SURFACE CONTROLLED SUBSURFACE SAFETY VALVE

This invention relates to surface controlled subsurface safety valves used in the oil and gas industry and particularly including a mechanism for temporarily locking the valves open and for remedial cycling of the valves.

It is common practice to complete oil and gas producing wells with systems including a subsurface safety valve controlled from the well surface to shut off fluid flow in the well tubing string. Generally such a valve is controlled in response to control fluid pressure conducted to the valve from a remote location at the well surface via a small diameter conduit permitting the well

to be selectively shut in as well conditions require. However, the present invention is not limited to use with safety valves that respond only to fluid pressure signals. The surface controller is typically equipped to respond to emergency conditions such as fire, broken flow lines, oil spills, etc. Frequently it is necessary to conduct well servicing operations through a subsurface safety valve. When a safety valve malfunctions, it may be necessary to install a second safety valve. In any event, it may be desirable either permanently or temporarily to lock the safety valve open. For example, if the well servicing operation requires a wireline tool string to extend through the subsurface safety valve, it is preferable to use a lock open system which is not dependent upon control fluid pressure from the well surface. When operations are being carried out through an open subsurface safety valve such as pressure and temperature testing, it can be extremely expensive and time-consuming for a valve to accidentally close on the supporting wireline causing damage to the wireline and sensing apparatus supported therefrom. Additional well servicing procedures are required to retrieve the damaged equipment. Subsurface safety valves including both permanent and temporary lock open mechanism are disclosed in United States Patents Nos. 3,786,865; 3,882,935; 4,344,602; 4,356,867; and 4,449,587. The present

invention particularly relates to a subsurface safety valve of the type concerned in United States Patents Nos. 3,786,865 and 4,449,587 employing a temporary lockout arrangement for the flapper type of valve closure included in the subsurface safety valves. These listed prior patents are incorporated by reference for all purposes in this application.

According to one aspect of the present invention, there is provided a safety valve for downhole use in a well comprising:

a. housing means having a longitudinal bore extending therethrough;

b. valve closure means mounted in the housing means to control fluid flow through the longitudinal bore;

c. the valve closure means having a first position which allows fluid flow through the longitudinal bore and a second position which blocks fluid flow therethrough;

d. an operator tube in the housing means to shift the valve closure means from its second position to its first position;

e. means for moving the operator tube in response to a control signal from the well surface; and

f. means for releasably engaging the operator tube with a shifting tool whereby the

shifting tool can cycle the valve closure means between its first and second positions.

The invention relates primarily to tubing retrievable flapper type safety valves having a housing connectable with a well tubing string and a bore therethrough for communicating well fluid flow with the tubing string, a flapper valve mounted in the housing for movement between a first open position and a second closed position, and an operator tube in the housing to shift the flapper valve between its second position and its first position. The operator tube normally moves in response to a control signal from the well surface but a shifting tool can releasably engage the operator tube for movement independent of the control signal. A lockout sleeve may be mounted in the housing in tandem with the operator tube for movement between a first position engaging and holding the flapper valve open, eg. during well servicing operations, and a second position of disengagement from the flapper valve. A shifting tool can also be provided having selective locating keys and latch dogs for releasably coupling with the operator tube and the lockout sleeve, respectively. An alternative embodiment of the present invention can be used with any type of surface controlled subsurface safety valve to cycle the valve closure mechanism if it is stuck or the control signal is inoperative.

A subsurface safety valve according to the

invention may comprise a modified operator tube and an alternative shifting tool which may be used to move the operator tube of the valve to free the operator tube or valve closure means when jammed by sand or other well debris.

It is to be noted that the term "operator tube" as used in this specification and claims refers to a fixed length tubular member that can be acted on both by the shifting tool and the movement means responsive to control signals.

The invention will now be described in more detail, purely by way of example, with reference to the accompanying drawings which also appear in our co-pending application 89.04601 relating to another invention of which they illustrate a number of embodiments. In the drawings:

Fig. 1 is a schematic sectional elevation illustrating a typical well completion including a tubing retrievable subsurface safety valve with a flapper type

valve closure means;

Figs. 2A, 2B, 2C and 2D taken together form a longitudinal part-sectional elevation illustrating a subsurface safety valve and lockout sleeve incorporating the present invention showing the safety valve in its open position;

Figs. 3A and 3B taken together form a longitudinal part-sectional elevation illustrating one embodiment of the shifting tool fo the present invention;

Fig. 4 is a section taken along the line 4-4 of Fig. 3;

Figs. 5A, 5B and 5C taken together form a longitudinal part-sectional elevation showing the safety valve of Figs. 2A to 2D with the valve closure means open, the lockout sleeve of the safety valve in its inoperative position, and the shifting tool of Fig. 3 engaged therewith;

Figs. 6A, 6B and 6C taken together form a view similar to Figs. 5A, 5B and 5C showing the shifting tool and the safety valve after shifting of the lockout sleeve to hold open the valve closure means;

Figs. 7A, 7B and 7C taken together form a view similar to Figs. 6A to 6C showing the shifting tool released from the operator tube in the safety valve after

shifting the lockout sleeve to hold open the valve closure means;

Fig. 8 is a view similar to Figs. 7B and C showing the valve closure means temporarily locked open with the shifting tool removed;

Figs. 9A and 9B taken together form a longitudinal part-sectional elevation illustrating an alternative embodiment of the shifting tool; and

Figs. 10A and 10B taken together form a longitudinal part-sectional elevation illustrating another alternative embodiment of the shifting tool.

