylinder 12 and prevent downward movement of the mandrel relative to the cylinder.

In the use of the apparatus disclosed in the drawings and described above, the lower cylinder section 15 may be connected to a suitable tool, such as the body A of a well packer, which may be a packer of the retrievable type shown in United States Patent No. 2,368,400. This well packer has a friction drag device adapted to engage the wall of a well casing disposed in the well bore, which tends to resist both rotation and longitudinal movement of the lower tool A within the well casing or well bore. The upper end 11 of the mandrel 10 is connected to the lower end of a string of tubing or drill pipe, or the like, and the entire combination is then lowered in the well bore. Preferably, during such lowering the mandrel 10 is locked in its upper position within the cylinder 12, so that fluid in the well bore can pass freely up through the body A of the lower tool into the cylinder 12, around the mandrel 10 and in through the ports 26 to the interior of the mandrel. Fluids can also pass upwardly through the lower passage 33 in the lower mandrel section 14, elevating and unseating the ball valve element 31 and flowing around the latter into the interior of the mandrel 10 for continued upward passage through the tubular string thereabove. Despite the downward motion of the mandrel, the engagement of the lower surface 39 of the flange 35 with the upper end 38 of the keys 37 prevents the mandrel from being shifted to its closed position shown in Fig. 2.

During the running of the apparatus on the tubular string down through the well bore or well casing disposed therewithin, the tubular string may be tested at any desired time to detect the presence of any leaks. When the testing is to occur, the mandrel 10 is rotated to the left until the sides 42 of the lugs engage the sides 37a of the keys, which brings the slots 40 in alignment with the keys 37, whereupon the mandrel 10 can be lowered with respect to the cylinder 12 to place the lower seals 21 in engagement with the cylindrical seat 19, which closes the cylinder against downward passage of fluid into the lower cylinder section 14 and the body A of the lower tool. Pressure can now be applied to the fluid in the tubular string, mandrel 10 and cylinder 12, this fluid being incapable of passing downwardly through and out of the

mandrel by virtue of the engagement of the ball valve 31 with its seat 32. It is also prevented from passing in a downward direction between the mandrel 10 and the cylinder 12 by the sealing engagement of the lower seals 21 against the lower seat 19, and from passing in an upward direction by the sealing engagement of the upper seals 20 with the upper seat 18. The desired pressure can be imposed on the fluid to determine the presence of any leaks in the tubular string.

After the test has occurred, the mandrel 10 can be elevated, to place its flange 35 in engagement with the lower end 36 of the upper cylinder section 17, whereupon it is turned to the right to again relock the tool. The tubular string, mandrel 10, cylinder 12 and lower tool A can then be caused to descend to a further extent, the tester and control device remaining in its open position. At any time, the tubular string and mandrel 10 can be turned to the left to align the slots 40 with the keys 37, the mandrel again being lowered with respect to the cylinder 12 to place the tester in the closed position shown in Fig. 2. The relative rotation between the mandrel 10 and cylinder 12, as well as the relative longitudinal movement between the mandrel and cylinder can occur, inasmuch as the lower tool A has the friction drag device thereon engaging the casing, which resists movement of the cylinder 12 within the well bore.

When the apparatus has been lowered in the well bore to the point at which a particular operation is to take place, as for example, the pumping of cement slurry, and the like, down through the tubular string, through the valve control device and out through the well packer A therebelow, the mandrel 10 is placed in its upper position and is relocked in that position to hold the valve in its open or circulating position, allowing the fluid to pass downwardly through the mandrel 10, out through its ports 26, through the annulus 27 between the mandrel 10 and cylinder 12, and down through the lower cylinder section 15 into the tubular body A of the lower tool. The mandrel cannot be inadvertently shifted in a downward direction with respect to the cylinder, in view of the engagement of the lower surface 39 of the range 35 with the upper ends 38 of the keys 37. When the operation has been completed, the mandrel can remain in that position, the lower tool A being released from the well casing disposed in the well bore and the tubular string raised to lift the control valve and the lower tool in the well casing, enabling it to be withdrawn from the well casing. During such elevating movement, the control device is in its open or circulating position, allowing fluid to drain out the tubing string and down through the mandrel 10 and its ports 26 into the annular space 27 between the mandrel and cylinder, continuing on down through the lower cylinder section 15 and through the body A of the lower tool for discharge into the casing below the apparatus. In the event it is desired to reverse the circulating fluid in the well casing, so as to more readily remove any excess cement slurry that might be present in the tubing string and the control valve, fluids pumped down the annulus between the tubular string and the well casing will pass upwardly through the body A of the tool and up through the cylinder 12, flowing through the annulus 27 and the ports 26 into the mandrel 10. This fluid will also pass upwardly through the lower mandrel passage 33, unseating the ball 31 and flowing around the latter to the interior of the mandrel 10, for continued upward passage through the tubular string to the top of the well bore.

