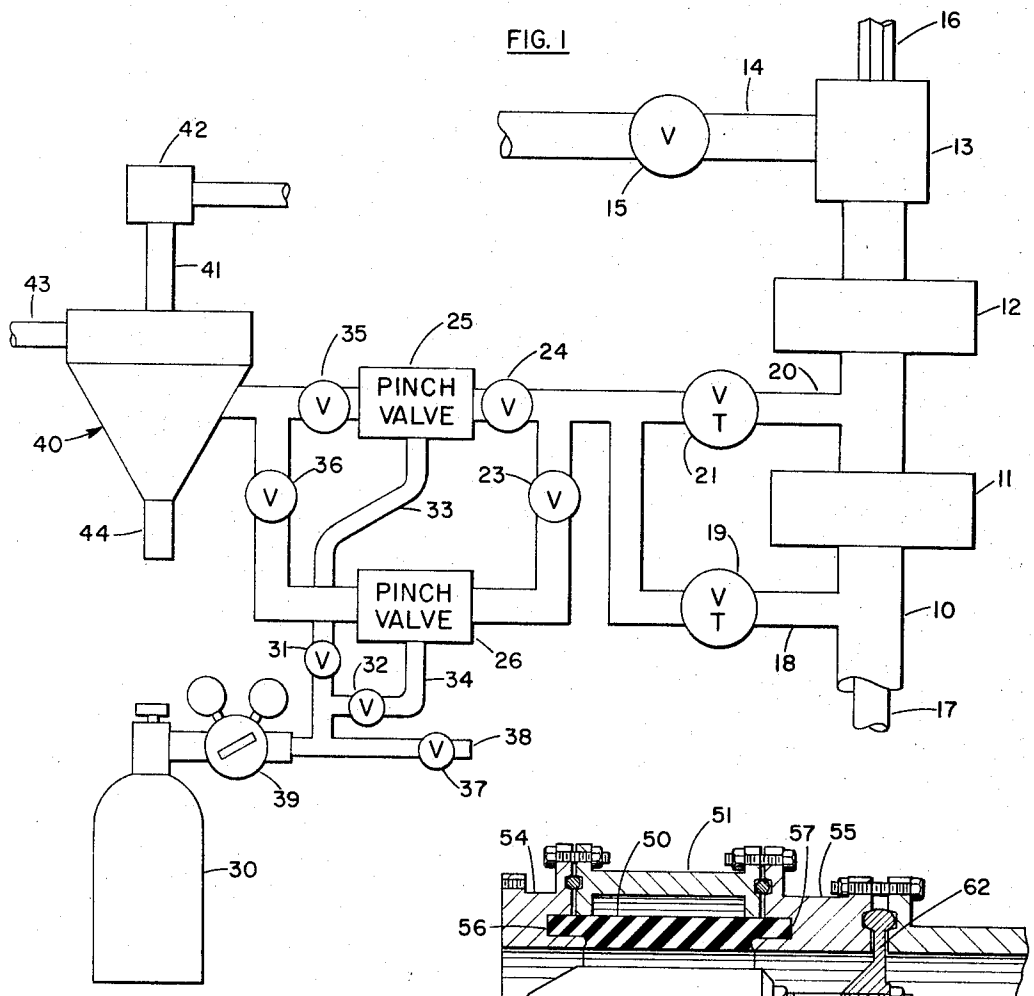
Nov. 28, 1967 J. L. LUMMUS 3,354,970

CONTROLLING HIGH-PRESSURE WELLS WHILE DRILLING

Filed Feb. 8, 1965

FIG. 1



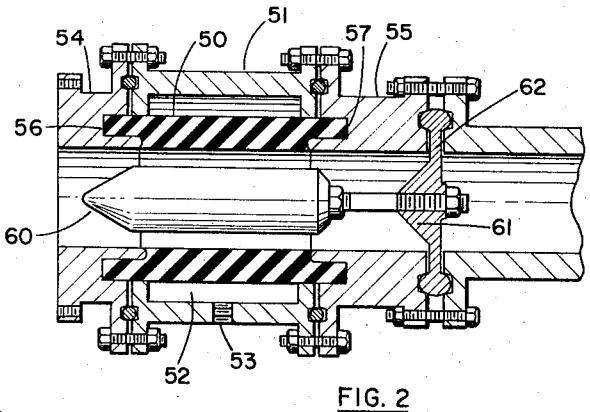


FIG. 2

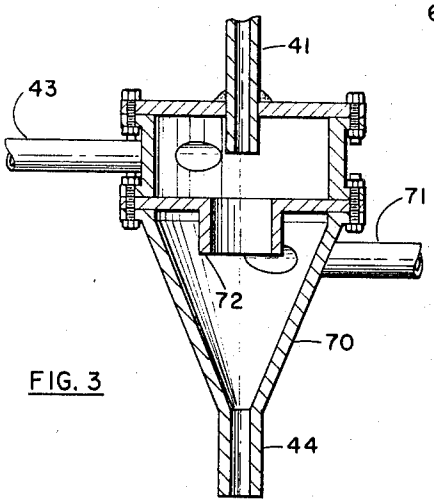


FIG. 3

JAMES L. LUMMUS
INVENTOR.

BY Buell B. Hamilton

ATTORNEY

United States Patent Office 3,354,970
Patented Nov. 28, 1967

3,354,970

CONTROLLING HIGH-PRESSURE WELLS WHILE DRILLING

James L. Lummus, Tulsa, Okla., assignor to Pan American Petroleum Corporation, Tulsa, Okla., a corporation of Delaware

Filed Feb. 8, 1965, Ser. No. 430,918
7 Claims. (Cl. 175—218)

ABSTRACT OF THE DISCLOSURE

An automatic blowout control system for a drilling well includes a seal between the casing and drill pipe, a conduit connected to the casing below the seal and an automatic back-pressure control valve on the conduit. The automatic valve includes a flexible sleeve which can be caused to pinch down to a smaller diameter, or closed completely, by application of pressure outside the sleeve. The valve may contain a cylindrical body extending through the flexible sleeve.

This invention relates to drilling wells. In particular it relates to apparatus for controlling entrance of high-pressure fluids into a drilling well.

When drilling oil and gas wells by the rotary drilling method, the drilling fluid is circulated down the drill pipe through the bit and up around the outside of the drill pipe. When a liquid is used as the drilling fluid, the hydrostatic head of this liquid outside the drill pipe imposes a pressure on the formations at the bottom of the well. In some cases the drilled formations contain a gas, a liquid or a mixture of gas and liquid at a pressure greater than this hydrostatic head. When the well reaches such a formation, the high pressure fluid enters the well and flows toward the surface with the drilling fluid outside the drill pipe.

