Dec. 19, 1967 W. O. BERRYMAN 3,358,771

MULTIPLE-OPENING BYPASS VALVE

Filed Jan. 19, 1966 3 Sheets-Sheet 1

Fig. 2

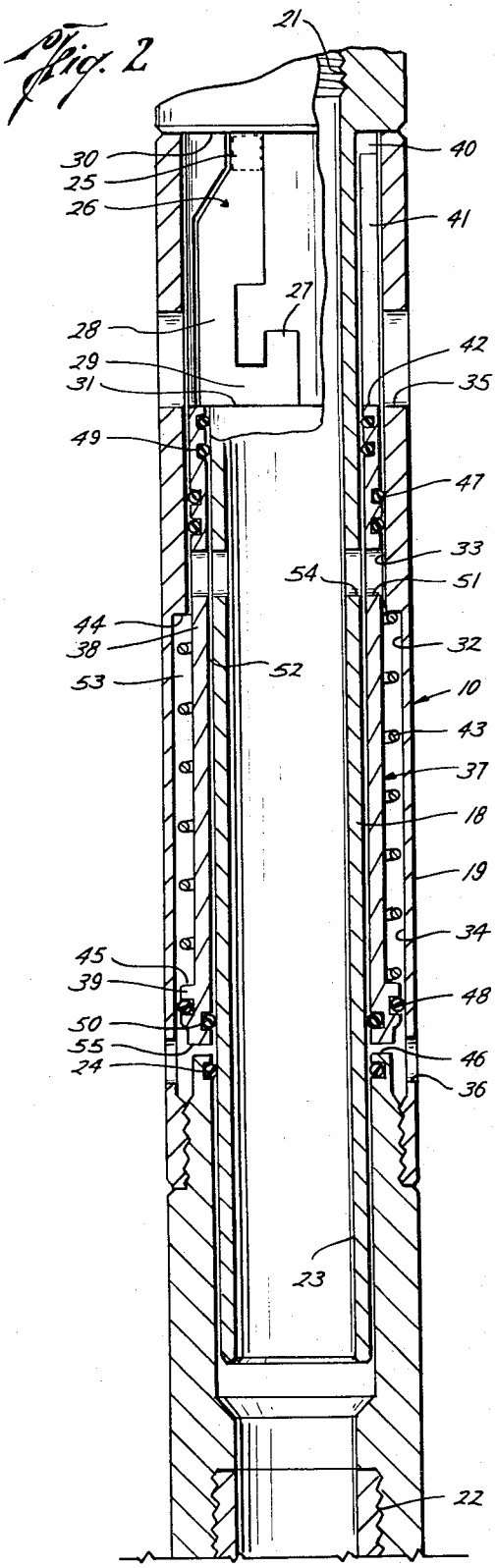
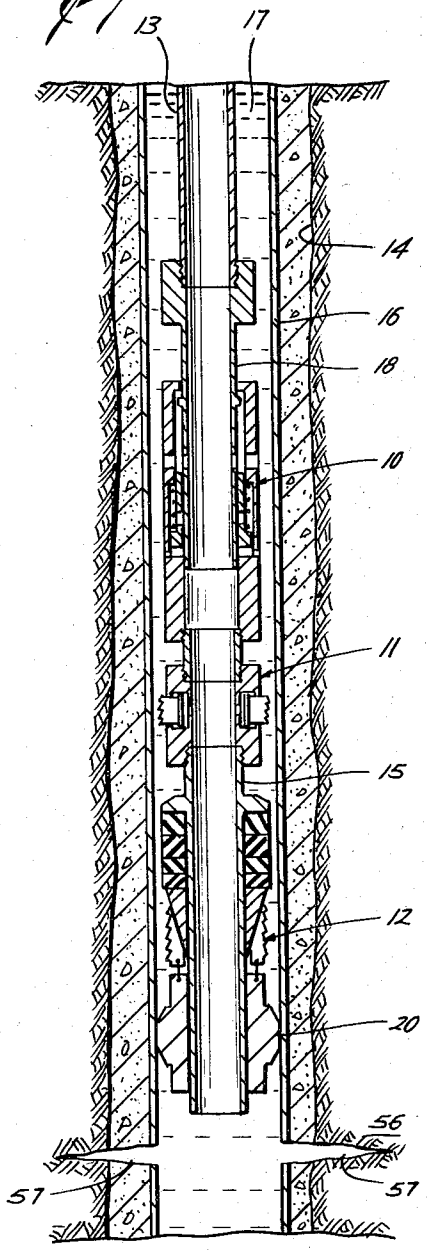


Fig. 1



William O. Berryman
INVENTOR.

