SAFETY VALVE FOR USE IN WELLS

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ABSTRACT
A differential pressure safety valve for use in oil and gas wells and the like which comprises an elongated tubular element having upper and lower ends connected by a bore. An annular seat is positioned in the upper portion of the elongated tubular element, and a valve closure member is positioned below the seat. A valve stem is connected to the valve closure member and extends downwardly in the tubular element bore. A piston element is secured to the lower end of the valve stem, and is slidingly positioned in the tubular element bore with a portion of the piston element projecting from the lower end of the tubular element. Plug means sealingly surrounds the valve stem within the bore of the tubular element between the piston element and the valve closure member. A radial port is formed through the wall of the tubular element in communication with the bore at a location between the seat and the plug means. An adjustable resilient control means is located externally of the tubular element, and cooperates with the projecting portion of the piston element to resiliently bias the piston element in a direction away from the annular seat with a predetermined force. A by-pass conduit is connected to by-pass fluid from a point in the bore of the tubular element between the plug means and the piston element, to a point in the bore of said tubular element located above said annular seat.

19 Claims, 6 Drawing Figures
SAFETY VALVE FOR USE IN WELLS

BACKGROUND OF THE INVENTION

1. Field of the Invention
This invention relates to downhole devices and structures used in the production of fluids from subterranean locations to the surface, and more particularly, to a pressure differential operated safety valve which can be run into a bore hole in the earth to obstruct fluid communication between a lower portion of the hole and the surface at a time when the pressure differential across the safety valve exceeds a predetermined value.

2. Brief Description of the Prior Art
A problem which is encountered in the production of oil and gas is one in which a substantial pressure drop occurs in the production tubing at or near the surface of the well, thus causing a dangerous or economically disastrous situation. For example, where a well head is accidentally damaged or destroyed by a bulldozer or, in the case of offshore wells, by an anchor dragging, the chokes or other mechanisms used to effectively restrict the pressure at the surface of the well, and thus control production of oil and gas from the well, are destroyed or damaged, and the result is a wild well or one in which valuable hydrocarbons are lost, or the most economic and efficient production thereof cannot be realized. Moreover, loss of pressure controls at the surface frequently constitutes a serious hazard to operating personnel in the vicinity.

Although one approach to the avoidance of pressure drop problems of the type described has been to incorporate pressure differential valves of various types at various depths within the production tubing or within a casing, such valves have not been sufficiently dependable, or have been associated with difficulties of installation or cost such that they are not widely employed.

BRIEF DESCRIPTION OF THE PRESENT INVENTION

The present invention provides an improved, highly reliable safety valve for location at substantially any depth in a well bore, which valve is operated by variations in the pressure drop across the valve, and which can be used either in an uncased, open bore hole, or in association with production tubing or well casing.

Broadly described, the safety valve structure of the present invention comprises an elongated tubular element having an upper end and a lower end with a bore extending therebetween. An annular seat is removably positioned in the bore, and a valve closure member is positioned in the bore below the seat. The valve closure member is positioned on the upper end of an elongated valve stem extending downwardly in the bore. Sealing means surrounds the stem below the valve member to form and seal between the stem and the tubular element, yet facilitate sliding movement of the stem through the sealing means.

A piston is secured to the lower end of the valve stem and is slidingly positioned in the bore of the tubular element with a portion of the piston projecting out of the lower end of the tubular element. An adjustable resilient control means is located externally of the tubular element, and cooperates with the projecting portion of the piston to resiliently bias the piston downwardly in the bore in the tubular element and communicates with the bore at a location between the seat and the sealing means. By-pass conduit means is provided for establishing fluid communication between a first location in the bore between the piston and sealing means, and a second location in the bore at a point above the seat.

The safety valve functions by the closure of the valve closure member against the seat to interrupt fluid flow from a well bore exterior of the tubular element, through the radial port, through the seat and upwardly in a tubing string to which the safety valve is attached. Pressure below the seat is also then isolated from pressure above the seat. The closure of the valve closure member is effected by the development of a differential pressure between a location above the valve seat at the upper end of the by-pass conduit means and a location below the tubular element where fluid pressure acts on the relatively large cross sectional area of the protruding portion of the piston which extends below the tubular element. A pressure differential of a predetermined magnitude will be effective to bring about closure of the valve closure member to isolate the upper portion of the tubing string from that portion of the well bore so or above the radial port. The predetermined pressure differential which will close the valve is determined by the particular setting of the adjustable resilient control means which is located externally of the tubular element, and therefore readily accessible for selective adjustment prior to the lowering of the safety valve into the well bore.