Referring firstly to Fig. 1, a well completion 20 includes a casing string 28 extending from the well surface to a hydrocarbon producing formation (not shown), a tubing string 21 is concentrically disposed within the casing string 28 and extends from wellhead 23 through a production packer 22 which seals between the tubing string 21 and the casing 28. The packer 22 directs formation fluids, such as oil, gas, water or the like, into the tubing string 21 from perforations (not shown) in the casing 28, which perforations admit formation fluids into the well bore. Flow control valves 24a and 24b at the well surface control fluid flow from the tubing

string 21. A wellhead cap 27 is provided on the wellhead 23 to permit servicing of the well 20 via the tubing string 21 by wireline techniques which include the installation and removal of various flow control devices such as valves (not shown) from within the tubing string 21. Other well servicing operations which may be carried out through the tubing string 21 are bottom hole temperature and pressure surveys.

A surface controlled subsurface safety valve 30 embodying the features of the invention is installed in the well 20 as a part of the tubing string 21 to control fluid flow to the well surface via the tubing string 21 from a downhole location. The safety valve 30 is operated by control fluid conducted from a hydraulic manifold 25 at the well surface via a control line conduit 26 which directs control fluid signals to the safety valve 30. The hydraulic manifold 25 generally includes pumps, a fluid reservoir, accumulators, and control valves (not shown in detail) for the purpose of providing control fluid pressure signals for holding the safety valve 30 open or allowing this valve 30 to close when desired. The manifold 25 also includes apparatus which functions in response to temperature, surface line leaks, and other emergency conditions under which the well 20 should be shut in.

The safety valve 30 includes flapper type valve closure means 31 mounted by hinge 34 (see Fig. 2C) for swinging ebtween a closed position schematically represented in Fig. 1 and an open position which permits fluid flow in tubing string 21. When a predetermined pressure signal is applied to the safety valve 30 through the control line 26 from the manifold 25, the valve closure means 31 is maintained in its first or open position. When the control pressure signal is released, the valve 30 is allowed to move ot its second or closed position. A lockout sleeve 50 is provided in the valve 30 for movement between a first position which holds the valve closure means or flapper 31 open and a second position in which the valve closure means or flapper 31 is free to open or close. With the flapper 31 restrained open by the lockout sleeve 50, various well servicing operations may be conducted without fear of inadvertent closure of the valve 30 which can be damaging to the servicing equipment.

Details of the construction of a preferred form of the safety valve 30 and the lockout sleeve 50 are shown in Figs. 2A to 2D. A shifting tool 70 for operating the lock-out sleeve 50 is illustrated in Figs. 3A and 3B and will also be described in detail. The subsurface safety valve 30 has housing means 60 formed by a top sub 61a, a bottom

sub 61b, and interconnected housing subassemblies 62, 63, 64, 65 and 66 which are suitably interconnected by threaded joints as illustrated. The housing means 60 can be generally described as being a long thick-walled cylinder with a longitudinal bore 67 extending therethrough. The top and bottom subs 61a and 61b may be internally or externally threaded to provide means on opposite ends of the housing means 60 for connection with the tubing string 21 as represented in Fig. 1. The top sub 61a includes locking grooves 68 machined on its inside diameter. The locking grooves 68 provide means for installing a secondary or retrievable safety valve (not shown) within the longitudinal bore 67 if the safety valve 30 should become inoperative. The secondary valve may be designed to operate in response to the same control signal as the safety valve 30 or may be designed to respond directly to changing well conditions.

The housing subassembly 62 has a threaded connection 29 to allow connection of the control line 26 to the safety valve 30. Control fluid pressure signals are communicated from the well surface via the control line 26, the threaded connection 29, a passageway 81, and an opening 82 to the longitudinal bore 67. A cylinder 83 is positioned within the longitudinal bore 67 adjacent to the opening 82. During normal operation of the safety

valve 30, control fluid pressure signals are directed to an operator tube 40 via an annular passageway 84 formed between the inside diameter of the housing subassembly 62 and the outside diameter of the cylinder 83.

