Jan. 16, 1968 W. O. BERRYMAN 3,363,696

FULL BORE BYPASS VALVE

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Fig. 2

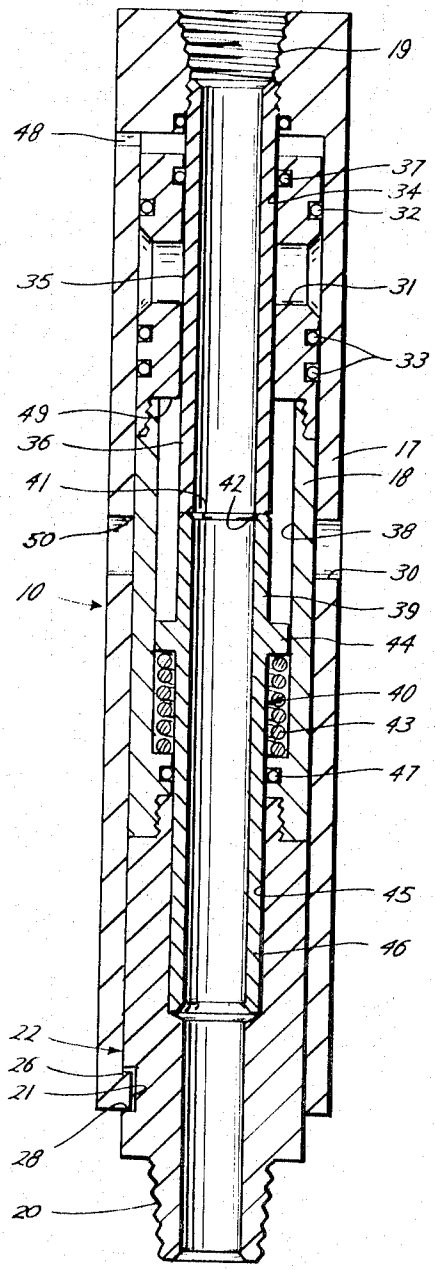
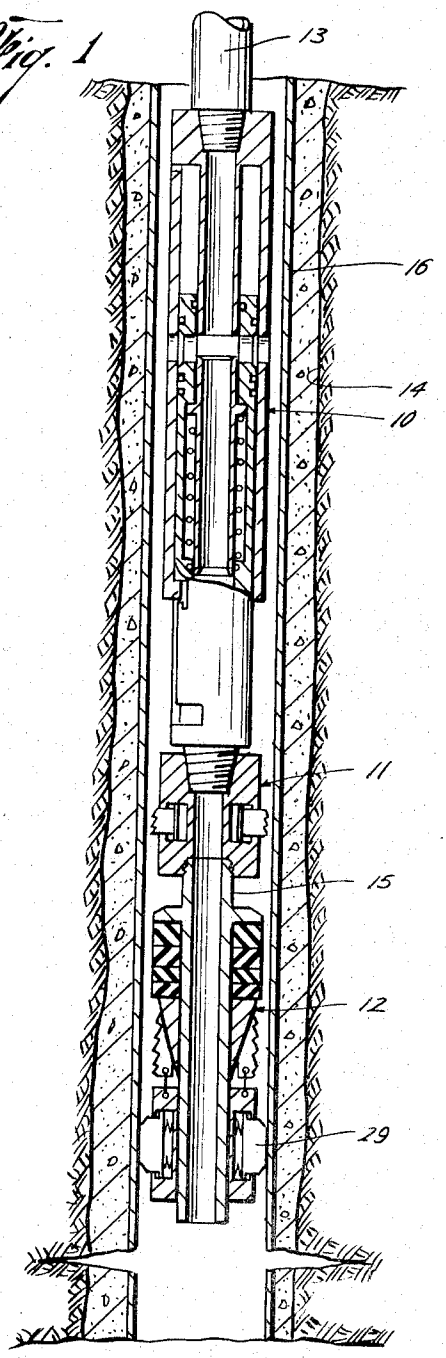