The present invention is further directed, in one usage, to a particular combination of the safety valve hereinafore described with a down hole dual packer device utilized for cementing on opposite sides of a production zone without cementing across the face of the production zone.

In a preferred embodiment of the safety valve of the invention, the annular seat is made removable from the tubular element so that it can be replaced with a seat having a differently sized opening formed therethrough and thus different pressure drops across the seat can be accommodated if changing needs within the well bore so dictate. Moreover, a preferred embodiment of the invention also includes a mercury pool and column located above the piston and extending upwardly in the by-pass conduit means to prevent the infiltration of dirt or trash from the tubing string above the seat into an enclosed space defined as that segment of the well bore between the plug and the piston.

An important object of the invention is to provide an improved safety valve for use in well bores or in down hole locations, whether within a tubing or casing, or in an uncased well bore, for isolating a relatively high pressure zone in the lower portion of the well bore from a relatively low pressure zone in the upper portion of the well bore.

A further object of the invention is to provide a safety valve which is simple and economical in construction and is reliable in use.

An additional object of the invention is to provide a safety valve for use in down hole locations during the production of oil and gas, which safety valve includes a removable seat which can easily be changed out by the use of appropriate tools extended into the well bore for that purpose, without removing the entire safety valve, thereby permitting valve seats of differing di-
dimensions and flow capacities to be changed out in the safety valve.

Additional objects and advantages of the invention will become apparent as the following detailed description of the invention is read in conjunction with the accompanying drawings which illustrate the invention.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1a is a sectional view showing the upper portion of the safety valve structure of the present invention as it is used in combination with a dual packer well cementing tool in which it is incorporated.

FIG. 1b is a vertical sectional view showing that portion of the safety valve and dual packer combination tool which is located immediately below that portion of the tool shown in FIG. 1a.

FIG. 2 is a sectional view taken along line 2—2 of FIG. 1b.

FIG. 3 is a sectional view taken along line 3—3 of FIG. 1b.

FIG. 4 is a sectional view taken along line 4—4 of FIG. 1b.

FIG. 5 is a view of the safety valve of the present invention disposed in an uncased well bore and showing parts of the tool in section and parts thereof in elevation.

**DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION**

Referring initially to FIGS. 1a and 1b of the drawings, shown therein is the combination safety valve and dual packer tool of the present invention as it appears when located in the lower portion of a cased well bore. The casing which cases the well bore is designated by reference numeral 10, and the production tubing string disposed within this casing is designated by reference numeral 12. The combination safety valve and dual packer tool of the invention is designated generally by reference numeral 14.

The tool 14 is positioned in the tubing string 12 by means of suitable joints, and is positioned opposite a producing zone 15 opposite the well bore, at which location the casing 12 carries radial perforations 13. The composite tool 14 includes an elongated tubular section 16 connected in the tubing string 12 through a suitable inbore or nipple 18 which has an inside diameter smaller than the inside diameter of the tubing string 12 and the tubular section 16. The tubular section 16 is secured by suitable spacers or connecting members 18 projecting radially from the outer periphery thereof, an external packer-carrying sleeve 20 which concentrically surrounds the tubular section 16 and extends over a major portion of the length thereof. At its opposite ends, the sleeve 20 carries a pair of inflatable or expandable packer elements 22 and 24 which can be expanded into sealing contact with the internal walls of casing 10 using any one of several conventional methods and structures well known in the art. It will be noted that the packers 22 and 24 define the limits of an annular zone 25 between the sleeve 20 and the casing 10 which bridges across the perforated interval of the casing at the location where a subterranean hydrocarbon producing formation is located.

At a location opposite the perforated interval on the casing 10, a plurality of short tubular sections define radial ports 26 which place the annular section or zone 25 between the tubular section 16 and the casing 10 in communication with the interior of the tubular section 16. In other words, fluid in the annulus 25 between the casing 10 and tubular section 16, and between the packers 22 and 24, can flow through the ports 26 to the interior of the tubular section.

