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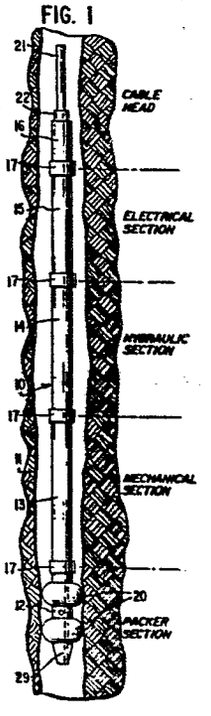
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(54) Method and apparatus for obtaining selected samples of formation fluids.

(57) A method and apparatus operable on a wireline logging cable for sampling and testing bore hole fluids, transmitting the results obtained from such testing to the surface for determination whether or not the particular sample undergoing testing should be collected and brought to the surface. The apparatus comprises a downhole tool having an inflatable double packer for isolating an interval of the bore hole coupled with a hydraulic pump, the pump being utilized sequentially to inflate the double packer and isolate an interval of the bore hole and to remove fluids from the isolated interval to test chamber means where resistivity, redox potential (Eh) and acidity (pH) are determined, and finally to dispose of selected samples to one or more sample container chambers within said tool or to reject them into the bore hole if not selected.

FIG. 1



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METHOD AND APPARATUS FOR OBTAINING SELECTED SAMPLES OF FORMATION FLUIDS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for obtaining samples of formation fluids at different levels in a bore hole. The characteristics of formation fluids obtained from various levels within a bore hole are of considerable interest to geologists as an aid to determining subsurface structure as well as to those engaged in well completion and production. This invention provides a method and apparatus for lowering a logging tool into an uncased bore hole on a conventional wireline, positioning the tool at preselected elevations and obtaining formation fluid samples. The samples are tested within the tool without withdrawing it from the bore hole and the test results transmitted to the surface. If it is determined that the sample should be recovered it is transferred to one of a plurality of collection chambers within the tool, and, if not, it is ejected into the bore hole. The logging tool can then be moved to another level, without withdrawal from the well and the process repeated until all of the sample collection chambers in the tool are filled.

2. Description of the Prior Art

Formation fluid sample collection tools have been in use in the industry for a number of years. See for example the descriptive matter found in the Composite Catalog of Oil Field Equipment and Services--1978-1979, pages 3286-3291 for a description of services and equipment provided by Halliburton Services. See also in the 1976-1977

edition of the same catalog the description of the Johnson Inflatable Packer Test Systems at pages 3607-3609. Both the Halliburton and Johnson systems involve attaching the sampling tool to the drill pipe string and are not designed for wireline logging. Moreover, they do not have means for isolating and testing formation fluids at various selected levels within the bore hole to make a determination as to the desirability of collecting and retaining the sample without withdrawal of the tool from the well. These two differences are of considerable significance when the time the well must be out of commission for sampling is taken into consideration. To run a tool into a well on a wireline requires but a small fraction of the time required to run in a drill pipe string and the advantage of being able to collect a number of pretested samples each time the tool is sent down the well further greatly reduces the time during which the well is out of commission.

Wireline formation testers have been available since the early 1950's and have been used to obtain fluids, flow rates and pressures from prospective reservoirs. Because of limited tool capacity and capabilities, however, recovered fluids often are entirely or mostly drilling mud filtrate. Moreover, there is no fluid property monitoring capability. Thus these tools are useful only in the case of reservoirs where adequate flow is obtained and recovered fluids are relatively free of mud filtrate. They tend not to be useful in those cases where geological exploration is involved and fluid samples other than those containing hydrocarbon are desired.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a method for obtaining formation fluid samples from a bore hole which method comprises:

a) lowering a tool into said bore hole to a preselected level;

b) expanding a pair of packers carried by said tool into sealing contact with said bore hole to isolate an interval of said bore hole;

c) collecting fluid entering said isolated interval and measuring a property thereof;

d) determining on the basis of the measured property whether it is desired to retain a sample of said collected fluid and, if the determination is positive, transferring said fluid to a sample collection chamber within said tool;

e) contracting said packers to free said tool for vertical movement; and

f) raising the tool and the collected sample to the surface.

