PRESSURE RESPONSIVE AUXILIARY DISC VALVE AND THE LIKE FOR WELL CLEANING, TESTING, AND OTHER OPERATIONS

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ABSTRACT

A full opening pressure operated disc valve particularly suited for cleaning formation perforations by surging and for other operations comprises a rupturable sealing element and a sliding tubular rupture member actuated by a controlled pressure differential between the tubing chamber and the casing annulus, with said element and rupture member being located concentrically within a tubular body and having an ID substantially the same as that of the tubing string.

5 Claims, 10 Drawing Figures
PRESSURE RESPONSIVE AUXILIARY DISC VALVE AND THE LIKE FOR WELL CLEANING, TESTING, AND OTHER OPERATIONS

BACKGROUND OF THE INVENTION

Surgings is not a new technique, and apparatus for surging a formation can be obtained commercially. Some of the types of valves obtainable include those which utilize rupture discs such as in U. S. Pat. Nos. 2,565,731; and 2,263,412. Most of the tools available in the prior art contain complex rupturing mechanisms with bulky configurations so that, after the disc is ruptured, flow of fluid from the formation through the tool is hindered by the presence of the rupturing mechanisms. The devices utilize rupturing techniques consisting of dropping heavy metal bars down the tubing to strike the rupture mechanism and cause the rupturing of the disc.

Other tools capable of surging and which utilize a surge chamber are those similar to the one disclosed by U. S. Pat. No. 3,589,442, which uses an explosive charge to open the surge chamber. These devices occupy a great amount of the cross-sectional area of the tool and greatly restrict flow. They also lack the instantaneous surging effect because the actuation mechanism or explosion may initially force fluid and debris further into the formation before the reaction back into the surge chamber can occur. Further restrictions in the flow area into the surge chamber prevent an instantaneous surge.

Tools which utilize fluid pressure to actuate the valve include those disclosed in U. S. Pat. Nos. 3,361,212; 2,855,952; 3,205,955; and 3,211,232. These and other devices generally utilize bell valves or check valves in the tubing passage which restrict flow of fluids therethrough. Other types use flow passages running inside the wall of the tool in conjunction with sliding mandrels inside the tool for opening and closing ports in the interior passages. All of these tools are impractical for surging due to their restricted flow passages and slow opening nature.

Still other valves in the prior art require lifting and rotating the tubing string one or more times in order to open and close the valve ports.

SUMMARY OF THE INVENTION

The present invention overcomes these and other problems by providing a full-opening instantaneous surging tool which is actuated from the surface by applying fluid pressure to either the inside of the tubing or the annulus between the tubing and the casing, which pressure acts on a tubular rupture member forcing it into a rupturable sealing element, breaking the seal in the tubing passage and allowing fluid in the formation to surge through the fully opened tool into the air-filled surge chamber above the sealing element, carrying sediment, debris, and perforating by-products with it. The tool can then be allowed to set in the well bore until the debris settles out of the fluid into the trap or "rathole" at the bottom of the well bore, and then normal testing or production operations can be continued, with the tool offering no hindrance to such operations due to its full opening characteristic.

The tool is particularly useful as a testing valve when complicated testing equipment, commonly termed a "christmas tree," is located on the well at the surface, atop the tubing string, and it is impractical to have to lift and rotate the tubing string or drop heavy metal bars or balls through the tubing in order to actuate the valve. Use of this invention allows pressure to be easily applied through the annulus or through the testing apparatus into the tubing to open the valve when testing is to begin. After the valve has been used there is no need to withdraw it immediately or drill it out to allow further operations in the well. Due to its large inner diameter, almost equal to that of the tubing string, other tools or devices can be passed down the string and through the valve without any trouble.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view partly in section of the annulus pressure responsive valve, including a tubular housing, the cutting sleeve, and one rupture disc;

FIG. 2 is a view partly in section of the tubing pressure responsive valve, including the tubular housing, the cutting sleeve, and one rupture disc;

FIGS. 3 and 4 show the use of single rupture valve as an auxiliary valve or testing valve;

FIGS. 5, 6, and 7 are elevational cross-sections of a tubing pressure responsive disc valve used in conjunction with an annulus pressure responsive disc valve and other standard tools showing the different stages of surging operations;

FIG. 8 is an axial view of the rupture disc illustrating the scoring in the disc to allow it to be broken into small parts when rupturing is initiated;

FIG. 9 represents the method and apparatus for altering surge chamber length; and

FIG. 10 is a view of an alternative cutting edge for the rupture member.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1–10, number 1 represents the pressure responsive rupture disc valve in which an upper adapter 2, with internal threads at 20 for securing to the tubing string, is threadedly connected to the valve seat collar 3 containing a valve seat shoulder 30 upon which is seated the rupturable sealing element, or rupture disc 4. Valve seat collar 3 contains internal threads 31 at its upper end and external threads 32 at its lower end. Internal threads 31 mate with external threads 21 of the upper adapter 2.

