

May 27, 1958

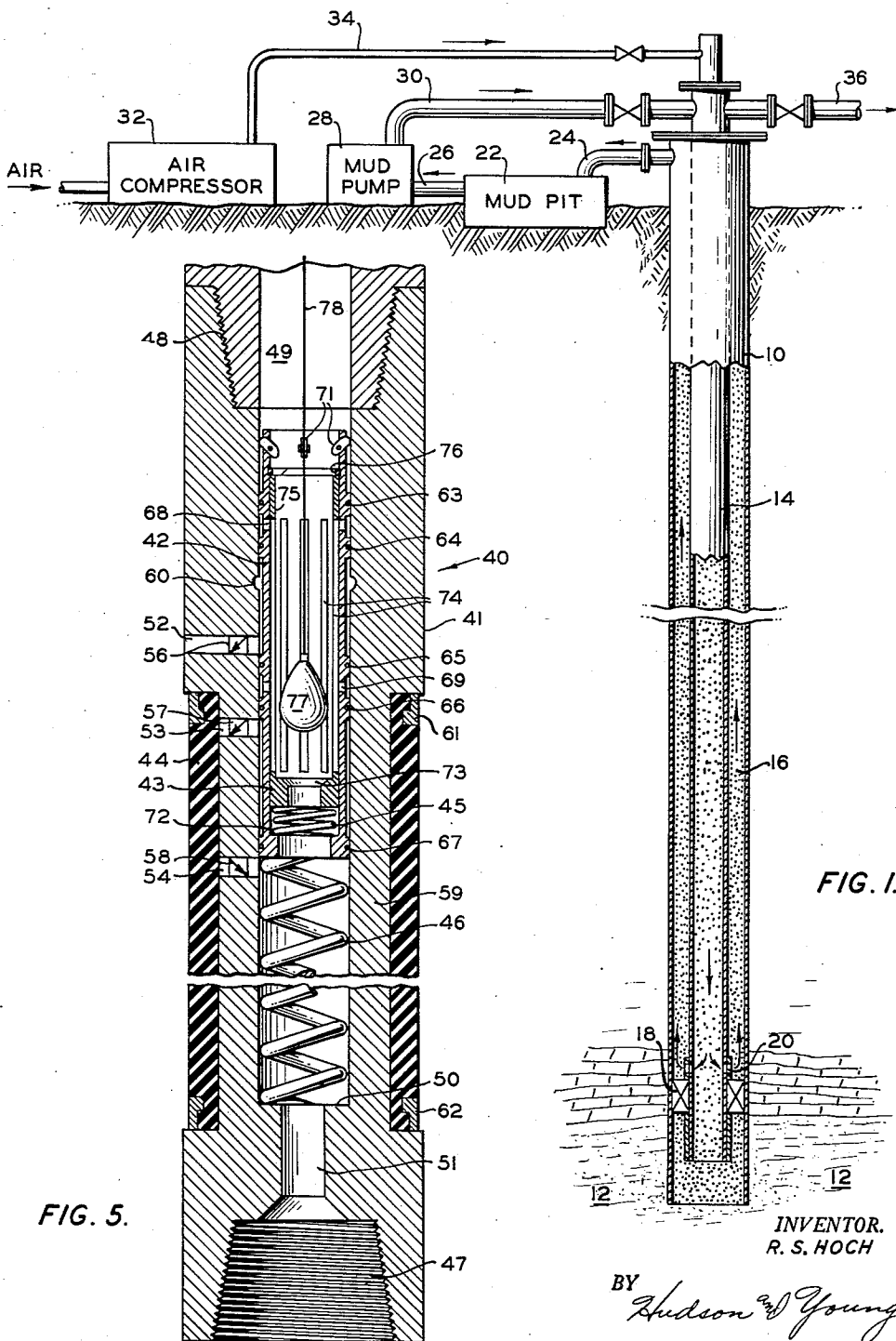
R. S. HOCH

2,836,246

METHOD OF REMOVING LIQUID FROM WELL BORE HOLE

Filed Aug. 30, 1956

2 Sheets-Sheet 1



INVENTOR.
R. S. HOCH

BY *Hudson & Young*
ATTORNEYS

