Nov. 11, 1958 P. S. WILLIAMS 2,859,828

DOWN HOLE HYDRAULIC PUMP FOR FORMATION TESTING

Filed Dec. 14, 1953 2 Sheets-Sheet 1

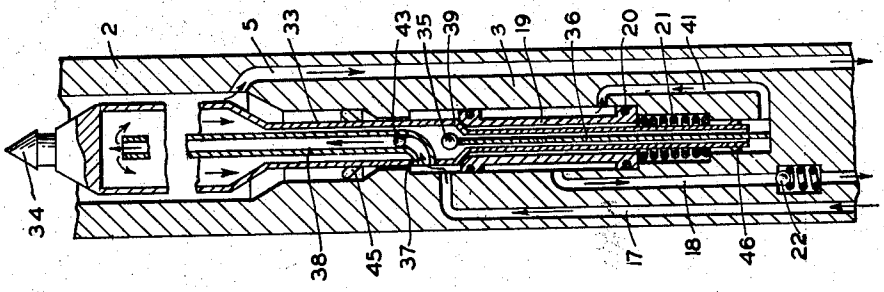


FIG. 4

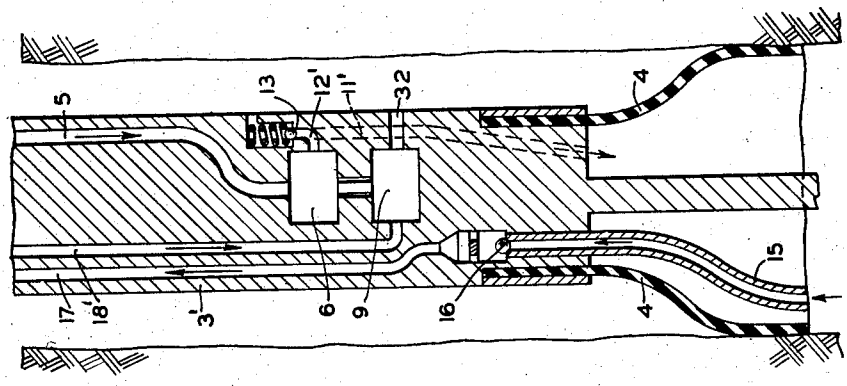


FIG. 3

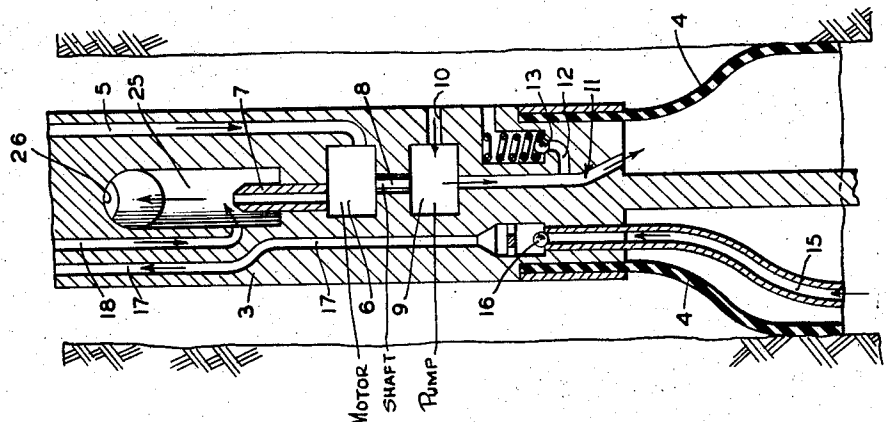


FIG. 2

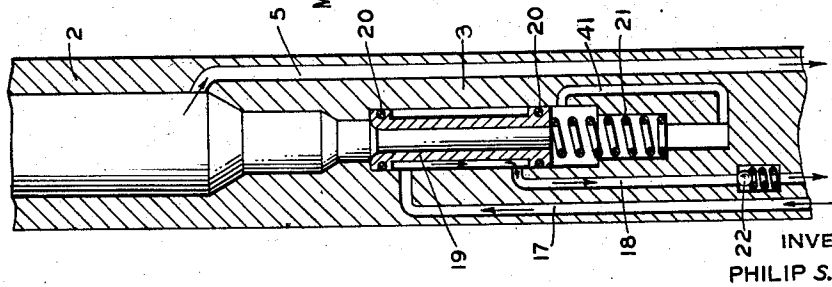


FIG. 1

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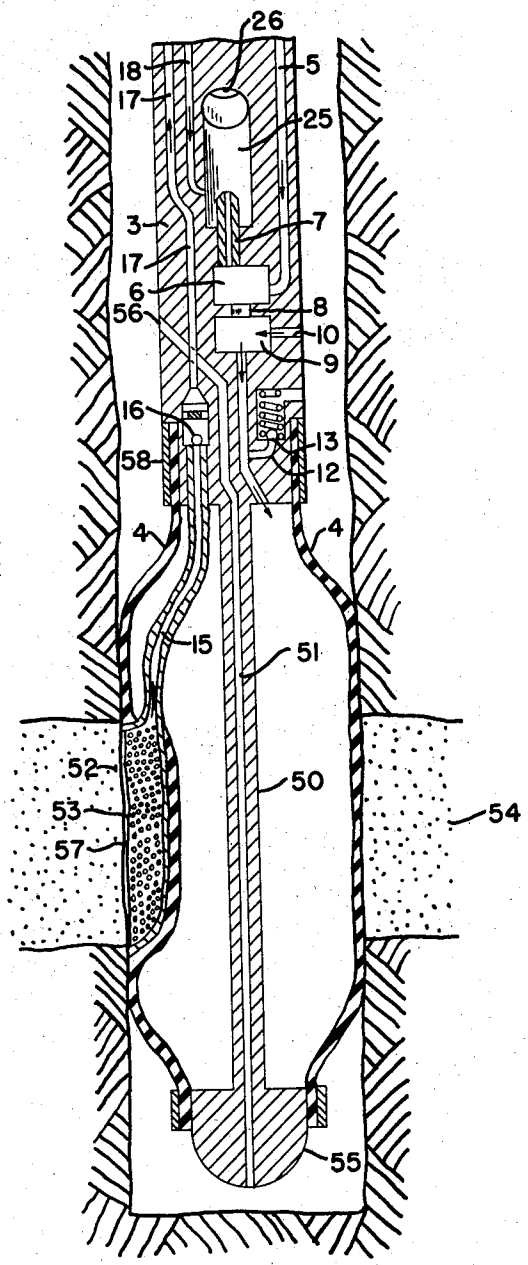


FIG.-5

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DOWN HOLE HYDRAULIC PUMP FOR FORMATION TESTING

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4 Claims. (Cl. 166—187)

This invention is concerned with the sampling of fluids from a well bore employed in exploration for and production of petroleum from the earth. The invention is concerned with a hydraulic pump of a character which can be suspended within a well bore for operation by circulation of drilling mud through the bore hole. The mud pump arrangement disclosed herein is adapted for usage with any type of formation tester to permit obtaining the full benefits of formation testing procedures while at the same time providing certain unique features.

In drilling a bore hole during exploration for oil deposits in the earth, it is essential at various stages in the operation to test the nature of fluids present in the bore hole to determine when oil, gas, or water deposits have been encountered during drilling. The problem of sampling fluids from a bore hole is complicated by the fact that drilling mud is conventionally used in the bore hole to maintain a high hydrostatic pressure during drilling. Consequently, in order to sample fluids present in a bore hole, it is necessary to make provision for at least locally sealing off a portion of the bore hole to be sampled for fluid production so as to exclude drilling mud and to permit lowering of the hydrostatic pressure in this local portion so that fluid can be produced. Formation testing apparatus is employed for this general purpose. Formation testers of a wide variety are employed, but one of the most attractive forms of such devices is the inflatable packer type. Inflatable packer formation testers are provided with an elastic packer arrangement which can be used to seal off a portion of the bore hole so as to exclude drilling mud and so as to permit decreasing the hydrostatic pressure at the sealed portion of the bore hole. Suitable channels for fluid flow must be provided from the sealed portion of the bore hole to a suitable sample chamber or to a fluid passage extending to the surface of the earth.