The fluid entering the well may be salt water, oil or natural gas. Oil and gas are almost always less dense than the circulated liquid drilling fluid. In most cases even salt water is less dense than weighted drilling fluids. If these less-dense fluids dilute the heavier drilling fluid, the hydrostatic pressure is further reduced and still more fluids enter from the formation. This process can continue until the well is flowing.

In order to regain control of the well, the blow-out preventers may be closed while a highly weighted drilling liquid is circulated down the well. In order to fill the annular space between the drill string and the well wall with the heavier liquid, it is necessary to allow some flow from the well below the blow-out preventers. It is customary to provide a choke valve on a line from the casing below the blow-out preventers. Fluids can be bled off through this choke permitting the highly weighted drilling fluid to be circulated up the well outside the drill pipe. The choke valve must hold a back pressure on the top of the well to restrict flow of the high pressure formation fluids into the well.

The highly restricted flow through the choke valve has several very detrimental effects. Three of the most important effects are: First, the rate of circulation of liquids through the well is greatly reduced. Second, the high velocity of abrasive drilling fluid through the choke quickly destroys the choke valve. Third, the choke valve frequently is plugged by bit cuttings, lost circulation materials and the like. The resulting pressure surge which occurs until the mud pumps can be shut down can easily fracture drilled formations resulting in serious lost circulation problems.

