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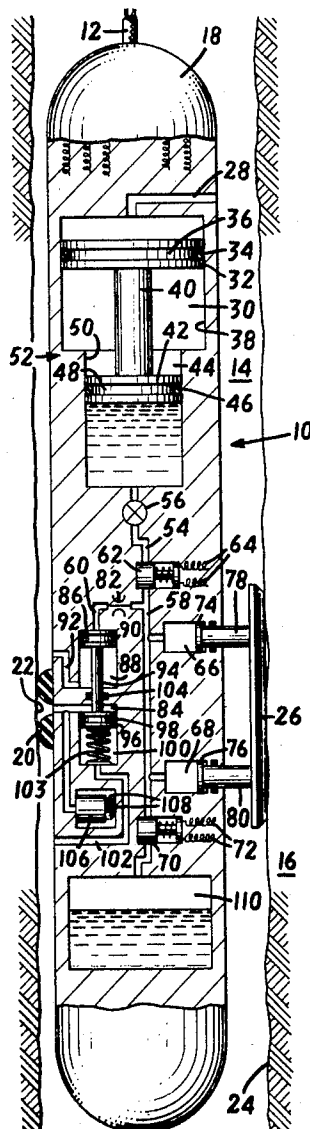
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[54] **TOOL TO TAKE MULTIPLE FLUID MEASUREMENTS**
 10 Claims, 3 Drawing Figs.

- [52] U.S. Cl. 73/152,
 73/421
 [51] Int. Cl. E21b 47/06
 [50] Field of Search 73/155,
 421, 152; 166/264

- [56] **References Cited**
UNITED STATES PATENTS
 3,115,775 12/1963 Russell 73/152

ABSTRACT: A plurality of readings with respect to fluids in formations traversed by a well bore is obtained in a single traverse of the well bore by a special tool. The tool includes a piston-cylinder assembly having two pistons of differential diameter and serving as a pressure multiplier responsive to the pressure of fluid in the well bore for generating pressure in an operating fluid in a branching conduit in the tool greater than the pressure of the fluid in the well bore at the depth of the tool. Upon opening of a valve in the conduit, the operating fluid sets a shoe against the wall of the well bore and, by reaction, forces annular sealing means on the tool against the wall of the well bore to seal off an area of the wall from fluid in the well bore. After a short delay to permit the setting and sealing, a collection chamber in the tool in communication with the annular sealing means is expanded to reduce the pressure therein and facilitate collection of a fluid sample from the formation. The delay is facilitated by a choke formed in one branch of the conduit and, in one embodiment, by a check valve and a piston-cylinder assembly mounted in the same branch.