May 27, 1958

R. S. HOCH

2,836,246

METHOD OF REMOVING LIQUID FROM WELL BORE HOLE

Filed Aug. 30, 1956

2 Sheets-Sheet 2

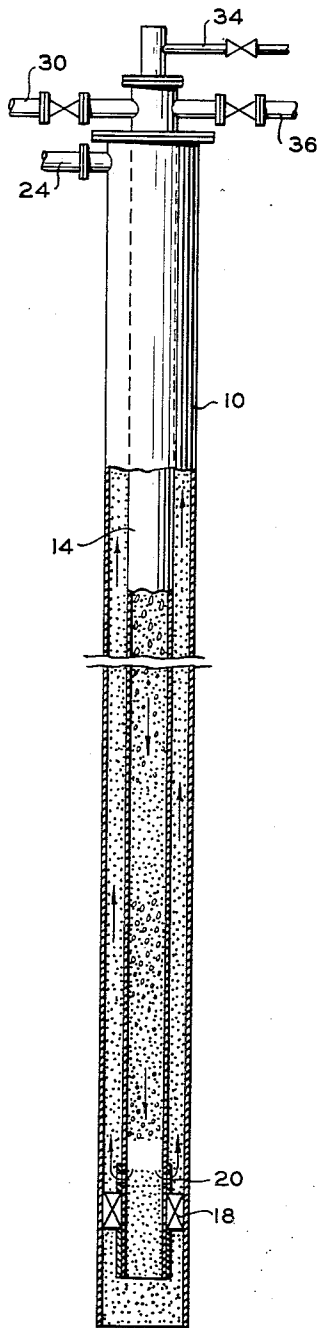


FIG. 2.

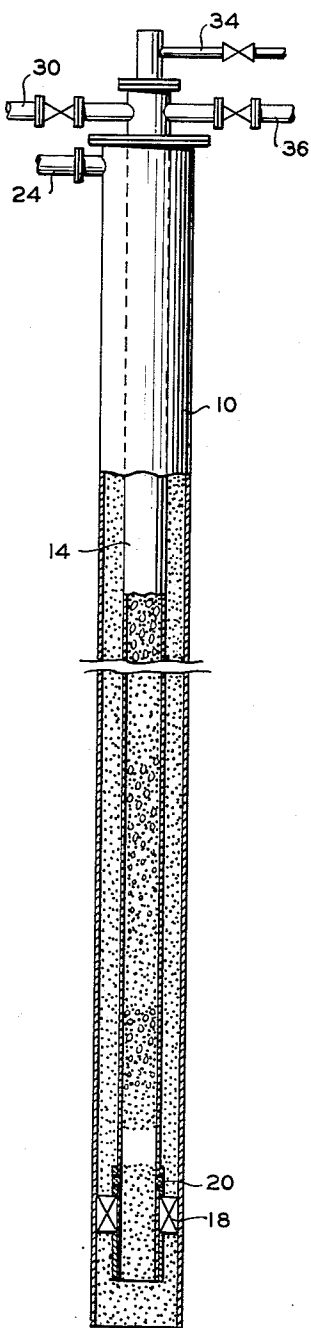


FIG. 3.