All these problems and others are described in more detail in articles in the "Oil and Gas Journal" September

10, 1962, page 106, and June 29, 1964, page 52. These articles describe one solution to the problems. The solution is to use two large surge tanks, each operating under different carefully controlled pressures. The two vessels with their associated equipment weigh about 25,000 lbs., require considerable space and at least one full-time operator. Some idea of the seriousness of the problems can be obtained from the fact that this large complex equipment has found considerable use on wells in spite of its high cost. The equipment does seem to work well to hold back pressure on the well and sometimes to separate gas from the drilling fluid while permitting high rates of circulation so the well can be quickly filled with a heavier drilling fluid. All this is without danger of plugging which may cause high surge pressures. One problem which remains unsolved by this two-chamber equipment is very high pressures. Due to the large size of the chambers, there are definite upper limits on pressure for which the chambers can be designed while staying within practical limits. For example, the descriptions of the equipment point out that it is sometimes necessary to employ a choke valve in front of the chambers to provide at least a small pressure drop in order to avoid exposing the chambers to pressures beyond their design limits.

An object of this invention is to provide apparatus for controlling a drilling well into which high-pressure fluids are entering from a drilled formation. A more specific object is to provide a long lasting, simple, automatic apparatus for holding back pressure on the well outside the drill pipe while permitting high rates of drilling fluid circulation and minimizing the danger of high-pressure surges. A still more specific object is to provide control apparatus of the type described which will withstand the very high pressures which must sometimes be controlled.

In general, I accomplish the objects of my invention by placing on the line which usually carries the choke valve a special type of back-pressure valve. This valve is of the general type in which flow occurs through a substantially cylindrical sleeve of flexible resilient material such as rubber, for example. A pressure is applied to the outside of the sleeve to squeeze the sleeve and cause a decrease in internal diameter of the sleeve. If the pressure of fluids flowing inside the sleeve is greater than the pressure outside the sleeve, the sleeve expands, opening the valve until the pressures inside and outside are equalized. If the pressure of fluids flowing inside the sleeve is less than the pressure outside the sleeve, the sleeve is squeezed, closing the valve until the pressures are equalized. The valve can be called a rubber sleeve valve for convenience although it will be apparent that the sleeve can be made of many flexible polymers other than rubber. The valve is sometimes referred to as a pinch valve.

In the drawing FIGURE 1 shows the assembly of equipment used in my invention. FIGURE 2 shows a more detailed view partly in section of the pinch valve used in my invention. FIGURE 3 shows a sectional view of a hydrocyclone modified for use in degassing the drilling fluid.

In FIGURE 1 well casing **10** emerges from the well being drilled. Mounted on this casing are blow-out preventers **11** and **12**. Above the blow-out preventers a rotating kelly seal **13** is used such as that shown on page 2852 of the "Composite Catalog of Oil Field Equipment and Services," 1960–1961. Mud flow line **14** is tied onto seal **13**. Valve **15** is provided on line **14**. Passing through the seal **13** is kelly **16**. The kelly is connected to drill pipe **17** which extends through the blow-out preventers and into the well. Connected onto casing **10** below the bottom blow-out preventer is a small line **18** used to kill the well in case of trouble. This line also customarily carries choke valve **19**. Preferably, a second small line **20** is provided between the blow-out preventers. This line also carries a

choke valve 21. These small lines are variously called kill lines or relief lines.

All the above equipment with the possible exception of valve 15 and rotating seal 13 is standard equipment on many wells where high pressures are anticipated. Lines from valves 19 and 21 ordinarily lead to the mud pits. In my system, however, the lines from valves 19 and 21 are manifolded together in an arrangement including valves 23 and 24. By manipulation of valves 19, 21, 23 and 24 a mud stream from below at least one of the blow-out preventers can be sent through at least one of the flexible-sleeve or pinch valves 25 or 26. One such valve is shown in more detail in FIGURE 2 and will be described later. Compressed gas from cylinder 30, for example, can be applied to valves 25 and 26 through valve 31 or 32 and line 33 or 34, respectively, to control the back pressure held on the mud system. A small valve 37 and orifice 38 are provided between diaphragm-type pressure regulator 39 and pinch valves 25 and 26 so the pressure outside the sleeves of the pinch valves can be decreased as well as increased.