BY

E. R. Archambeau Jr.
ATTORNEY

Dec. 19, 1967 W. O. BERRYMAN 3,358,771

MULTIPLE-OPENING BYPASS VALVE

Filed Jan. 19, 1966 3 Sheets-Sheet 2

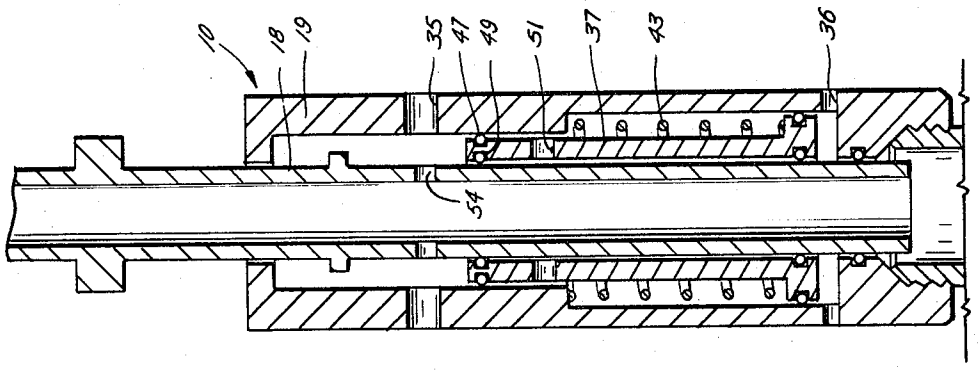


Fig. 3C

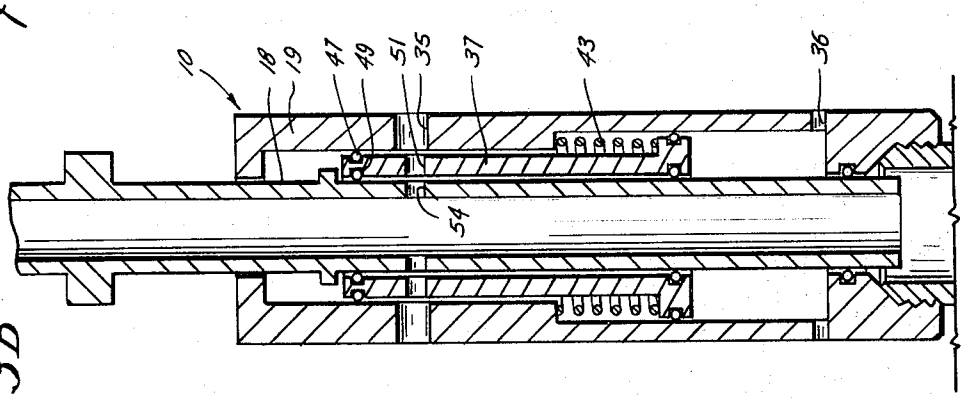


Fig. 3B

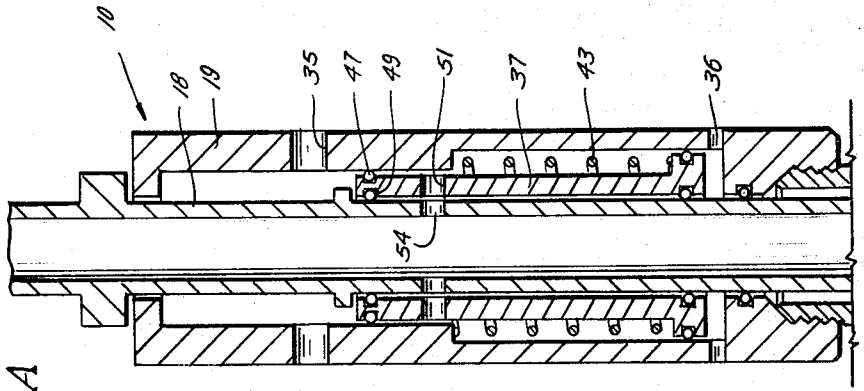


Fig. 3A

William O. Berryman
INVENTOR.