Threadedly attached to valve seat collar 3 are one or more sleeve housings 5. Each sleeve housing has internal threads 51 mating with external threads of the adjacent upper member, and has external threads 52 at its lower end mating with internal threads on the adjacent lower member. Each housing 5 has a fluid port 53 communicating from the exterior of the tool to the expansion chamber 6. Interior to and concentric with the cylindrical sleeve housing 5 is a tubular rupture member 7 comprising one or more piston sleeves 7A and rupture device 7B all of which are hollow tubular cylinders. Abutting the top of the piston sleeve 7A is a rupture device 7B with an angular cutting edge 71. The piston sleeves 7A contain shoulders 72 which act as pistons in expansion chamber 6. Expansion chamber 6 and backflow chamber 61 are formed between the lower end 33 of the upper adjacent threadedly secured member, the inner surface of the outer wall 54 of the sleeve housing 5, lower chamber shoulder 55 of the sleeve housing 5, and the piston sleeve itself, which is slidable positioned inside the inner passage of the tool.
Circular seals 8 located between the sleeve housing 5 and the piston sleeve 7A serve to maintain a pressure-tight chamber 6.

Threadedly secured to the lowermost sleeve housing 5 is the bottom adapter 9 with internal threads 91 and external threads 92. External threads 92 are for securing the tool to the next tool or next joint of regular tubing.

Circular seals 10 serve to prevent fluid seepage or pressure loss from the interior of the tool to the exterior of the tool or vice versa, and are placed between all components which are threaded together. Circular disc seal 11 is placed circumferentially around the rupture disc 4 to prevent premature loss of fluid around the rupture disc.

Ports 73 in piston sleeve 7A provide fluid communication between back flow chamber 61 and the interior of the sleeve passage.

In typical operation, referring to FIGS. 3 and 4, the tool 1, as described above, is placed in the tubing string 102 and lowered into the well bore 103. A packer 114 is usually located beneath the tool 1 on the tubing string 102 and is used to isolate the annulus 104 from the tubing passage 105. The packer 114 is set when the valve tool 1 has been lowered to the proper depth in the well. The testing apparatus, or “christmas tree” (not shown) can then be attached to the tubing string at the surface and when it is desirable to begin testing flow, pressure is applied to the annulus fluid from pumps at the surface, causing a pressure differential across the piston shoulder 72 in FIG. 1, causing the piston sleeve 7A to move upwardly toward the rupture disc 4. This forces the cutting sleeve 7B upward toward the disc 4. The cutting edge 71 of the cutting sleeve 7B contacts the rupture disc 4 and when the annulus pressure reaches a predetermined level, the cutting sleeve is driven through the rupture disc 4, fully opening the inner passage of the tool 1. The rupture disc may be deeply scored 41 as shown in FIG. 8 to facilitate breaking up of the disc while the cutting sleeve 7B is passing through it, thereby preventing clogging of the passage through the cutting sleeve by the severed disc. When the valve is opened, the disc is almost completely cut out leaving an opening in the disc at least as large as the outer diameter of the cutting sleeve and allowing passage of additional tools and devices down through the valve tool 1 to other tools below it. The opening of the valve is thus accomplished without disturbing the testing apparatus at the wellhead. The lack of inner restrictions allows further work to be done in the well without need of removing the valve 1.

In FIG. 2, a tubing pressure responsive (TPR) valve 101 is revealed wherein all the elements of the annulus pressure responsive (APR) valve 1 are present but in slightly different color. The valve seat collar 3 and rupture disc 4 have been removed from between the upper adapter 2 and the sleeve chamber 5, the disc rotated 180°, and both components placed between the sleeve chamber 5 and the bottom adapter 9. The upper adapter 2 and the sleeve chamber 5 are then threadedly secured to each other. The cutting sleeve 7B is removed from its abutting position atop the piston sleeve 7A, is rotated 180° so that the cutting edge 71 is pointing downward toward the relocated rupture disc 4, and is inserted in abutting position at the lower end of the piston sleeve 7A. In its initial position, the piston sleeve 7A in the TPR valve is pushed to the uppermost point within the valve passage so that shoulder 72 is almost touching lower lip 56 of the upper adjacent member 2. In operation, the TPR tool 101 is lowered into the well on the tubing string, a packer is set below the tool which isolates the tubing passage from the annulus, and pressure is applied to the tubing passage causing fluid pressure to act through ports 73 and against shoulder 72 attempting to reach the lower pressure area in expansion chamber 6. The resulting pressure differential across shoulder 72 forces cutting and piston sleeves 7A and 7B downward, thereby cutting disc 4 which opens the tool completely.