Slidably disposed within the tubular section 16 is a closure sleeve 28. The closure sleeve 28 is slidably mounted within the tubular section 16, and has its lower end bearing against a stop ring 30 mounted in and keyed to the tubular section. Near its upper end, the closure sleeve 28 is slotted in its inner peripheral wall to accommodate locking slips 34 carried on a safety valve subassembly 36 constructed in accordance with the present invention. It will be noted that in the illustrated position, the closure sleeve extends across and blocks the ports 26.

The safety valve subassembly 36 includes an elongated tubular body which, in the illustrated embodiment of the invention, includes an upper tubular section 38 which carries the locking slips 34, and which has secured theretoward, seating cups 40 which are diametrically dimensioned to seat against and engage the inner peripheral surface of the nipple 18 during the operation of the tool as hereinafter described. The tubular section 38 also has formed on the upper end thereof, a fishing neck 42. At its lower end, the tubular section 36 is threadedly connected by a box and a pin joint to an elongated tubular element 44.

The tubular element 44 has a bore 45 which extends from one end thereof to the other, which bore is aligned and communicates with the bore through the tubular section 38. Positioned on the lower end of the tubular element 44 by means of a threaded connection is a lower body section 46. The lower body section 46 has a bore or opening formed centrally therethrough, with this opening having an inside diameter which is smaller than the diameter of the bore 45 through the tubular element 44 so that an upwardly facing shoulder 47 is defined by the body section 46 at the lower end of the bore through the tubular element. In a preferred construction of the invention, the tubular element 44 is made in two sections, an upper section 44a and lower section 44b which are interconnected through a threaded plug 50 which is threadedly engaged with the upper end of the lower section 44b, and the lower end of the upper section 44a of the tubular element 44.

Above the plug 50, within the tubular element 44, is an annular valve seat 52. The annular valve seat 52 is pressed into the bore through the tubular element 44, and is sealed against the internal walls of the upper section 44a of this element by means of a sealing ring 54. It will be noted that the annular valve seat 52 has a fluid flow passageway 56 formed in the lower side thereof, which passageway communicates with a threaded bore 58 formed in the upper side of the valve seat.

For the purpose of closing the flow passageway 56 in the annular valve seat 52, a ball valve member 60 is provided. The ball valve member 60 is carried on the upper end of an elongated valve stem 62 which projects downwardly through a bore formed through the plug 50 and through a chevron packing 64 positioned in this bore and sealingly surrounding the valve stem. The packing 64 is retained under compression by a suitable spring 66 positioned between the packing and a spring retainer plate 68 threaded into the upper end of the plug 50. It will thus be seen that the plug 50 and the packing 54 provide a sealing means which seals be-
between the elongated valve stem 62 and the internal wall of the tubular element 44. The valve stem 62 is slidable movably with respect to the packing 64 so that the ball valve member 60 can be reciprocated between valve opening and valve closing positions in a manner hereinafter described.

The elongated valve stem 62 is connected through a suitable connector collar 70 to a neck formed on a threaded cap 72 which is threaded into the upper end of a hollow, elongated piston element 74. The piston element 74 is geometrically configured to have an enlarged, hollow central body portion which defines a downwardly facing shoulder 76, and an upwardly facing shoulder 78. An annular sealing ring 79 surrounds the piston element 74 and forms a sliding seal with the tubular element 44. The size of the downwardly facing shoulder 76 formed on the hollow piston element 74 is such that this shoulder will contact the shoulder 47 formed on the lower body section 46 when the piston is reciprocated downwardly to a certain point within the bore through the tubular element 44.

Below the shoulder 76, the piston element includes an elongated neck 80 which projects through the lower body section 46 to the outside of the tubular element 44. The lower end of the neck 80 is threaded to permit it to receive an adjusting nut 82 provided for a purpose hereinafter described. A resilient compression spring 83 is positioned between the lower end of the lower body section 36 and the nut 82 carried on the lower end of the neck portion 80 of the piston element 74 and functions to continuously bias the piston element downwardly in the bore 45 through the tubular element 44. The limit of travel of the piston element downwardly is, of course, established by contact of the downwardly facing shoulder 76 with the shoulder 47 formed on the lower body section 46.

A relatively small diameter first conduit 86 extends from outside the hollow piston element 74 through the wall thereof to a point adjacent the lower end of the hollow interior of the piston body. An air bleed tube 118 also extends from the exterior of the body of the hollow piston element 74 into the hollow interior thereof through the air bleed tube terminating at a point spaced vertically above the lower end of the first conduit 86.