BY

E. R. Archambeau Jr.
ATTORNEY

Dec. 19, 1967 W. O. BERRYMAN 3,358,771

MULTIPLE-OPENING BYPASS VALVE

Filed Jan. 19, 1966 3 Sheets-Sheet 3

Fig. 4A

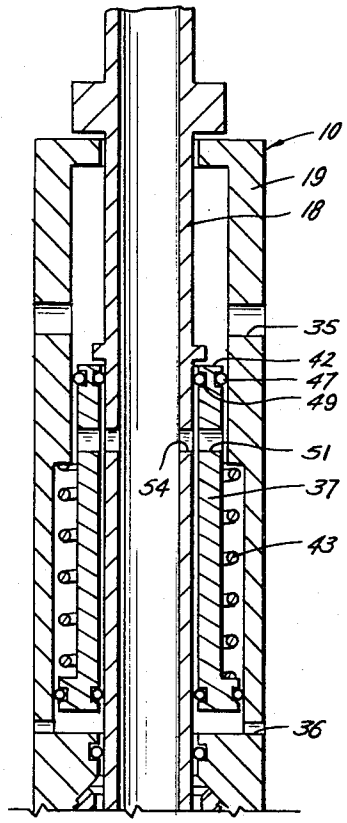
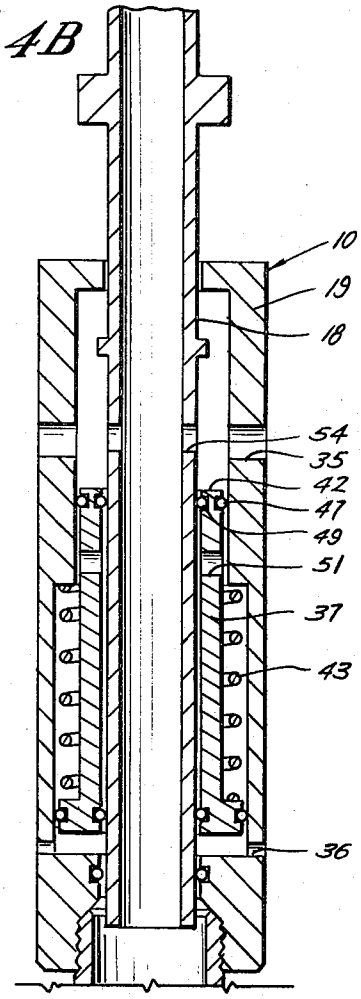


Fig. 4B



William O. Berryman
INVENTOR.

BY

E. R. Archambeau Jr.
ATTORNEY

United States Patent Office 3,358,771
Patented Dec. 19, 1967

3,358,771

MULTIPLE-OPENING BYPASS VALVE

William O. Berryman, Houston, Tex., assignor to Schlumberger Well Surveying Corporation, Houston, Tex., a corporation of Texas

Filed Jan. 19, 1966, Ser. No. 521,590
12 Claims. (Cl. 166—226)

This invention relates to well tools; and, more particularly, to a new and improved bypass valve for use in well bore treating and testing operations that is arranged to minimize the failure of the fluid seals therein.

In conducting a typical well completion operation such as cementing, fluid fracturing, acidizing and the like, it is customary to dependently couple a full-bore packer, a hydraulic holddown, and a so-called bypass or unloader valve from the lower end of a tubing string. This string of tools is then lowered into a well bore and the packer set to isolate the lower portion of the well bore from the hydrostatic pressure of the well control fluids in the remainder of the well bore thereabove. Treating fluids are then pumped at high pressure downwardly through the tubing string and out of the open lower end of the full-bore packer through previously located perforations into a particular formation. Upon completion of the operation, the packer is unseated and the string of tools removed.

It will be appreciated that the bypass valve provides selective communication between the interior of the tubing string and the annulus of the well bore above the packer. Thus, during the course of a typical completion operation, it is not at all uncommon for the bypass valve to be operated at one stage in the operation where the pressure in the tubing string is greater than that in the annulus; and then, at a different stage, where the pressure in the annulus is greater than the pressure in the tubing string. Moreover, it may often depend upon particular circumstances as to which pressure is the greater.

