March 19, 1968 L. H. ROBINSON, JR., ETAL 3,373,820

APPARATUS FOR DRILLING WITH A GASEOUS DRILLING FLUID

Filed May 16, 1966 2 Sheets-Sheet 1

FIG. 1.

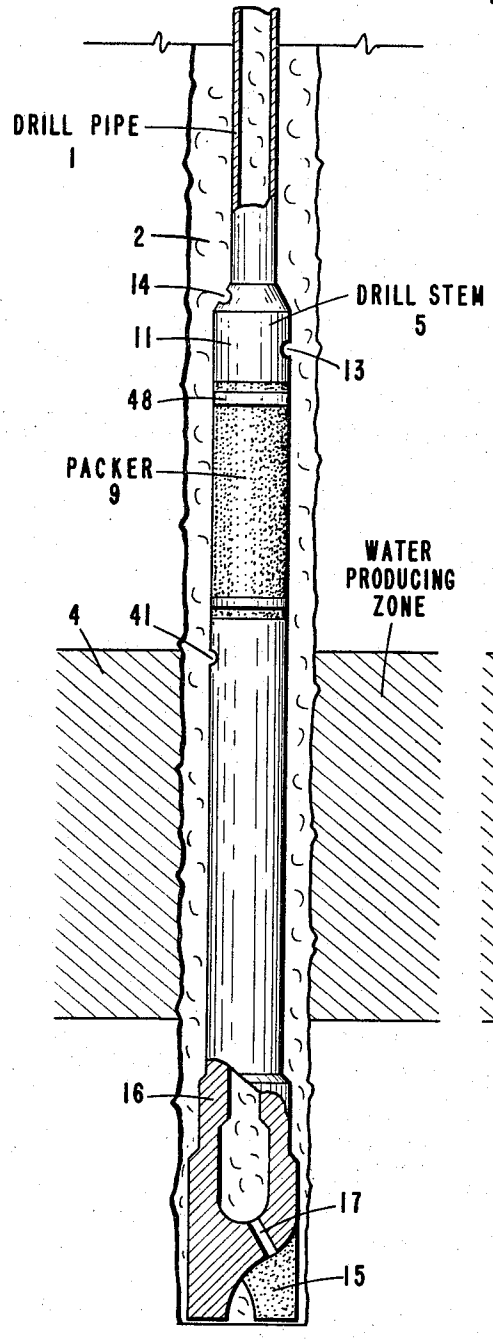
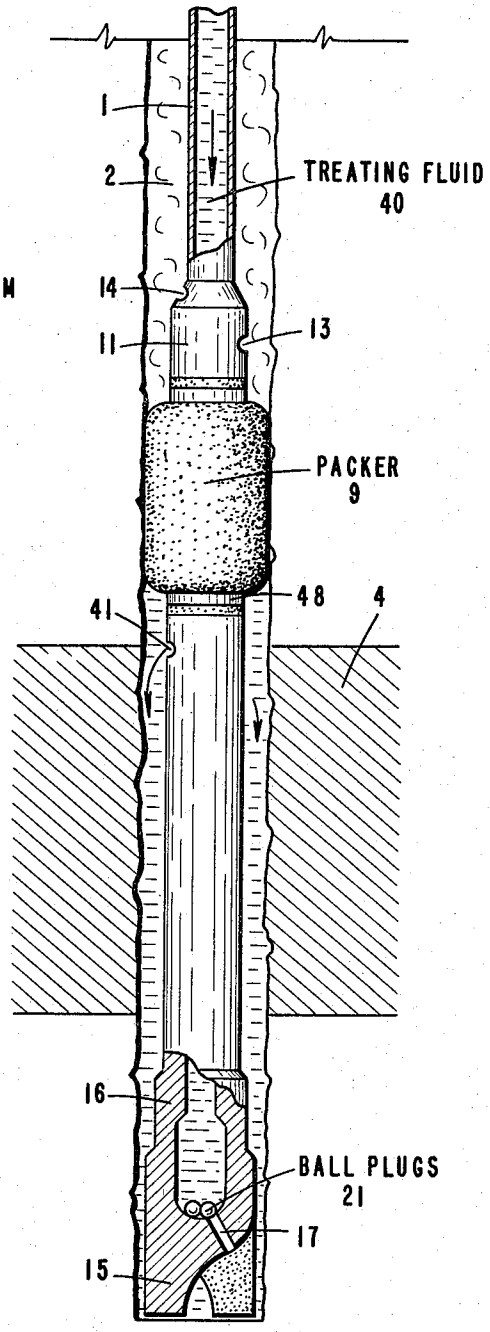


FIG. 2.