At a location between the plug 50 and the annular valve seat 52, at least one production fluid flow passageway 94 is extended radially through the upper section of the tubular element 44. By-pass conduit means is also provided in association with the tubular element 44. In the illustrated embodiment, the by-pass conduit means includes an upper mercury reservoir 98, a radial port 101 which communicates with the bore 45 through the tubular element 44 below the plug 50 and above the piston element 74, and an elongated passageway 102 which interconnects the port 101 with the mercury reservoir 98. A part of the reservoir 98, the passageway 102 and the bore 45 between the piston element 74 and the plug 50 are filled with mercury.

An optional part of the safety valve subassembly 36 illustrated in FIGS. 1a and 1b, there is provided a seat retrieval device designated generally by reference numeral 103. The seat retrieval device 103 includes a slip extending neck 104, and a fishing neck 106, both of which are tubular elements having hollow bores or fluid passageways extending therethrough in axial alignment with each other. In accordance with known practice in the art, the slip extending neck 104 is slidingly reciprocable in the fishing neck 106 and functions, when pushed downwardly within the fishing neck 106, to extend or radially expand a plurality of slips 108 so that the slips bite into or engage the walls of a surrounding tubular member, or, in some instances, engage slip recesses in such surrounding tubular member as shown in FIG. 1a of the drawings. Here, the slips 108 are shown engaging slip recesses 109 formed in the tubular section 38.

At its lower end, the seat retrieval device 103 carries a tubular body 110 of reduced outside diameter so that a small annulus is provided between this tubular section and the surrounding internal wall of the tubular section 38. At its lower end the tubular body 110 carries a plurality of seating cups or rings 112 which bear against the internal wall of the upper portion 44a of the tubular element 44, and are susceptible to expansion under fluid pressure from below to firmly and sealingly engage this wall. A threaded pickup nipple 114 projecting from the body 110 is threaded into the seat 52 for a purpose hereinafter explained. It will be understood that fluid communication is established through the passageway 56, through the seat 52 and through the aligned bores or passageways formed through the tubular body 110, the fishing neck 106 and the slip extending neck 104. It should be further pointed out that the mercury reservoir 98 communicates through a small radial port 116 with the annular space between the tubular body 110 and the tubular elements which surround it, so that fluid communication is actually established between the mercury reservoir and the upper portion of the bore through the tubular section 38, bypassing the slot retrieval device which is positioned therein.

OPERATION

In the operation of the composite dual packer-safety valve tool depicted in FIGS. 1a and 1b and in FIGS. 2-4, the tubular section 16 is first incorporated in the tubing string 12, and is positioned in the well bore at a location where the packers 22 and 24 are disposed on opposite sides of the perforated interval of the casing 10 which, in turn, is opposite the producing formation 15. The packers 22 and 24 are deflated during the lowering of the tool into the well, and therefore will pass through the casing without interference. At the time of lowering the tubing section 16 and the sleeve 20 concentrically surrounding this into the well bore, the tubular member 38 and the entire safety valve subassembly 36 is not in a position within the tubular section 16. Also, at the time of lowering the tubular section 16 and surrounding sleeve 20 into the casing, the sleeve 28 is in its port closing position where the lower end of this sleeve rests against the stop ring 30.

After the tubular section 16 and sleeve 20 are lowered in the tubing string 12 to the position illustrated in FIGS. 1a and 1b, the packers 22 and 24 are inflated or expanded into the illustrated position in which they seal against the walls of the casing 10. Cement is then pumped down the interior of the tubing string 12 and flows around the lower end of the tubing string and up into the annulus between the tubing string and the casing. As the cement rises in this annulus to the point where the lowermost packer 24 is located, the cement is forced to continue its upward movement through the annular space defined between the sleeve 20 and the
tubular section 16. The cement moves upwardly in this space until it passes out the top end of the sleeve 20. It then continues to fill the annulus between the production tubing string 12 and the casing 10. The result is that cementing between the tubing string and casing is continuous except over the producing interval of the formation, at which point, the cement fills only the annular space between the sleeve 20 and the tubing section 16. Of course, communication across this cemented zone is afforded by the short tubular sections 26 which define ports which place the interior of the tubular section 16 in communication with the annulus between the sleeve 20 and the casing 10.