While the general requisites of formation testing have long been appreciated and while many desirable types of formation testers have been suggested, the need still exists for improving formation testing practices in several ways. For one thing, it is a problem to suitably reduce hydrostatic pressure adjacent a formation to be tested so as to permit the recovery of fluids which may be present at low formation pressures. This problem is particularly serious in the case of certain "tight" producing zones where the presence of oil may easily be overlooked by conventional techniques. For example, in order to reduce hydrostatic pressure at a stratum to be sampled, it has been suggested that a vacuum pump may be employed at the surface of the earth to lower hydrostatic pressure in a drill string or conduit in fluid communication with the formation to be tested. This technique, however, is seriously limited by the fact that a pressure differential can only be developed equivalent to a head of about thirty feet of water. It therefore becomes desirable to develop a suitable form of force pump which may be located down the hole adjacent the formation to be tested so that the pumping limitation referred to can be avoided. It is one object of this invention to provide an attractive form of

hydraulic force pump for this purpose in which circulation of drilling mud in the bore hole is used to secure the pumping action.

Other particular problems associated with formation testing which have not been fully solved concern the retention of clean uncontaminated samples of fluid produced during testing, the problem of determining when testing has proceeded far enough so that testing can be terminated, and the problem of permitting repetition of formation testing at different levels in the bore hole without necessity for retrieving the apparatus from the bore hole. The present invention accomplishes each of these purposes in providing a novel and attractive form of hydraulic pump assembly for use in combination with any desired type of formation tester.

In order to describe a preferred embodiment of the invention, the invention will be described with particular reference to the type of formation tester disclosed and claimed in U. S. Patent 2,600,173, issued to Ben W. Sewell et al. on June 10, 1952. The formation tester identified in this patent is of the elastic packer type suspended on a drill string to be used within a bore hole and normally employing the circulation of drilling mud through the drill string in order to control inflation and deflation of the packer. The present invention is particularly attractive for use in combination with this type of formation tester. In fully describing the nature of this invention, reference will be made to the accompanying drawings, in which:

Figure 1 diagrammatically illustrates in cross-sectional, elevational detail the upper portion of the hydraulic pump assembly;

Figure 2 is a lower continuation of the apparatus of Figure 1 terminating at its lower portion in a formation tester of the nature described in Patent No. 2,600,173;

Figure 3 is a cross-sectional, elevational detail drawing of an alternative form of the invention using a different type of hydraulic pump assembly than that shown in Figure 2;

Figure 4 illustrates the use of a sample chamber in combination with the apparatus of Figures 1 and 2 and essentially illustrates the same portion of the apparatus illustrated in Figure 1 with a suitable sample chamber in operative position in the apparatus, and;

Figure 5 is a lower continuation of the apparatus of Figure 1 utilizing a formation tester similar to the one described in Patent No. 2,600,173.