By way of example, it is generally preferred to begin such treating operations by leaving the bypass valve open until just before the treating fluids reach the bypass valve so that only a minimum volume of the well control fluids will be forced into the formation ahead of the treating fluids. Thus, it will be appreciated that as the bypass valve is being closed, the treating fluids are still in motion and can develop dynamic shock pressures within the tubing string and bypass valve substantially greater than the hydrostatic pressure in the annulus.

On the other hand, upon completion of a fracturing operation, the tubing string is often "swabbed" to test the effectiveness of the operation. This swabbing, of course, substantially reduces the pressure in the tubing so that whenever the bypass valve is re-opened, the hydrostatic pressure outside of the valve will be significantly greater than that inside.

Upon completion of a cementing operation, for example, the packer is then unseated with the bypass valve preferably kept closed and the well control fluids are "reverse-circulated" by pumping them downwardly through the annulus and into the lower end of the packer to flush residual cement back up and out of the tubing string. Once the tubing string is flushed, the bypass valve is opened and the tubing string and tools are retrieved. Circumstances may necessitate, however, that the bypass valve be opened before the packer is unseated. In this instance, it will depend upon how much excess cement is in the tubing string as well as the pressure in the annulus as to whether the tubing pressure will be greater or less than the annulus pressure as the bypass valve is opened.

Accordingly, it will be appreciated that the valve port seals in such bypass valves will alternately experience extreme pressure differentials from both directions during

the course of typical completion operations. Those skilled in the art recognize, however, that to reduce the possibility of damage to the valve port seals, elastomeric seals, such as O-rings, should be in the downstream member of the sliding pair of the tubular elements. As pointed out in such articles as "Elastomeric Seals for Valves" by E. B. Pool, ASME Publication 65–PET–16 (1965), it makes little difference whether this downstream member is either the moving or the stationary member of the pair. By locating such O-rings so that they are supported within a confining groove on the downstream member as the sealing contact is made or broken, their extrusion and resultant failure are prevented. On the other hand, should a valve port seal instead by in the upstream member of the pair, the O-ring is unsupported as the seal is made or broken and, as it crosses the port, it will tend to be extruded from within its confining groove and will possibly be sheared off as it passes under the opposite side of the port.

With conventionally arranged bypass valves, such design practices cannot be observed in all instances because of the reversal of the pressure differential across the valve during the course of many completion operations. Thus, it is not at all uncommon for a valve port seal to fail during a completion operation. Such failures obviously require the removal of the string of tools and tubing string from the well bore for repair with an attendant loss of valuable rig time and quite possibly treating materials as well.

Accordingly, it is an object of the present invention to provide a bypass valve having means for assuring that its valve port seals will be in a proper position according to such abovementioned recommended design practices irrespective of the direction of the pressure differential acting across the valve when it is being operated.

This and other objects of the present invention are obtained by providing within a bypass valve having telescoping inner and outer telescoping members, a slidable sleeve having seals inside and outside of that member. This sleeve is placed between and fluidly sealed to both of the tubular members to block communication between the respective ports through these members when the bypass valve is closed. Then, as the bypass valve is operated, means, responsive to the direction of the pressure differential acting across the bypass valve, are provided to shift the sleeve in such a manner that the sleeve will constitute a portion of the downstream member of the bypass valve and have its seals correctly positioned in accordance with good design criteria.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows a typical string of well tools, including a bypass valve employing the principles of the present invention, as they may appear within a well bore:

FIG. 2 is an elevational view in partial cross-section of one embodiment of a bypass valve of the present invention;

FIGS. 3A–3C schematically illustrate the operation of the bypass valve of FIG. 2 where the pressure differential is acting from the exterior of the valve to its interior; and

FIGS. 4A and 4B schematically illustrate the operation of the bypass valve of the present invention where the pressure differential is acting from the inside to the outside.