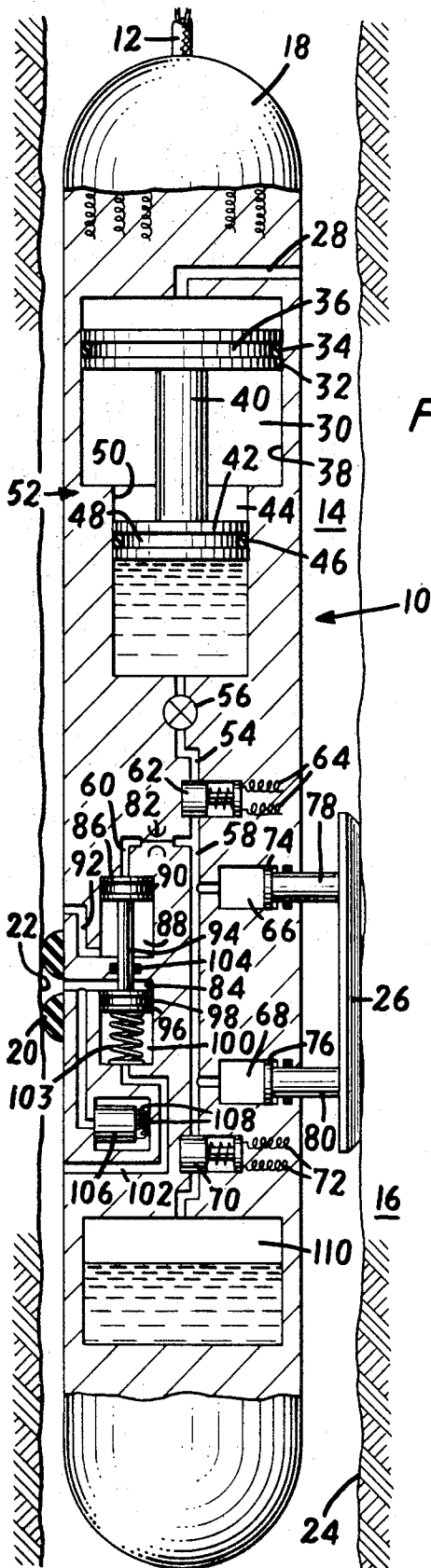


FIG. 2

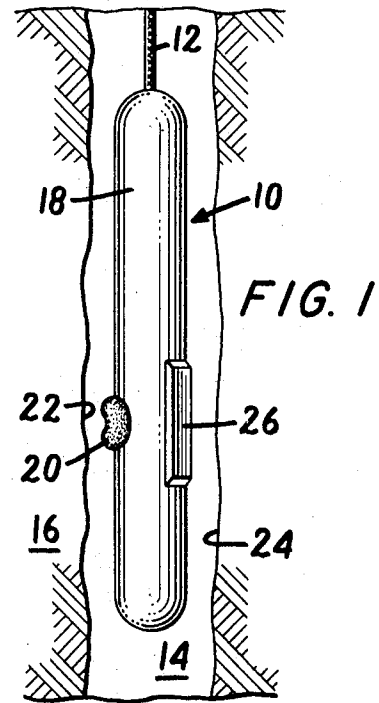


FIG. 1

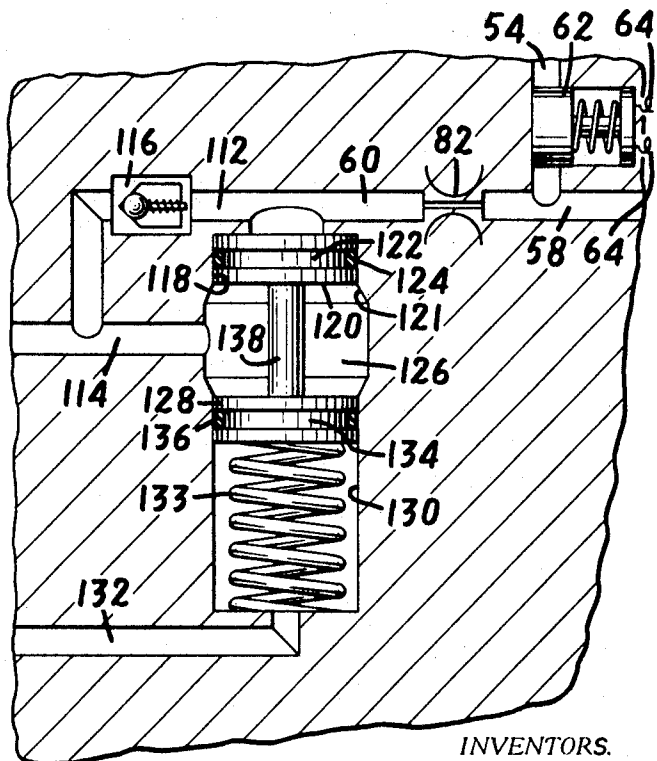


FIG. 3

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TOOL TO TAKE MULTIPLE FLUID MEASUREMENTS

CROSS-REFERENCE TO RELATED APPLICATION

The present invention is an improvement of an invention disclosed and claimed in a copending application of Maurice P. Lebourg and Roger Q. Fields, Ser. No. 790,321 filed Jan. 10, 1969 for "TOOL TO TAKE MULTIPLE FORMATION FLUID PRESSURES."

BACKGROUND OF THE INVENTION

This invention relates to well surveying and, in particular, to novel and highly effective apparatus facilitating the obtaining of a plurality of readings with respect to fluids in formations traversed by a well bore in a single traverse of the well bore.