Referring first to Figures 1 and 2, the basic features of the hydraulic pump assembly of this invention can be appreciated. In these figures it is assumed that the pump assembly is supported in a bore hole by means of a drill string or tubular support member **2** which may be integrally connected with the pump assembly sub or body **3** having the same external diameter as the drill string **2** and supporting at the lower portion an inflatable packer formation tester **4**. In the apparatus of Figures 1 and 2 drilling mud forced downwardly through the drill string **2** from the surface of the earth enters a channel **5** which passes downwardly to a hydraulic motor **6**. Drilling mud passing through channel **5** flows through the hydraulic motor **6** so as to exhaust through the nozzle **7**. This nozzle together with intake passage **18** constitutes a jet pump as hereafter described. The hydraulic motor is directly coupled through shaft **8** to a pump **9**. In the particular apparatus illustrated in Figures 1 and 2, it is assumed that the hydraulic motor is of the turbine type while the pump **9** may constitute a simple impeller type pump. The intake of pump **9** is connected through a conduit **10** to the bore hole annulus so that drilling mud will be pulled through the pump and discharged through conduit **11**. This drilling mud may be used to inflate the elastic packer **4** in the manner more particularly described in Patent 2,600,173. While pump **9** may be so constructed

and operated as to provide the desired inflation pressure for the packer 4, it is generally desirable to employ a pressure limiting arrangement to prevent possibility for rupturing the elastic packer. Such a pressure limiting arrangement is illustrated by conduit 12 connecting to conduit 11 and opening into the annulus of the bore hole through the check valve 13. The retaining spring on check valve 13 is selected so that when suitable inflation pressure is provided through conduit 11 to the inflatable packer, drilling mud will simply exhaust to the bore hole through the check valve 13.

The inflatable packer is illustrated in Figure 5 and is more fully explained in Patent No. 2,600,173. The inflatable packer of the formation tester may consist of any suitable form of flexible, non-porous membrane. The lower end of the packer is sealingly affixed to the base 55, and the upper end is sealingly affixed at 58 to the lower portion of sub 3. An inner steel mandrel 50 extends through the inflatable packer with a passage 51 extending through the mandrel. The lower end of the passage 51 is in open communication with the borehole and the upper end communicates with outlet port 56. This provision has the effect of equalizing the hydraulic pressure acting on the elastic packer so that no pressure will exist to force the packer either upwardly or downwardly in the borehole.

The tubing 15 positioned within the packer 4 connects at its lower portion to the fluid producing inlets of the formation tester. The fluid-producing inlets comprise a recess or trough 52 formed in the wall of the packer in communication with tubing 15 and in operation normally positioned opposite formation 54 to be tested. Recess 52 is packed with interconnected packing elements 53 held in place by a supporting wire 57. Alterations of the formation of these inlets may be found in Patent No. 2,600,173. Thus fluid produced from a stratum adjacent the bore hole will pass into the formation tester upwardly through tube 15. A check valve 16 is positioned in this fluid passage to prevent possibility for drilling mud to pass in the opposite line of flow downwardly into the formation testing line. For reasons which will later become clear, tube 15 is connected to a fluid channel 17 so as to connect to a second channel 18 through a slide valve arrangement 19. Slide valve 19 may be of conventional character provided with suitable seals 20 so as to slidably operate within the central portion of the assembly sub 3. As illustrated in Figure 1, slide valve 19 is normally biased in the open position by means of spring 21 so as to permit fluid flow from conduit 17 into conduit 18. A check valve 22 is positioned in conduit 18 so that fluid flow will be permitted from the slide valve and through the check valve, but so that fluid flow will be prevented in the opposite direction. Conduit 18 terminates in a cavity within pump assembly sub 3 adjacent the nozzle 7. This cavity, identified by numeral 25, opens outwardly into the bore hole annulus through a suitable port or ports 26.

With this description of the elements of the apparatus illustrated in Figures 1 and 2, one way in which this apparatus can be used can now be understood. The apparatus, assembled on a drill string 2, will be lowered into the bore hole without the circulation of drilling mud through the bore of the drill string. Consequently, during the lowering operation, the mud pump 9 will not be in operation and the elastic packer will remain in the deflated condition. When the assembly has been lowered to the selected position in the bore hole, drilling mud will be forced into the drill string 2 at the surface of the earth. Circulation of the drilling mud through the hydraulic motor 6 will activate the mud pump 9 so as to inflate the elastic packer 4 as described. At the same time, exhaust of the circulating drilling mud from motor 6 through nozzle 7 will create an aspirating effect within the cavity 25 serving to pull fluid from fluid producing conduit 15 through conduits 17 and 18. This fluid will pass outwardly from cavity 25 and port 26 into the bore hole annulus.