When the cementing operation, carried out in the manner described, has been completed, the safety valve subassembly 36 is lowered in the tubing string on a wire line, or by other suitable means, facilitated by the fishing neck 42 carried at the upper end of the tubular section 38. When the safety valve subassembly 36 has been lowered sufficiently far within the tubing string 12, it is pulled upwardly, or in some other manner is manipulated to set the slips 34 into the recesses 32 formed in the sleeve 28. Methods of extending the slips 34 to accomplish this status are well understood in the art. With the slips 34 so extended, the safety valve subassembly 36 is locked against axial movement within the sleeve 28.

After this status is achieved, a wire line or other suitable structure communicating with the surface is used to engage the fishing neck 42 on the tubular section 38. An upward pull is then exerted on the safety valve subassembly 36 so that the entire subassembly is pulled upwardly in the tubing string 12. The upward movement of the safety valve subassembly 36 is continued until the seating cups 40 seat firmly against the inner periphery of the inset nipple 18. Upward movement of the safety valve subassembly 36 causes a concurrent upward movement of the sleeve 28 which is continued until the lower end of the sleeve passes above the ports provided through the short tubular sections 26. Thus, when the seating cups 40 are seated against the inset nipple 18, these ports are opened and fluid communication is established between the bore through the tubular section 16 and the annulus between the sleeve 20 and the casing 10. Production fluid can now flow into the interior of the tubular section 16.

The safety valve subassembly 36 of the invention functions during the production of hydrocarbons from the producing formation 15 via the perforations 13 in the casing 10. Production fluid passes through the short tubular section 26 into the bore through the tubular section 16. From this point, the production fluid passes through the ports 94 formed through the elongated tubular element 44 and then traverses the fluid flow passageway 56 through the annular valve seat 52. The production fluid continues upwardly through the hollow interior of the seat retrieval device 103, through the bore extending upwardly through the tubular section 38, and ultimately into the production tubing 12 which conveys the production fluid to the surface.

It will be perceived from this description of the path of production fluid flow that, considering the relatively high pressures which are characteristic of many subterranean producing zones, a substantial pressure drop will exist between the point of admission of the production fluids to the safety valve subassembly 36 via the tubular section 16 ad ports 94, and a location near or at the surface to which the production fluids are conveyed. The size of the pressure differential or drop which exists will be determined in part by the size of the fluid flow passageway 56 through the annular valve seat 52. Control of the pressure drop is also maintained by chokes and other conventional control devices located at the well head, and adjustable to control the pressure drop and in turn control the rates of production of the production fluids.

It will be noted in referring to the construction of the safety valve of the invention that when the sleeve 28 has been moved upwardly to expose or open the ports through the tubular sections 26, production fluids are then permitted to communicate with the lower portion of the tubing string 12, including that portion of the bore through the tubular section 16 which is below the piston element 74, the nut 82 and the spring 83. Thus, the cross-sectional area of the threaded neck 80 of the piston element is continuously exposed to the pressure of the production fluid as it acts over this area. Opposing this fluid pressure is the downward pressure exerted by the compression spring 83. Also acting in opposition to the pressure tending to force the piston element 74 upwardly within the elongated tubular element 44 is a pressure which acts downwardly on that portion of the piston element 74 which is above the seal ring 79. This fluid pressure is that which is transmitted through the mercury (located in the space between the annular seal ring 79 and the plug 50, as well as in the passageway 102 and mercury reservoir 98) by production fluid in the tubing string 12 and the tubular section 38 above the annular valve seat 52. This fluid pressure is communicated back to the body of mercury through the open port 116, and will, of course, be substantially less than the fluid pressure acting on the lower end of the neck portion 80 of the piston element 74 as a result of the pressure drop across the annular seat 52.

It will also be observed that production fluid entering the elongated tubular element 44 through the ports 94 exerts a downward pressure on the ball valve 60 and its associated valve stem 62. The effective force exerted is, of course, equivalent to the magnitude of the pressure multiplied by the cross-sectional area of the valve stem 62 where it passes through the chevron packing 64. It will be readily apparent that such force must necessarily be much less than the upwardly acting force which is developed as a result of the production fluid pressure acting on the lower end of the neck 80 of the piston element 74.