The invention also provides apparatus for sampling and testing bore hole formation fluids, said apparatus comprising a downhole tool having:

a) a pair of expandable packers for isolating an interval of the bore hole;

b) means for expanding the packers;

c) means for withdrawing fluid from the space between the packers;

d) a test chamber for receiving fluid withdrawn from said interval;

e) means for measuring a property of fluid located in said test chamber;

f) a sample collection chamber arranged to receive fluid from said test chamber;

g) signal transmission means for transmitting a data signal representative of said measured property; and

h) means operable in response to said data signal for controlling flow of fluid from the test chamber to the sample collection chamber.

The present invention enables a plurality of high quality samples of formation fluids to be obtained from the wall of a bore ——————

hole on a single passage of a logging tool into the bore hole by locating the tool at various levels within the bore hole, isolating an interval of the bore hole, withdrawing fluid from the isolated interval, testing the properties of the withdrawn fluid while within the tool, transmitting the test results to the surface for determination of the suitability of the sample for collection and, if it is found suitable, transferring the sample to a collection chamber within the tool for ultimate removal to the surface.

A second and related feature of this invention is to provide a logging and sample collecting tool operable in connection with a conventional wireline for carrying out the method of this invention.

This invention thus can provide an improved method and apparatus for obtaining formation fluid samples from a bore hole. The method involves initially lowering a tool suspended by a wireline into the bore hole to a preselected level; and utilizing a pair of packers carried by the tool to isolate an interval of the bore hole by inflating the packers to expand them into sealing contact with said bore hole. Fluid is withdrawn from the isolated interval between the packers and its electrical resistivity is measured in a resistivity test chamber located within the tool. The resistivity measurement is sent to the surface via the wireline and when the resistivity becomes constant, indicating that formation fluids uncontaminated by drilling mud components are being withdrawn into the tool, the withdrawn fluids are directed into a second test chamber wherein the redox potential (Eh), acidity (pH) and temperature of the fluids are measured and the results are sent to the surface by the wireline. It is then determined from the thus transmitted results whether it is desired to retain a sample and, if determination is positive, the fluid is pumped to one of a plurality of sample collection chambers within said tool. If

the determination is negative the fluid is returned to the bore hole, the packers are deflated to free the tool for vertical movement and the tool is moved to another preselected location; where the above-referred to steps are repeated. This procedure is followed until the sample chambers in the tool are filled with desired samples, and finally the wireline is retracted to return the tool and the contained samples to the surface.

A preferred embodiment of the apparatus of this invention comprises a tool adapted to be introduced into a bore hole on a conventional seven conductor wireline and having a pair of spaced apart inflatable packers for isolating an interval of the bore hole. A hydraulic pump is provided within the tool for pumping fluids from the interval between the packers, initially for inflating the packers, and subsequent to their inflation for pumping fluids through a resistivity test chamber and a second test chamber where redox potential (Eh), acidity (pH) and temperature measurements are obtained, and finally into one or more sample collection chambers located within the tool. Conventional means are associated with each of the chambers for performing the above-described measurements and for transmission of the results thereof to the surface through the wireline. In addition, there are provided suitable valve means electrically controlled from the surface for sequentially carrying out the method steps of this invention.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a side view of a preferred embodiment of a logging tool of this invention disposed within a section of a bore hole;

Figure 2 is a schematic view showing the relationship of the various elements of the tool of this invention during the packer inflation step;

Figure 3 is a similar view showing the relationship of the elements during the testing step; and

Figure 4 is a similar view showing the relationship during the sample collection step.

DETAILED DESCRIPTION OF THE INVENTION

In Figure 1 a preferred embodiment of the tool 10 of this invention is shown in a downhole position in a bore hole 11. In this embodiment the tool is made up in tubular sections 12 through 16 which are connected in sealed relationship by collars 17. During movement through the bore hole and when the packers 20 are not set, the tool 10 is suspended from the cable head section 16 to which the supporting wireline 21 is securely attached by coupling 22. The use of individual sections 12-16 each containing certain kinds of components is, of course, optional but it provides a convenient way to manufacture, assemble and service the tool 10. The maximum diameter of the tool 10 is, of course, limited by the size of the bore hole 11 and the effectiveness of the expandable packers 20. A convenient arrangement is to make the sections 13-16 of somewhat smaller diameter so that these portions of the tool can be utilized in smaller bore holes and to utilize a packer section 12 appropriately sized to perform adequate sealing in a particular bore hole to be tested and sampled. The following Table gives preferred packer sizes for different bore hole diameters:

TABLE

Minimum Bore Hole Diameter in Inches	Packer Size in Inches	Packer Expansion Capacity in Inches
6.25	5.00	9.00
7.88	6.25	11.25
8.75	7.25	13.00

From the foregoing it will be seen that, for a versatile tool, the maximum diameter of the sections 13-16 is about five inches. The length of a tool of five-inch diameter will depend upon the degree of miniaturization in hydraulic and electric circuitry and in the size and number of samples which are to be collected. Usually the length is between 6 and 12 feet.

In Figures 2-4 the hydraulic relationship of the various parts of the tool 10 during various steps of the preferred method are shown. In each of these Figures the main fluid flow for the particular step involved is indicated by a heavy line.

In Figure 2 the step of inflating the packers is illustrated. Fluid from the bore hole 11 is withdrawn into the tool 10 through an open port 24 in packer section 12 passing through a filter 25 and resistivity test chamber 26. This test chamber which is preferably conventional can contain a pair of spaced apart electrodes across which a voltage is impressed. The resulting current flow between the electrodes provides an indication of resistivity. Suction for withdrawing the fluid is provided by a pump 27 driven by an electric motor 28 powered from the surface by an electric current delivered through the wireline 21. From pump 27 the withdrawn fluid passes through conduit 30 to the packers 20 which are inflated thereby to engage the wall of the wellbore in sealing relationship and isolate an interval thereof. To prevent the development of a pressure differential in the bore hole 11 above and below the tool 10 when the packers 20 are inflated, a passage 29 is provided through the packer section 12 as shown in Figure 1. A pressure relief valve shown at 31 vents fluid to the bore hole when the packers 20 are filled. A back flow check valve 32 prevents fluid from flowing back out of the packers 20 when pump 27 is not operating. An electrically controlled packer deflate valve 33 is provided for venting conduit 30 to

the wellbore when it is desired to deflate the packers 20.

Following inflation of the packers 20 the pump 27 continues to pump fluid from the bore hole through the resistivity test chamber venting the fluid to the bore hole through valve 31. This action is preferably continued until the resistivity measurement, which is conveyed to the surface through the wireline 21 becomes constant indicating that formation fluids free of drilling mud components are being withdrawn. At such time the pump 27 is stopped and the various valves are set to provide the flow pattern shown in Figure 3.

To better illustrate the invention the various flow controlling valves have been schematically indicated. A preferred procedure, as will be appreciated by those familiar with the art, is to use a pair of rotary solenoid actuated valves (not shown) which are positioned by pulses sent down from the surface. Preferably, one of these rotary solenoid valves, as will be described later, is employed to control the pumping of samples to the sample containers and the other is preferably employed to control all of the other fluid flows.

After the packers 20 have been set and the resistivity cell 26 indicates that a uniform formation fluid is being withdrawn, the flow control valve (not shown) is rotated to place the schematically indicated valve elements in the positions shown in Figure 3. Thus the filter control valve element 35 is actuated to cause the fluid to flow through line filter 36 instead of the large coarse filter 25 improving the quality of the withdrawn sample and the control valve 37 is actuated to divert the fluid flow through the second test chamber 38 to the bore hole 11.

The second test chamber 38 preferably contains a three electrode system for measuring acidity (pH) and redox potential (Eh). A temperature sensor (not shown) is also provided as the temperature at which

potential readings are made affects calibration. The preferred electrodes are as follows:

pH Reference--silver
Eh Reference--platinum
Reference electrode-antimony

but as will be appreciated any of the well known arrangements can be utilized. Moreover, in certain cases it may be desirable to adapt the test chamber 38 to perform other or additional kinds of tests such as retractive index, opacity, density of dissolved gas content all of which are known to those familiar with the art. Conventional electrical circuits are utilized to send appropriate signals through the wireline to the surface where pH, Eh and temperature of the formation fluid can be displayed or read out. It should be noted in Figure 3 that a portion of the fluid does not pass through test chamber 38 but passes through sample control valve 40 and back to the bore hole 11 through conduit 41. By this arrangement test chamber 38 is not overloaded and there is more certainty of obtaining a sample representative of the fluid undergoing test in chamber 38 with the same fluid also simultaneously flowing to and through the sample control valve 40.