The copending application identified above also discloses methods and apparatus facilitating the obtaining of a plurality of readings with respect to fluids in formations traversed by a well bore in a single traverse of the well bore, and the generic invention is claimed there.

The art of gathering information regarding earth formations is developed to a high state, as evidenced by a U.S. Pat. to Desbrandes et al. No. 3,011,554, U.S. Pat. to Whitten No. 3,104,712 and No. 3,261,402, and a U.S. Pat. to Voetter No. 3,329,208. There remains a need, however, for improved means for obtaining a plurality of readings with respect to fluids in earth formations.

It is possible, of course, to obtain a plurality of readings with respect to fluids in earth formations traversed by a well bore by the expedient of lowering a conventional measuring tool or instrument a plurality of times in the well bore, each time obtaining information with regard to fluids in a formation at a selected depth in the well bore. This process is time consuming and expensive, however, because of the delay occasioned each time it is necessary to withdraw the tool from the well bore following a given reading, prepare the tool to take a subsequent reading, and lower the tool into the well bore to the depth selected for the subsequent reading.

Withdrawal of the tool between successive readings is the conventional practice, because of the limited capacity of conventional tools to receive fluid samples for pressure or other measurements.

SUMMARY OF THE INVENTION

An object of the present invention is to provide improved apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore. Another object of the invention is to reduce the cost and time involved in the surveying of a well. A further object of the invention is to provide rugged and compact apparatus that is inexpensive to manufacture and repair and that can obtain as many readings as may be desired in a single traverse of a well bore.

The foregoing and other objects of the invention are accomplished, in representative apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, by the provision of apparatus including a housing, annular sealing means mounted on the housing for sealing off an area of the wall of the well bore from fluid within the well bore, formation-fluid-sample-receiving chamber means within the housing in communication with the sealed-off area of the wall, gauge means operatively associated with the sample chamber means for obtaining a reading with respect to formation fluid within the chamber means, and motive means for bringing the sample chamber means into cooperation with discrete samples of formation fluid collected at spaced-apart locations within the well bore, whereby a plurality of readings with respect to fluid in the formations is obtainable in a single traverse of the well bore by the apparatus.

In accordance with the invention, the motive means comprises pressure means within the housing responsive to the pressure of the fluid within the well bore for boosting the pressure of an operating fluid within the housing to a pressure greater than the pressure of the well bore fluid, positioning means mounted on the housing, the positioning means when

set forcing the annular sealing means against the wall of the well bore, conduit means communicating with the pressure means, the conduit means being divided into a fast-action branch communicating with the positioning means and a delayed-action branch communicating with the sample chamber means, and operating valve means in the conduit means which when opened permits operating fluid flow from the pressure means to the conduit means. In this way, upon opening of the operating valve means to permit operating fluid flow from the pressure means to the conduit means, the operating fluid flow is initially effective in the fast-action branch to cause setting of the positioning means and is thereafter effective in the delayed-action branch to expand the sample chamber means to reduce the pressure therein and facilitate collection of a formation fluid sample.

BRIEF DESCRIPTION OF THE DRAWINGS

An understanding of additional aspects of the invention may be gained from a consideration of the following detailed description of representative embodiments of apparatus constructed in accordance with the invention and of the accompanying figures in the drawing, in which:

FIG. 1 is a diagrammatic view of apparatus constructed in accordance with the invention suspended in a well bore;

FIG. 2 is an elevational view, partly in section, of a first representative embodiment of apparatus constructed in accordance with the invention; and

FIG. 3 is a fragmentary view of a second embodiment of a portion of the apparatus of FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a tool or device 10 constructed in accordance with the invention suspended by a cable 12 in a well bore 14 traversing earth formations 16. The tool 10 includes a housing 18 on which are annular sealing means 20 adapted to seal off an area 22 of a well bore 24 and positioning means such as a shoe or pad 26 adapted to be moved outwardly with respect to the housing 18 against the wall 24 of the well bore 14 and, by reaction, force the annular sealing means 20 against the area 22 to be sealed off from fluid in the well bore 14.