Drilling fluid from pinch valve 25 or 26 passes through valve 35 or 36 to hydrocyclone 40 or other degassing means. Hydrocyclone 40 is preferred for this purpose since when it is modified as shown in FIGURE 3, gas escapes from the drilling fluid through the top conduit 41 and the volume can be measured by meter 42. The degassed drilling fluid emerges through overflow outlet 43 and any bit cuttings which are present are rejected through underflow outlet 44.

In ordinary drilling operations, valve 15 is open and valves 19 and 21 are closed. Blow-out preventers 11 and 12 are, of course, open. With this arrangement drilling fluid circulation is down the drill pipe, up around the drill pipe and out through line 14 and valve 15 to the mud pits.

When a formation containing a high pressure gas, for example, is drilled, the gas enters the drilling fluid flowing up the well. The first evidence of this condition may be a decreased density of drilling fluid due to gas cutting or an increase in the level of mud in the pits. In my preferred method for using my apparatus, when gas cutting of the mud is detected, or other evidence is obtained of high pressure gas entering the well, valve 15 is closed and valves 21, 24 and 35 are opened. This permits flow of the drilling fluid through pinch valve 25. A pressure is applied from compressed gas tank 30 through valve 31 and line 33 to the outside of the flexible sleeve in valve 25. The result is that a back pressure, of about the same magnitude as the pressure applied outside the sleeve, is held on the circulating drilling fluid.

Gas-cut mud from valve 25 flows into hydrocyclone 40 where the gas is separated and may be measured by meter 42. When back pressure is applied to the mud system by means of valve 25, the amount of gas entering the well should decrease. This decrease may or may not be sufficient to reverse the cycle of events leading to a continued increase in the gas content of the mud. Meter 42 will indicate whether the decrease in density has been stopped. By increasing the back pressure held by valve 25, and watching the gas meter over a period of time, it is possible to set the back pressure at a value where the amount of gas in the drilling fluid remains substantially constant or decreases. Calculations for selecting appropriate back pressures are explained in the "Oil and Gas Journal" articles to which reference was previously made.

Referring to FIGURE 2, a sleeve 50 of flexible and resilient material such as rubber is surrounded by a generally cylindrical case or housing 51. The inside diameter of housing 51 is sufficiently larger than the external diameter of sleeve 50 to provide a chamber 52 between these elements of the valve. An opening 53 is provided through outer housing 51 so pressure can be applied around sleeve 50. End members 54 and 55 are secured to the ends of case 51 by suitable means such as the flanges shown. These end members include grooves 56 and 57 which hold the ends of sleeve 50.

A central body or mandrel 60 is mounted through sleeve 50. This body is preferably cylindrical in shape and of uniform diameter through sleeve 50 and has tapered ends. The body is mounted by means of webs 61 attached to ring 62 which can be secured to end member 54 or 55 as shown. It is possible to operate the valve without central body 60 if sleeve 50 is thin. In order to withstand the high pressures to which the valve may be subjected in my apparatus, however, the sleeve should be rather thick. Such a thick sleeve should not be deformed too far if permanent deformation is to be avoided. The presence of the central body permits use of a thick flexible sleeve and still allows the valve to close completely if necessary without permanent deformation of the sleeve.

The clearance between the flexible sleeve and central body must be great enough to permit passage of large bit cuttings. Thus, the clearance should preferably be at least about an inch. The webs supporting the cylindrical body should also be widely spaced to leave wide openings through which large bit cuttings, lost circulation material and the like can pass. If desired, the cylindrical body and supporting webs may be covered with a resilient material such as rubber to reduce wear.