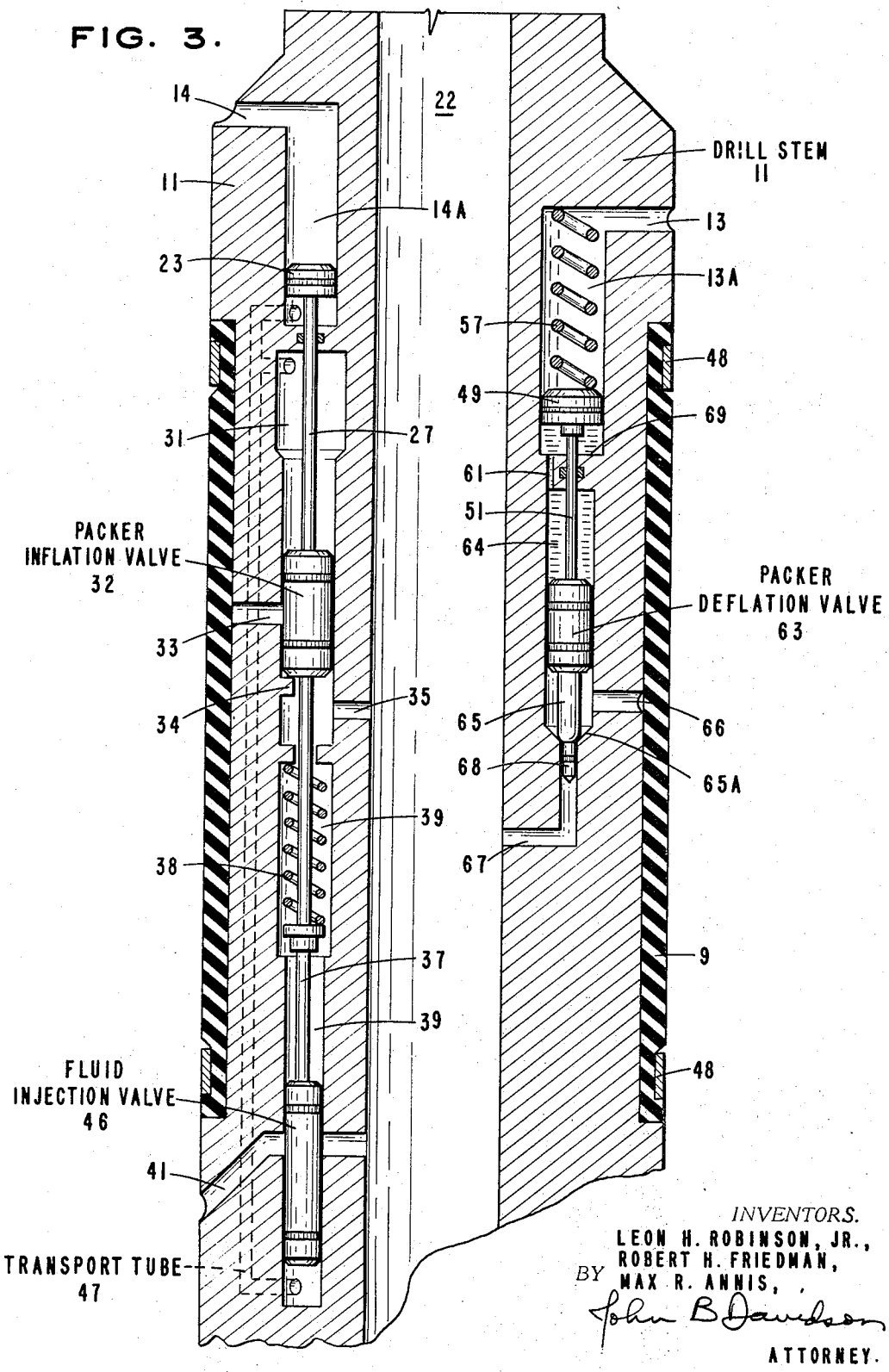
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FIG. 3.