The cable 12 runs to means (not shown) at the head of the well bore 14 for raising and lowering the tool 10 in the well bore 14. In accordance with the invention, the annular sealing means 20 may be forced successively against a plurality of areas of the well bore wall 24 for collecting a plurality of samples from the formation 16 without withdrawing the tool 10 from the well bore 14 between the taking of successive samples.

FIG. 2 shows in detail the structure of the tool 10. A channel 28 communicates with fluid in the well bore 14 and with a mud cylinder 30 in which is mounted a mud piston 32. The mud piston 32 is slidable within the mud cylinder 30 but includes an O-ring 34 mounted in a groove 36 extending around the periphery of the mud piston 32 and tightly engaging the wall 38 of the mud cylinder 30 for preventing passage of fluid from one side of the mud piston 32 to the other.

A ram extension 40 extends from the mud piston 32 to a high-pressure piston 42 within a high-pressure cylinder 44. The high-pressure piston 42 mounts an O-ring 46 in a groove 48 extending peripherally of the high-pressure piston 42. The O-ring 46 tightly engages the wall 50 of the high-pressure cylinder 44 and prevents leakage of fluid from one side to the other of the high-pressure piston 42.

The diameter of the high-pressure piston 42 is less than that of the low-pressure piston 32, and, as a result, the pressure within the high-pressure cylinder 44 is greater than the pressure within the mud cylinder 30. The pistons 32 and 42 and the cylinders 30 and 44 therefore constitute a piston-cylinder assembly functioning as a pressure multiplier 52. The pressure multiplier 52 is a part of motive means for bringing the annular sealing means 20 into contact with a selected area 22 of the wall 24 of the well bore 14.

Conduit means 54 communicates through a regulator valve 56 with the high-pressure cylinder 44. The regulator valve 56 may be similar or identical to the valve 65 shown in U.S. Pat. to Desbrandes No. 3,011,554. These valves are typically used to prevent the hydraulic pressure downstream thereof from being excessive where the hydrostatic or mud pressure is particularly high. By way of illustration, where the mud pressure is only 2,000 p.s.i. (gauge pressure), the developed hydraulic pressure might have to be 4,000 to 5,000 p.s.i.g. to be certain that there is a sufficient pressure differential to, for example, extend the backup shoe 26. On the other hand, since the pressure multiplier 52 has a fixed multiplication factor, the developed pressure could easily exceed 30,000 or 40,000 p.s.i.g. when the mud pressure is in the order of 15,000 to 20,000 p.s.i.g. Thus, the pressure regulator 56 is provided as a safeguard to maintain the hydraulic pressure downstream thereof at a reasonable differential above the hydrostatic pressure once high mud pressures are encountered. The purpose of this regulator 56 is, therefore, to keep the differential acting across the seals (e.g., the O-rings around the extensions 78 and 80) within reasonable limits. Thus, although these regulator valves are typically used in field operations, they are not necessary.

An alternative solution to the problems caused by excessively high hydraulic pressures is to use a pressure multiplier such as shown in a U.S. Pat. to Voetter No. 3,269,462. In accordance with this patent, the pressure multiplier piston comprises a number of telescoped members which can be selectively engaged or disengaged to permit the operator to select a desired ratio of pressure multiplication.

The conduit 54 includes a fast-action branch 58 and a delayed-action branch 60. Flow through the conduit 54 is controlled by an operating valve 62 provided with leads 64 extending to a remote location such as the head of the wall for controlling the valve 62.

When the valve 62 is opened by application of a suitable signal to the leads 64, flow of operating fluid is permitted from the portion of the cylinder 44 below the piston 42 through the conduit 54 and the branches 58 and 60 of the conduit 54.

Flow through the branch 58 of the conduit 54 is relatively rapid, inasmuch as this branch of the conduit is a low-impedance branch. The operating fluid therefore quickly enters setting cylinders 66 and 68. A dump valve quickly enters setting cylinders 66 and 68. A dump valve 70 controlled by leads 72 extending to a remote location which may conveniently be at the head of the well is closed at this point. The entry of operating fluid into the setting cylinders 66 and 68 forces to the right (as seen in FIG. 2) setting pistons 74 and 76, respectively. The pistons 74 and 76 are respectively integral with ram extensions 78 and 80 which are in turn integral with the setting shoe 26. In this way, the setting shoe 26 is forced against the wall 24 of the well bore 14. By reaction, the annular sealing means 20 is forced against a selected area 22 of the wall 24 of the well bore 14.