In using the invention in this manner, the pressure drop through hydraulic motor 6 is kept as low as possible consistent with providing suitable inflation pressure for the packer by operation of the pump 9. Since relatively low inflation pressures can be used, essentially the full mud circulation pressure is available for exerting an aspirating effect at the nozzle 7. The apparatus described therefore functions efficiently for dropping the hydrostatic pressure at the stratum contacted by the formation tester so as to produce fluid from this stratum as described. In the apparatus illustrated in Figures 1 and 2, the produced fluid is simply exhausted into the bore hole annulus as described and the nature of the fluid may be determined at the surface of the earth by "mud logging" or other means of detection. Consequently, in this use of the invention, operation of the apparatus is continued until suitable results are obtained by inspection of the fluid in the bore hole annulus at the surface of the earth. When the test has been completed, by discontinuing the circulation of drilling mud into the drill string 2, operation of the hydraulic motor 6 is stopped and elastic packer 4 will be deflated. Thereafter the assembly may be moved to a different level in the bore hole for additional formation tests.

The apparatus described in Figures 1 and 2 essentially utilizes a jet pump action effective by exhaust of drilling mud through the nozzle 7 to produce fluid from a formation to be tested. The apparatus is readily adaptable to use of other pumping techniques for producing the tested fluid. Figure 3 illustrates one alternative form of pump arrangement in which a hydraulic pump is substituted for the jet pump arrangement of Figure 2. In Figure 3 elements of the apparatus which are analogous to those of Figure 2 are identified by similar numerals (using the prime notation to identify elements having a similar function) and attention will be directed to those portions of the apparatus which are different from the apparatus of Figure 2.

In the apparatus of Figure 3, drilling mud circulated through the drill string 2 and channel 5 is passed through the hydraulic motor 6, which is exhausted through a conduit 11' connecting to the inflation conduit of the elastic packer 4. As described in connection with Figure 2, conduit 11' is bypassed to the bore hole annulus through a conduit 12' and check valve 13. In this case the hydraulic motor uses the full pumping pressure of the drilling mud through the drill string with only sufficient pressure remaining to provide the necessary inflation pressure. Again, the hydraulic motor is directly coupled to a pump 9 which may be of the impeller type. The intake of pump 9 is connected to conduit 18' formerly described and the outlet of the pump 9 is connected to the bore hole annulus through a conduit 32. It will be apparent that the formation fluid produced through the formation tester follows the same fluid path described in connection with Figures 1 and 2. However, the apparatus of Figure 3 provides the advantage that greater pumping pressure is available to produce formation fluid and to exhaust this fluid to the bore hole annulus.

It is a particular feature of both embodiments of the invention described that these pumping assemblies may be used in connection with a suitable sample chamber of the nature illustrated in Figure 4. For clarity the description of Figure 4 is to be read with Figure 1 in order to see the operative relationship of the sample chamber with the pump assembly. The sample chamber of Figure 4 constitutes an elongated cylindrical body 33 terminating at its upper portion in a spearhead 34 which may be used to lower and retrieve the sample chamber by means of a wire line. The sample chamber 33 is constructed to have an external configuration so that the sample chamber will fit within the pump assembly body 3 but so that a lower section of the sample chamber provided with a shoulder 39 will fit within and contact the

slide valve **19**. Consequently, when the sample chamber is lowered into position, slide valve **19** will be moved from the position illustrated in Figure 1 downwardly to the position illustrated in Figure 4. The sample chamber will be of sufficient mass so as to compress spring **21** for this purpose.