In FIGURE 3 a modified hydrocyclone is shown. This is the preferred equipment for degassing the gas-cut mud. Other degassing means are well known in the art and can be used if desired, however. The cyclone is made up of the usual conical shell 70, inlet 71, overflow outlet 43 and underflow outlet 44. It also has the usual vortex finder 72. All these are preferably within the limits described in U.S. Patent 3,016,962 so that little if any underflow stream is present unless cuttings are in the drilling fluid. The modification of the hydrocyclone consists of tube 41 extending into the center of the top of the cyclone. There is always a vortex here, usually gas-filled. If little gas is in the drilling fluid, tube 41 can be closed and any excess gas simply leaves the cyclone through outlet 43 as it does in the normal operation of a hydrocyclone. It is possible, however, to draw off excess gas through opening 41 and thus separate it from the drilling fluid. By withdrawing the gas in this way, the cyclone operates not only to separate bit cuttings from the drilling fluid, but also acts to degas the mud very efficiently. In this connection it might be pointed out that field experience with the two-chamber system described in the "Oil and Gas Journal" has shown that when this system is used with a thick mud, a high pressure must be maintained in the second chamber to force a sufficiently rapid rate of discharge of the drilling fluid. The high pressure and the relatively quiescent state of the drilling fluid in the large chamber prevent adequate removal of gas in some cases. In the hydrocyclone, on the other hand, the drilling fluid is in rapid turbulent motion so degassing is easily accomplished.

The flexible-sleeve pinch valve is particularly advantageous when used in combination with downstream equipment such as the hydrocyclone degasser. Pressure drop across a hydrocyclone varies with different flow rates. Thus, the pressure at the downstream end of the pinch valve may vary considerably. Operation of the pinch valve is substantially independent of the downstream pressure as long as it does not exceed the desired upstream pressure. Therefore, the pinch valve will maintain a substantially constant back pressure on the well at any downstream pressure up to the desired back pressure on the well. Thus, the pressure drop across the hydrocyclone can be whatever is necessary whether one or more hydrocyclones are used or whether part of the mud stream is bypassed around the hydrocyclone, for example. In addition, since the function of the pinch valve is also substantially independent of mud flow rates, these rates can be adjusted to provide optimum operation of the hydrocyclone, hydrocyclones, or other apparatus without affecting the back pressure held on the well.

Returning to FIGURE 1, it will be noted that two pinch valves are shown manifolded together. The principal reason is to permit valve repair without shutdown of drilling operations. The flexible-sleeve pinch valves tolerate the flow of abrasive fluids over long periods of time before wear requires replacing the sleeves. A hardened, streamlined central body or one covered with a resilient coating also has a fairly long life. Nevertheless, repair is eventually necessary, requiring the presence of a second valve if continuous drilling operations are to be possible. It may sometimes be found desirable to open both valves to permit higher rates of flow. In this connection, however, it should be noted that one of the advantages of the pinch valve is the high rate of flow which is possible at all values of back pressure.

The apparatus can be used in many ways. For example, all the functions except drilling ahead can be performed even if valve **15** on the main flow line and rotating seal **13** are eliminated. The seal between the drill pipe and casing is then provided by blow-out preventer **12**. It is also possible to use a flexible-sleeve pinch valve as valve **15** so back pressure can be held on the well without using the kill lines. In the case of high pressure oil or brine flows, it will be advisable to weight-up the drilling fluid to balance formation pressure. A means for degassing the mud will not, of course, be necessary in case of oil or brine flows substantially free of gas. It will also be advisable to weight-up the drilling fluid if gas is present in large volume rather than as a small-volume gas pocket.

Many other uses of the apparatus will be apparent to those skilled in the art. In general, my apparatus can be used for all the purposes for which the large, expensive equipment described in the previously mentioned "Oil and Journal" articles can be used. My apparatus, however, is much smaller, less expensive and more easily controlled. Due to the small size of the outer case of the pinch valve, it can be used to control very high pressures, particularly when a central body is used inside the valve to help support the flexible sleeve.