With the apparatus disclosed, it may be lowered on the tubular string in the well casing, with the mandrel 10 in its unlocked or released position, in which the lower seals 21 will engage the lower cylindrical valve seat 19. When in this position, the fluids in the well bore can still pass upwardly through the body A of the tool into the mandrel 10 and tubing string by virtue of the upward unseating of the ball valve element 52 from

the companion seat 32. Accordingly, whenever a string of tubing is to be tested, it is merely necessary to impose pressure on the fluid in the tubular string and mandrel 10, this fluid being incapable of passing down into the lower cylindrical section 15 and body A of the lower tool. Then again, if the mandrel 10 happens to be located in its downward or closed position within the cylinder 12, it is still possible to reversely circulate down through the annulus between the tubing string and casing, the fluid passing up through the body A of the lower tool and the lower cylinder section 15, unseating the ball valve member 31 and proceeding up through the interior of the mandrel 10, and the tubing string to the top of the well bore.

The diameter of the upper cylindrical seat 18 is made substantially equal to the diameter of the lower cylindrical valve seat 19, to provide a pressure balanced condition. When pressure is present in the cylinder 12, with the device in the closed position shown in Fig. 2, there are no hydraulic forces tending to shift the mandrel and cylinder in one direction or the other longitudinally of the well bore. Accordingly, even with full pressure in the mandrel 10 and the cylinder 12, the mandrel can still be shifted longitudinally of the cylinder between open and closed positions, without any need for offsetting hydraulic forces. The only forces that need be overcome are the friction forces, such as the friction of the seal rings 20, 21 against their companion valve seating surfaces, which is small and relatively negligible in value.

To facilitate the free operation of the equipment, a suitable rubber wiper ring 50 may be secured to the upper portion of the upper head 17, this ring slidably engaging the periphery of the mandrel 10. Moreover, the fluid above the upper mandrel seals 20 may be allowed to pass freely into and out of the upper cylinder head 17 through a bleeder port 51 in the upper cylinder head below and adjacent the rubber wiper ring 50.

It is, accordingly, apparent that a tubing tester and circulating valve has been provided that is relatively easy to manipulate between its open and pressure testing positions. The tester may be maintained in pressure testing position during the lowering of the apparatus in the well bore, inasmuch as the upward movement of the ball valve element 31 from its seat 32 will allow the fluid in the well bore to pass automatically into the mandrel 10 and the tubing string. All that need be done whenever a test is to occur is to apply pressure to the fluid in the tubing string, mandrel 10 and cylinder 12. In the event it is desired to lock the apparatus in an open or circulating position, it is a simple matter to elevate the mandrel within the cylinder and then turn it to the right until the lugs 41 engage the keys 37, insuring complete disalignment between the flange slots 40 and the keys, thereby precluding any substantial downward movement of the mandrel relative to the cylinder. The resistance to turning and longitudinal movement of the cylinder in the well bore is provided either by the inertia of the parts or by the lower tool A, such as the drag device associated therewith, which normally engages the wall of the well casing in which the apparatus is used. Reverse circulation through the device can occur at any time, despite the fact that it might be placed in the pressure testing and non-circulating position shown in Fig. 2.

Attention is directed to my application for "Tubing Tester and Well Packer Apparatus," Serial No. 394,109, filed November 24, 1953, in which a similar apparatus is described and in which the broad aspects of the invention are claimed. This application also discloses the cooperation between the apparatus and a retrievable well packer connected to the lower portion of the apparatus, which embodies the friction drag device.

The inventor claims:

1. In a well tool for use in a well bore: an outer tubular member; an inner tubular member telescopically

arranged in said outer member and having means thereon for attaching said inner member to a tubular string to lower the tool in the well bore; said inner member having a side port for discharging fluid through said outer member and said inner member being closed below said port against downward passage of fluid; said inner and outer members having upper and lower longitudinally spaced coengageable seals on opposite sides of said port; said upper and lower seals both being engageable when said inner member is disposed in a lower position within said outer member to prevent fluid passing out through said port from flowing upwardly from said outer member and downwardly through said outer member; said inner member being shiftable upwardly relative to said outer member to disengage said lower seal and permit fluid pumped down said inner member to pass into and down through said outer member; said outer member having a longitudinally extending key; said inner member having a flange engageable with the upper end of said key to prevent downward movement of said inner member within said outer member to hold said lower seal disengaged, said flange having a slot for receiving said key to allow said inner member to move downward within said outer member to engage said lower seal, and means on said inner member engageable with said key upon turning of said inner member within said outer member to selectively align said slot with said key or disalign said slot with said key.