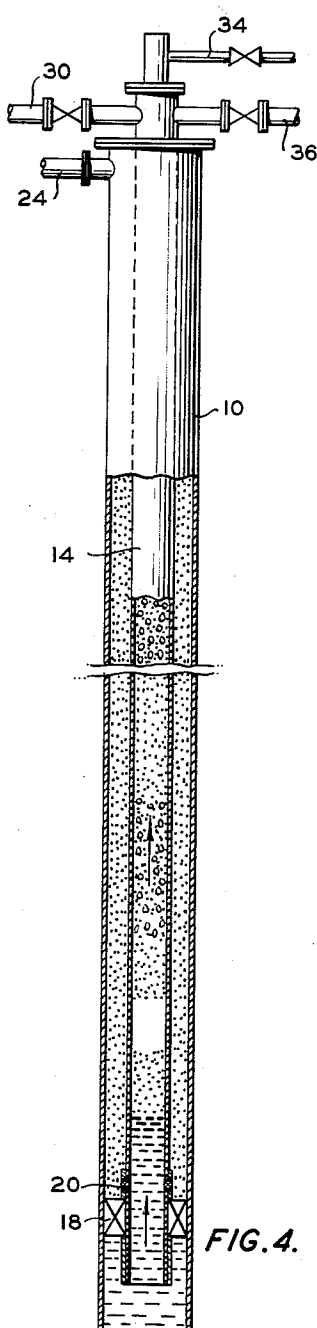


FIG. 4.

INVENTOR.
R. S. HOCH

BY *Hudson & Young*
ATTORNEYS

1

2,836,246

**METHOD OF REMOVING LIQUID FROM
WELL BORE HOLE****Robert S. Hoch, Houston, Tex., assignor to Phillips
Petroleum Company, a corporation of Delaware****Application August 30, 1956, Serial No. 607,025****8 Claims. (Cl. 166—3)**

This invention relates to a method of removing liquids from well bores. A specific aspect of the invention pertains to testing a drilled formation for formation fluid.

The necessity for obtaining fluid samples from drilled formations during drilling of oil wells is well recognized. U. S. Patent 1,896,492 to Macready discloses a method of obtaining samples from a drilled well wherein air is pumped into the drill string or well conduit so as to displace the regular drilling mud from an upper section of the drill string by forcing same thru a valve in a lower section of the drill string into the surrounding annulus above a packer therein blocking off the formation to be sampled or tested. After displacement of mud from the drill string to a permissible depth, the compressed air source is cut off and the upper end of the string is opened to the atmosphere so that static pressure of the formation and expansion of the air cause formation fluid (oil) to flow up the drill string to an equilibrium level.

It is apparent that in deep wells the method of Macready requires extremely high compressor pressure since the deeper the mud column in the string is forced, the greater the compression force, due to the pressure of the column of mud in the annulus and the necessity of balancing same with the column of mud and gas pressure in the string.

It is accordingly an object of the invention to provide a novel method of removing liquid from a deep well bore. Another object is to provide a method of testing a formation penetrated by a well bore efficiently utilizes available compressor pressure. A further object is to provide a novel method of testing a formation during drilling without removing the drill string. Other objects of the invention will become apparent from consideration of the accompanying disclosure.

I have devised a method for displacing the drilling liquid or mud from a drill string in a well to the depth of the formation being tested regardless of the depth of the formation utilizing a compressor such as one which develops 1500 p. s. i. at the outlet of the compressor. The method comprises displacing the non-compressible drilling liquid or mud inside the drill pipe with a regulated mixture of air and mud (aerated drilling mud) by forcing the mixture into the drilling string so as to force the regular drilling liquid down the drill string and into the annulus surrounding same from which the mud flows out the well head into the mud pit. An alternative method comprises introducing alternate slugs of air and mud so that the air-mud sequence progressively displaces the continuous column of mud inside the drill string. The discharge pressure of the air compressor and the mud pump steadily increases up to the pressure rating of the air compressor when operating in deep wells and it is then necessary to cut off the supply of air and use the mud pump only. The introduction of a slug of mud reduces the surface pressure in proportion to the length of the slug of mud and permits the injection of more air. Aerated mud injection can then be resumed until the pressure reaches the pressure capacity of the com-

2

pressor at which time the compressor is again shut off and continuous phase mud is injected to again reduce the surface pressure. This on-again-off-again technique is continued until the air-mud mixture reaches the depth at which fluid evacuation is assured.

In the procedure described the mud passes from the drill string to the annulus thru a control valve which either closes automatically to the back flow of mud or can be operated so as to prevent the return flow of mud into the drill string from the annulus. The next step in the process comprises closing the valve between the annulus and hollow drill string. The annulus is packed off below the valve in the drill string so that mud cannot flow thru the annulus below the packer. In other words the annulus is packed off above the formation to be tested and below the conduit or valve leading from the drill string to the annulus.