Referring now to FIGS. 5, 6, and 7, a method for cleaning perforations in a formation by surging is illustrated using a combination of the annulus pressure responsive (APR) valve 1 and the tubing pressure responsive (TPR) valve 101. The APR valve 1 is placed in the drill string below the TPR valve 101 and is installed such as to leave an air-tight chamber 112 between the two rupture discs 4. As shown in FIG. 9, the length of the air chamber 112 can be controlled by the amount of tubing 115 inserted between the APR valve and the TPR valve, if any.

The tools are lowered into the well to the desired depth and circulating valves 113 may be used above and below the disc valves 1 and 101. Circulating valves 113 are held open while the tools are being inserted in order to allow fluid in the well to flow through the tubing while it is being lowered into the hole. This facilitates the lowering step and allows the establishment of a fluid cushion 107 above the top disc and extending to the surface. A packer 114 located at the bottom of the well string is set and the circulating valves 113 are closed. Commercially available packers and circulating valves such as those manufactured and sold by Halliburton Company under the designation RTTS circulating valves and RTTS packers can be used.

Pressure is applied to the annulus 104 which opens the lower disc valve 4 exposing the air chamber 112, which is at a comparatively low pressure, to the comparatively high fluid pressure in the formation 108. The fluid 109 in the formation 108 rushes instantaneously into the air chamber carrying with it debris and perforation by-products, cleaning the perforations in the formation. The annulus pressure is released and operations may be ceased for a period of time sufficient to allow the debris to settle into the trap 110, or “rat-hole,” usually five minutes or more. The tubing passage 105 is then pressurized up to the pressure required to open the TPR valve 101 which opening then occurs, and the tubing inner passage 105 is then completely clear all the way from the formation 108 to the surface (not shown). If desired, fluid can then be pumped down the annulus and up the tubing carrying out the debris. Flow tests, stimulation treatment, or consolidation applications may be performed, without interference, through the tubing, and the valves 101 and 1 can be easily removed from the hole if desired.

The tremendous advantages from the use of this invention for surging operations derive in part from the full opening characteristics of the tool due to the large ID of the disc cutting means, and from the instantaneous opening and quick surge obtained. Other tools which are available for surging lack the instantaneous surging effect and the full opening feature of this invention.
It is common knowledge that the velocity of a fluid determines its ability to sweep debris out of the formation. For a given perforation’s cross-sectional area the flow velocity therethrough is dependent upon the mass flow rate of the fluid which is permitted into the surge tool. This in turn is a function of the cross-sectional flow area of the tool in its opened position. Due to the large flow area of the tool of this invention, maximum flow rates are achieved, giving maximum flow velocity in the perforations and in turn maximum cleaning effect. These maximums are far above those of the prior art tools due to the restricted flow areas of those tools.

The surge can be controlled by this invention by the use of varying lengths of surge chamber. A surge chamber is used because it is not desirable to have surging completely to the surface, for safety reasons and because such unchecked surging is destructive to the formation.

FIG. 9 illustrates the use of standard tubing 115 between the APR valve 1 and the TPR valve 101. The length of the surge chamber 112 can thus be varied from a few feet in length with no tubing inserted between the two valves, to as long as is needed by the insertion of tubing or tubular members threaded between the two valves 1 and 101. Standard tubing is used because of its comparatively low cost and widespread availability although any strong tubular member of any desired length could serve as an air chamber extension as long as it contained sufficient connecting means at its ends to interconnect it between the two valves.

Another advantage of this invention when using in testing with complicated apparatus attached to the well-head is that it is wholly operable by fluid pressure from the surface and requires no lifting and setting down nor any rotational motion to activate either type valve.

Other advantages of this invention include the effect of a positive indication to the operator at the surface as to when the surge begins so that he can time the settling period accurately. This indication consists of a sharp jerk on the tubing string at the opening, which indication can be amplified by the use of shear means between the rupture device and the housing in order to achieve an over-pressuring and a more decisive jerk on the tubing.

Also due to the flow-through design above and below the surge chamber through the use of circulating valves above and below the tools, the tool is pressure balanced going into the hole and premature opening is prevented. The tool is safer to use because no manipulation of the tubing is required to open it. It is very simple to operate, dependable, and can be used over and over again merely by replacing the low-cost rupture disc.