Turning now to FIG. 1, a number of full-bore well tools 10–12 are shown tandemly connected to one an-

other and dependently coupled from the lower end of a tubing string 13 in a cased well bore 14. At the lower end of these tools 10–12, a conventional full-bore packer 12 is arranged for selectively packing-off the well bore 14. A conventional hydraulic holddown 11 coupled to the mandrel 15 of the packer 12 is arranged to selectively engage the casing 16 and secure the mandrel against upward movement whenever the packer is set and the pressure within the tubing string 13 exceeds the hydrostatic pressure of the well control fluids 17 in the well bore 14. Coupled to the lower end of the tubing string 13 is a bypass valve 10, incorporating the principles of the present invention, that is connected above the holddown 11 and suitable arranged to be opened to facilitate shifting of the tools 10–12 within the well bore 14 by diverting a substantial portion of the fluids 17 through the central bore of the retracted packer 12.

In FIG. 2, a partially cross-sectioned elevational view is shown of the bypass valve 10 as it will appear in its closed position. As seen there, the bypass valve 10 is comprised of a movable tubular mandrel 18 that is telescopically disposed within a tubular housing 19 and arranged to be shifted therein by the tubing string 13 between a lower position as shown and an elevated position (not shown). Means, such as conventional drag blocks 20 on the packer 12, are provided to frictionally engage the casing 16 and secure the housing 19 so that the mandrel 18 can be moved relative thereto.

The upper end of the mandrel 18 is provided with threads 21 for coupling to the tubing string 13 (FIG. 1). Similarly, threads 22 are provided on the lower end of the housing 19 for connecting the bypass valve 10 to other well tools (such as the hydraulic holddown 11 shown in FIG. 1). The mandrel 18 and housing 19 are suitably arranged to provide a continuous axial bore 23 through the bypass valve 10 that is substantially the same diameter as that of the tubing string 13. At the lower end of the bypass valve 10, an O-ring 24 is disposed in a confining groove around the lower end of the housing 19 and fluidly sealed around the lower portion of the mandrel 18.

For establishing the longitudinal position of the mandrel 18 relative to the housing 19, an inwardly projecting lug 25 on the upper end of the housing is slidably received within a so-called "J-slot" 26 formed in the exterior wall of the mandrel. This J-slot 26 is formed of a short, vertical slot portion 27 having a closed upper end and an open lower end that is interconnected to an adjacent longer vertical slot portion 28 by a short transverse slot portion 29. Shoulders 30 and 31 respectively around the upper end and lower end of the elongated slot portion 28 in the mandrel 18 determine the maximum extent of travel of which the mandrel is capable of moving with respect to the housing 19. It will be appreciated that the packer drag blocks 20 secure the housing 19 to the casing 16 so that the mandrel 18 can be manipulated by the tubing string 13 to shift the mandrel lug 25 from the shorter slot 27 to the longer slot 28.

The central portion of the housing bore 32 is suitably proportioned to provide an upper bore portion 33 of a reduced diameter that joins a lower bore portion 34 of an enlarged diameter. Longitudinally spaced lateral ports 35 and 36 formed in the housing 19 respectively provide fluid communication between the exterior of the bypass valve 10 and the reduced bore portion 33 and enlarged bore portion 34.

A sleeve member 37 having a reduced upper portion 38 and an enlarged lower portion 39 is slidably disposed within the bore portions 33 and 34. To prevent the sleeve member 37 from rotating relative to the mandrel 18, an elongated longitudinal slot 40 is formed in the exterior wall of the mandrel and arranged to slidably receive the distal end of an upright extension 41 from the upper end 42 of the sleeve. A relatively weak compression spring 43 is compressed and held between the downwardly facing housing shoulder 44 formed by the junction of the bore portions 33 and 34 and the upper face 45 of the enlarged sleeve portion 39 to normally urge the sleeve 37 downwardly. An upwardly facing housing shoulder 46 at the lower end of the enlarged bore portion 34 normally supports the sleeve 37. The shoulder 31 around the mandrel 18 prevents upward travel of the sleeve 37 so long as the mandrel is in its lower position as shown in FIG. 2.