A permanent lockout sleeve 80 is slidably disposed within the longitudinal bore 67. This permanent lockout sleeve 80 is sized to fit concentrically within the cylinder 83. During normal operation of the safety valve 30, a knockout plug 85 holds the permanent lockout sleeve 80 in its inactive position shown in Fig. 2A. If the safety valve 30 should become inoperative, a profile 86 on the inside diameter of the permanent lockout sleeve 80 can be engaged by a suitable shifting tool (not shown) to force the sleeve 80 into abutting contact with the operator tube 40 and to open the safety valve 30. Movement of the sleeve 80 causes the knockout plug 85 to shear, allowing communication fo control fluid pressure signals therethrough, A snap ring 87 is carried by the housing subassembly 62 within the longitudinal bore 67 to lock the sleeve 80 in place after it has moved. Matching teeth 88 are carried on the outside diameter of the sleeve 80 and the inside diameter of the snap ring 87. The use of locking grooves or recesses 68, the permanent locking sleeve 80, and associated components to instal a secondary safety valve within a bore, such as the longitudinal bore 67, is well known in the art.

Operator tube 40 is slidably disposed within the longitudinal bore 67 to shift the valve closure means 31 from its second, closed position to its first, open position as shown in Fig. 2C. For ease of manufacture and assembly, the operator tube 40 is constructed from two generally hollow cylindrical subassemblies designated 40a and 40b. These subassemblies 40a and 40b are joined together by a threaded connection 41. Movable piston seal means 42 is carried on the exterior of the operator tube 40 to form a sliding fluid barrier with the inside diameter of the housing subassembly 63 adjacent thereto. Stationary seal means 43 is carried by the cylinder 83 to form a fluid barrier with the exterior of the operator tube 40. The stationary seal means 43, the movable piston seal means 42, and the exterior of the operator tube 40 therebetween define in part a variable volume control fluid chamber 48. Control fluid pressure from the annular passageway 84 is received within the chamber 48 to act upon the piston seal means 42 and to slide the operator tube 40 longitudinally towards the valve closure means 31 in response thereto. Biasing means in the form of a spring 44 is carried on the exterior of the operator tube 40 between a shoulder 64a on the inside diameter of the housing subassembly 64 and a shoulder 45 on the exterior of the operator tube 40. This biasing means 44 applies a force to shift the operator tube 40 longitudinally opposite from control

fluid pressure in the chamber 48. When control fluid pressure in the chamber 48 is decreased below a pre-selected value, the spring 44 moves the operator tube 40 longitudinally upwards to allow the valve closure means 31 to return to its closed position. A spring 35 coiled around the hinge 34 also assists in moving the flapper 31 to its closed position.

A selective key profile 46 is formed on the interior of the operator tube 40 intermediate the ends thereof. This profile 46 provides means for releasably engaging the operator tube 40 with a shifting tool whereby the shifting tool can move the operator tube 40 independently of the control signal. The use of shifting tools 70, 170, and 270 with respect to the profile 46 and the operator tube 40 will be described later in detail. The configuration and dimensions of the profile 46 are selected to be different from the locking recess 68 and the profile 86. Therefore, the operator tube 40 can be engaged only by a shifting tool having selective keys which the match profile 46.

The lockout sleeve 50 which is a second lockout sleeve, is slidably disposed in the housing means 60 in tandem with the operator tube 40. In comparison to first lockout sleeve 80, the second sleeve 50 can be classified as a temporary lockout device. This lockout sleeve 50

has a first position, shown in Fig. 8, which holds the valve closure means 31 in its first position, and a second position, shown in Fig. 2D, which does not restrict movement of the valve closure means 31 between its first and second positions. As shown in Figs. 2D and 8, the lockout sleeve 50 has a relatively smooth uniform inside diameter. Therefore, it is difficult for a wireline tool accidentally to engage the lockout sleeve 50 and shift it to an undesired position. The smooth, uniform inside diameter of the lockout sleeve 50 is an important preferred feature of the present invention.

A plurality of longitudinal slots 51 are machined through the sleeve 50 intermediate the ends thereof. These slots 51 are circumferentially spaced to provide a plurality of collet fingers 52. An external boss 53 is provided on each collet finger 52. Internal grooves 54 and 55 are provided on the interior of the housing subassembly 66 to receive the bosses 53 therein. The grooves 55 and 54 are spaced longitudinally from each other to correspond respectively with the first position and second position for the lockout sleeve 50. The collet fingers 52, the bosses 53, and the grooves 54 and 55 cooperate to provide means for releasably holding the lockout sleeve 50 in its first or second position.

Longitudinal movement of the lockout sleeve 50 within the longitudinal bore 67 is limited by a shoulder 66a on the interior of the housing subassembly 66 contacting a shoulder 57 on the exterior of the sleeve 50 and by the sleeve 50 resting on a spacer ring 69. As best shown in Fig. 2D, the inside diameter of the spacer ring 69 is larger than either the sleeve 50 or the bottom sub 61b of the housing. The spacer ring 69 is used to define a recess 58 in the housing means 60 below the lockout sleeve 50. It will be explained later how the recess 58 is used to shift the lockout sleeve 50 to its first position.