Operating fluid is also permitted to flow through the branch 60 of the conduit 54 upon opening of the valve 62. However, flow through the branch 60 is much slower than flow through the branch 58, because the branch 60 is formed with a choke 82 presenting a high impedance to the flow of operating fluid therethrough.

The choke 82 delays the effect of the operating fluid in producing an expansion of a sample collection chamber means 84 which is in communication with the annular sealing means 20. Following the setting action described above, however, the collection chamber 84 begins to expand because of the pressure of the operating fluid on a piston 86 in a cylinder 88. The piston 86 is provided with an O-ring 90 similar in function to the O-rings 46 and 34. No fluid is able to pass from one side of the piston 86 to the other. A passage 92 communicates with the exterior of the housing 18 and permits fluid in the well bore 14 to be evacuated from the cylinder 88 as the operating fluid forces the piston 86 downwardly as seen in FIG. 2.

A ram extension 94 is connected to the cylinder 86 at one end and to a cylinder 96 at its other end. The cylinder 96 is provided with an O-ring 98 similar in function to the O-rings 90, 46 and 34. Thus, fluid is unable to flow from one side of the piston 96 to the other. The piston 96 is slidable within a cylinder 100 connected by a passage 102 to the exterior of the housing 18. The piston 96 is thus able to be moved downwardly in response to the pressure of the operating fluid on the piston 86, fluid within the chamber 100 being expelled through the passage 102 to the exterior of the housing 18.

Biasing means such as a compression coil spring 103 urges the pistons 86 and 96 upwardly (as seen in FIG. 2) so that, upon release of the pressure acting downwardly on the piston 86, the pistons 86 and 96 are moved upwardly to the position illustrated in FIG. 2.

A seal 104 fits tightly about the ram extension 94 to permit leakage of fluid about the ram extension 94 from one side of the seal 104 to the other.

The downward movement of the piston 96 described above enlarges the chamber 84, thereby reducing the pressure within the chamber and facilitating the withdrawal of a fluid sample from the formation 16 and the collection thereof within the chamber 84. Because of the delay effected by the choke 82, the downward movement of the piston 96 that occurs prior to the setting of the shoe 26 and the forcing of the annular sealing means 20 against the area 22 of the wall 24 of the well bore 14 is negligible. Thus, a negligible amount of fluid from the well bore is drawn into the sample chamber 84, most of the fluid within the sample chamber 84 being formation fluid.

Gauge means such as a gauge 106 containing leads 108 extending to a suitable remote location is provided for measuring a property of the collected fluid. In a representative embodiment of the invention, the measured property is the pressure of the fluid. Other properties may, however, be measured, including, for example, temperature, resistivity and radioactivity. The gauge may be read at the surface or, if desired, the gauge may be any suitable type designed to make a recording within the tool 10, and the recording may be read after the tool 10 is recovered from the well bore 14.

After the making of the reading, the operating fluid employed in the collection of the sample is dumped into a dump chamber 110 by closing the valve 62 and opening the valve 70. The dump chamber 110 is of large capacity, so that a large number of samples can be collected serially in the chamber 84 without withdrawing the tool 10 from the well bore 14. Clearly, the cylinders 30 and 44 are also of large capacity for the same reason. The opening of the valve 70 exposes the portions of the conduit 54 downstream of the valve 62 to low pressure within the dump chamber 110, and fluid within the conduit 54 downstream of the valve 62, or at least a significant portion thereof, flows into the dump chamber 110. The compression coil spring 103 and mud pressure acting through the lines 92 and 102 force the pistons 86 and 96 upwardly (as seen in FIG. 2), thereby forcing operating fluid through the branch 60 and the choke 82 and into the branch 58, whence it flows through the valve 70 and into the dump chamber 110. Similarly, the pressure of fluid in the well bore 14 forces the pistons 74 and 76 to the left (as seen in FIG. 2), thereby withdrawing the shoe 26 from the wall 24 of the well bore 14. The operating fluid within the cylinders 66 and 68 likewise flows through the valve 70 and into the dump chamber 110. The tool 10 is then moved to another selected location in the well bore 14, and the sequence of events described above is repeated to collect and measure the properties of another sample of fluid from the formation 16.

FIG. 3 discloses an alternate embodiment of a portion of the apparatus of FIG. 2. Flow of operating fluid in the conduit 54 is controlled by the valve 62 in accordance with signals supplied to the valve by lines 64 as in the embodiment of FIG. 2. Also as in the embodiment of FIG. 2, the conduit 54 divides into branches 58 and 60 facilitating, respectively, setting of the shoe 26 and enlargement of the collection chamber means 84. Finally, the branch 60 includes the choke 82, as in the embodiment of FIG. 2.

The embodiment of FIG. 3 differs from the embodiment of FIG. 2 in that the branch 60 is further divided into subbranches 112 and 114. The subbranch 112 includes a check valve 116 preventing flow of operating fluid toward the piston 86 and collection chamber 84 but permitting flow of operating fluid away from the piston 86 and collection chamber 84. The subbranch 114 includes a delay cylinder 118 within which is slidably mounted a delay piston 120. The delay piston 120 is formed with a groove 122 within which is mounted an O-ring 124 tightly engaging the wall of the cylinder 118 so that, in the position of the delay piston 120 shown in FIG. 3, no fluid can pass from one side thereof to the other.

When the valve 62 is opened to permit operating fluid to flow from the oil reservoir through the conduit 54, the shoe 26 is rapidly set because flow is unimpeded through the fast action branch 58. There is initially no flow whatever through the delayed-action branch 60 between the subbranches 112 and 114 and the collection chamber 84, because the check valve 116 does not permit flow of operating fluid therethrough toward the chamber 84, and, in the position of the delay piston 120 shown in FIG. 3, operating fluid cannot pass from one side of that piston to the other.

When the pressure in the branch 60 reaches a value greater than the well bore pressure plus the equivalent pressure exerted by spring 133, the delay piston 120 slowly descends in response to opening of the valve 152 until the piston 120 is withdrawn from the delay cylinder 118 and is within an enlarged chamber 126 having a diameter greater than that of the delay piston 120. At this point, operating fluid can flow around the delay piston 120 and through the subbranch 114. The operating fluid then forces the piston 86 (FIG. 2) downwardly in the manner described above to enlarge the chamber 84 and facilitate the collection of formation fluid. The upward force exerted by the spring 133 on the delay piston 120 is such that the delay piston 120 is not withdrawn from the cylinder 118 until the oil pressure to the shoe pistons 66, 68 is sufficient to set the shoe 26 completely following the opening of the valve 62 and the annular sealing means 20 is therefore firmly pressed against the area 22 of the wall 24 of the well bore 14, sealing off the area 22 from fluid in the well bore 14. In accordance with the embodiment of FIG. 3, therefore, the fluid collected in the chamber 84 consists mostly of formation fluid.

Upon the completion of the collection of the formation fluid and the obtaining of a measurement with respect thereto by the gauge 106, the valve 62 is shut and the valve 70 (FIG. 2) is opened to dump the operating fluid into the dump chamber 110. The pressure of the fluid in the well bore 14 communicates with the lower side of a piston 128 mounted within a cylinder 130. The communication is established through a passage 132 extending to the exterior of the housing 18. The pressure of the fluid in the well bore 14 therefore urges the piston 128 and the piston 120 upwardly (as seen in FIG. 3). In addition, a compression coil spring 132 urges the piston 120 and 128 upwardly, so that the apparatus is restored to the position illustrated in FIG. 3. The piston 128 is formed with a groove 134 accommodating an O-ring 136 similar in function to the O-ring 124 and preventing passage of fluid from one side to the other of the piston 128. A ram 138 rigidly connects the pistons 120 and 128 so that they move together.