The pressure required to operate the valve can be varied over an extremely broad range in several ways. One manner of variation is to vary the thickness and/or composition of the rupture disc to vary its rupture strength. Another method involves varying the differential pressure area between the piston sleeves and the sleeve housings to vary the activating pressure required. Another method would involve changing the cutting angle or the sharpness of the cutting edge of the cutting sleeve. Another method of increasing the available rupturing force is to add one or more identical piston sleeves 7A and a corresponding number of sleeve housings 8 to the tool.

Also due to the simplicity of the component parts and their interchangeability between TPR usage and APR usage, the tool is very inexpensive to manufacture when compared to the complex tools of the prior art. The rupture discs can be made of any frangible material such as magnesium and its alloys, copper and its alloys, aluminum and its alloys, hard rubber, plastic, epoxy with glass fibers, phenolics, wood, or glass, as long as the material has sufficient rupture strength to prevent premature opening when going into the well. The discs may be flat or, as in one preferred embodiment herein, they can be domed for additional strength against ambient pressures which does not substantially effect the force required for rupturing. The discs can be scored as in FIG. 8 to obtain several small particles upon rupturing rather than one large piece.

The remaining components of the tool can be of any tough metal or metal alloy such as steel or stainless steel.

The rupture member 7B is stated as being a tubular sleeve with an angular cutting edge. While this is the preferred embodiment it is possible that the rupture element might be of non-circular cross section and have a squared off cutting edge or a multangular cutting edge 77 with two or more points for rupturing as in FIG. 10. The rupture member is preferably made of a tough metal such as steel or stainless steel or can be a drillable material such as aluminum alloy or cast iron.

Seals used may be composed of any commercially available suitable sealing material such as natural or artificial rubber and can be of the O-ring type.

Although a specific preferred embodiment of the present invention has been described in the detailed description above, the description is not intended to limit the invention to the particular forms or embodiments disclosed herein, since they are to be recognized as illustrative rather than restrictive and it will be obvious to those skilled in the art that the invention is not so limited. For example, the tool of this invention is described for use as a testing valve or surging tool but it can also be used as an auxiliary valve. Also, the ID of the valve is stated to be near that of the tubing string but this is not a necessary limitation as the ID could be reduced to any desirable dimension by several methods, such as increasing the wall thickness of the tubular housing and/or the tubular rupture element. Thus, the invention is declared to cover all changes and modifications of the specific example of the invention herein disclosed for purposes of illustration, which do not constitute departures from the spirit and scope of the invention.

What is claimed is:

1. A pressure responsive rupture valve adapted to be attached in a tubing string or a tool string and lowered into a borehole penetrating an underground earth formation, said rupture valve comprising:
   a. an elongated tubular housing having port means through the wall thereof communicating between the interior of said housing and its exterior;
   b. rupturable sealing means located within said tubular housing and sealingly fixed within said housing transversely to the longitudinal axis of said housing for sealing the internal passage of said housing against liquid or gas flow therethrough; and
   c. rupture means located telecentrically and concentrically within said tubular housing near said rupturable sealing means, said rupture means having
piston means located thereon; said rupture means, said piston means, and said tubular housing arranged to form coacting piston chamber means in said rupture valve, said piston means and chamber means fluidically communicating with said port means and adapted to receive fluid pressure through said port means and transmit said pressure into transverse movement of said rupture means through said rupturable sealing means, said rupture means having pressure relief means therein for preventing hydraulic lock by the action of said piston means in said chamber means, said pressure relief means further comprising port relief means in said rupture means on the opposite side of said piston means from said port means.

2. The valve of claim 1 wherein said tubular housing further comprises:
   a. one or more cylindrical housing members having connector means at each end;
   b. a valve seat collar attached to said cylindrical housing members and containing a valve seat shoulder for seating said rupturable sealing means;
   c. a tubular upper adapter for securing the upper end of said tubular housing to a standard well tubing or other tool; and
   d. a tubular lower adapter for securing the lower end of said tubular housing to standard well tubing or other tool.

3. The valve of claim 2 wherein said cylindrical housing members and said upper and lower adapters are connected with one another by mated threaded ends and are sealingly engaged with one another by a plurality of circular seals located concentrically between every two adjacent joined members.

4. The valve of claim 3 wherein said rupturable sealing means comprises a domed circular rupture disc made of a material selected from the group consisting of magnesium, magnesium alloys, aluminum, aluminum alloys, plastic, rubber, copper, copper alloys, glass fiber reinforced epoxy, wood, and glass.

5. The valve of claim 3 wherein said rupture means comprises a tubular cutting sleeve in abutment with one or more tubular piston sleeves, with said tubular cutting sleeve having an angular cutting edge at one end pointing toward said rupturable sealing element, and the other end of said cutting sleeve being in abutment with one of said piston sleeves.

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