The third step comprises opening the upper end of the drill string to vent the fluid therein which, because of the highly compressed nature of the air-mud mixture, quickly expands and flows back to the surface reserve mud pit. The highly compressed air in the drill string produces adequate energy to displace most of the fluid from the drill string and any fluid pressure from the formation being tested causes the formation fluid to rapidly rise thru the drill string.

In order to provide a more complete understanding of the invention, reference is made to the accompanying schematic drawing of which Figure 1 is an elevation in partial section of an arrangement of apparatus in a formation in accordance with the invention; Figure 2 is a similar elevation showing the position of continuous-phase mud and aerated mud during mud displacement from the drill pipe; Figure 3 shows a similar arrangement to that of Figure 2 with the ports leading from the drill string to the annulus in closed position just prior to venting; Figure 4 is a similar elevation showing conditions in the apparatus during the testing step with the vent from the upper end of the drill string opened; and Figure 5 is a vertical longitudinal partial section of a drill stem packer. Corresponding parts in the various figures are correspondingly numbered.

Referring to Figure 1, a casing 10 penetrates the earth formation to an oil bearing formation 12. A drill or test string 14 extends to the vicinity of formation 12 and provides an annulus 16 between the drill string and the casing. Annulus 16 is packed off above the formation to be tested by means of packer 18. Valved openings 20 in string 14 provide flow of fluids between the drill string and the annulus. These valves may comprise check valves permitting flow only into the annulus or valves operable from the surface by means conventional in the art to permit flow in either direction and to shut off flow as desired.

A mud pit 22 is connected by a discharge conduit 24 with casing 10 and the annulus therein. A conduit 26 connects mud pit 22 with mud pump 28 which in turn is connected by valved conduit 30 with the upper end of drill string 14. When testing during drilling the mud pump is connected by conduit to the kelly. An air compressor 32 is connected with the upper end of drill string 14 by means of valved conduit 34 thru its discharge port. Valved conduit 36 is connected with the upper end of drill string 14 for the purpose of venting the compressed fluid in the drill string at the start of the testing step. Prior to testing, drill string 14 and annulus 16 are filled with non-compressible drilling liquid such as ordinary drilling mud. The condition shown in Figure 1 is that existing during operation of mud pump 28 without the use of air compressor 32.

Referring to Figure 2 the mud in drill string 14 has been displaced by alternate slugs of aerated mud and

slugs of continuous phase mud (non-compressible) and valves 20 are still open at the end of the displacement step of the process.

Figure 3 corresponds to Figure 2 except for the closed position of valves 20. With the apparatus in the position and condition shown in this figure initiation of testing is commenced by opening the valve in conduit 36 which permits rapid escape of the compressed fluid in the drill string 14 and since the mud in annulus 16 cannot exert pressure in drill string 14 because of closure of valves 20 and packer 18, the pressure on the formation fluid in the lower end of the drill string is greatly reduced as the compressed fluid escapes from the drill string and formation fluid therefore flows up the drill string. In most instances the fluid or oil from formation 12 will rise completely through the drill string and flow out conduit 36 so that the same may be adequately analyzed and tested. In some instances in which formation pressure is insufficient to cause the formation fluid to flow to the outlet conduit 36 it will rise in the drill string to a sufficient level to permit recovery by conventional means of a large sample for testing.