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APPARATUS FOR DRILLING WITH A GASEOUS DRILLING FLUID

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This invention relates to apparatus for injecting fluids into an earth formation, and more particularly to an apparatus for sealing off a formation that has been found to produce water or other earth fluids during air drilling operations.

In boreholes drilled for the purpose of recovering oil and gas from productive earth formations, it is customary to circulate a drilling fluid down a drill pipe and up the annulus thereabout for the purpose of removing earth cuttings and generally facilitating drilling operations. While liquid drilling fluids are customarily, used in many areas it has been found feasible and desirable to use a gas, such as air, as the drilling fluid. When air is used as a drilling fluid, however, it is necessary to seal off any earth formations which produce fluids such as water which will interfere with drilling operations by producing mud in the bottom of the drill hole which will seriously interfere with the removal of earth cuttings by the gaseous drilling fluid. Manifestly, it is desirable to inject a fluid through the drill stem into the liquid-producing formation so that the drill stem will not have to be removed from the borehole.

In accordance with the present invention, there is provided a fluid expansible annular packer mounted on a tubular drill string section, such as the drill collars, which packer is constructed and arranged so that fluid pressure exerted on the inner surface thereof will expand the packer to the walls of the borehole. Within the drill string section there are provided first and second fluid passageways connected in parallel between the bore of the drill string section and the exterior of the drill string under the packer. There is also provided a third fluid passageway in the drill string section between the bore and the exterior of the drill string opening to the exterior of the drill string section beneath the level of the packer. Within the walls of the drill string section there is provided a first valve means, a portion of which is disposed to borehole pressure around the drill string section in the vicinity of the packer, constructed and arranged to close the first passageway until pressure in the drill string section is greater by a first predetermined differential pressure than the borehole pressure above the packer. Thus, when pressure is exerted sufficient to produce the predetermined differential pressure, fluid in the bore of the drill string section will inflate the packer. A second valve means connected to the first valve means and actuated thereby is arranged to close a third fluid passageway until the second valve means is subjected to pressure in the drill string bore that is greater by a second predetermined differential pressure than the pressure in the borehole above the packer. At this time the second valve means will open so that liquid in the drill string bore can be injected into the borehole beneath the packer under pressure and into the earth formation to seal the formation. Third valve means is also provided which is positioned in the second passageway and is constructed and arranged to close the second passageway until pressure in the drill string section is greater than a third predetermined differential pressure

in the borehole above the packer. Means are also provided for holding the second valve means open for at least a predetermined time interval so that the packer can be deflated. The second predetermined differential pressure is greater than the first predetermined differential pressure, and the third differential pressure is greater than either the first or the second differential pressures mentioned above so that the valves are opened in sequence.

Objects and features of the invention not apparent from the above discussion will become evident upon consideration of the following detailed description taken in connection with the accompanying drawings, wherein:

FIGS. 1 and 2 are elevational views, partially in cross section, of a drill string section in a borehole, including apparatus in accordance with the invention illustrating two operative positions of the apparatus; and

FIG. 3 is a cross-sectional view of apparatus within the drill collars 5 in accordance with the invention.

With reference generally to FIGS. 1 and 2, there is shown a drill string 1 including drill collars 5 positioned in a borehole 2 penetrating a given liquid-producing earth formation 4. The borehole drilling operation is assumed to be conducted using air as a drilling fluid. The drill collars 5 include a section 11 near the upper end thereof to which fluid expansible packer 9 is affixed. At the lower end of the drill string is a bit sub 16 to which is affixed a drilling bit 15, here shown as a fishtail bit including at least one port or nozzle 17 for directing a jet of drilling fluid downwardly to facilitate drilling operations. The drill string is illustrated as being on bottom, but it will be evident that it may be raised if necessary to place the packer element above the water-producing formation to be treated.