Spaced O-rings 47 and 48 are respectively placed around the reduced and enlarged sleeve portions 38 and 39 to fluidly seal those sleeve portions to the housing 19 within their associated bore portions 33 and 34 and between the housing ports 35 and 36. Similarly, O-rings 49 and 50 are spaced within the sleeve 37 to fluidly seal the sleeve around the external surface of the mandrel 18. Means, such as a lateral port 51 through the sleeve 37 between the O-rings 47–50, provide fluid communication from the clearance space 52 between the sleeve 37 and mandrel 18 and the intermediate space 53 defined by those portions of the housing bores 33 and 34 between the external sleeve O-rings 47 and 48. A lateral port 54 through the mandrel 18 is suitably arranged to be between the O-rings 49 and 50 whenever the mandrel is in its lower position relative to the sleeve 37 as shown in FIG. 2.

Thus, with the bypass valve 10 in the "closed" position as shown in FIG. 2, it will be recognized that fluid communication between the central bore 23 of the mandrel 18 and the exterior of the housing 19 is blocked by the O-rings 47–50 and sleeve 37. The housing port 36 and mandrel port 54, however, communicate the external and internal pressures to both faces 45 and 55 of the enlarged sleeve portion 39. Similarly, the other housing port 35 admits the external ambient pressure to the upper face 42 of the reduced end portion 38 of the sleeve 37. It will be appreciated, therefore, that the pressure within the tubing and the hydrostatic pressure will be acting in opposite directions on the effective cross-sectional area of the enlarged sleeve portion 39 represented by the annular area between the O-rings 47 and 48.

Accordingly, disregarding the negligible biasing force imposed by the spring 43, a hydrostatic pressure higher than the tubing pressure will shift the sleeve 37 upwardly relative to the housing 19 and against the mandrel shoulder 31 as the mandrel 18 is shifted to its upper position as determined by the length of the elongated slot portion 28. Conversely, a tubing pressure that is greater than the hydrostatic pressure will maintain the sleeve 37 in its lower position as shown in FIG. 2 regardless of the position of the mandrel 18.

To better illustrate the operation of the bypass valve 10, FIGS. 3 and 4 schematically depict the successive positions of the valve members 18, 19 and 37 in both situations of fluid pressure differentials across the bypass valve.

In FIGS. 3A–3C, the bypass valve 10 is shown as it functions under a condition where the external or hydrostatic pressure is greater than that within the tubing string 13, with FIG. 3A depicting the bypass valve before it is opened. Although the hydrostatic pressure tends to shift the sleeve 37 upwardly against the restraint of the spring 43, the mandrel shoulder 31 will prevent such movement until the mandrel 18 is moved upwardly. It will be recalled that the frictional engagement of the drag blocks 20 will restrain the housing 19 from moving. As the mandrel 18 is pulled upwardly toward its position shown in FIG. 3B, it will be appreciated that the differential between the hydrostatic pressure and the tubing pressure will shift the sleeve 37 upwardly along with the mandrel. In this instance, the sleeve 37 will be functioning as a portion of the mandrel 18 and the external O-ring 47 will serve as the valve port seal. Thus, as the O-ring 47 reaches and crosses the housing port 35, the greater hydrostatic pressure will be urging the O-ring into its confining groove in accordance with accepted design prac-

tices to place such a valve port seal in the downstream member.

Once the sleeve **37** and mandrel **18** have moved to their positions as shown in FIG. 3B, the ports **35**, **51** and **54** will be in alignment and the exterior and internal pressures will equalize. Once these pressures equalize, it will be seen from FIG. 3B that the hydrostatic pressure is acting uniformly in both directions on the sleeve member **37** so that the spring **43** will restore the sleeve to its original position as shown in FIG. 3C. Since the pressure differential is equalized, there is no tendency for the O-ring **47** to be damaged as it recrosses the port **35**.

It will be understood, however, that to close the bypass valve **10** during reverse-circulation from the position shown in FIG. 3C, the inner O-ring **49** would be the valve port seal and will not be in the most favored position with respect to the above-mentioned design criteria since this seal would be in the upstream member rather than in the downstream member. Since an occurrence will rarely occur, however, during typical well completion operations.

The usual conditions where the hydrostatic pressure is greater than the tubing pressure will arise, for example, following a swabbing test where the tubing pressure is greatly reduced after the bypass valve **10** is closed. In this situation, the bypass valve **10** will have been closed prior to the swabbing operation and will instead be opened rather than closed following the operation. Thus, under these circumstances, the sequence of operation for the bypass valve **10** will be as shown and already described in succession from FIGS. 3A–3C and the effective sealing member (O-ring **47**) will be correctly located on the downstream member.