Upon the seating of the delay piston 120 in the delay cylinder 118, which is facilitated by a chamfer 121, no additional fluid can flow around the piston 120 towards the dump chamber 110. However, the check valve 116 permits free flow towards the dump chamber 110, and the upward movement of the pistons 86 and 96 (FIG. 2) in response to the urging of the spring 103 and the pressure of the fluid in the well bore 14 transmitted through the lines 92 and 102 is readily effected.

Thus there is provided in accordance with the invention novel and highly effective apparatus facilitating the obtaining of a plurality of readings with respect to fluid in formations traversed by a well bore in a single traverse of the well bore. The apparatus is inexpensive to manufacture and repair and greatly reduces the time required to survey a well.

Many modifications of the representative embodiments of the invention disclosed above will readily occur to those skilled in the art. Accordingly, the invention is to be construed as including all of the modifications thereof within the scope of the appended claims.

We claim:

1. In apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, said apparatus including a housing, annular sealing means mounted on said housing for sealing off an area of the wall of said well bore from fluid within said well bore, formation-fluid-receiving chamber means within said housing in communication with said sealed-off area of said wall, gauge means operatively connected to said chamber means for obtaining a reading with respect to formation fluid within said chamber means, and motive means for bringing said chamber means into cooperation with discrete samples of formation fluid collected at spaced-apart locations in said well bore, whereby a plurality of readings with respect to fluid in said formations is obtainable in a single traverse of said well bore by said apparatus, the improvement wherein said motive means comprises pressure multiplier means within said housing responsive to the pressure of said fluid within said well bore for boosting the pressure of an operating fluid within said housing to a pressure greater than the pressure of said well bore fluid at the depth of said apparatus, positioning means mounted on said housing and movable between a retracted position and a set position, conduit means communicating with said pressure multiplier means, said conduit means being divided into a fast-action branch communicating with said positioning means and a delayed-action branch communicating with said chamber means, and operating valve means in said conduit means which when opened permits operating fluid flow from said pressure multiplier means to said conduit means, whereby, upon opening of said operating valve means to permit operating fluid flow from said pressure multiplier means to said conduit means, said operating fluid flow is initially effective in said fast-action branch to cause setting of said positioning means, said positioning means when set forcing said annular sealing means against the wall of said well bore, and is thereafter effective in said delayed-action branch to expand said chamber means to reduce the pressure within said chamber means and facilitate collection of said formation fluid in said chamber means.

2. Apparatus according to claim 1 wherein said pressure multiplier means comprises a mud cylinder communicating with said fluid within said well bore, a mud piston within said mud cylinder, a high-pressure piston rigidly connected to said mud piston, said high-pressure piston being of smaller diameter than said mud piston, and a high-pressure cylinder housing said high-pressure piston, said high-pressure cylinder communicating with said conduit means.

3. Apparatus according to claim 1 wherein said delayed-action branch is formed with a choke to slow the flow of operating fluid therethrough.

4. Apparatus according to claim 1 wherein said delayed-action branch is divided into subbranches in parallel one of said subbranches comprising a check valve preventing operating fluid flow therethrough towards said chamber means and permitting operating flow therethrough away from said chamber means and the other of said subbranches comprising a delay cylinder and a delay piston mounted in said delay cylinder, said delay piston being normally within said delay cylinder to prevent operating fluid flow therethrough towards said chamber means but being forced out of said delay cylinder sufficiently to permit operating fluid flow toward said chamber means beginning a finite time following opening of said operating valve means, whereby, during operating fluid flow in said fast-action branch causing setting of said positioning means, there is initially no operating fluid flow in said delayed-action branch between said subbranches and said chamber means.

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5. Apparatus according to claim 4 further comprising biasing means for preventing said delay piston from being forced out of said delay cylinder until after setting of said positioning means.

6. Apparatus according to claim 1 further comprising a dump valve means in said conduit means and a dump chamber connected to said conduit means, said dump valve means when open permitting dumping of operating fluid from said conduit means into said dump chamber.

7. Apparatus according to claim 1 wherein said gauge means is a pressure gauge.

8. Apparatus according to claim 1 wherein said gauge means is a temperature gauge.

9. Apparatus according to claim 1 wherein said gauge means is a resistivity gauge.

10. Apparatus according to claim 1 wherein said gauge means is a radioactivity gauge.

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