When the test results transmitted to the surface indicate that the formation fluids being withdrawn are suitable for collection, the pump 27 is stopped and the sample control valve 40 is electrically actuated to a position to discontinue flow of fluid to the bore hole through conduit 41 and to instead convey fluid to the first sample chamber indicated at 42. The chambers need not be evacuated or vented to the bore hole 11 as downhole pressures are so large that any air brought down from the surface in the tool 10 will be so compressed as to occupy but a small fraction of chamber volume. When sample chamber 42 has been filled the pump 27 is stopped and the rotary control valve is actuated to packer deflate position

opening the valve port indicated at 33 to the bore hole and permitting the packers 20 to deflate. Suitable valved connections (not shown) are provided through the side of tool 10 for withdrawal of the samples from the chambers 42.

Following deflation of the packers 20 the tool 10 is again free to be moved to other preselected levels in the bore hole 11, and the above described steps can be repeated. Alternatively if it is decided at the surface that the formation fluid passing through test chamber 38 will not produce a sample desired for retention and transport to the surface no sample is collected at that level in the bore hole; and the pump 27 can be stopped, the packers 20 deflated and the tool moved to another level.

In the preferred embodiment of the logging-sampling tool 10 of this invention, the capability of determining formation fluid pressure is provided by means of a pressure sensor 45 connected to the fluid conduit downstream of the pump 27. This sensor 45 which preferably contains a transducer monitors formation fluid pressure during periods when the pump 27 is not operating and sends appropriate signals through the wireline 21 to the surface.

As will be apparent to those skilled in the art any of the conventional logging techniques, such as gamma ray, neutron, induction, sonic, etc. adaptable for wireline logging, can be practiced in conjunction with the method and apparatus of this invention by incorporating appropriate conventional sensing and transmission apparatus within the tool 10. Information from such ancillary apparatus can be of considerable aid in initially placing the tool in the bore hole for the testing and sampling procedure of this invention. Incidentally the words "bore hole" have been used herein and in the claims in their generic sense and are meant

to include any cased or uncased generally cylindrical opening, sealable by means of a packer and whether intended for exploration or production purposes. Thus the expression includes drill hole, well bore and other equivalent terms.

In the foregoing detailed description, the circuitry for obtaining signals from the various sensing devices and transmitting them to the surface and for transmitting electrical commands from the surface to the tool have not been included as these techniques are well known to those skilled in the art and a multitude of different arrangements are available and may be used in the practice of this invention.

Various changes and/or modifications such as will present themselves to those familiar with the art may be made in the method and apparatus described herein without departing from the spirit of this invention whose scope is commensurate with the following claims:

CLAIMS

1. A method for obtaining formation fluid samples from a bore hole which method comprises:

a) lowering a tool into said bore hole to a preselected level;

b) expanding a pair of packers carried by said tool into sealing contact with said bore hole to isolate an interval of said bore hole;

c) collecting fluid entering said isolated interval and measuring a property thereof;

d) determining on the basis of the measured property whether it is desired to retain a sample of said collected fluid and, if the determination is positive, transferring said fluid to a sample collection chamber within said tool;

e) contracting said packers to free said tool for vertical movement; and

f) raising the tool and the collected sample to the surface.

2. A method according to Claim 1 wherein the fluid is collected by withdrawing fluid from said isolated interval to a first test chamber, a property of the withdrawn fluid is measured in said test chamber, and when said measured property indicates that formation fluid is being withdrawn into said tool, the withdrawn fluid is directed to a second test chamber where the property on the basis of which said determination is made is measured.

3. A method according to Claim 2, wherein said first test chamber is a resistivity test chamber, the resistivity of the withdrawn fluid is measured therein and the withdrawn fluid is directed to the second test chamber when the resistivity of the withdrawn fluid indicates that formation fluid is being withdrawn into said tool.