In summary, the inherent pressure level of the fluids to be produced from the formation 15 acts across the area of the exposed bottom face of the neck 80 of the piston element 84 and tends to force the piston element upwardly within the elongated tubular element 44. Opposing this force, and overcoming it under normal operating conditions, is the outward resilient force exerted by the spring 83, the substantially smaller fluid pressure-originated force acting back through the body of mercury and against the top side of the piston element 74, and a minor component of force developed by the production fluid acting over an area equivalent to the cross-sectional area of the valve stem 62 where it passes through the chevron packing 64. In this status of the valve, the valve will remain open unless there is an unusual or severe pressure drop across the annular valve seat 52, such as would occur if a pressure control device at the well head should be lost as a result of
some accident tearing away, destroying or rendering inoperative a part of the well head equipment. In this case, the pressure level above the annular valve seat 52 would be greatly reduced and, in turn, the pressure transmitted back through the body of mercury into the portion of the bore 45 disposed between the movable piston element 74 and the plug 50 would also be greatly reduced. This would permit the pressure acting on the neck 80 of the piston element to overcome the opposing force exerted by the compression spring 83, and the result would be that the piston element 74 would be forced upwardly within the elongated tubular element 44 and the valve member 60 would seat against and close the annular valve seat 52. Thus, loss of production fluids to the surface would immediately be stopped by the closure of the valve member 60 against the valve seat 52, and the substantial safety hazard to operating personnel at the surface would be alleviated.

In some instances, it will be desirable, after a period of operation, to change out the valve seat 52. To this end, the seat retrieval device 103 can be employed by passing a wire line fishing device of appropriate operating characteristics into the well bore so as to traverse the tubing string 12 and permit the device to pass into the relatively large bore in the tubular section 38. The fishing device will press down on the slip extending at neck 104 causing it to reciprocate within the fishing neck 106 and thereby retract the slips 108. At the same time, the fishing tool will slip over and engage the fishing neck 106 so that the seat retrieval device 103 is now ready for retrieval, and with it, the annular seat 52 which is threadedly engaged with the threaded neck 114 on the lower end thereof.

It will be understood that during the retrieval operation in which the seat 52 is to be removed from the safety valve subassembly 36, the well is shut in and pressure is therefore allowed to equalize from the surface downwardly to the producing formation. Under these conditions, the seating cups 112 will be released from their engaging status, and the seat and seat retrieval device 103 can be easily pulled, and retrieved at the surface. A new seat having a differently sized fluid flow passageway 56 therethrough can then be threaded on the pickup nipple 114 of the seat retrieval device 103 and this assembly then lowered back into the tubing string, and the seat replaced in substantially the reverse of the manner hereinbefore described for removing the seat.

In FIG. 5 of the drawings, another embodiment of the invention is illustrated. Here, the safety valve of the invention is being utilized in an open or uncased bore hole 120 formed in the earth 122 and extending to a substantial depth for the purpose of producing hydrocarbons, water or other minerals from a subterranean formation. Extended down into the bore hole 120 is a production tubing string 124 in the manner depicted in FIG. 5 functions to prevent excessive pressure drop between the pressure of connate fluids in the lower end of the bore hole 120 and the pressure obtaining at the well head. Thus, as previously explained, in the event pressure control at the well head is lost for any reason, the pressure differential acting across the seat 140 will function to permit the bottom hole pressure of production fluids to overcome the force exerted by the spring 150, and to reciprocate the movable piston element 148 in the elongated tubular member 130. This will have the effect of closing the valve by bringing the ball valve member 142 into seating engagement with the annular valve seat 140. The packer 128 and safety valve of the present invention thus, at such time, function to isolate the lower portion of the hole from the well head area at the surface.

Although certain preferred embodiments of the invention have been hereinbefore described in order to apprise those skilled in the art of the manner in which the invention should be practiced, it will be understood that various changes and innovations in the described embodiments of the invention can be effected without departure from the basic principles of the invention. Changes and innovations of this type are therefore deemed to be circumscribed by the spirit and scope of the present invention except as the same may be necessarily limited by the appended claims, or reasonable equivalents thereof.

What is claimed is:

1. A safety valve tool for use in wells comprising:
an elongated tubular element having an upper end and a lower end interconnected by a bore;
an annular valve seat positioned in the upper portion of the elongated tubular element;
a valve closure member positioned below the seat;
an elongated valve stem connected to the valve closure member projecting downwardly in the bore in said tubular element;
a piston element connected to the lower end of the valve stem and slingly and sealingly positioned in the bore of the tubular element with a portion of the piston element projecting from the lower end of the tubular element;
plug means sealingly surrounding the valve stem within the bore of the tubular element and disposed between the piston element and the valve closure member;
at least one radial port through the tubular element at a location between the seat and the plug means and placing the bore in communication with the outside of said tubular element;
an adjustable resilient control means positioned between said tubular element and the lower end of the projecting portion of said piston element, said resilient control means resiliently urging said piston element downwardly in the bore in said tubular element; and
by-pass conduit means providing a pressure transmission path from a point in said bore above said seat to a point in said bore between said plug and said piston element.
2. A safety valve tool as defined in claim 1 wherein said annular valve seat is removably mounted in said tubular element to facilitate removal of said seat by means of a seat retrieval device engaged with the seat from above.
3. A safety valve tool as defined in claim 1 and further characterized as including mercury at least partly filling said by-pass conduit means to prevent dirt from entering the portion of said bore between said piston element and said plug.
4. A safety valve tool as defined in claim 1 wherein said tubular element comprises:
an upper tubular section;
a lower tubular section; and
wherein said upper and lower tubular sections are interconnected by said plug means.
5. A safety valve tool as defined in claim 1 wherein said adjustable resilient control means comprises:
a lower body section secured to the lower end of said tubular element;
a spring having one end bearing against said lower body section; and
an adjusting nut threaded on the end of said piston element and bearing against the opposite end of said spring from the end in contact with said lower body section.
6. A safety valve tool as defined in claim 5 wherein said tubular element comprises:
an upper tubular section having said radial ports formed therethrough;
a lower tubular section having said lower body section secured to the lower end thereof; and
wherein said upper and lower tubular sections are interconnected by said plug means.
7. A safety valve tool as defined in claim 6 wherein said annular valve seat is removably mounted in said tubular element to facilitate removal thereof from said tubular element by means of a retrieval device lowered in the well from the surface.
8. A safety valve tool as defined in claim 7 and further characterized as including mercury at least partly filling said by-pass conduit means to prevent dirt from entering the portion of said bore between said piston element and said plug.
9. A safety valve tool as defined in claim 1 and further characterized as including:
a tubular section concentrically surrounding said tubular element;
a production tubing string having said tubular section interposed therein;
a cylindrical sleeve concentrically surrounding said tubular section and spaced therefrom to define an annulus therewith;
a pair of expandable packers secured around said cylindrical sleeve and spaced from each other axially therealong around said annulus; and
means for conveying a fluid from externally of said cylindrical sleeve through said sleeve and through said tubular section to the interior of said tubular section.
10. A safety valve tool as defined in claim 9 and further characterized as including a closure sleeve slidably positioned in said tubular section and movable axially therein from a first position in which said means for conveying fluid is covered to obstruct conveyance of fluid to the interior of said tubular section to a second position in which said sleeve does not obstruct said means for conveying fluid and fluid can flow through said cylindrical sleeve and through said tubular section to the interior of said tubular section for production through said tubing string to the surface.
11. A safety valve tool as defined in claim 10 wherein said valve seat is removably mounted in said tubular element.
12. A safety valve tool as defined in claim 11 and further characterized as including a seat retrieval device connected to said valve seat.
13. A safety valve tool as defined in claim 10 and further characterized as including means carried by said tubular element and releasably engaging said closure sleeve whereby said tubular element and closure sleeve are concurrently axially movable in said tubular section.
14. A safety valve tool as defined in claim 13 and further characterized as including anchor means connected to said tubular element for engaging said tubular section when said tubular element is moved axially upwardly in said tubular section.
15. A safety valve tool as defined in claim 10 wherein said means for conveying a fluid comprises a plurality of tubing sections extending radially between ports in said first mentioned tubular section and ports in said cylindrical sleeve whereby said annulus can be filled with cement without obstructing the conveyance of fluid from externally of said cylindrical sleeve to the interior of said first mentioned tubular section.
16. A safety valve tool as defined in claim 15 wherein said valve seat is removably mounted in said tubular element.
17. A safety valve tool as defined in claim 16 and further characterized as including a seat retrieval device connected to said valve seat.
18. A safety valve tool as defined in claim 16 and further characterized as including means carried by said tubular element and releasably engaging said closure sleeve whereby said tubular element and closure sleeve are concurrently axially movable in said tubular section.

19. A safety valve tool as defined in claim 18 and further characterized as including anchor means connected to said tubular element for engaging said tubular section when said tubular element is moved axially upwardly in said tubular section.