I claim:

1. Apparatus for controlling a drilling well in which a high-pressure fluid enters the well from drilled formations, said apparatus comprising:

a casing extending into said well,

a drill pipe extending into said well through said casing,

a seal between said casing and said drill pipe near the top of said well,

a conduit extending through the wall of said casing at a level below said seal,

a pinch valve on said conduit, said pinch valve including a flexible sleeve through which drilling fluid containing large bit cuttings and lost circulation material can flow from said conduit, and a high-pressure housing surrounding said sleeve, the internal dimensions of said housing being sufficiently greater than the external diameter of said sleeve to provide a chamber into which gas can be introduced around said sleeve,

high pressure fluid to be applied to the outside of the sleeve of said pinch valve,

and means for regulating the pressure of the fluid applied to the outside of the sleeve of said pinch valve.

2. The apparatus of claim **1** in which said seal is a rotating seal, whereby rotation of the drill pipe can continue while the seal is closed.

3. The apparatus of claim **1** in which said seal is a blow-out preventer and said conduit is a kill line below said blow-out preventer.

4. The apparatus of claim **1** in which said pinch valve also includes a central body extending through the inside of said sleeve to limit the distance to which said sleeve can be squeezed by pressure applied around said sleeve.

5. The apparatus of claim **1** in which said fluid entering said well is gas and said apparatus includes a means for degassing drilling fluid after said drilling fluid leaves said pinch valve.

6. Apparatus for controlling a drilling well in which a high-pressure gas enters the well from drilled formations, said apparatus comprising:

a casing extending into said well,

a drill pipe extending into said well through said casing,

a seal between said casing and said drill pipe near the top of said well,

a conduit extending through the wall of said casing at a level below said seal,

a pinch valve on said conduit, said pinch valve including a flexible sleeve through which drilling fluid containing large bit cuttings and lost circulation material can flow from said conduit, and a high-pressure housing surrounding said sleeve, the internal dimensions of said housing being sufficiently greater than the external diameter of said sleeve to provide a chamber into which gas can be introduced around said sleeve,

high pressure gas to be applied to the outside of the sleeve of said pinch valve,

means for regulating the pressure of the gas applied to the outside of the sleeve of said pinch valve,

and a hydrocyclone downstream from said pinch valve, said hydrocyclone including a conduit extending into the center of the vortex formed by liquids flowing through said hydrocyclone to permit withdrawal of gas from said vortex.

7. Apparatus for controlling a drilling well in which a high-pressure fluid enters the well from drilled formations, said apparatus comprising:

a casing extending into said well,

a drill pipe extending into said well through said casing,

a seal between said casing and said drill pipe near the top of said well,

a conduit extending through the wall of said casing at a level below said seal,

a pinch valve on said conduit, said pinch valve including a flexible sleeve through which drilling fluid containing large bit cuttings and lost circulation material can flow from said conduit, and a high-pressure housing surrounding said sleeve, the internal dimensions of said housing being sufficiently greater than the external diameter of said sleeve to provide a chamber into which gas can be introduced around said sleeve,

high-pressure gas to be applied to the outside of the sleeve of said pinch valve, said gas being contained in a cylinder,

and means for regulating the pressure of the gas applied to the outside of the sleeve of said pinch valve, said means for regulating the pressure being a diaphragm-type regulator and an orifice to permit slow escape of gas from the chamber surrounding said sleeve.

References Cited

UNITED STATES PATENTS

994,167	6/1911	Koppitz	137—492
1,586,923	6/1926	Towsend	166—77
1,873,138	8/1932	Mitchell	251—5
2,082,329	6/1937	Foran et al.	175—206
2,150,887	3/1939	Mueller et al.	166—47
2,627,874	2/1953	Johnson	251—5
2,766,765	10/1956	Bolanowski et al.	251—5 X
2,786,642	3/1957	Comb	251—5 X
2,898,088	8/1959	Alder	251—5 X
2,923,151	2/1960	Engle et al.	175—206
3,004,602	10/1961	Kofahl	166—97 X
3,021,909	2/1962	Postlewaite	175—7

FOREIGN PATENTS

1,008,484	2/1952	France.

CHARLES E. O'CONNELL, *Primary Examiner.*

RICHARD E. FAVREAU, *Assistant Examiner.*