The shifting tool 70, shown in figs. 3A and B, is used to shift the lockout sleeve 50 from its second to its first position. This shifting tool 70 is adapted for insertion into the longitudinal bore 67 by use of conventional wireline techniques. The shifting tool 70 has an inner mandrel or core means 71 slidably disposed within cylindrical housing means 72. For ease of manufacture and assembly, the core means 71 comprises several subsections 71a, 71b and 71c. The subsections 71a and 71b are two generally solid cylindrical rods connected to each other by threads 73. A fishing neck 74 is provided on the upper end of the subsection 71a which extends from housing means 72. This fishing neck

74 provides means for attaching the shifting tool 70 to a conventional wireline tool string (not shown).

The housing means 72 comprises several generally hollow cylindrical subsections designated 72a, 72b, and 72c which are attached to each other by appropriate threaded connections. During initial insertion of the shifting tool 70 into the longitudinal bore 67, a first releasable means, in the form of a shear pin 75, extends through both the core means 71 and the housing means 72, as shown in fig. 3A, to prevent undesired relative longitudinal movement therebetween.

A plurality of selective keys 76 are disposed within windows 77 extending through the housing subsection 72a. Leaf springs 78 are carried on the inside diameter of the subsection 72a adjacent to these selective keys 76. The springs 78 are designed to project the keys 76 radially outward through the windows 77. The core means 71 has a reduced diameter portion 91 which allows the keys 76 to be compressed radially inward by restrictions in either the tubing string 21 or the safety valve 30. The shear pin 75 is used to hold the reduced diameter portion 91 radially adjacent to the keys 76 during insertion of the tool 70. A plurality of bosses 92 are provided on the reduced diameter portion 91 adjacent to each key 76.

The bosses 92 and the interiors of the keys 76 are designed to allow inward compression of the keys 76 when the shear pin 75 is installed.

The keys 76 each have an exterior profile which matches the profile 46 of the operator tube 40. Engagement of the keys 76 with the profile 46 prevents further downward movement of the shifting tool 70 relative to the safety valve 30 due to the presence of square shoulders 93 and 94 (see Figs. 3A and 2B). Force can then be applied to the core means 71 to shear the pin 75 and slide the core means 71 longitudinally relative to the housing means 72. This longitudinal movement positions the bosses 92 radially adjacent to and contacting a portion of their respective keys 76 to lock the keys 76 radially projected as shown in Fig. 5A.

A second shear pin 95 is carried by the housing subsection 72a and is biased radially inwards by a leaf spring 96. The exterior of the core means 71 has an annular groove 97 formed on its exterior. The location of this annular groove 97 is selected so that the shear pin 75 will normally hold the groove 97 spaced longitudinally from the second shear pin 95. When the core means 71 moves relative to the housing means 72, the groove 97 is designed to be engaged by the second shear

pin 95. The groove 97 and the shear pin 95 cooperate to provide second releasable means for preventing undesired relative movement between the core means 71 and the housing means 72 to hold the keys 76 radially expanded.

The shifting tool 70 has a plurality of latching dogs 100 spaced longitudinally from the selective keys 76. These latching dogs 100 are slidably disposed within second windows 101 of the housing subsection 72c. A leaf spring 102 is provided to project each dog 100 radially outward. The inner core means section 71c has a reduced diameter portion 103 which allows the dogs 100 to be compressed radially inward by restricting in the tubing string 21 including portions of the safety valve 30. The dogs 100 are specifically sized to fit within the recess 58 below the lockout sleeve 50.

The shear pin 75 normally holds the reduced diameter portion 103 radially adjacent to the dogs 100. When the pin 75 is sheared, the core means 71 can move longitudinally to position an enlarged outside diameter portion 104 of subsection 71c radially adjacent to the dogs 100. The enlarged portion 104 prevents the dogs 100 from flexing radially inwards. The second shear pin 95 and the annular groove 97 cooperate to lock the dogs 100 radially expanded.

Operating sequence

For purposes of describing the operation of this embodiment, it will be assumed that the safety valve 30 is installed in a well completed as shown in Fig. 1. Control fluid pressure is communicated from the manifold 25 via the control line 26 to the housing means 60 of the safety valve 30. Using standard well servicing techniques and surface wireline equipment (not shown), the shifting tool 70 is introduced into the tubing string 21 via the wellhead cap 27.

In Figs. 5A, 5B, and 5C, the safety valve 30 is shown in its first position with control fluid pressure in the chamber 48 acting on the operator tube 40 to hold the flapper 31 open. A wireline tool string (not shown) would be attached to the fishing neck 74 to enable the shifting tool 70 to be manipulated within the longitudinal bore 67. The selective keys 76 are engaged with the profile 46 in the operator tube 40 to prevent further downward movement of the shifting tool 70 relative to the safety valve 30. This engagement allows force to be applied to the fishing neck 74 by the wireline tool string to shear the pin 75 into two pieces 75a and 75b as shown in fig. 5A. The force applied to the fishing neck 74 causes the inner core means 71 to slide longitudinally downward until the fishing neck 74 rests on the top of the housing means 72. This downward movement of the

core means 71 will position the bosses 92 behind their respective keys 76 and the enlarged outside diameter portion 104 behind the dogs 100. Leaf spring 96 will force the shear pin 95 into the annular recess 97 which locks the keys 76 and the latching dogs 100 in their radially expanded conditions.

With the safety valve 30 and the shifting tool 70 positioned as shown in figs. 5A, 5B, and 5C, the next step towards temporarily locking open the safety valve 30 is to decrease control fluid pressure in the chamber 48 below a preselected value. Since the keys 76 are locked into the profile 46 and the latching dogs 100 are locked outward into the recess 58, the operator tube 40 and the lockout sleeve 50 must move in unison. Force can be applied to the shifting tool 70 via the wireline attached to the fishing neck 74 to assist the spring 44 in shifting the operator tube 40 to its second position and the lockout sleeve 50 to its first position as shown in Figs. 6A, 6B, and 6C.

With the lockout sleeve 50 in its first position, additional upward force can be applied to the fishing neck 74 to shear the pin 95 into two pieces as indicated at 95a and 95b. The inner core means 71 is then free to move to its initial longitudinal position with respect to the housing means 72 which allows the keys 76 and the

latch dogs 100 to be compressed raially inward. Figs. 7A and 7B show the shifting tool 70 in this configuration while it is being withdrawn from the longitudinal bore 67.

The final result of these operations is shown in Fig. 8. The lockout sleeve 50 is in its first position holding the flapper 31 open. The operator tube 40 has been returned to its second position. The shifting tool 70 has been removed from the longitudinal bore 67. As previously noted, the smooth uniform inside diameter of the lockout sleeve 50 greatly reduces the possibility of a wireline service tool or tools accidentally shifting the sleeve 50 and returning it to its second position. When the desired well maintenance has been completed, the safety valve 30 can be returned to normal operation by simply applying control fluid pressure to the chamber 48. This pressure causes the operator tube 40 to move to its first position. During this movement the operator tube 40 abuts the second lockout sleeve 50 and returns such sleeve 50 to its second position.

During the initial installation of the tubing string 21 withing the casing 28, the lockout sleeve 50 can be used to check the integrity of the control line 26 and the proper functioning of the safety valve 30. During installation, the safety valve 30 is preferably

attached to the tubing string 21 with the valve closure means 31 and the lockout sleeve 50 both in their first position. The collet fingers 52, the bosses 53 and the groove 55 are designed to allow a substantial amount of control fluid pressure to be applied to the chamber 48 before the operator tube 40 can shift the lockout sleeve 50 to its second position. By applying less than this amount of pressure to the control line 26 from the manifold 25, the integrity of the control line 26 can be monitored. A drop in the control line pressure or a decrease in control fluid level at the manifold 25 indicates a possible leak in the control line 26 which should be investigated before completing the well 20. After the tubing string 21 is properly disposed within the casing 28, sufficient pressure can be applied to the control line 26 to shift the lockout sleeve 50 to its second position. Proper operation of the safety valve 30 can be verified by monitoring the control line pressure and volume required for this shifting.

Alternative Embodiments

The above description has been directed towards an operator tube which opens a flapper type valve closure means. U.S. Patent 3,860,066 to Joseph L. Pearce el al demonstrates that the operator tube 40 could be modified to open and close ball type and poppet type valve

closure means as alternatives to the flapper 31. Therefore, the present invention is not limited to flapper valves. The shifting tool 170 shown in Figs. 9A and 9B may be used to cycle any type of valve closure means between its open and closed position as long as the valve operator tube has been modified for releasable engagement with the tool 170. Generally, the shifting tool 170 will be used to open the valve closure means, However, it could be used to move the operator tube 40 to close the valve closure means if required.

Some components and features of the shifting tool 170 are identical to those of the shifting tool 70 and have given the same (reference numerals). The principal structural differences between the shifting tool 170 and the above-described shifting tool 70 are the replacement of the fishing neck 74 by an equalising valve and packing assembly 180 and removal of the core means subsections 71b and 71c and the housing means subsections 72b and 72c. The principal operating differences are that the equalising valve and packing assembly 180 allows fluid pressure in the tubing string 21 to be applied to the operator tube 40, and latching dogs 100 are not provided to shift the lockout sleeve 50.

The equalising valve and packing assembly 180 as shown in Fig. 9A includes a fishing neck 174 for attachment to a standard wireline tool string. This fishing neck 174 is connected by threads to a poppet valve plunger 181 which is slidably disposed in a valve housing 182. Ports 183 communicate fluid between the interior and exterior of the valve housing 182. A valve seat 184 is disposed within the valve housing 182 for engagement with the valve plunger 181.

A packing carrier 185 is attached to the valve housing 182 by threads 187. Packing or seal means 186 is carried on the exterior of the packing carrier 185. The dimensions of the seal means 186 are selected to form a fluid barrier with the inside diameter of the housing top sub 61a when the shifting tool 170 is engaged with the operator tube 40. A hollow longitudinal spacer 188 is used to attach the packing carrier 185 to the core means section 71a by suitable threaded connections. A longitudinal flow passageway 189 extends through the valve housing 182, the packing carrier 185 and the spacer 188. A prot 190 communicates between the exterior of the spacer 188 and the longitudinal flow passageway 189.

During installation of the shifting tool 170, the plunger 181 is spaced longitudinally above the valve

seat 184 to allow fluid in the tubing string 21 to bypass the seal means 186. When the keys 76 engage the profile 46, the plunger 181 is lowered to contact the valve seat 184 to block fluid flow via the longitudinal passageway 189. The length of the spacer 188 is preferably selected so that the seal means 186 form a fluid barrier with the inside diameter of housing bottom sub 61a immediately below the locking recesses 68. Hydraulic fluid pressure can then be applied from the well surface via the tubing string 21 to act on the seal means 186. Since the effective piston area of the seal means 186 is much larger than the piston seal means 42 carried by the operator tube 40, the shifting tool 170 can apply considerably more force to the operator tube 40 to cycle the valve closure means 31. This feature may be particularly desirable for ball type valve closure means. Also, the spacer 188 could be removed if the operator tube 40 is modified to allow the seal means 186 to form a fluid barrier therewith.

The shifting tool 170 is released from engagement with the operator tube 40 in the same manner as previously described for the shifting tool 70. When sufficient upward force is applied to the fishing neck 174 to shear the pin 95, the core means subsection 71a will move upwards to allow the keys to be compressed

radially inwards.

The above described has also been directed towards a safety valve which is opened and closed in response to a hydraulic fluid control signal from the well surface. The present invention can be used with any type of safety valve control signal including electrically operated valves such as shown in U.S. Patent 3,731,742 to Phillip S. Sizer et al or U.S. Patent 4,002,202 to Louis B. Paulos et al.

Another alternative embodiment of the present invention involves shifting tool 270 shown in Figs. 10A and 10B and allows both the opening of a safety valve and locking the valve open, if desired, without regard to the presence of the valve's normal control signal. This embodiment is particularly important as a backup feature for safety valve control systems which use electrical, electronic, sound, electro-hydraulic, hydraulic pilot or similarly sophisticated control systems. During periods when the sophisticated control systems are being repaired, the shifting tool 270 allows a safety valve having an operator tube with the profile 46 and the lockout sleeve 50 to be temporarily locked open without regard to the presence of the normal control signal. A direct-acting safety valve would preferably be installed until repair of the

control system had been completed. Therefore, the present invention is not limited to hydraulically controlled safety valves and may in fact provide sufficient reliability to make more complicated control systems commercially acceptable for downhole safety valves.

In the event of a serious control line leak, it may not be desirable to use the permanent lockout sleeve 80 to shift the valve closure means 31 to its first position because formation fluids can then escape via the control line leak. The shifting tool 270 allows the valve closure means 31 to be locked open without the use of control fluid pressure and without disturbing the permanent lockout sleeve 80. A direct acting safety valve or STORM CHOKE (Registered Trade Mark) safety valve which does not require hydraulic control fluid can then be installed within the longitudinal bore 67 to maintain well safety. Prior to the present invention, the only solution to a serious control line leak was to remove the tubing string 21 from the well bore, which is a very expensive procedure.

The shifting tool 270 is substantially identical with the shifting tool 70, except that the fishing neck 74 has been replaced by the equalising valve and packing assembly 180 of the shifting tool 170. The shifting tool

270 can use fluid pressure in the tubing string 21 to open the valve closure means 31 as previously described for the shifting tool 170. The shifting tool 270 can be manipulated by a wireline tool string attached to the fishing neck 174 to shift the lockout sleeve 50 to its first position as previously described for the shifting tool 70.

CLAIMS

1. A safety valve for downhole use in a well comprising:

a. housing means having a longitudinal bore extending therethrough;

b. valve closure means mounted in the housing means to control fluid flow through the longitudinal bore;

c. the valve closure means having a first position which allows fluid flow through the longitudinal bore and a second position which blocks fluid flow therethrough;

d. an operator tube in the housing means to shift the valve closure means from its second position to its first position;

e. means for moving the operator tube in response to a control signal from the well surface; and

f. means for releasably engaging the operator tube with a shifting tool whereby the shifting tool can cycle the valve closure means between its first and second positions.

2. A safety valve as claimed in claim 1 wherein the releasable engaging means further comprises a profile provided on the interior of the operator tube to receive selective keys on the shifting tool.

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3. A safety valve as claimed in claim 2 further comprising:

a. a lockout sleeve in the housing means in tandem with the operator tube;

b. the lockout sleeve having a first position which holds the valve closure means in its first position and a second position which does not restrict movement of the valve closure means between its first and second positions;

c. the lockout sleeve having a relatively uniform inside diameter to prevent accidental shifting of the lockout sleeve by a well tool or tools moving through the longitudinal bore; and

d. releasable holding means for releasably holding the lockout sleeve in either its first position or its second position.

4. A safety valve as claimed in claim 3 wherein the releasable holding means comprises circumferentially spaced longitudinal collet fingers having external bosses and the housing means includes spaced internal grooves for engagement with the bosses on the collet fingers.

5. A safety valve as claimed in claim 3 or claim 4 in combination with a shifting tool:

a. the shifting tool adapted for insertion into the longitudinal bore;

b. selective keys on the shifting tool to releasably engage the profile of the operator tube;

c. latch dogs carried by the shifting tool and spaced longitudinally from the selective keys;

d. the latch dogs sized to abut the lower end of the lockout sleeve when the selective keys are located in the profile of the operator tube; and

e. the shifting tool providing means for moving the lockout sleeve in unison with the operator tube when the selective keys are in the profile and the latch dogs abut the lower end of the lockout sleeve.

6. A combination as claimed in claim 5 wherein the housing means includes a recess below the lockout sleeve to allow the latch dogs to abut the lower end thereof.

7. A combination as claimed in claim 6 wherein the shifting tool further comprises seals carried on the exterior of the shifting tool to form a fluid barrier within the safety valve whereby the fluid pressure can be applied to the shifting tool from the well surface to shift



the valve closure means from its second position to its first position.

8. A safety valve as claimed in any one of claims 2 to 4 in combination with a shifting tool, in which the shifting tool is adapted for insertion into the longitudinal bore and selective keys are provided on the shifting tool releasably to engage the profile of the operator tube, and further including force applying means for applying force to the shifting tool to move the operating tube in response thereto.

9. A combination as claimed in claim 8 wherein the force applying means comprises seals carried on the exterior of the shifting tool to form a fluid barrier with the interior of the safety valve whereby fluid pressure can be applied to the shifting tool from the well surface to shift the valve closure means from its second position to its first position.

10. A surface controlled subsurface tubing supported well safety valve comprising:

a. tubular housing means having a longitudinal bore therethrough and means at opposite ends for connecting the housing means in a well tubing string to form a portion thereof;

b. valve closure means mounted in the housing means to control fluid flow through the

longitudinal bore;

c. the valve closure means having a first position which allows fluid flow through the longitudinal bore and a second position which blocks fluid flow therethrough;

d. an operator tube in the housing means to shift the valve closure means from its second position to its first position;

e. an annular piston means on said operator tube for moving the operator tube and valve closure means to their first position;

f. the housing means in combination with the piston means partially defining a control fluid chamber around the piston means;

g. the housing means having passage means to the chamber for conducting control fluid to the chamber to move the operator tube;

h. means for biasing the operator tube in a direction to shift the valve closure means to its second position;

i. means for releasably engaging the operator tube with a shifting tool whereby the shifting tool can move the operator tube independent of the control fluid;

j. the releasable engaging means including a selective key profile provided on the interior of the operator tube for releasable engagement by the shifting tool.

* C L M S *

11. A safety valve as claimed in claim 10 further comprising:

a. a lockout sleeve in the housing means in tandem with the operator tube;

b. the lockout sleeve having a first position which holds the valve closure means in its first position and a second position which does not restrict movement of the valve closure means between its first and second position;

c. the lockout sleeve having a relatively uniform inside diameter to prevent accidental shifting of the lockout sleeve by well tools moving through the longitudinal bore; and

d. means for releasably holding the lockout sleeve in either its first position or its second position.

12. A safety valve as defined in claim 11 in combination with a shifting tool wherein the shifting tool comprises:

a. latch dogs and spaced longitudinally from selective keys provided on the shifting tool for releasably engaging the key profile on the operator tube;

b. the latch dogs being sized to abut the lower

end of the lockout sleeve when the selective keys are located in the profile of the operator tube;

c. the shifting tool providing means for moving the lockout sleeve in unison with the operator tube when the selective keys are in the profile and the latch dogs abut the lower end of the lockout sleeve; and

d. a recess below the lockout sleeve to allow the latch dogs to abut the lower end thereof.

13. A combination as claimed in claim 12 wherein means for applying force to the shifting tool for movement of the operator tube in response thereto comprises seals carried on the exterior of the shifting tool to form a fluid barrier with the interior of the safety valve whereby fluid pressure can be applied to the shifting tool from the well surface to shift the valve closure means from its second position to its first position.

14. A surface controlled subsurface tubing-supported well safety valve comprising:

a. tubular housing means having a longitudinal bore therethrough and means at opposite ends for connecting the housing means in a well tubing string to form a portion thereof;

b. valve closure means mounted in the housing

means to control fluid flow through the longitudinal bore;

c. the valve closure means having a first position which allows fluid flow through the longitudinal bore and a second position which blocks fluid flow therethrough;

d. an operator tube in the housing means to shift the valve closure means from its second position to its first position;

e. an annular piston means on said operator tube for moving the operator tube and valve closure means to its first position;

f. the housing means in combination with the piston means partially defining a control fluid chamber around the piston means;

g. the housing means having passage means to said chamber for conducting control fluid to the chamber to move the operator tube;

h. means for biasing the operator tube in a direction to shift the valve closure means to its second position;

i. means for releasably engaging the operator tube with a shifting tool whereby the shifting tool can move the operator tube independent of the control fluid;

j. a lockout sleeve in the housing means in tandem with the operator tube;

k. the lockout sleeve having a first position

which holds the valve closure means in its first position and a second position which does not restrict movement of the valve closure means between its first and second positions;

l. the lockout sleeve having a relatively uniform inside diameter to prevent accidental shifting of the lockout sleeve by well tools moving through the longitudinal bore; and

m. means for releasably holding the lockout sleeve in either its first position or its second position.

15. A safety valve as claimed in claim 14 in combination with the shifting tool further comprising:

a. the shifting tool adapted for insertion into the longitudinal bore;

b. selective keys on the shifting tool to releasably engage the profile of the operator tube;

c. latch dogs carried by the shifting tool and spaced longitudinally from the selective keys;

d. the latch dogs sized to abut the lower end of the lockout sleeve when the selective keys are located in the profile of the operator tube; and

e. the shifting tool providing means for moving the lockout sleeve in unison with the operator tube when the selective keys are in the profile and the latch dogs abut the lower end of the lockout sleeve.

16. A safety valve as claimed in claim 15 wherein the housing means includes a recess below the lockout sleeve to allow the latch dogs to abut the lower end thereof.

17. A method of operating a surface controlled sub-surface safety valve having an operator tube and a valve closure means with the safety valve positioned in a tubing string to control fluid flow at a downhole location in a well comprising:

a. inserting a shifting tool into the operator tube from the well surface via the tubing string;

b. releasably engaging the shifting tool with a selective key profile in the interior of the operator tube;

c. forming a fluid barrier within the interior of the safety valve;

d. applying fluid pressure from the well surface to act upon the fluid barrier to shift the operator tube and to open the valve closure means;

e. engaging a lockout sleeve in the safety

valve with the shifting tool; and

f. moving the lockout sleeve and operator tube in unison to a position whereby the lockout sleeve holds the valve closure means open.

18. The method of claim 17 further comprising engagement of selective keys on the shifting tool with the selective profile and latch dogs on the shifting tool abutting the lower end of the lockout sleeve.

19. The method of claim 18 further comprising using a wireline attached to the shifting tool from the well surface to move the operator tube and lockout sleeve in unison to hold open the valve closure means.

20. The method of claim 19 further comprising:

a. removing the shifting tool from within the operator tube; and

b. installing a direct acting safety valve at a downhole location in the tubing string.

21. A combination of safety valve and shifting tool for downhole use in a well, the safety valve comprising:

a. housing means having a longitudinal bore extending therethrough;

b. valve closure means mounted in the housing means to control fluid flow through the longitudinal bore;

c. the valve closure means having a first position which allows fluid flow through the longitudinal bore and a second position which blocks fluid flow therethrough;

d. an operator tube in the housing means to shift the valve closure means from its second position to its first position;

e. means for moving the operator tube in response to a control signal from the well surface;

f. a lockout sleeve in tandem with the operator tube for holding the valve closure means in its first position;

the shifting tool comprising:

g. inner core means slidably disposed within a housing means;

h. means for attaching one end of the inner core means to a wireline tool string;

i. first means for releasably engaging the inner core means to the housing means to prevent relative movement therebetween;

j. selective profile keys projecting radially through first windows in the housing means;

k. latch dogs projecting radially through second windows in the housing means and spaced longitudinally from the selective keys;

l. the first releasable engagement means

holding the inner core means in its first position which allows compression of the selective keys and latch dogs radially inward;

m. second means for releasably engaging the inner core means to the housing means and holding both the selective keys and the latch dogs radially expanded:

the shifting tool providing means for moving the lockout sleeve in unison with the operator tube when the selective keys are engaged with a profile of the operator tube and the latch dogs abut the lower end of the lockout sleeve.

22. The method of operating a surface controlled subsurface safety valve having an operator tube and a valve closure means to cycle the valve closure means between its open and closed positions comprising:

a. inserting a shifting tool into the operator tube from the well surface via the tubing string;

b. releasably engaging the shifting tool with a selective key profile in the interior of the operator tube; and

c. applying force to the shifting tool to cycle the valve closure means between its open and closed positions.

23. A safety valve substantially as hereinbefore

described with reference to and as illustrated in Figs. 1 to 8, in Figs. 9A and 9B, or in Figs. 10A and 10B of the accompanying drawings.