The invention is applicable to drill string testing during drilling operations. The present method of drill stem testing is a time-consuming and costly process because, prior to testing the formation, the drill string must be removed from the hole in order to place the testing packer at the bottom of the drill string and, also, for the purpose of floating the pipe into the hole. This "floating in" procedure is necessary to insure a pressure differential in the well bore after the packer is set and the tool is opened. The method of the invention permits the testing of the formation or formation fluid without removing the drill stem. The technique involved requires the running of a formation type packer above the bit so that when an oil show or zone is encountered, the packer is hydraulically or mechanically expanded above the prospective zone so as to seal off the annulus and the drill stem evacuation and testing in accordance with the invention is applied without "tripping" the drill string. This technique depends upon the use of a formation packer which can be run with the drill string and operated without removing the drill string from the hole. Such a packer is shown in Figure 5 and is disclosed and claimed in copending application of J. H. Hughes, Serial No. 640,453, filed February 15, 1957. In Figure 5 packer 40 comprises the body 41, a valve sleeve 42, inner sleeve 43, packer element 44, and springs 45 and 46. The body 41 is provided with threaded ends 47 and 48 for attachment within the drill string. Inner bore 49 terminates in a shoulder 50. The fluid passageway continues through port 51. Ports 52, 53, and 54 are provided with check valves 56, 57, and 58 respectively, the flow through the valves being in the direction of the arrows. A reduced diameter section 59 of body 41 provides space for the packer element 44 which is held in place by clamping rings 61 and 62. An annular depression 60 is cut in the inner bore 49 as shown.

Valve sleeve 42 is provided with seal rings 63, 64, 65, 66, and 67 and with ports 68 and 69. A plurality of hinged dogs 71, attached near the upper end of valve sleeve 42, are provided with torsion springs (not shown) which urge the upper ends outward. A shoulder 72 supports spring 45. Inner sleeve 43 is provided with a valve seat 73, a plurality of slots 74, and an upper sealing portion 75, which can be provided with seal rings if desired. A ring 76, attached in the upper portion of valve sleeve 42, restricts upward movement of inner sleeve 43. An actuating member 77, which is not in place in normal drilling operations, is lowered on wire line 78 when it is desired to actuate the apparatus.

In operation, while the well is being drilled, circulation of drilling fluid is through bore 49, the inner portion of valve sleeve 42, and inner sleeve 43, past valve seat 73, through port 51 and downward through any drill collars

located below the packer and the bit. Port 52 is sealed between seal rings 64 and 65, and port 53 between rings 66 and 67. Port 54 is uncovered but is closed by check valve 58.

When a test is to be made, actuating member 77 is lowered on line 78 until it seats on valve seat 73. Pressure is then applied to the drill string, thus moving inner sleeve 43 downward against the force of spring 45, causing sealing portion 75 to close ports 68. Further application of pressure results in downward movement of the entire inner assembly including valve sleeve 42. The first result of the downward movement is the closure of port 54, followed immediately by the opening of port 53 to ports 69. The fluid under pressure thus enters the space between packer element 44 and body 41 through valve 57 and expands the element 44 into contact with the well bore.

When element 44 is expanded tightly against the well bore, further application of pressure moves the assembly still farther downward, again sealing off port 53, and aligning ports 68 with ports 52. It will be noted that port 54 still is closed between seal ring 66 and 67 and port 68 is closed by sealing portion 75. When hinged dogs 71 are opposite annular groove 60, they spring outward thus preventing upward movement of sleeve 42. The pressure then is reduced and actuating member 77 raised a short distance so that it is between valve seat 73 and the dogs 71. This allows inner sleeve 43 to be raised by spring 45 thus uncovering port 68 and permitting circulation through ports 52. The column can then be aerated followed by the drill stem test.

When the test has been completed, in accordance with the invention, actuating member 77 is raised from the well bore. As it passes by dogs 71, it contacts their inner ends thus forcing them to be rotated in a direction to disengage their upper ends from groove 60. This permits spring 46 to restore the apparatus to the position illustrated, thus uncovering ports 54, allowing the fluid under pressure-expanded element 44 to be discharged, allowing the element to return to the position illustrated.

Although actuating member 77 is relatively heavy it may, if the flow through the tool is excessive, be forced upward, thus releasing dogs 71 allowing the packer to be released. Normally this can be prevented by controlling the rate of flow by means, such as a choke, at the surface. If desired, however, flow actuated means can be provided to prevent upward movement of member 77. For example, one or more perforated flappers can be provided, hinged to the inner wall of inner sleeve 43. The weight of such flappers will cause them to fall to a retracted position, allowing free movement of member 77 either up or down. Under a condition of excessive flow, however, such flapper would be moved upward much in the manner as the flapper of a check valve, thus obstructing the passageway sufficiently to prevent upward movement of member 77.

