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Mott

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[54] **SUBSURFACE SAFETY VALVE WELL TOOL OPERABLE BY DIFFERENTIAL ANNULAR PRESSURE**

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[52] **U.S. Cl.** **166/212**, 166/224

[51] **Int. Cl.** **E21b 43/12**, E21b 40/00

[58] **Field of Search** 166/208, 224, 212; 285/18, 285/DIG. 21

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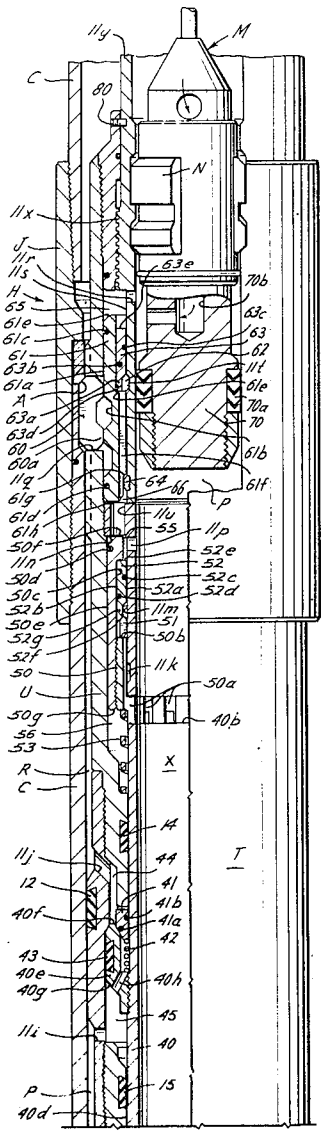
Primary Examiner—James A. Leppink

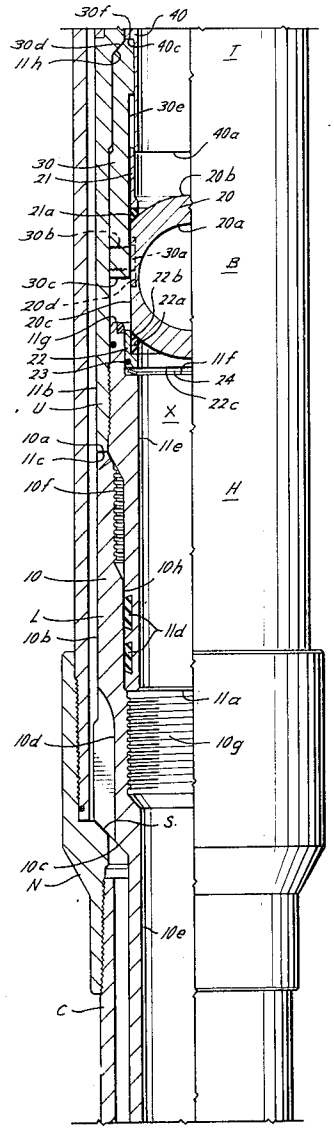
Attorney, Agent, or Firm—Pravel & Wilson

[57] **ABSTRACT**

A well tool apparatus adapted for connection in a production tubing including a separable flow housing having a bore extending therethrough with a rotatable ball bore closure means positioned in said bore which is operable in response to differential fluid pressure in an annular area about the tubing and a means for releasably securing the separable portions of the housing for effecting housing separation by either a directional fluid pressure or mechanical movement to enable retrieval of the rotatable ball.

12 Claims, 5 Drawing Figures





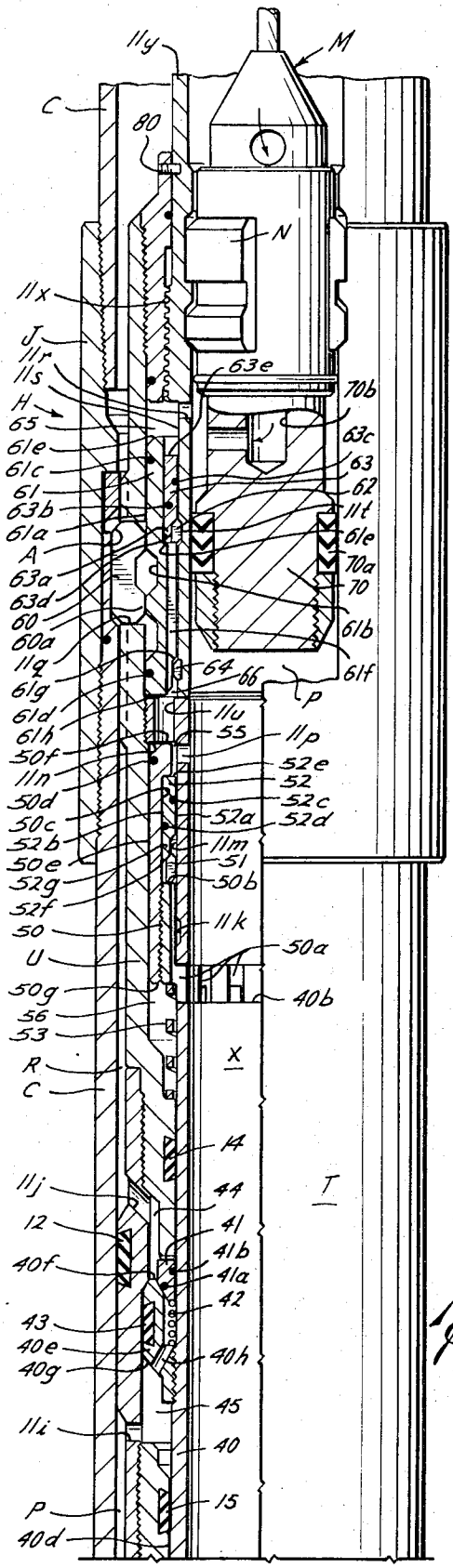

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Fig. 1A

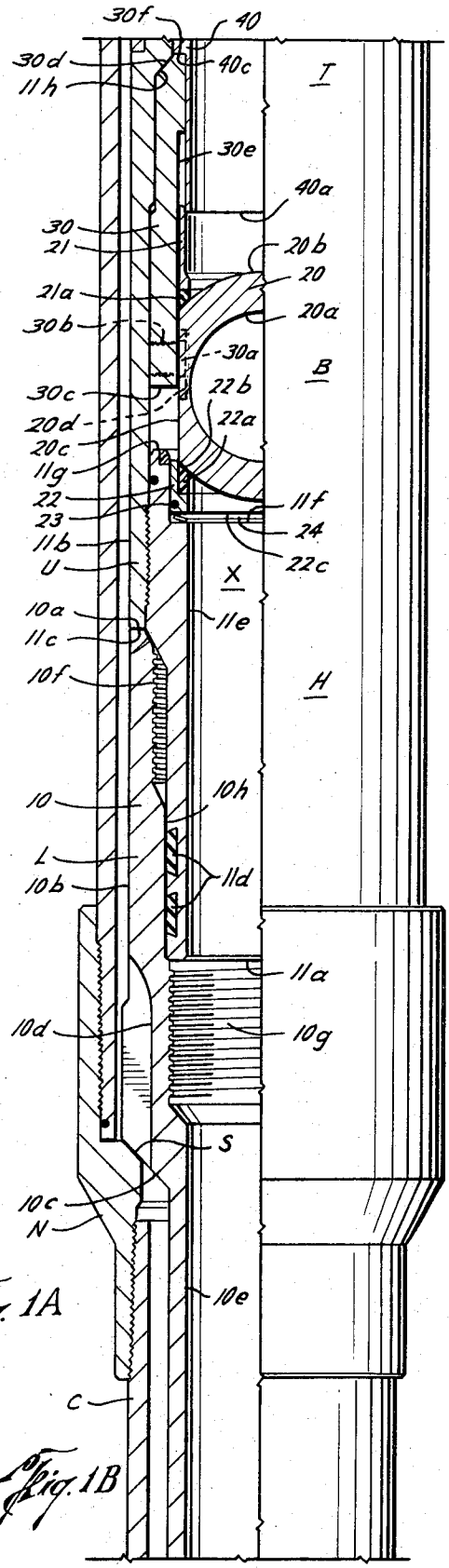

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Fig. 1B

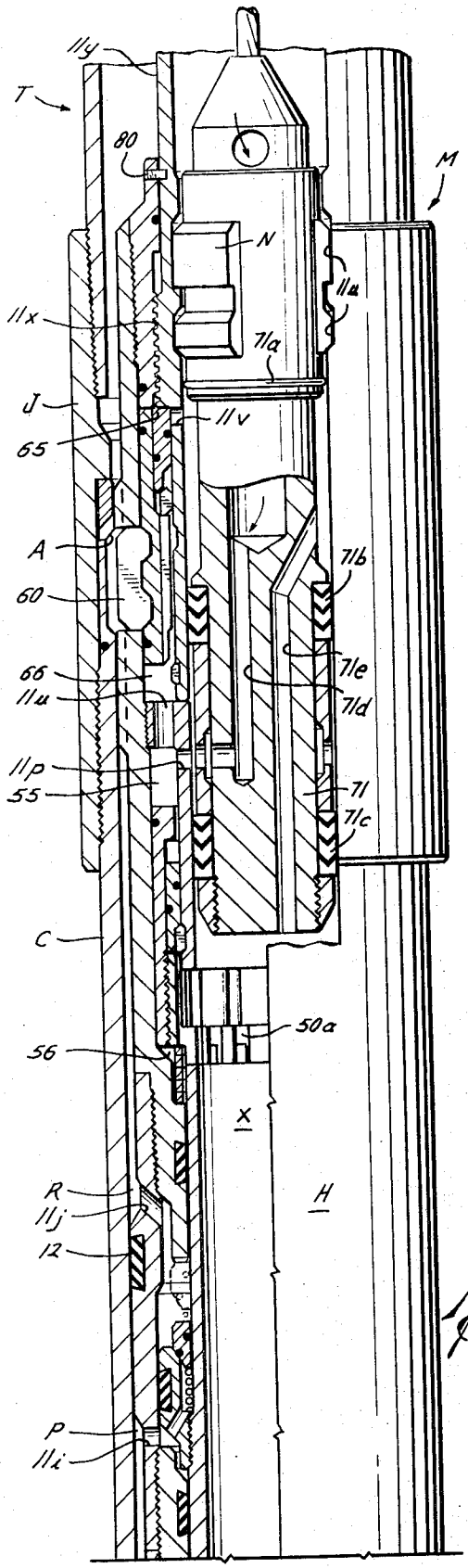


Fig. 2A

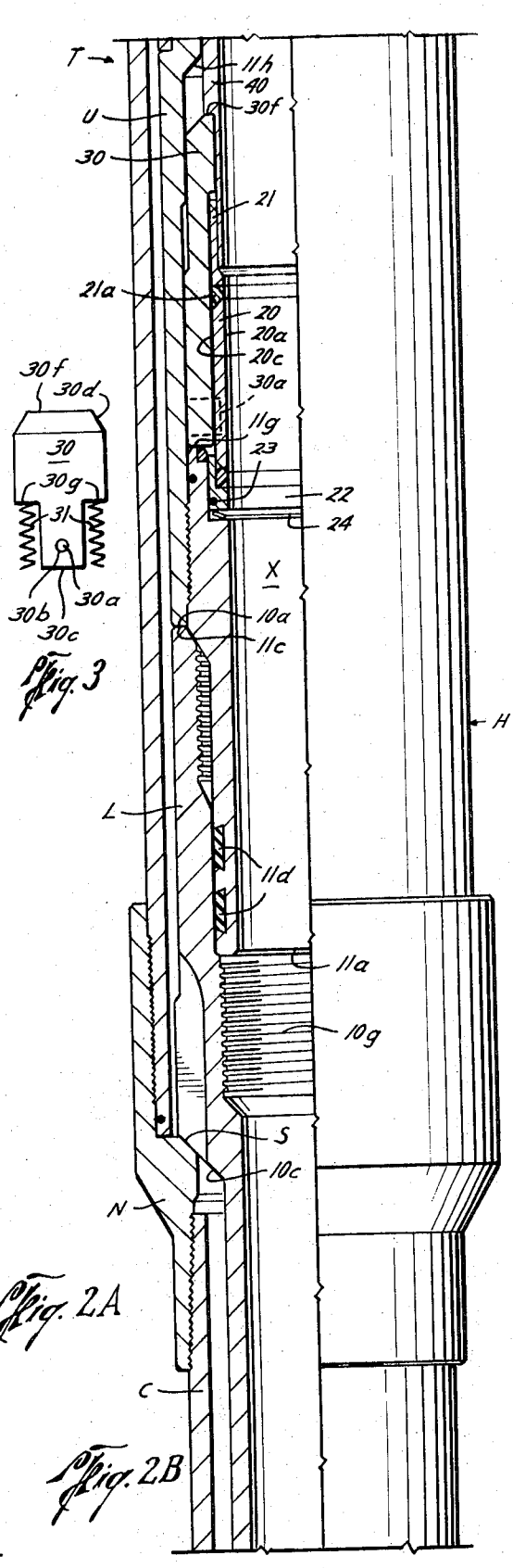


Fig. 2B

Fig. 3

SUBSURFACE SAFETY VALVE WELL TOOL OPERABLE BY DIFFERENTIAL ANNULAR PRESSURE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to my co-pending applications Ser. No. 359,757, filed of even date with the present application, entitled "METHOD AND APPARATUS FOR A SUBSURFACE SAFETY VALVE OPERATING WITH DIFFERENTIAL ANNULAR PRESSURE" and Ser. No. 359,758, filed of even data with the present application, entitled, "IMPROVED SUBSURFACE SAFETY VALVE WELL TOOL OPERABLE BY DIFFERENTIAL ANNULAR PRESSURE", both of which are assigned to the assignee of the present application.

BACKGROUND OF THE INVENTION

This invention relates to the field of a subsurface safety valve well tool operable by differential annular pressure.

The differential annular pressure operated subsurface safety valves disclosed in my co-pending applications, identified hereinabove, serve a most useful purpose of preventing undesired blow-out flow from a well through a production tubing. Both of these disclosures employed releasable securing means requiring either tubing rotation or a reduction of well pressure to effect housing release. The tubing rotation release is undesirable because inadvertent and unexpected tubing joint separation may occur which requires a fishing operation to retrieve the disconnected tubing. The well pressure reduction release required additional operations of setting a plug or killing the well prior to separating the housing. The additional time and effort to effect housing release utilizing those means was costly and yet a positive release and separation of the housing with those inventions was not assured.

SUMMARY OF THE INVENTION

A new and improved differential annular pressure operated rotatable ball subsurface safety valve well tool having separable housing portions releasably secured together to form a portion of a production tubing during safety valve operation which are selectively released by either a directional fluid pressure or mechanical manipulation to enable retrieval of the rotatable ball when desired without requiring retrieval of the production tubing connected below the well tool.

An object of the present invention is to provide a new and improved subsurface safety valve well tool.

Another object of the present invention is to provide a new and improved subsurface safety valve well tool having a housing separating selectively by either a fluid pressure or a mechanical manipulation of the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B are side views, partially in section, from top to bottom of the well tool of the present invention, illustrating the well tool releasably securing the housing portion S;

FIGS. 2A and 2B are views, similar to FIGS. 1A and 1B, illustrating the housing portions of the well tool prior to effecting separation; and

FIG. 3 is a side view, illustrating construction of the well tool pivot member.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The well tool of the present invention, generally designated T in the Figs., is connected at a subsurface location in a production tubing (not illustrated) to control undesired upwardly flow from the well through a bore of the production tubing to the ground or earth surface (not illustrated). The well tool T includes a flow housing H comprising two releasably secured separate portions to enable selective desired separation of the housing H and having a longitudinal flow passage or bore X in communication with the bore of the production tubing for flowing well fluids through the secured housing H. Disposed in the bore X is a movable bore closure means B to control flow of fluid therethrough which is retrievable with a portion of the housing H and is normally operable in response to a differential fluid pressure in an annular area adjacent the flow housing H for controlling the undesired flow in the bore X and which may be releasably locked in an open position when desired.

The flow housing H is connected with the production tubing at its upper and lower ends by suitable means, such as threaded box and pin connections (not illustrated) as is well known in the art, to form a portion of the production tubing for flowing well fluids and the like through the bore X of the flow housing H.

As illustrated in FIG. 1B, the flow housing H includes a lower or first portion L and an upper or second portion U which are releasably secured together to form the flow housing H. Preferably, the lower portion L is in the form of a sleeve **10** which extends upwardly from the lower threaded pin connection (not illustrated) to an upwardly facing annular shoulder **10***a* for supporting the upper housing portion U. The sleeve **10** includes an outer surface **10***b* having a downwardly facing annular shoulder surface **10***c* which is partially machined away to form fluted openings **10***d* for communicating fluid pressure by the shoulder **10***c*. The production tubing is positioned within a well casing C having a reducer or adapter N providing an upwardly facing annular shoulder S engaging the shoulder **10***c* for mounting the flow housing H at a desired subsurface location with the well casing C to support the flow housing H and connected production tubing thereto in the well casing C. While the well tool T of the present invention is described as being positioned in the well casing C, it will be immediately appreciated by those skilled in the art that the production tubing and the well tool T may be positioned in the bore of any well conduit, such as within the bore of another production tubing, with no change in the operation of the well tool T of the present invention as herein disclosed.

The tubular member **10** includes an inner surface **10***e* defining the bore X through the tubular member **10** and having a left-hand thread **10***f* formed thereon adjacent the shoulder **10***a* and a right-hand thread **10***g* located below and in spaced relationship to the thread **10***e* to provide a sealing surface **10***h* therebetween.

The upper portion U of the housing preferably includes a tubular member **11** extending downwardly from the upper threaded box connection (not illustrated) to telescope within the lower sleeve **10** to position a lower annular shoulder **11***a* adjacent the threads

10g. The tubular member 11 includes an outer surface 11b forming a downwardly facing annular shoulder 11c engaging the shoulder 10a to support and block further downward movement of the tubular member 11 and for positioning a pair of replacable seal rings 11d to effect an annular fluid seal with the surface 10h to block leakage of fluid therebetween.

The bore closure means B is disposed in the bore X of the housing H formed by an inner surface 11e of the tubular member 11 and is movable to and from an open position for enabling flow of fluid through the bore X and the production tubing and to and from a closed position for blocking the flow of fluid through the bore X. The bore closure means B preferably includes a ball member 20 having a flow port 20a formed therethrough which is rotatable to an from a closed or transverse position (FIG. 1B) for blocking flow of fluid through the bore X and to and from an opened or aligned position (FIG. 2B) for enabling flow of fluid through the aligned flow port 20a. The ball 20 includes a spherical outer sealing surface 20b having two separate portions removed to form a pair of parallel flat portions 20c with each of the circular shaped flats 20c having a radially extending elongated recess 20d formed therein for operably connecting the ball 20 with the flow housing H. Reference is made to my two copending applications, identified hereinabove for a more detailed illustration and description of the ball 20.

The bore closure means B further includes a longitudinally movable upper seat ring 21 which is concentrically positioned in the bore X immediately above the ball 20 and in engagement therewith with a sealing element 21a and a lower seat ring 22 which is also concentrically positioned in the bore X immediately below the ball 20 and also in engagement therewith. The lower seat ring 22 mounts thereon a ring shaped sealing element 22a having an arcuate upwardly facing annular surface 22b for effecting an annular fluid seal with the spherical surface 20b of the ball 20 for blocking passage of fluid therebetween and an O-ring 22 and the tubular member 11 to block passage of fluid therebetween. The bore closure means B also includes a biasing means or seal spring 24 which is located between a downwardly facing annular shoulder 22c of the seat ring and an upwardly facing annular shoulder 11f for biasing the seat ring 22 to move upwardly for maintaining sealing contact with the spherical surface 20b of the ball 20.

The flow housing H includes an operator member 40 and a pivot member 30 for effecting desired rotational movement of the ball 20 to and from the open and closed positions. The pivot sleeve member 30 is concentrically mounted in the bore X between the ball 20 and the tubular member 11 and is longitudinally movable between a first or upper position (FIG. 1B) for rotating the ball 20 closed and a second or lower position (FIG. 2B) for rotating the ball 20 to the open position. The pivot member 30 includes a pair of inwardly projecting eccentric fingers 30a, which are secured to the pivot member 30 by suitable fastening means, such as threaded engagement at 30b, and which extend into the corresponding recesses 20d for rotating the ball 20 when there is relative longitudinal movement between the ball 20 and the pivot member 30. The pivot member 30 further includes a lower annular shoulder 30c for engaging an upwardly facing annular shoulder 11g to provide a lower movement limit stop to the pivot member 30 when the ball 20 is rotated open and an upwardly facing tapered annular shoulder 30d for engaging a tapered downwardly facing annular shoulder 11h to provide an upper movement limit stop for the pivot member 30 when the ball 20 is rotated closed. The pivot member 30 includes an inner surface 30e which guides the longitudinal movement of the seat ring 21.

The tubular operator member 40 is concentrically positioned in the bore X above the pivot member 30 and is also longitudinally movable between an upper position (FIGS. 2A and 2B) and a lower position (FIGS. 2A and 2B) for moving the pivot member 30 to rotate the ball 20 to and from the open and closed positions. The operator member 40 extends upwardly from a downwardly facing annular shoulder 40a (FIG. 1B) telescoped within the pivot member 30 and adjacent the upper seat ring 21 to an upwardly facing annular shoulder 40b (FIG. 2B). The operator member 40 includes a downwardly facing annular shoulder 40c formed on an outer surface 40d which engages an upwardly facing flat annular shoulder 30f of the pivot member 30 for moving the pivot member 30 to the lower position along with the operator 40 to rotate the ball 20 open.

As illustrated in FIG. 1A, secured on the outer surface 40d of the operator 40 is an outwardly projecting annular collar 40e forming an upwardly facing annular shoulder surface 40f and a downwardly facing annular shoulder surface 40g with a flow passage 40h extending through the collar 40e between the annular shoulders 40f and 40g. Concentrically mounted with the outer surface 40d of the operator 40 above the collar 40e and movable relative thereto is a directional flow valve or closure ring 41 which serves as a check valve for enabling some upwardly flow through the low passage 40h while blocking downwardly flow through the flow passage 40h by moving into engagement with the surface 40f. The closure ring 41 includes a pair of seal rings 41a and 41b which effect annular fluid seals with the surfaces 40f and 40d, respectively, to block leakage of fluid therebetween. The closure ring 41 is biased away from the surface 40f by a spring 42 to enable passage of fluid through the flow passage 40h under certain desired production tubing leak testing conditions as set forth in greater detail in my related application identified hereinabove.

The operator 40 is slideably sealed by a pair of seal rings 14 and 15 with the tubular member 11 at spaced locations above and below the collar 40e, respectively, and by a seal ring 43 mounted with the collar 40e to block leakage of fluid therebetween. The three annular seals so effected form a pair of annular expansible chambers 44 and 45 located above and below the annular collar 40e, respectively. The upwardly facing annular shoulder surface 40f between the seal rings 15 and 43 and the closure ring 41 between the seals 41a and 41b form a portion of the chamber 44 for enabling the fluid pressure in the chamber 44 to urge thereon for urging movement of the operator member 40 downward to the lower position for rotating the ball 20 open. The annular surface 40g between the seal rings 14 and 43 forms a portion of the chamber 45 for enabling the fluid pressure in the chamber 45 to urge thereon for urging movement of the operator member 40 to the upper position for enabling the ball 20 to rotate closed.

The outer surface 11*b* mounts a packing or seal ring 12 thereon adjacent the operator 40 for effecting an annular fluid seal between the well casing C and the tubular member 11 to block leakage of fluid in the annular area therebetween. The seal 12 divides the annular area between the production tubing and the well casing C into an upper chamber or reservoir R above the seal 21 and a lower chamber or reservoir P below the seal 12 and above a well packer (not illustrated). The lower reservoir P communicates with the chamber 45 through a passageway 11*i* formed through the tubular member 11 while the chamber 44 communicates with the reservoir R through a flow aperture or port 11*j* formed through the tubular member 11. Thus, the annular pressure differential between the upper reservoir R and the lower reservoir P will be sensed across the collar 40*e* of the operator 40 for rotating the ball 20 to and from the open and closed position. A greater pressure in the upper reservoir R urging downwardly on the annular shoulder 40*f* will move the operator 40 to the lower position to rotate the ball 20 open while a greater pressure in the lower reservoir P will urge upwardly on the annular shoulder 40*g* for moving the operator 40 upwardly to rotate the ball 20 closed. The flow passage 40*h* is of such small flow capacity in comparison with the volume of the reservoirs R and P, that the differential pressure urging upwardly from the reservoir P when the ring 41 moves from sealing engagement with the surface 40*f* will move the operator 40 to the upper position prior to equalizing with the pressure in the upper reservoir R. As illustrated in FIG. 3, the urging of the plurality of springs 31, located in a pair of recesses 30*g* formed in the surface 30*c* of the pivot member 30 and engaging the shoulder 11*g* is normally sufficient to move the pivot member 30 and the operator 40 to the upper position when the pressures in the reservoirs R and P are substantially equal.

As illustrated in FIG. 1A, the flow housing H further includes means for releasably locking the ball 20 in the open position in response to a directional fluid pressure to thereafter block movement of the ball 20 to the closed position comprising a lug ring 50, a detent 51 and a piston ring 52, all of which are movably mounted in the bore X above the operator 40. The lug ring 50 includes a plurality of circumferentially spaced downwardly extending fingers or lugs 50*a* engaging the upper annular shoulder 40*b* of the operator 40 while enabling fluid communication through the ring 50 between the lugs 50*a*. The lug ring 50 is longitudinally movable between an upper position (FIG. 1A) and a lower position (FIG. 2A) moving the engaged operator 40 downwardly for rotating the ball 20 to the open position. The detent 51 is a gapped, radially expansible ring positioned above and in engagement with an upwardly facing annular shoulder 50*b* formed on the lug ring 50 above the lugs 50*a* and which is also longitudinally movable with the lug ring 50 between an upper expanded position (FIG. 1A) and lower position (FIG. 2A), where the detent will radially contract to move into an annular locking recess 11*k* of a chamber defining surface 11*m* of the tubular member 11. The piston ring 52 is positioned above the detent ring 51 and is longitudinally movable along the surface 11*m* with the lug ring 50 from an upper position (FIG. 1A) to a lower position (FIG. 2A) for locking the detent 51 in the recess 11*k* where it blocks upward movement of the lug ring 50. The piston ring 52 includes a constant diameter inner surface 52*a* adjacent the surface 11*m* and a constant diameter outer surface 52*b* engaging a constant diameter inner surface 50*c* of the lug ring 50 for guiding relative longitudinal movement therebetween. The surfaces 52*a* and 52*b* mount O-rings 52*c* and 52*d*, respectively, for effecting sliding seals with the tubular member 11 and the lug ring 50 to block leakage of fluid about the piston ring 52. Sealed in this manner, the piston ring 52 provides an upwardly facing annular shoulder 52*e* and a downwardly facing annular shoulder 52*f* for a direcitonal fluid pressure to urge thereon to effect longitudinal movement of the piston ring 52. The inner surface 52*a* includes an annular locking recess 52*g* adjacent the lower annular shoulder 52*f* for blocking radial expansion of the detent 51 out of the recess 11*k* when the piston ring 52 is in the lower position to lock the ball 20 open. The lug ring 50 mounts an O-ring 50*d* on an outer surface 50*e* thereof for slidably sealing the lug ring 50 with the tubular member 11. By sealing the lug ring at this location, the lug ring 50 is provided with a pressure responsive annular effective surface area between seals effected by the O-rings 52*d* and 50*d* in order that the differential pressure urging on the piston ring 52 will also urge on this pressure responsive effective surface area for effecting the desired movement of the lug ring 50 along with the piston 52. The lug ring 50 includes an upwardly facing annular shoulder 50*f*, which will be referred to as the upwardly facing pressure responsive effective surface area of the lug ring 50 for urging downwardly movement thereof for purposes of this disclosure, and which also engages a downwardly facing annular shoulder 11*n* of the tubular member 11 to provide an upper movement limit stop for the lug ring 50. The lug ring 50 further includes a downwardly facing annular shoulder 50*g*, which will also be referred to as the downwardly facing pressure responsive effective surface area for purposes of this disclosure, for urging upwardly movement of the lug ring 50 in response to directional fluid pressure urging thereon. Mounted in the bore X below the lug ring 50 is a biasing means or spring 53 for urging the lug ring 50 to remain in the upper position until the predetermined directional pressure urges downwardly thereon.

The fluid pressure seals effected by the O-rings 50*d*, 52*c* and 52*d* block fluid communication by the lug ring 50 and the piston ring 52 for forming an upper or first chamber 55 above the lug ring 50 and a second or lower chamber 56 below the annular shoulder 52*f* of the piston ring 52 and adjacent the lugs 50*a*. The upper annular expansible chamber 55 communicates with the bore X through a port 11*p* formed in the tubular member 11 adjacent the annular shoulder 11*n* while the lower annular expansible chamber 56 communicates with the bore X through the area between the lugs 50*a* and which are spaced from the port 11*p* to enable the establishment of a fluid seal in the bore 11 therebetween. Normally, fluid pressure in the bore X is communicated into both the chamber 55 and the chamber 56 to provide equal and offsetting urging on the lug ring 50 and the piston ring 52, wherein the spring 53 maintains the lug ring 50, the piston ring 52 and the detent 51 in the upper position.

The flow housing H additionally includes a means for releasably securing the sleeve 10 with the tubular member 11 in response to a predetermined directional fluid pressure to enable normal pressure responsive opera-

tion of the ball **20** for controlling flow of fluid in the bore X comprising a plurality of four movable latch dogs **60** mounted with the tubular member **11** in a corresponding plurality of windows or apertures **11***q* which are formed equally circumferentially spaced about the tubular member **11.** The plurality of latch dogs **60** move radially to and from a retracted or free position enabling separation of the tubular member **11** from the sleeve **10** (FIG. 2A) and to and from an extended or locking position for securing the tubular member **11** with the sleeve **10** (FIG. 1A) in response to the directional fluid pressure. The casing C includes a section or joint J forming a tapered downwardly facing annular locking shoulder A engaging the latch dogs **60** in the locking position for securing the tubular member **11** by blocking upward movement of the tubular member **11** in the casing C from the sleeve **10.** When the plurality of latch dogs **60** are moved radially inwardly to the free position, the tubular member **11** may be removed from the sleeve **10** and withdrawn from the well with the production tubing below the sleeve **10** supported by the sleeve **10** and remaining in the well casing C.

The means for releasably securing the flow housing H includes a lock member **61** disposed in the tubular member **11** adjacent the latch dogs **60** and which is longitudinally movable to and from a first or lower position (FIG. 1A) for locking the latch dogs **60** in the locking position and to and from an upper or second position (FIG. 2A) for enabling the latch dogs **60** to move radially inwardly to the free position. The lock member **61** is preferably in the form of a sleeve having a constant diameter outer surface **61***a* adjacent the latch dogs **60** with a pair of spaced, tapered edged annular recesses **61***b* formed therein for receiving corresponding inwardly projecting annular collars **60***a* formed on the latch dogs **60** to enable the latch dogs **60** to move to the free position when the lock member **61** moves to the upper position to align the recesses **61***b* with the collars **60***a*. Downward movement of the lock member **61** to the lower position will cam or wedge the latch dogs **60** with the tapered edges of the recesses **61***b* to move radially outwardly to the locking position in engagement with the shoulder A and in which position the latch dogs **70** are locked by the surface **61***a* moving adjacent the latch dog collars **60***a*. Thereafter, when the lock members **61** move back to the upper position, engagement of the latch dogs **60** with the tapered annular shoulder L will wedge the latch dogs **60** radially inwardly to the free position when the tubular member **11** is elevated.

The locking member **61** mounts a pair of O-rings **61***c* and **61***d* thereon adjacent the latch dogs **60** for effecting an annular fluid seal with the tubular member **11** above and below the latch dogs **60,** respectively, for blocking leakage of fluid between the tubular member **11** and the locking member **61.**

The means for releasably securing the flow housing H further includes a detent **62** and a latch piston **63** located adjacent the locking member **61.** The detent **62** is a radially expansible gapped split ring which is longitudinally movable to and from an upper position (FIG. 2A), along a constant diameter surface **11***s* of the tubular member **11** and to and from a lower position (FIG. 1A), where it moves into a tapered edge annular recess **11***t* formed in the surface **11***s*. The latch piston **63** is a ring-shaped member positioned above the detent **62** which is also movable longitudinally to and from an upper or free position (FIG. 2A) and to and from a lower or latching position (FIG. 1A), where it blocks radial expansion of the detent **62** from the recess **11***t* with a downwardly extending concentric ring extension **63***a*. The latch piston **63** mounts a pair of O-rings **63***b* and **63***c* for effecting sliding seals with the locking member **61** and the surface **11***s* and tubular member **11** to block leakage of fluid therebetween. The locking member **61** includes an upwardly facing annular shoulder **61***e* adjacent the detent **66** which engages the detent **61** locked in the recess **11***t* to block upward movement of locking member **61** when the detent **62** is held in the recess **11***t* by the latch piston extension **63***a*. The locking member **61** is fluted at **61***f* to enable communication of fluid pressure between the shoulder **61***e* and a downwardly facing annular shoulder **61***g* which engages a lower movement limit stop ring **64** secured to the tubular member **11.** A vertically extending flow passage or port **11***u* formed in the tubular member **11** communicates the fluid pressure in the chamber **55** to the area adjacent the stop **64.**

By sealing the locking member **61** and the latch piston **63** with the O-rings **61***c*, **61***d*, **63***b* and **63***c*, a first or upper annular expansible chamber **65** is formed above and a second or lower annular expansible chamber **66** is formed below the locking member **61** and the latch piston **63.** Fluid pressure in the lower chamber **66** will urge upwardly on the locking member **61** on a downwardly facing annular pressure responsive surface area between the O-rings **61***d* and **63***b*, designated **61***h* for urging the locking member **61** to move upwardly. The pressure in the chamber **66** will also be communicated along the flukes **61***f* for urging on a downwardly facing annular pressure responsive effective surface area between the O-rings **63***b* and **63***c*, designated **63***d*, for moving the latch piston **63** to move upwardly. The flow port **11***u* communicating the chambers **55** and **66** insures that the fluid pressure in these chambers is equal and the same as the fluid pressure communicated through the port **11***p*.

Fluid pressure in the upper chamber **65** will urge on an upwardly annular facing pressure responsive effective surface area of the latch piston **63** between the O-rings **63***c* and **63***d* designated **63***e*, for moving the latch piston **63** to the lower position. The fluid pressure in the chamber **65** will also urge downwardly on an upwardly facing annular effective surface area **61***e* of the lock member **61** between the O-rings **61***c* and **63***b* to urge the lock member **61** to move downwardly. The tubular member **11** includes a flow port **11***v* formed therethrough for communicating the bore X with the chamber **65** which is spaced from the flow port **11***p* to enable the establishment of a seal therebetween in the bore X.

The well tool T includes a plurality of plug means M for controlling the directional urging of the fluid pressure to effect operation of the well tool T. The control fluid pressure is provided by connecting a pump or other fluid pressure generating source to the bore of the production tubing above the well tool T which is communicated by the plug means M positioned in the bore X of the housing H in a controlled manner to provide a predetermined directional fluid pressure for accomplishing desired operation of the well tool T. Preferably the plug means M includes a movable lug N which radially expands into a pair of annular landing recesses **11***w* formed in the bore X of the tubular mem-

ber **11** to secure and position the plug means M therewith. The plug means M may be moved through the bore of the production tubing by either a wireline or a pump-down operation to position the plug means M in the bore X.

The plug means M, which are old and well known in the art, are provided with seals and internal passages to communicate the fluid pressure above the plug means M through the ports **11***p* and **11***v* or the openings adjacent the lugs **50***a* in a manner predetermined by the selection of the plug means M to accomplish desired operation of the well tool T.

As illustrated in FIG. 1A, the plug means M includes a locking plug **70** mounting a replacable packing **70***a* thereon to seal the bore X of the housing H between the port **11***v* and the port **11***p*. The locking plug **70** includes a flow passage **70***b* formed therethrough which communicates the pressure above the plug **70** to a location adjacent the port **11***v* for communication therethrough into the chamber **65** for urging the lock member **61** and the latch piston **63** to move downwardly for locking the latch dogs **60** in engagement with the annular shoulder L for securing the tubular member **11** with the sleeve **10.** The fluid seal effected by the packing **70***a* blocks communication of this increased pressure past the plug **70** where it would be communicated into the chamber **66** and thus enables the escape of fluid from the chamber **66** into the bore X below the plug **70** as the locking member **61** and the latch piston **63** move downwardly.

As illustrated in FIG. 2A, the plug means M includes a cross-over or unlocking plug **71** mounting a plurality of replacable packings or O-rings **71***a*, **71***b* and **71***c*, for effecting three annular spaced seals along the plug **71** to block communication of fluid pressure thereacross. The unlocking plug **71** includes a first flow channel **71***d* formed therein for communicating the fluid pressure above the plug **71** to the area of the bore X adjacent the port **11**p and a vent passage **71***e* for communicating the area in the bore X adjacent the flow port **11***v* with the bore X below the plug **71.** Fluid pressure in the bore of the production tubing above the plug **71** will thus be communicated into the chamber **55** and **66** where it will urge the latch piston **63** to move upwardly to release the detent **62** from the recess **11***t* and thereafter move the latch piston **63,** the detent **52** and the lock member **61** to the upper position for enabling the latch dog **60** to move to the free position. The fluid pressure in the chamber **65** will move the lug ring **50,** the detent **51** and the locking piston **52** downwardly as a unit for moving the operator **40** and the pivot member **30** downwardly to rotate the ball **20** open and for locking the ball **20** in the open position by the movement of the detent **51** into the recess **11***k* where it will be locked by additional downward movement of the locking piston **52.** This arrangement of the plug **71** is preferred in that it allows the pulling of the production tubing and the tubular member **11** dry instead of wet.

By the use of a plug means M (not illustrated), effecting an annular seal below the flow port **11***p*, the ball **20** may be rotated and locked open by communicating the controlled pressure into the chambers **55** and **66** while preventing its communication through the openings between the lugs **50***a* and which also communicates the fluid pressure above the plug means M into the chamber **65** in order that the fluid pressure urging on the lock member **61** and the latch piston **63** are equal and offsetting and the tubular member **11** remains secured to the sleeve **10.**

In addition to the hydraulic means for releasably securing the sleeve **10** with the tubular member **11,** the means for releasably securing the flow housing H includes a mechanical manipulation release which may selectively be used to effect separation of the housing H which includes a left-hand threaded engagement at **11***x* of the tubular member **11** above the chamber **65.** A righthand rotation manipulation of the production tubing above the flow housing H will shear the threaded pin **80** and move the inner threaded sleeve **11***y* upwardly relative to the remainder of the tubular member **11** a sufficient distance to move the lock member **61** with the stop ring **64** secured to the portion **11***y* to the upper position to effect release of the latch dogs **60.**

In the use and operation of the present invention, the sleeve **10** is connected in the production tubing using the pin connection and the left-handed thread connection **10***f* is engaged with a well conduit (not illustrated) for lowering the sleeve **10** with the production tubing into the well until the shoulder **10***c* engages the shoulder S of the casing adapter N which blocks further downward movement of the sleeve **10** and the production tubing in the casing C. Right-hand rotation is then imparted to the well conduit above the sleeve **10** for disengaging the threaded connection at **10***f* to retrieve the well conduit from the casing C.

The tubular member **11** is then connected in the production tubing using the box connection and is lowered into the casing C while adding joints of tubing until the shoulder **11***c* engages the shoulder **10***a* of the sleeve **10** with the tubular member **11** telescoped within the sleeve **10** for effecting a fluid seal with packing **11***d.* When the tubular member **11** is supported on the tubular member **10,** the seal **12** effects the annular fluid seal between the tubular member **11** and the well casing C to form the upper and lower reservoirs R and P, respectively. The locking plug **71** is then run through the bore of the production tubing to be received in the bore X where it is secured by movement of the lugs N into the recesses **11***w.* Fluid pressure, normally hydraulic, is then increased in the bore X above the plug **71** which is communicated through the port **11***v* to move the locking member **61** downwardly to force the dogs **60** to the locking position for securing the tubular member **11** with the sleeve **10.** The plug **71** is then retrieved from the bore X back to the surface. The well is then completed by any suitable well known method and hydrocarbons and other well fluids are thus enabled to flow upwardly through the bore of the production tubing and the bore X of the flow housing H.

When it is desired to produce hydrocarbons and the like from the well, the pressure in the upper reservoir R is increased by a pressure generating source or means which is communicated through the port **11***j* into the chamber **44** for urging the operator **40** to move downwardly along with the engaged pivot member **30** to rotate the ball **20** to the open position.

When it is desired to close in the well at the subsurface location or a catastrophic well failure resulting in a well blow-out occurs, pressure in the upper reservoir R is decreased or otherwise vented to reduce the pressure in the chamber **44** to a pressure less than the pressure in the chamber **45** for moving the operator **40** to the upper position. The pressure in the lower reservoir P when the ball **20** is rotated open will expand the cas-

ing C below the seal 12 to provide a latent fluid pressure in the reservoir P for closing the ball 20 when the pressure in the upper reservoir R is reduced. The flow passage 40*h* is of such a small size when compared to the volume of reservoirs P and R, that the pressure equalization therebetween will not occur until after the operator 40 is moved to the upper position and is maintained in that position by the spring 31. When rotated closed, the ball 20 co-acts with the sealing element 22*a* and the O-ring 23 to substantially block upwardly flow of fluid through the bore X of the housing H and the production tubing.

A subsequent increase in pressure in the reservoir R above the pressure in the lower reservoir P will again rotate the ball 20 to the open position for enabling production of hydrocarbons and other well fluids.

When it is desired to run various well tools and the like through the bore X of the production tubing Y to a location below the well tool T and in necessary operations for completing the well, the ball 20 may be releasably locked in the open position by the use of a suitable plug means M (not illustrated) which is received and secured in the bore X of the housing H to communicate fluid pressure above the plug means M through the port 11*p* while blocking communication of that pressure to the area of the bore X adjacent the lugs 50*a*. Fluid pressure above the plug means M is then increased and communicated through the port 11*p* and into the expansible chamber 55 to urge downwardly on the upwardly facing annular shoulder 52*e* and 50*f* of the piston ring 52 and the lug ring 50, respectively, for moving the lug ring 50, the detent 51 and the piston ring 52 downwardly from the upper position, as a single engaged unit relative to the tubular member 11. When the detent 51 is adjacent the annular recess 10*k*, the detent 51 will move into the recess 10*k* and enable the piston ring 52 to move downwardly relative to both the detent 51 and the lug ring 50 for locking the detent 51 in the recess 10*k* and blocking subsequent upward movement by engagement of the lug ring 50. The downward movement of the lug ring 50 moves the operator member 40 downwardly along the pivot member 30 for rotating the ball 20 open and in which position it is locked by engagement of the lug ring 50 with the detent 51. Thereafter, differential fluid pressure in the reservoirs R and P is ineffective to rotate the ball 20 from the open position. The plug means M may thereafter be released and retrieved from the bore X to enable the running and retrieval of other well tools through the bore of the production tubing all of which is well known in the art.

When it is desired to return the ball 20 to pressure responsive operation, an unlocking plug means M (not illustrated) is run in through the bore of the production tubing in the bore X of the housing H. The unlocking plug means M communicates the increased fluid pressure to the area of the bore X adjacent the lugs 50*a* and on into the chamber 56 while blocking communication through the ports 11*p*. The pressure differential so established across the lug ring 50 and the piston ring 52 will initially move the piston ring 52 upwardly relative to the detent 51 and the lug ring 50 for releasing the detent 51 from the annular recess 10*k*. Thereafter, the differential pressure urging on the lug ring 50 and the piston ring 52 will move the lug ring 50, the detent 51 and the piston ring 52 upwardly, as a unit relative to the tubular member 11, to the upper position. This movement enables the spring 31 to urge the pivot member 30 to move upwardly for rotating the ball 20 to the closed position. The unlocking plug means M is retrieved to the surface with the ball 20 restored to the normal pressure responsive operation. Preferably in locking and unlocking the ball 20, the plug means M is suitably sealed and provided with flow passages to maintain the same fluid pressure in the chambers 65 and 66.

Should the valve malfunction for any reason, such as, but not limited to, a scored sealing surface, a broken spring or the like, the tubular member 11 mounting the ball 20 may be selectively released and retrieved without the need to pull the sleeve 10 and the lower production tubing thus enabling the use of more inexpensive workover equipment for replacement. Preferably, the ball 20 is locked open during the retrieval operation, but that operation is not required.

The preferred manner to release the tubular member 11 from the sleeve 10 is to run in the unlocking plug 71 and then increase the pressure in the bore X above the plug 71 for controlled communication into the chamber 66 while blocking communication into the chamber 65 to establish a pressure differential across the lock member 61 and the latch piston 63. Initially the latch piston 63 will move upwardly in response to the pressure to free the detent 62 and enable movement of the lock member 61 to the upper position for releasing the latch dogs 60. The initial upward movement of the tubular member 11 wedges the latch dogs 60 radially inwardly with the shoulder A. The ball 20 is then retrieved for enabling desired work to be accomplished. Thereafter, the tubular member 11 may be lowered into telescoping engagement with the sleeve 10 and be releasably secured therewith by controlled fluid pressure as set forth hereinabove.

Should the fluid pressure fail to effect release of the securing means, a right-hand rotational manipulation of the production tubing imparted to the tubular member 11 may be employed to effect release. Such rotation shears the pin 80 and enables the sleeve section 11*y* to move upwardly relative to the remainder of the tubular member 11 to move the lock member 61 to align the recesses 61*b* with the collar 60*a*. The stop ring 64 engages the lock member 61 at the shoulder 61*g* to move the lock member 61 to release the latch dogs 60.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials as well as in the details of the illustrated construction may be made without departing from the spirit of the invention..

What is claimed is:

1. A well tool adapted for connection in a production tubing including:

a. a flow housing having a bore formed therethrough and comprising a first housing portion and a second housing portion, said housing adapted for connection in the production tubing to form a portion thereof with said bore in communication with a flow passage of the production tubing for enabling flow of fluid through said bore;

b. bore closure means mounted with said flow housing for movement in said bore to and from an open position for enabling flow fluid through said bore

and to and from a closed position for blocking flow of fluid through said bore; and

c. means with said flow housing for releasably securing said first housing portion of said flow housing with said second housing portion of said flow housing, said means for releasably securing comprising means moving in response to a predetermined directional fluid pressure thereon to release said second housing portion from said first housing portion to enable removal of said bore closure means from the well.

2. The invention as set forth in claim **1**, wherein:

said means releasably securing said first housing portion of said flow housing with said second housing portion of said flow housing includes means responsive to a predetermined directional fluid pressure thereon to separate said first and second housing portions.

3. The invention as set forth in claim **1**, wherein:

said means for releasably securing said first housing portion of said flow housing with said second housing portion of said flow housing inclues means responsive to a mechanical manipulation imparted to said housing to separate said first and second housing portions.

4. The invention as set forth in claim **1**, wherein:

said means for releasably securing said first housing portion of said flow housing with said second housing portion of said flow housing includes means selectively operable to separate said first and second housing portions in response to either the urging of a predetermined directional fluid pressure or a mechanical manipulation of said housing.

5. The invention as set forth in claim **1**, wherein said means for releasably securing said first housing portion of said flow housing with said second housing portion of said flow housing includes:

a. a latch dog mounted with said flow housing and movable to and from a locking position for securing said first housing portion with said second housing portion and to and from a free position for releasing said first housing portion from said second housing portion; and

b. a lock member mounted with said flow housing and movable to and from a first position for moving said latch dogs to the locking position in response to the urging of a predetermined directional fluid pressure and to and from a second position for enabling said latch dogs to move to the free position.

6. The invention as set forth in claim **5**, wherein:

said latch dog moves radially outwardly relative to the longitudinal axis of said flow housing in moving from the free position to the locking position wherein said first portion and said second housing portion of said flow housing are secured.

7. The invention as set forth in claim **5**, wherein the apparatus is adapted for use in a well casing having a surface forming a downwardly facing shoulder and wherein:

said latch dog has a surface which moves into engagement with the shoulder when moving to the locking position wherein said flow housing is releasably secured.

8. The invention as set forth in claim **5**, including:

a plurality of latch dogs mounted with said flow housing and simultaneously movable to and from the locking position and to and from the free position.

9. The invention as set forth in claim **5**, including:

a. means with said first housing portion of said flow housing for mounting said flow housing with a well casing at a subsurface location for supporting said flow housing in the well; and

b. said bore closure means mounted with said second housing portion of said flow housing to enable removal of said bore closure means from the well when said second housing portion of said flow housing is released from said first housing portion of said flow housing.

10. The invention as set forth in claim **1**, wherein:

said bore closure means includes a ball member having a flow port formed therethrough which is rotated to and from the open position enabling flow of fluid through said flow port and to and from the closed position where said ball member blocks flow of fluid through said bore of said flow housing.

11. The invention as set forth in claim **1**, including:

means with said flow housing for effecting movement of said bore closure means to and from the open and closed position in response to a fluid pressure differential in an annular area between the production tubing and the well casing.

12. The invention as set forth in claim **1**, including:

means with said flow housing for locking said bore closure means in the open position in response to a directional fluid pressure.

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