4. A method according to any preceding claim wherein is step (d), the fluid is transferred to one of a plurality of sample collection chambers if said determination is positive and if the determination is negative the fluid is returned to the bore hole, in step (e) said tool is moved to another preselected location, and then steps (b) to (e) are repeated until a desired number of the sample chambers in said tool contain samples.

5. A method according to any preceding claim wherein said packers are expanded by inflating them with fluid pumped from said isolated interval.

6. A method for obtaining formation fluid samples from a bore hole according to Claim 1 which method comprises:

a) lowering a tool suspended by a wireline into said bore hole to a preselected level;

b) utilizing a pair of packers carried by said tool to isolate an interval of said bore hole by inflating said packers to expand them into sealing contact with said bore hole;

c) withdrawing fluid from said isolated interval and measuring its resistivity in a resistivity test chamber within said tool and sending the resistivity measurement to the surface via said wireline;

d) when the resistivity becomes constant, indicating that formation fluid uncontaminated by drilling mud components is being withdrawn into said tool, directing the withdrawn fluid into a second test chamber and measuring therein the redox potential, acidity and temperature of said fluid and sending results thereof to the surface by said wireline;

e) determining from the thus transmitted results whether it is desired to retain a sample and, if the determination is positive, pumping said fluid to one of a plurality of sample collection chambers within said tool, if the determination is negative returning said fluid to said bore hole;

f) deflating said packers to free said tool for vertical movement and moving said tool to another preselected location;

g) repeating steps (b) through (f) until the sample chambers in said tool are filled with desired samples; and

h) retracting said wireline to return the tool and the collected samples to the surface.

7. A method for obtaining formation fluid samples from a bore hole according to Claim 1 which method comprises:

a) lowering a tool suspended by a wireline into said bore hole to a preselected level;

b) utilizing a pair of packers carried by said tool to isolate an interval of said bore hole by inflating said packers to expand them into sealing contact with said bore hole;

c) withdrawing fluid from said isolated interval and measuring its resistivity in a resistivity test chamber within said tool;

d) when the resistivity becomes constant, indicating that formation fluid uncontaminated by drilling mud components is being withdrawn into said tool, directing the withdrawn fluid into a second test chamber and measuring therein properties of said fluid and sending results thereof to the surface by said wireline;

e) determining from the thus transmitted results whether it is desired to retain a sample

and, if the determination is positive, pumping said fluid to one of a plurality of sample collection chambers within said tool and if the determination is negative returning said fluid to said bore hole;

f) deflating said packers to free said tool for vertical movement and moving said tool to another preselected location;

g) repeating steps (b) through (f) until the sample chambers in said tool are filled with desired samples; and

h) retracting said wireline to return the tool and the collected samples to the surface.

8. A method for obtaining formation fluid samples from a bore hole according to Claim 1 which method comprises:

a) lowering a tool suspended by a wireline into said bore hole to a preselected level;

b) utilizing a pair of packers carried by said tool to isolate an interval of said bore hole by inflating said packers to expand them into sealing contact with said bore hole;

c) withdrawing fluid from said isolated interval and measuring its resistivity in a resistivity test chamber within said tool and sending the resistivity measurement to the surface via said wireline;

d) when the resistivity measurement indicates that formation fluid is being withdrawn into said tool, directing the withdrawn fluids into a second test chamber and measuring therein the redox potential, acidity and temperature of said fluids, sending results thereof to the surface by said wireline;

e) determining from the thus transmitted results whether it is desired to retain a sample and, if the determination is positive, pumping said fluid to one of a plurality of sample collection chambers within said tool, if the determination is negative returning said fluid to said bore hole;

f) deflating said packers to free said tool for vertical movement and moving said tool to another preselected location;

g) repeating steps (b) through (f) until the sample chambers in said tool are filled with desired samples; and

h) retracting said wireline to return the tool and the collected samples to the surface.