Fig. 1



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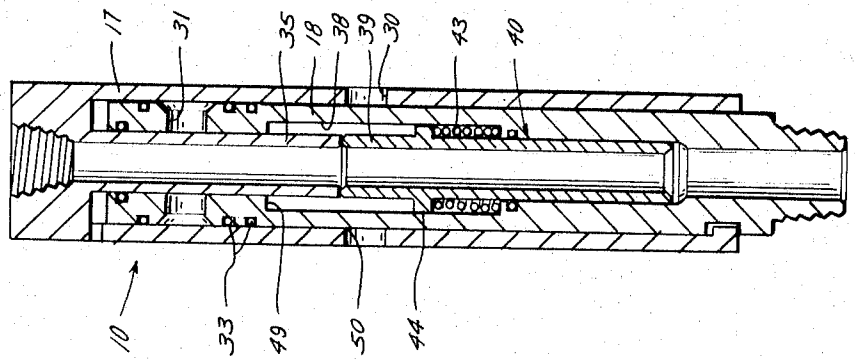


Fig. 3C

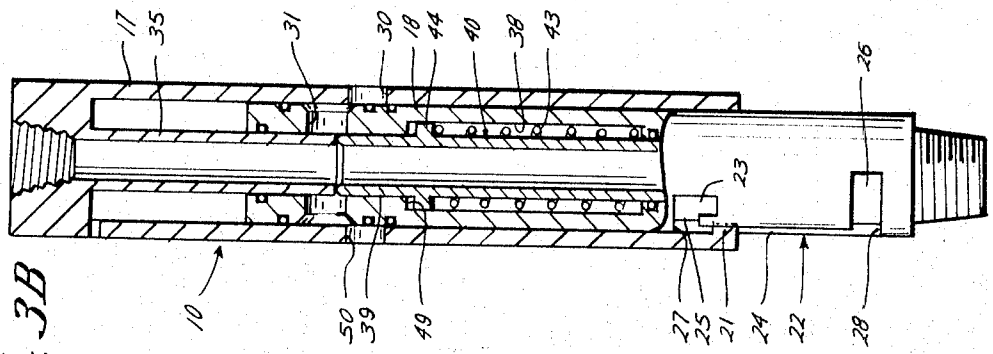


Fig. 3B

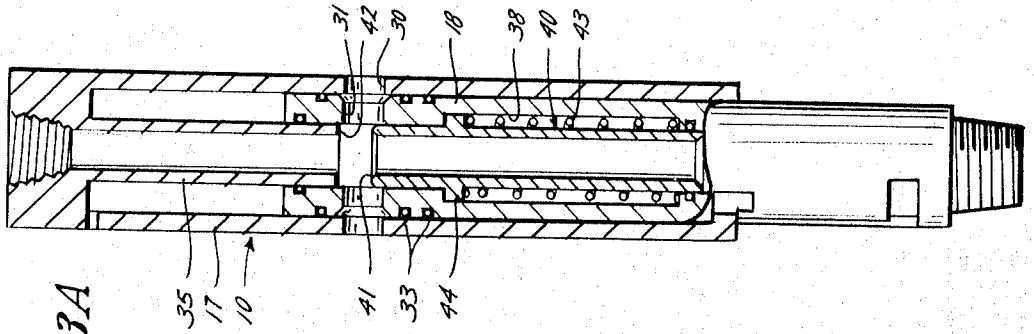


Fig. 3A

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3,363,696

FULL BORE BYPASS VALVE

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10 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.

The bypass valves typically used for such operations are generally comprised of an inner and outer tubular member telescoped together and arranged for movement relative to one another between spaced longitudinal positions. Ports in each member are suitably arranged to be in registration when the members are in one of their relative positions. In the other of these positions, the ports are displaced from one another and spaced sealing members above and below the ports in the inner member block fluid communication therethrough.

It will be appreciated that the function of the bypass valve is to provide 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 of the operation where 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 quantity of the well control fluids will be forced into the formation ahead of the treating fluids. It will be appreciated, therefore, 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 string so that, whenever the bypass valve is re-opened, the 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 as well control fluids are "reverse-circulated" by pumping them downwardly through the annulus and into the lower end of the packer and back up and out of the tubing string. Once the tubing string is flushed, the bypass valve is then 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 upon 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 may alternately experience extreme pressure differentials from both directions during the course of typical completion operation. Those skilled in the art recognize that to reduce the possibility of damage to the 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. P. 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 their 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 port seal instead be in the upstream member of the pair, as it is being closed against a pressure differential, the O-ring is unsupported as the seal crosses a port; and, as it does, the pressure differential will tend to lift the O-ring from within its confining groove where it will possibly be sheared off as it attempts to pass under the opposite edge of the port.

With conventionally arranged bypass valves, such design practices obviously 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 port seal to be sheared and fail as a result 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 pressures are equalized across its effective port seals as the valve is being closed to minimize the premature failure of these seals.

This and other objects of the present invention are obtained by providing within a bypass valve having inner and outer telescoping members, means suitably arranged to effect an initial port closure as the valve is being closed that is sufficient to at least substantially block or retard fluid communication through the valve before its ports are fully closed. Thus, as the bypass valve is being moved to its fully-closed position, the pressure across the effective valve port seals will be equalized to prevent the seals from being extruded from their grooves as the valve members move to their respective port-closing positions.

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 a certain embodiment 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; and

FIGS. 3A–3C schematically illustrate the operation of the bypass valve of FIG. 2 as it is being closed.

Turning now to FIG. 1, a number of full-bore well

tools 10–12 are shown tandemly connected to one another and dependently coupled from the lower end of the 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. The 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 pressure within the tubing string 13 exceeds the hydrostatic pressure of the fluids in the well bore 14. Coupled to the lower end of the tubing string 13 is a bypass valve 10 incorporating principles of the present invention that is conected above the holddown 11 and suitably arranged to be opened to facilitate shifting of the tools 10–12 within the well bore 14 by diverting a substantial portion of the well fluid through the central bore of the retracted packer 12.

In FIG. 2, a partially cross-sectional 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 17 that is telescopically disposed over the upper portion of a tubular housing 18 and arranged to be shifted relative thereto by the tubing string 13 between a lower position as shown and an elevated position (not shown). The upper end of the mandrel 17 is provided with threads 19 for coupling the bypass valve 10 to other tools or the tubing string 13 (FIG. 1). Similarly, threads 20 are provided on the lower end of the housing 18 for connecting the bypass valve 10 to other well tools therebelow (such as the hydraulic holddown 11 shown in FIG. 1).

For establishing various longitudinal positions of the mandrel 17 relative to the housing 18, an inwardly projecting lug 21 on the lower end of the mandrel is slidably received within a so-called "J-slot" 22 formed in the exterior wall of the housing. As best seen in FIG. 3B, this J-slot 22 is formed of a short, vertical slot 23 having a closed lower end and an open upper end that is inter-connected to the upper end of an adjacent longer vertical slot 24 by a short transverse slot 25. The lower end of the longer slot 24 is provided with a short transverse slot 26 for locking the valve 10 in a closed position. Shoulders 27 and 28 respectively around the upper and lower ends of the elongated slot 24 in the housing 18 determine the maximum extent of travel of which the mandrel 17 is capable of moving with respect to the housing. It will be appreciated that means, such as the typical drag blocks 29 on the packer 12, will frictionally secure the housing 18 to the casing 16 so that the mandrel 17 can be manipulated relative thereto by the tubing string 13 to shift the mandrel lug 21 into the various slots 23–26.

Lateral ports 30 are suitably located through the intermediate portion of the mandrel 17 to be moved upwardly into registry with corresponding lateral ports 31 through the uppermost portion of the housing 18 whenever the mandrel is shifted to its uppermost position as determined by the longer slot 24 of the J-slot 22. Sealing means, such as O-rings 32 and 33, are spaced above and below the housing ports and slidably sealed with the mandrel 17 so that, until the mandrel ports are shifted upwardly into registry therewith, fluid communication is blocked through the ports 30 and 31.

The upper portion of the central bore through the housing 18 is suitably arranged, as at 34, to telescopically receive a co-axially disposed sleeve or tubular member 35 within and dependently secured from the upper end of the mandrel 17 and having a free end 36 terminating substantially even with the top of the mandrel ports 30. Sealing means, such as an O-ring 37, mounted around the upper portion 34 of the central bore of the housing 18, fluidly seal the housing around the depending tubular member 35.

The intermediate portion of the central bore through the housing 18 is enlarged, as at 38, to slidably receive the upper portion 39 of a movable sleeve or tubular member 40 co-axially disposed therein. The upper marginal end surface 41 of the movable tubular member 40 is normally urged upwardly into abutting engagement with the downwardly facing marginal end surface 42 of the free end 36 of the inner tubular member 35 by biasing means, such as a compression spring 43 engaged between a fixed housing shoulder, such as the lower surface of the enlarged housing bore 38, and an external shoulder 44 on the slidable tubular member 40. The lower portion 45 of the central bore through the housing 18 is appropriately dimensioned to receive the lower portion 46 of the slidable tubular member 40. Sealing means, such as an O-ring 47, within the lower housing bore 45 fluidly seal the lower portion 46 of the slidable tubular member 40 relative to the housing 18.

To provide a relatively uninterrupted passage through the bypass valve 10, the central bores of the opposed sleeves 35 and 40 as well as the lowermost portion 45 of the central bore through the housing 18, are preferably arranged with substnatially the same diameter as the internal diameter of the tubing string 13. A lateral port 48 through the uppermost end of the mandrel 17 is provided to pressure-balance the sliding members and prevent entrapment of fluid in the annular space above the O-rings 32 and 37 and between the mandrel and housing 18.

In typical completion operations such as those previously described, the bypass valve 10 is generally left open until the tools 10–12 are positioned. Then, as the packer 12 is being set, it is customary to close the bypass valve 10 to block communication between the tubing string 13 and well annulus above the packer. Accordingly, to better illustrate the operation of the bypass valve 10, it has been schematically depicted in successive views in FIGS. 3A–3C to show the various sequential positions of the several elements as the bypass valve is being shifted from its "open" to its "closed" position.

Turning now to FIG. 3A, the bypass valve 10 is shown in its fully-open position. In this "open" position, the mandrel 17 is elevated relative to the housing 18 a distance as determined by the length of the elongated slot 24. With the mandrel 17 in this position, the mandrel ports 30 are in registry with the housing ports 31 and the marginal end surface 42 of the depending sleeve member 35 is substantially even with the top of the housing ports as well. To secure the mandrel 17 in this elevated position, the mandrel lug 21 is confined in the short transverse slot 25 at the upper end of the longer slot 24 or, if desired to "lock" the mandrel, in the short slot 23.

Of particular significance is the position of the slidable sleeve member 40 whenever the valve ports 30 and 31 are aligned in the "open" position of the valve 10. As previously described, when the bypass valve 10 is closed, the spring 43 is suitably arranged to normally urge the upper marginal end surface 41 of the slidable tubular member 40 into engagement with the lower marginal end surface 42 of the depending tubular member 35. When the bypass valve 10 is open, however, means are provided for restraining the slidable tubular member 40 to permit the depending tubular member 35 to move away from the slidable member as the mandrel 17 moves upwardly. To accomplish this, cooperative stop means, such as the external shoulder 44 on the slidable tubular member 35 and the downwardly facing surface 49 at the upper end of the enlarged housing bore 38, are appropriately arranged in relation to the free length of the upper portion 39 of the slidable member above the shoulder 44 to prevent the upper marginal end surface 41 of this member from moving upwardly relative to the housing 18 any further than about even with the bottom of the housing ports 31.

Accordingly, when the bypass valve 10 is in its "open" position as shown in FIG. 3A, the lower marginal end

surface 42 of the depending sleeve member 35 is substantially even with the top of the mandrel and housing ports and the upper marginal end surface 41 of the slidable sleeve member 40 is substantially even with the bottom of these ports 30 and 31. Thus, in this "open" position, there will be complete fluid communication through the ports 30 and 31 and the gap between the opposed ends 41 and 42 of the aligned tubular members 40 and 35.

To close the bypass valve 10, it is, of course, necessary only to shift the mandrel 17 downwardly with respect to the housing 18 to move the ports 30 and 31 out of registry. As previously mentioned, the frictional engagement of the drag blocks 19 on the packer 12 will secure the housing 18 relative to the casing 16 so as to permit movement of the tubing string 13 to shift the mandrel 17 relative to the housing.

Accordingly, as best seen in FIG. 3B, as the tubing string 13 and mandrel 17 are shifted downwardly relative to the stationary housing 18, the lower marginal end surface 42 of the depending tubular member 35 will engage the upper marginal end surface 41 of the slidable tubular member 40 and shift it downwardly against the restraint of the spring 43. As, for example, by arranging the stop means 44 and 49 where the upper end 39 of the slidable sleeve 40 will project slightly above the lower edge of the housing ports 31 as well as above the O-rings 33 therebelow, the opposed marginal surfaces 41 and 42 of the two sleeves 40 and 35 will be brought together before the upper inner edges 50 of the mandrel ports 30 have reached the O-rings 33. Thus, even though the engagement of the opposed marginal surfaces 41 and 42 may not necessarily effect a complete fluid seal, there will be a sufficient closure to permit the pressure within the housing ports 31 to substantially equalize with the pressure exterior of the mandrel 17 before the upper edges 50 of the mandrel ports 30 reach the O-rings 33.

Accordingly, by equalizing these pressures before the upper edges 50 of the mandrel ports 30 engage the O-rings 33, there will be little or no pressure differential that otherwise might tend to extrude the O-rings 33 even slightly outwardly of their confining grooves. It will be appreciated, therefore, that as the internal upper edges 50 of the mandrel ports 30 reach and pass the O-rings 33, the O-rings will be safely disposed within their confining grooves so as not to be sheared by these edges.

Turning now to FIG. 3C, the bypass valve 10 is depicted as it will appear when the mandrel 17 reaches the lower extreme of its travel relative to the housing 18. The continued abutting engagement of the opposed marginal end surfaces 41 and 42 has now depressed the slidable sleeve 40 toward the bottom of the enlarged housing bore 38 against the restraint of the spring 43. Then, once the mandrel 17 is rotated slightly so as to bring the mandrel lug 21 into the closed end of the transverse slot 26, the spring 43 will expand sufficiently to maintain the marginal end surfaces 41 and 42 of the tubular members 40 and 35 co-engaged.

Accordingly, it will be appreciated that the pressure across the effective port-sealing members, i.e. the O-rings 33, will always be substantially, if not completely, equalized as the bypass valve 10 is being opened or closed even when the pressure inside of the bypass valve is greater than that outside. By effecting a first closure at the opposed marginal end surfaces 41 and 42 of the two tubular members 40 and 35 before the effective port-sealing members 33 reach the inner edges 50 of the mandrel ports 30, the pressure across the O-rings 33 will at least be substantially equalized and cannot tend to displace them from their confining groove.

From this, it will be appreciated, therefore, that the present invention has provided new and improved means for preventing untimely failures of effective port-sealing members such as are often caused by the existence of a pressure differential across those sealing members that would otherwise tend to be extruded from within the protection of their confining grooves and be sheared by the inner edge of a port traversing the sealing member.

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 well tool adapted for connection to a pipe string and comprising: inner and outer tubular members telescoped together and movable relative to one another between spaced positions; means including a port in said inner member for providing fluid communication between the interior and exterior of said tubular members in one of their said positions; means including sealing means between said tubular members for closing fluid communication through said port in the other position of said tubular members; and means in said tubular members and responsive to movement of said tubular members toward their said other position for at least retarding flow through said port before said tubular members assume their said other position.

2. The well tool of claim 1 wherein said flow-retarding means includes a sleeve member co-axially mounted within one of said tubular members and having a free terminal portion telescopically received within the other of said tubular members; sealing means between said sleeve member and said other tubular member; and means in said other tubular member responsive to movement of said tubular members away from their said one position for closing said sleeve member before said tubular members reach their said other position.

3. The well tool of claim 2 wherein said free terminal end of said sleeve member is substantially even with said port whenever said tubular members are in their said one position and said closure means includes a second member co-axially disposed in said other tubular member and movable therein between a first position in engagement with said other sleeve member and a second position apart therefrom; biasing means normally urging said second member toward its said first position; and stop means for holding said second member in its said second position so long as said tubular members are in their said one position and operatively arranged relative thereto to allow said biasing means to shift said second member into its said first position before said tubular members reach their said other position.

4. A well tool adapted for connection to a pipe string and comprising: inner and outer tubular members telescoped together and movable relative to one another between spaced longitudinal positions; a sleeve member co-axially mounted within one portion of said outer member and having a free end received within said inner member; means including a lateral port in said inner member and substantially even with said free end of said sleeve member for providing fluid communication between the interior and exterior of said tubular members whenever said tubular members are in one of their said positions, said port being between said one portion and said free end of said sleeve member whenever said tubular members are in the other of said positions; first sealing means between said inner tubular member and said sleeve member; second sealing means between said tubular members for blocking flow communication through said port whenever said tubular members are in their said other position; and means within said inner member and responsive to movement of said tubular members from their said one position for at least retarding flow through said sleeve member and said port before said tubular members reach their said other position.

5. The well tool of claim 4 wherein said flow-retarding means includes a second sleeve member co-axially dis-

posed in said inner tubular member and slidable therein between a first position in flow-blocking inter-relation with said other sleeve member and a second position longitudinally spaced therefrom; biasing means between said slidable sleeve member and said inner tubular member normally urging said slidable sleeve member toward said other sleeve member; and stop means for holding said slidable sleeve member in its said second position so long as said tubular members are in their said one position and operatively arranged relative thereto to allow said biasing means to shift said slidable sleeve member into its said flow-blocking inter-relation with said other sleeve member before said tubular members reach their said other position.

6. The well tool of claim 5 in which, when said tubular members are in their said one position, they are relatively expanded in relation to their said other position in which said tubular members are relatively telescoped.

7. The well tool of claim 6 wherein said fluid communication means further include a second lateral port in said outer tubular member arranged to be substantially in registry with said other port whenever said tubular members are in their said expanded position and out of register therewith whenever said tubular members are in their said telescoped position.

8. The well tool of claim 6 wherein said flow-blocking inter-relation of said sleeve members is obtained by providing the opposed ends of said sleeve members with marginal surfaces arranged to abut one another whenever said slidable sleeve member is in its said first position.

9. The well tool of claim 8 wherein said fluid communication means further include a second lateral port in said outer tubular member arranged to be substantially in register with said other port whenever said tubular members are in their said expanded position and out of register therewith whenever said tubular members are in their said telescoped position.

10. The well tool of claim 9 further including means between said inner and outer tubular members for establishing their expanded and telescoped positions.

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