2. In a well tool for use in a well bore: an outer tubular member; an inner tubular member telescopically arranged in said outer member and having means thereon for attaching said inner member to a tubular string to lower the well tool in the well bore; said outer member having longitudinally spaced upper and lower cylindrical seats thereon; said inner member having a side port for discharging fluid into said outer member between said seats and said inner member being closed below said port against downward passage of fluid; said inner member having longitudinally spaced upper and lower sealing means thereon simultaneously engageable with said upper and lower seats, respectively, to prevent fluid passing out through said port from flowing upwardly from said outer member and downwardly through said outer member; said inner member being shiftable upwardly relative to said outer member to move said lower sealing means above said lower seat to permit fluid pumped down said inner member to pass into and down through said outer member; said outer member having a longitudinally extending key; said inner member having a flange engageable with the upper end of said key to prevent downward passage of said lower seal within said outer member to hold said lower seal above said lower seat, said flange having a slot for receiving said key to allow said inner member to move downward within said outer member to engage said lower seal with said lower seat; and means on said inner member engageable with said key upon turning of said inner member within said outer member to selectively align said slot with said key or disalign said slot with said key.

3. In a well tool for use in a well bore: an outer tubular member; an inner tubular member telescopically arranged in said outer member and having means thereon for attaching said inner member to a tubular string to lower the tool in the well bore; said inner member having a side port for discharging fluid through said outer member and said inner member being closed below said port against downward passage of fluid; said inner and outer members having upper and lower longitudinally spaced co-engageable seals on opposite sides of said port; said upper and lower seals both being engageable when said inner member is disposed in a lower position within said outer member to prevent fluid passing out through said port from flowing upwardly from said outer member and downwardly through said outer member; said inner

member being shiftable upwardly relative to said outer member to disengage said lower seal and permit fluid pumped down said inner member to pass into and down through said outer member; said outer member having a longitudinally extending key; said inner member having a flange engageable with the upper end of said key to prevent downward movement of said inner member within said outer member to hold said lower seal disengaged, said flange having a slot for receiving said key to allow said inner member to move downward within said outer member to engage said lower seal.

4. In a well tool for use in a well bore: an outer tubular member; an inner tubular member telescopically arranged in said outer member and having means thereon for attaching said inner member to a tubular string to lower the well tool in the well bore; said outer member having longitudinally spaced upper and lower cylindrical seats thereon; said inner member having a side port for discharging fluid into said outer member between said seats; said inner member having longitudinally spaced upper and lower sealing means thereon simultaneously engageable with said upper and lower seats, respectively, to prevent fluid passing out through said port from flowing upwardly from said outer member and downwardly through said outer member; said inner member being shiftable upwardly relative to said outer member to move said lower sealing means above said lower seat to permit fluid pumped down said inner member to pass into and down through said outer member; said outer member having a longitudinally extending key; said inner member having a flange engageable with the upper end of said key to prevent downward passage of said lower seal within said outer member to hold said lower seal above said lower seat, said flange having a slot for receiving said key to allow said inner member to move downward within said outer member to engage said lower seal with said lower seat; means on said inner member engageable with said key upon turning of said inner member within said outer member to align said slot with said key or disalign said slot with said key; said inner member having a valve seat below said port; and a valve element movable downwardly into engagement with said seat to prevent downward flow of fluid there-through.

5. In a well tool for use in a well bore: an outer tubular member; an inner tubular member telescopically arranged in said outer member and having means thereon for attaching said inner member to a tubular string to lower the tool in the well bore; said inner member having a side port for discharging fluid through said outer member and said inner member being closed below said port against downward passage of fluid; said inner and outer members having upper and lower longitudinally spaced co-engageable seals on opposite sides of said port; said upper and lower seals both being engageable when said inner member is disposed in a lower position within said outer member to prevent fluid passing out through said port from flowing upwardly from said outer member and downwardly through said outer member; said inner member being shiftable upwardly relative to said outer member to disengage said lower seal and permit fluid pumped down said inner member to pass into and down through said outer member; said outer member having a pair of diametrically opposed longitudinally extending keys; said inner member having a flange engageable with the upper end of said keys to prevent downward movement of said inner member within said outer member to hold said lower seal disengaged, said flange having diametrically opposite slots for receiving said keys to allow said inner member to move downwardly within said outer member to engage said lower seal; and lugs on said inner member engageable with one side of said keys upon turning of said inner member in one direction within said outer member to align said

slots with said keys and engageable with the opposite sides of said keys upon turning of said inner member in the opposite direction within said outer member to disalign said slots with said keys.

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