It will thus be seen that the device of Figure 5 provides a solid connection between the upper portion of the drill string and the drill bit but permits a packer to be provided when desired and communication between the inner and outer portions to be established, thus permitting the well test to be made.

Utilizing the technique described, deep wildcat wells can be drilled to total depth before initiating the drill stem testing program. After total depth is reached, a straddle type packer or a single packer and bottom plug arrangement are used to progressively test each prospective zone starting with the lower zone. Present testing methods require "tripping" of drill pipe between each formation test and the method of this invention eliminates this time consuming phase of present day testing operations.

Certain modifications of the invention will become apparent to those skilled in the art and the illustrative details

5

disclosed are not to be construed as imposing unnecessary limitations on the invention.

I claim:

1. A method for removing liquid from a conduit surrounded by an annulus in a well bore, said conduit and annulus containing a liquid and said annulus being packed off adjacent its lower end which comprises forcing a compressible fluid lighter than said liquid into an upper section of said conduit so as to displace liquid into said annulus thru a valve in a lower section of said conduit above the packer; then forcing a liquid heavier than said fluid into an upper section of said conduit above said fluid so as to displace additional liquid into said annulus; preventing backflow thru said valve; and thereafter opening the upper section of said conduit to fluid flow therefrom, thereby decreasing the effective downward pressure at the bottom of said conduit and causing fluid to flow out said upper section.

2. The process of claim 1 wherein said fluid is an aerated liquid.

3. The process of claim 1 wherein said liquid is a drilling mud and said fluid is an aerated liquid.

4. The process of claim 1 wherein said liquid is a drilling mud and said fluid is an aerated drilling mud.

5. The process of claim 1 including repeating the cycle of forcing said liquid and said fluid into said conduit before opening said upper section to fluid flow.

6. A method for testing a formation in a well bore containing a conduit forming an annulus with the wall of said well bore, said conduit and annulus being filled with non-compressible drilling liquid and said annulus being packed off just above said formation, which comprises forcing a compressible fluid into the upper end of said conduit so as to displace liquid into said annulus thru a valve in a lower section of said conduit above the packer; then forcing non-compressible liquid into said conduit above said compressible fluid so as to displace said compressible fluid downwardly and displace additional non-compressible liquid into said annulus; repeating the cycle of forcing steps so as to position alternate slugs of compressible fluid and non-compressible

6

liquid in said conduit and thereby decrease the total weight of fluid in said conduit; preventing backflow thru said valve; and thereafter venting the upper end of said conduit so as to effect expansion of fluid therein with attendant reduction of pressure in the lower end of said conduit adjacent said formation whereby flow from said formation into said conduit is induced.

7. The process of claim 6 wherein said non-compressible liquid is drilling mud and said compressible fluid is aerated drilling mud.

8. A method of testing a formation during drilling operations in a well bore therein without removal of the drill string which comprises running a packer in a hollow drill string above but relatively close to a bit on the bottom thereof; drilling said formation while flowing non-compressible drilling liquid thru the drill string and out through an annulus between said string and the wall of said well bore; when a formation is to be tested, setting said packer so as to pack off said annulus without removing said drill string; displacing said non-compressible drilling liquid from said drill string into said annulus above said packer by forcing compressible fluid into said string from its upper end; when the major portion of said non-compressible drilling liquid has been displaced, opening the upper end of said string so as to vent compressed fluid therefrom while preventing flow back into said string from said annulus so as to reduce the effective pressure on formation fluid at the lower end of said string, thereby effecting flow of formation fluid up said string.

References Cited in the file of this patent

UNITED STATES PATENTS

2,258,614	Kendrick	Oct. 14, 1941
2,726,063	Raglan et al.	Dec. 6, 1955
2,749,990	Carpenter	June 12, 1956

OTHER REFERENCES

Bobo-aerated mud drilling, *The Petroleum Engineer*, November 1955, pp. B-46, B-49, B-51.