In FIG. 3 is illustrated apparatus within the drill collar section 11 for the purpose of inflating and deflating packer 9 and for injecting a suitable sealant liquid 40 through port 41 into the borehole 2 for injection into water-producing formation 4 by selectively increasing and decreasing the hydraulic pressure within the drill string. Packer 9 is shown as being affixed to the drill collar section 11 in a recess within the drill collar section by means of clamping rings 48. Between the interior surface of packer 9 and the bore 22 of the drill collar section 11 there are provided two passageways for fluid. The first passageway comprises passageway section 35, a portion of chamber 39, and port 33. The second passageway comprises passageway section 67, a portion of chamber 64, and port 66. The first passageway is normally closed by a first valve between chambers 31 and 39, said valve including a valve piston comprising sections 23 and 32 connected together by rod 27. The piston abuts against stop 34 between passageway 35 and port 33 for closing the fluid passageway between port 33 and passageway section 35. Sufficient fluid pressure exerted on the underside of the valve piston section 32 will raise the valve piston so that fluid can flow from passageway section 35 through port 33 to the interior of the packer 9.

A third fluid passageway 41 below passageway section 35 interconnects bore 22 and the exterior of the drill string section and intersects chamber 39. A second valve including valve piston or valve stem 46 is connected to valve piston section 32 by rod 37. A helical spring 38 in chamber 39 engages the underside of a shoulder in the chamber 39 and biases against the rod 37 and valve piston 46 so as to normally close the port 41. The length of the valve piston 46 is such that when fluid pressure is imposed on the underside of valve piston 32 to raise the valve piston

and open fluid communication between passageway section 35 and port 33, passageway 41 will still remain closed. A substantially larger fluid pressure must be exerted on the valve piston 32 to further raise the valve pistons 32 and 46 to open the passageway 41. Sealing rings 50 are provided on valve piston 46 to sealingly engage the bore of chamber 39 above and below the passageway 41. A transport tube or vacuum relief passageway 47 is provided between chamber 31 and the lower end of chamber 39, and the chamber formed below member 23 to provide free movement of the movable portion of the valves. An upper pressure port 14, including a chamber 14A within which valve piston section 23 moves, opens into the annulus around the drill string above the packer 9 to permit movement of the valve mechanism responsive to differential pressure between the interior and exterior of the drill string.

For the purpose of deflating packer 9 by the simple expedient of increasing the differential pressure between the interior of drill collar section 11 and the annulus thereabout and above packer 9, there is provided a third valve arrangement in the second passageway mentioned above. The third valve element includes a piston 49 arranged in chamber 13A, and a valve piston member 63 arranged in chamber 64 and connected together by rod 51 which sealingly extends through wall 69. A small orifice passageway 61 is formed in wall 69 and fluidly communicates the two chambers. The chamber space between the two piston members is filled with hydraulic fluid so as to form a dash-pot effect upon vertical movement of the valve element. Formed on the lower end of member 63 is a seating member 65 which in the lowermost position of the valve element seats on seat 65A to close off passageway 67. A sealing prong 68 extends from the lower end of member 65 into passageway 67. The entire valve element is biased downwardly to a closed position by a helical coil spring 57 positioned above piston 49 in chamber 13A. Chamber 13A opens into the annulus about the drill string above packer 9 through port 13. A predetermined differential pressure between the interior of the drill string and the annulus thereabout which is greater than the pressure required to open the fluid passageway 41 will force the valve stem upwardly until fluid communication is established between port 66 and passageway section 67. Normally, the pressure will be sufficiently great to force the assembly a substantial distance up within chamber 64 against the restriction of the dash-pot arrangement. When the pressure within the drill string bore is lowered to reduce the differential pressure to less than the pressure required to open said first valve, the packer will deflate inasmuch as the third valve will not close because of the time delay action of the dash-pot. In other words, the valve stem will be lowered very slowly, providing sufficient time for the packer 9 to be deflated.