Turning now to FIGS. 4A and 4B showing the opposite situation, i.e., where the tubing pressure is greater than the hydrostatic pressure. To open the bypass valve **10**, the mandrel **18** is pulled upwardly. Although, as the mandrel **18** travels from its position shown in FIG. 4A to that shown in FIG. 4B, the mandrel shoulder **31** is disengaged from the upper end **42** of the sleeve **37**, the pressure differential will be effective to maintain the sleeve in its downward position. Thus, the inner O-ring **49** will serve as the valve port seal and the sleeve **37** will be a portion of the downstream member of the valve **10**. As the mandrel port **54** crosses the O-ring **49**, the greater tubing pressure will be effective to keep it within its confining groove.

The usual sequence of events where the tubing pressure is higher than the hydrostatic pressure will generally arise where the bypass valve **10** is being closed at the beginning of the treating operation. As previously mentioned, the treating fluid will be pumped downwardly and the bypass valve **10** closed just prior to the arrival of the treating fluid therein. Thus, as the bypass valve **10** is closed (from FIG. 4B to FIG. 4A), the mandrel **18** will move downwardly relative to the sleeve **37** and housing **19** and the effective sealing member (O-ring **49**) will again be in the proper position, i.e., in the downstream member.

It should also be recognized that the bypass valve **10** is also highly effective for use during the conduct of a typical drillstem test. In such a drillstem test, a tool (not shown) having a selectively removable testing valve and pressure-recording instruments is typically coupled into the string above the bypass valve **10**. Typical of such tools is that shown on page 3057 of the 1960–61 Composite Catalog of Oil Field and Pipeline Equipment.

This string of tools is then lowered into the well with the bypass valve **10** open and the testing valve closed. After setting the packer **12**, the bypass valve **10** is closed and the test valve opened. As the bypass valve **10** is closed, there is little or no pressure differential thereacross since the internal and external pressures will have equalized prior to its closing. After the test valve is opened, the inside of the tubing string **13** will be reduced to the pressure of the connote fluids produced, if any, from the formation **56** (FIG. 1). This pressure, of course, is typically lower than the hydrostatic pressure. Thus, at the time the bypass valve **10** will be in the position shown in FIG. 3A.

Following the drillstem test, it is usually necessary to reopen the bypass valve **10** before the packer **12** can be unseated. Thus, the bypass valve **10** will be opened as shown in succession in FIGS. 3A–3C. Hereagain, the effective sealing member (O-ring **47**) will be in the downstream member. This is of particular benefit following, for example, a so-called "dry test" (little or no formation pressure) since the tubing string **13** will essentially be at atmospheric pressure. Thus, the pressure differential between the hydrostatic pressure and the tubing pressure will be exceptionally large before the bypass valve **10** is opened.

Following completion of such tests, it is often desired to remove the testing valve and pressure recorders from the tubing string **13** and, for example, plug-off an unwanted perforation as at **57** (FIG. 1) by cementing. With a test tool as previously referred to, it is possible to remove its releasably secured testing valve and pressure recorders without first removing the other tools **10–12** or the tubing string **13** from the well bore **15**. Then, a cementing operation is conducted through the outer portion of the test tool as already described. Thus, the bypass valve **10** must again be closed as, for example, shown in succession in FIGS. 4B to 4A. Hereagain, the effective sealing member (O-ring **49**) will still be correctly placed on the downstream member.

Accordingly, it will be appreciated that the bypass valve **10** of the present invention provides a new and improved sleeve valve that will function to position the effective valve port sealing member in the downstream member of the valve as it is being opened or closed. By shifting the sleeve **37** with respect to one or the other of the inner and outer tubular members **18** and **19** in response to the direction of the pressure differential across the bypass valve **10**, the effective valve port sealing member (O-ring **47** or O-ring **49**) will be advantageously disposed relative to its associated port **35** or **54** in accordance with good design practices.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A tubular control valve adapted for connection to a tubular string for operation in a well bore comprising: inner and outer tubular members each having a lateral port and telescopically arranged together for relative movement between spaced positions; a sleeve member slidably disposed between said tubular members; sealing means on said sleeve member and fluidly sealed to said tubular members; means retaining said sleeve member and sealing means between said ports whenever said tubular members are in one of their said positions to block fluid communication between said ports; and means responsive to the pressure differential between the exterior and interior of said control valve for positioning said sleeve member with respect to the downstream one of said tubular members as said tubular members are relatively moved to the other of their said positions to open fluid communication between said ports, said pressure-responsive means responding to a greater interior pressure to maintain said sleeve member stationary relative to said outer member and responding to a greater exterior pressure to maintain said sleeve member stationary relative to said inner member.