9. A method for obtaining formation fluid samples from a bore hole according to Claim 1 which method comprises:

a) lowering a tool suspended by a wireline into said bore hole to a preselected level;

b) utilizing a pair of packers carried by said tool to isolate an interval of said bore hole by inflating said packers to expand them into sealing contact with said bore hole;

c) withdrawing fluid from said isolated interval and measuring its resistivity in a resistivity test chamber within said tool and sending the resistivity measurement to the surface via said wireline;

d) when the resistivity becomes constant, indicating that formation fluid uncontaminated by drilling mud components is being withdrawn into said tool, directing the withdrawn fluid into a second test chamber and measuring therein

selected physical properties of said fluid and sending results thereof to the surface by said wireline;

e) determining from the thus transmitted results whether it is desired to retain a sample and, if the determination is positive, pumping said fluid to a sample collection chamber associated with said tool;

f) deflating said packers to free said tool for vertical movement; and

g) retracting said wireline to return the tool and the collected sample to the surface.

10. Apparatus for sampling and testing bore hole formation fluids, said apparatus comprising a downhole tool having:

a) a pair of expandable packers for isolating an interval of the bore hole;

b) means for expanding the packers;

c) means for withdrawing fluid from the space between the packers;

d) a test chamber for receiving fluid withdrawn from said interval;

e) means for measuring a property of fluid located in said test chamber;

f) a sample collection chamber arranged to receive fluid from said test chamber;

g) signal transmission means for transmitting a data signal representative of said measured property; and

h) means operable in response to said data signal for controlling flow of fluid from the test chamber to the sample collection chamber.

11. An apparatus operable on a wireline logging cable for sampling and testing bore hole formation fluids said apparatus comprising a downhole tool adapted to be connected to said wireline, said tool having:

a) a pair of inflatable packers for isolating an interval of the bore hole when inflated;

b) an electrically driven hydraulic pump for withdrawing fluids from the space between said packers and conduit means interconnecting the outlet of said pump to said packers whereby inflation thereof may be accomplished to isolate said interval of said bore hole;

c) a resistivity test chamber through which said withdrawn fluids are conducted;

d) a second test chamber in communication with the outlet of said pump and adapted to measure properties of said withdrawn fluids;

e) a sample collection chamber adapted to be in communication with the outlet of said pump;

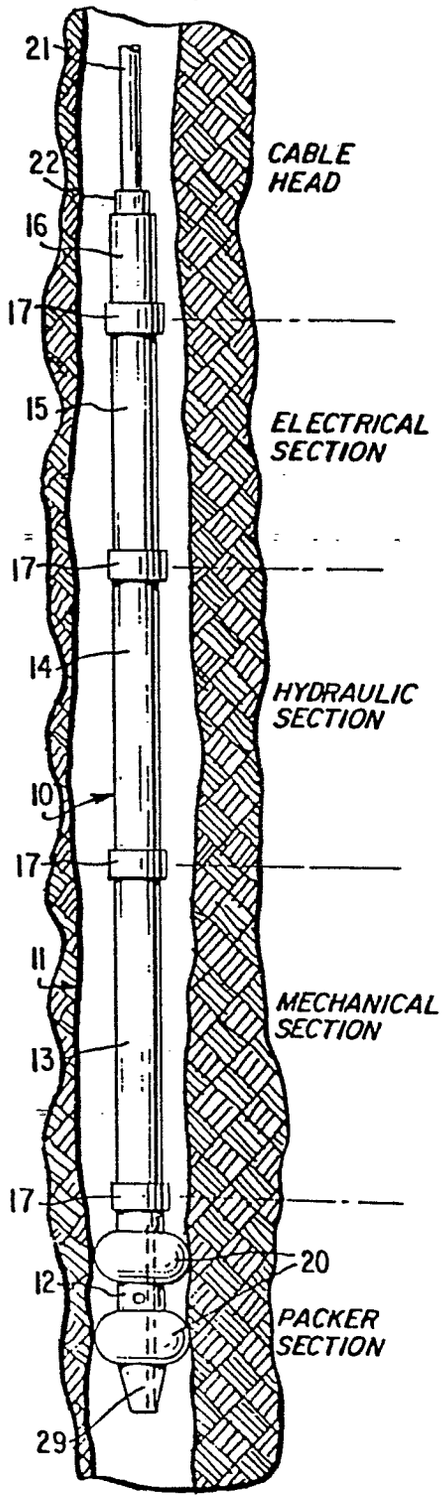
f) signal transmission means for transmitting to the surface the results of resistivity and other properties measured in said second test chamber; and

g) valve means controlled from the surface through said wireline for controlling the flow of said withdrawn fluids, initially to inflate said packers and subsequently to direct said fluids to said second test chamber and said sample collection chamber.

12. Apparatus according to Claim 11 in which the second test chamber is suitable to test acidity, redox potential and temperature.

13. Apparatus according to any one of Claims 10 to 12 in which a plurality of sample collection chambers are provided.

FIG. 1



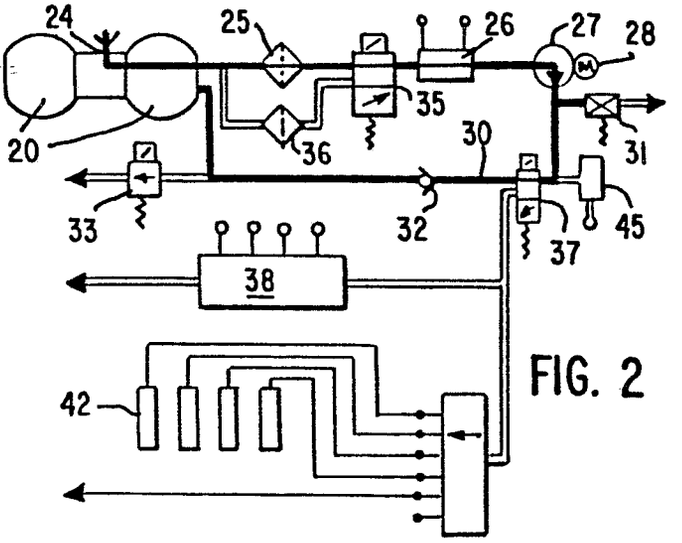


FIG. 2

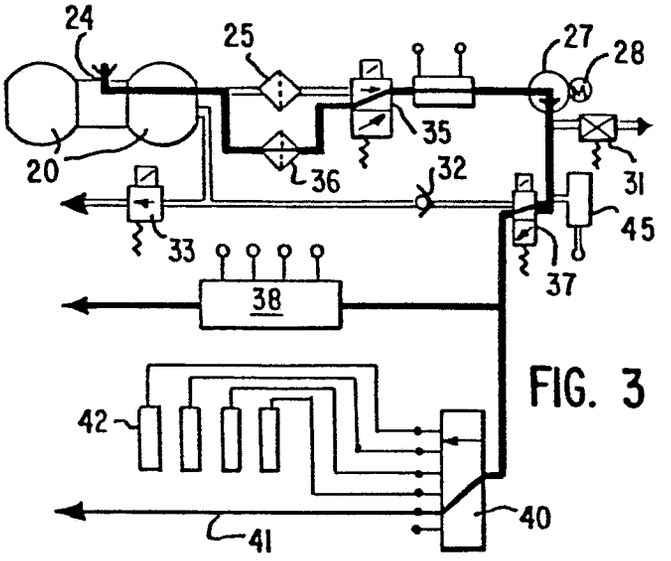


FIG. 3

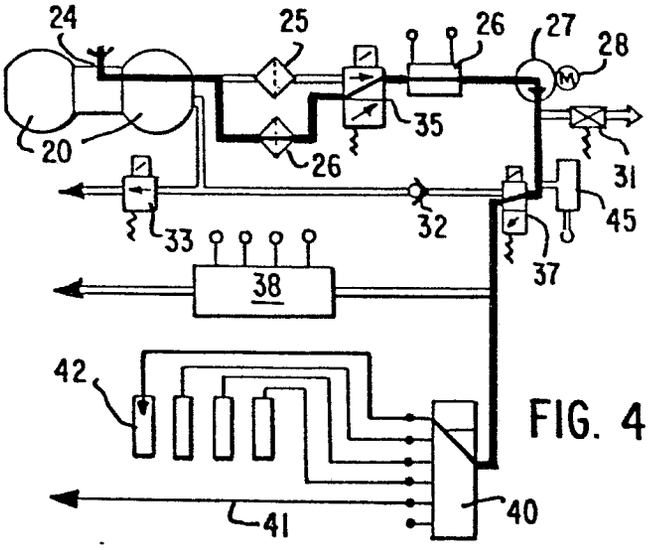


FIG. 4