The overall operation of the apparatus described above is as follows. Let it be assumed that during drilling operations a liquid-productive formation 4 has been encountered. Several ball plugs 21 will be dropped into the drill string so as to seal the ports 17 in the drill bit sub 16. A quantity of water is injected into the drill pipe followed by a quantity of a suitable earth sealing liquid, which may be known gums, resins, and silicates such as sodium silicate. The quantity of water should be sufficient to fill the portion of the annulus around the drill string below the packer 9, and to fill the bore of the drill string to a desired distance above the packer. The earth sealing liquid can be followed by water; however, nitrogen or other relatively inert gas may also be used for following the sealing liquid. The pressure within the drill string is again increased until the valve stem section 32 is forced upwardly off stop 34 to expand the packer 9. When the packer is sufficiently expanded by the fluid in the drill string, the pressure is increased further until passageway 41 is opened. Liquid from within the drill string is injected into the borehole around the drill string and below packer 9. Pressure is maintained at this level until the excess water and a desired quantity of the sealing liquid has been injected into the earth formation. The pressure is again increased to provide fluid communication between passageway section 67 and port 66 and to lift the piston 63 to a desired level within the chamber 64. The pressure in the drill string bore is then increased to a fourth level until the balls 21 extrude through ports 17. The pressure is then quickly lowered to less than the pressure required to open fluid communication between passageway section 35 and port 33 for the purpose of deflating packer 9. Alternatively, using only three levels of pressure the direction of drilling fluid circulation can be reversed so that the balls are carried up the drill string bore to the earth's surface. A high degree of drilling fluid (gas) circulation should be maintained until substantially all of the water is circulated out of the borehole. Manifestly, during this operation the bit should be as low in the borehole as possible. Normal drilling operations can thereupon be recommenced.

The invention is not to be restricted to the specific structural details or arrangement of parts herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of the invention.

What is claimed is:

1. Apparatus for injecting fluid into the lower portion of a borehole in the earth comprising:

a tubular drill string section;

a fluid expansible annular packer affixed to the outer surface of said drill string section, constructed and arranged so that fluid pressure exerted on the inner surface thereof will expand the packer to the walls of the borehole;

first and second fluid passageways in said drill string section connected in parallel between the bore of said drill string section and the exterior of said drill string section under the packer;

a third fluid passageway in the drill string section between the bore and the exterior of the drill string section opening to the exterior of the drill string section beneath the level of said packer;

first valve means positioned in said first passageway and having a portion thereof exposed to borehole pressure around said drill string section in the vicinity of the packer, constructed and arranged to close said first passageway until pressure in said drill string section bore is greater by a first predetermined differential pressure than the borehole pressure above said packer;

second valve means connected to said first valve means and actuated by said first valve means, constructed and arranged to close said third fluid passageway until said first valve means is subjected to pressure in said drill string bore that is greater by a second predetermined differential pressure than the pressure in said borehole above said packer;

third valve means positioned in said second passageway and having a portion thereof exposed to borehole pressure above said packer, constructed and arranged to close said second passageway until pressure in said drill string section bore is greater by a third predetermined differential pressure than the borehole pressure above said packer, said second predetermined differential pressure being greater than said first predetermined differential pressure, and said third predetermined differential pressure being greater than either of said first and second predetermined differential pressures; and

means for holding open said second valve means for at least a predetermined time interval.

2. The apparatus of claim 1 wherein said first and second valve means includes:

a piston chamber in said drill string section wall intersecting said first and second fluid passageways;

first and second interconnected valve piston means re-

spectively positioned in said piston chamber to normally close said first and second passageways, respectively; and

spring means in said piston chamber for permitting only limited movement of said first and second valve pistons prior to imposition of pressure sufficient to produce said second differential pressure to close said second valve means until said second differential pressure is produced.

3. Apparatus as defined in claim 2 further including a vacuum relief passage in said drill string section wall between the ends of said piston chamber.

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JAMES A. LEPPINK, *Primary Examiner.*