The lower elongated portion of the sample chamber **33** is provided with a check valve arrangement **35**. Check valve **35** may constitute a simple ball type check valve in which the ball is fixed to rod member **36** adapted to contact the bottom of the sample chamber recess within the pump assembly body **3** when the sample chamber is in the position illustrated in Figure 4. Consequently, check valve **35** will be forced to the open position when the sample chamber is in place.

Operation of the pump assembly will be just as described in connection with Figures 1, 2, and 3. However, formation fluid produced through conduit **17**, by actuation of slide valve **19**, will now follow a course such that the formation fluid will pass into and through sample chamber **33**. Thus, as illustrated, formation fluid passing upwardly through channel **17** will enter a port **37** connecting to a standpipe arrangement **38** within the cavity of sample chamber **33**. The fluid will pass upwardly through standpipe **38** and downwardly about standpipe **38**, so as to thoroughly flush the sample chamber, with the fluid finding an exit through check valve **35** and the lower termination of the sample chamber. A fluid passage **41** is provided in the body **3** of the assembly so that the formation fluid will flow back through slide valve **19** and through conduit **18** for exit to the bore hole annulus as formerly described.

In using the apparatus of Figure 4, formation fluid will be circulated through the sample chamber in this manner until there is assurance that the sample chamber is completely flushed with flowing formation fluid. Thus, circulation can be continued until this condition is indicated by mud logging at the surface of the earth or until operation has continued so long that it is certain that all contaminating fluids have been washed through the sample chamber. Thereafter the sample chamber is retrieved by a wire line attached to the spearhead **34** so that the sample may be brought to the surface of the earth. Lifting the sample chamber will cause check valve **35** to close and check valve **43** in the inlet to the sample chamber will similarly close, trapping the uncontaminated formation fluid within the sample chamber for inspection at the surface of the earth.

The invention described is subject to many modifications and refinements illustrated in the drawings but which have not heretofore been described. For example, to prevent any possibility of drilling mud contaminating the formation fluid brought into sample chamber **33** of Figure 4, a cup seal **45** may be positioned about the sample chamber in a manner to exclude any flow of drilling mud

about the sample chamber to the inlet port **37** of the sample chamber. A lower cup seal **46** may similarly be used to prevent formation fluid from bypassing the sample chamber, ensuring the circulation of all produced formation fluid through the sample chamber as described. It should also be noted that check valve **22** in suction line **18** leading to the pump assembly, as illustrated in Figure 1, provides the important function of preventing the possibility of drilling mud backing up into the sample chamber in the event pumping is stopped before the sample chamber is removed from the position shown in Figure 4.

What is claimed is:

1. A formation tester comprising in combination: a tubular support extending downwardly into a bore hole when in use, an inflatable packer fixed to the lower end portion of said support, a first conduit extending from the exterior surface of the packer through the inflatable packer to the interior of said support, a second conduit extending from the interior of said support through a cavity in said support to the exterior surface of said support, a pump supported by said support, an inflation conduit means extending from the exterior of said support through said pump to the interior of said packer, a hydraulic motor supported by said support and adapted for driving said pump, an inlet conduit extending from the bore of said support to said motor, an exhaust conduit extending from said motor through a jet nozzle to said cavity operative to produce an aspirating effect at said nozzle to force a stream of fluid inwardly through said first and second conduits when driving fluid is passing through said motor.

2. The formation tester defined by claim 1 including a pressure relief means in fluid communication with the inflatable packer.

3. The formation tester defined by claim 1 in which check valves are positioned in both the first and second conduits preventing fluid flow from the bore hole annulus back through these conduits.

4. The formation tester defined by claim 1 including a chamber insertable in the fluid path through said first and second conduits, said chamber including valved entrance and exit openings for passage of fluid through the chamber adapted to retain fluid in the chamber when withdrawn from said fluid path.

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