2. The control valve of claim **1** wherein said pressure-responsive means include differential piston means con-

nected to said sleeve member, first passage means from the exterior of said control valve to one side of said differential piston means, and second passage means from the interior of said control valve.

3. The control valve of claim 2 wherein one of said tubular members is adapted for connection to a tubular string and further including friction drag means connected to the other of said tubular members for resisting its movement in a well bore.

4. The control valve of claim 3 wherein said retaining means include a stop member on said one tubular member adapted to engage said sleeve member and movable out of such engagement upon movement of said one tubular member away from said sleeve member and further including biasing means between said other tubular member and sleeve member for urging said sleeve member away from said stop member.

5. The control valve of claim 1 wherein said retaining means includes stop means on one of said tubular members adapted to engage said sleeve member and movable out of such engagement upon movement of said one tubular member relative to said sleeve member.

6. The control valve of claim 5 further including means between the other of said tubular members and said sleeve member for urging said sleeve member away from said stop means.

7. The control valve of claim 6 wherein said one tubular member is adapted for connection to a tubular string and further including friction drag means connected to said other tubular member for resisting its movement in a well bore.

8. The control valve of claim 7 further including means between said tubular members limiting movement of said one tubular member relative to said other tubular member.

9. A tubular control valve adapted for connection to a tubular string for operation in a well bore comprising: inner and outer tubular members telescopically arranged together for relative movement between spaced positions and defining an annular space therebetween having a first portion of a greater cross-sectional area than that of a second portion; a slidable sleeve member having enlarged and reduced portions respectively coaxially disposed in said first and second portions of said annular space and slidable therein between first and second positions; first and second sealing means respectively on said enlarged and reduced sleeve portions and fluidly sealed to said tubular members for dividing said annular space into first

and second enclosed spaces respectively adjacent to said enlarged and reduced sleeve portions and a third enclosed space intermediate of said first and second spaces and sealing means; first passage means between the exterior of said control valve and said first enclosed space; second passage means from the exterior of said control valve and into said second portion of said annular space and arranged relative to said second sealing means to be in communication with said second enclosed space whenever said sleeve member is in its said first position and to be in communication with said third enclosed space whenever said sleeve member is in its said second position; third passage means through said sleeve member intermediate of said first and second sealing means; and fourth passage means from the interior of said inner member and into said annular space and arranged relative to said second sealing means whenever said sleeve member is in its said first position to be in communication with said third enclosed space whenever said tubular members are in one of their said positions and to be in communication with said second enclosed space whenever said tubular members are in the other of their said positions.

10. The control valve of claim 9 further including stop means on one of said tubular members for preventing movement of said sleeve member to its said second position whenever said tubular members are in their said one position.

11. The control valve of claim 10 wherein said one tubular member is adapted for connection to a tubular string and further including friction drag means connected to the other of said tubular members for resisting its movement in a well bore; and biasing means between said other tubular member and sleeve member for urging said sleeve member into its said first position.

12. The control valve of claim 11 further including means between said tubular members limiting movement of said one tubular member relative to said other tubular member.

References Cited

UNITED STATES PATENTS

2,815,925	12/1957	Fisher	166—226 X
2,988,323	6/1961	Conrad	166—226 X
3,305,023	2/1967	Farley	166—226
3,329,214	7/1967	Ehlert	166—226

CHARLES E. O'CONNELL, *Primary Examiner.*

DAVID H. BROWN, *Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,358,771 December 19, 1967

William O. Berryman

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

In the heading to the printed specification, lines 3 and 4, for "Schlumberger Well Surveying Corporation" read -- Schlumberger Technology Corporation --; column 2, line 14, for "by" read -- be --; column 3, line 14, for "suitable" read -- suitably --.

Signed and sealed this 11th day of February 1969.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents