73-152. 5\ SR

OR 3,577,781

United States Patent

[11] 3,577,781

[72] Inventors Maurice P. Lebourg;
Roger Q. Fields, Houston, Tex.
[21] Appl. No. 790,321
[22] Filed Jan. 10, 1969
[45] Patented May 4, 1971
[73] Assignee Schlumberger Technology Corporation
Houston, Tex.

[54] **TOOL TO TAKE MULTIPLE FORMATION FLUID PRESSURES**
12 Claims, 9 Drawing Figs.

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

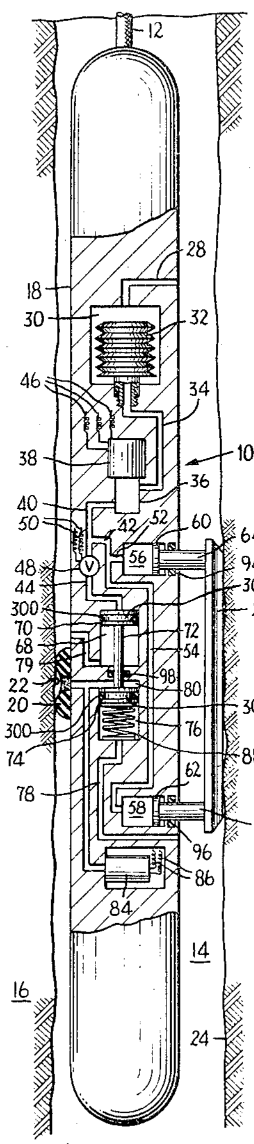
[56] **References Cited**

UNITED STATES PATENTS

2,905,247 9/1959 Vestermark 73/152UX
3,115,775 12/1963 Russell 73/152

Primary Examiner—Jerry W. Myracle
Attorney—Brumbaugh, Graves, Donohue and Raymond

ABSTRACT: A number of pressure readings with respect to fluids in formations traversed by a well bore are obtained in a single traverse of the well bore by a special tool. The tool has a sample chamber comprising one or more compartments for receiving separate samples of formation fluid. The pressure of the fluid in each sample (and hence the pressure of the corresponding fluid in the formation) is measured. In the one-compartment embodiment, fluid is expelled from the compartment after each collection and pressure measurement of a fluid sample. In the two-compartment embodiment, fluid is collected in one compartment and a pressure measurement is made, and fluid previously collected and measured for pressure is expelled. In one embodiment, the samples are expelled into the well bore; in another, into a dump chamber carried in the tool. In embodiments in which the chamber is divided into a large number of compartments, each compartment is used for the collection of only one sample, and the collected samples are not expelled until the tool is recovered.



Patented May 4, 1971 **3,577,781**

3 Sheets-Sheet 1

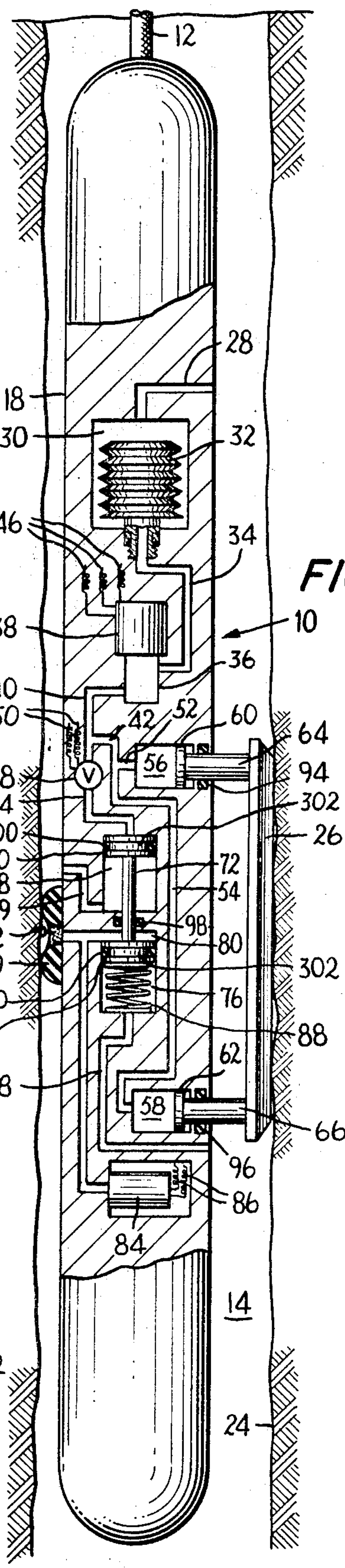


FIG. 2

FIG. 1

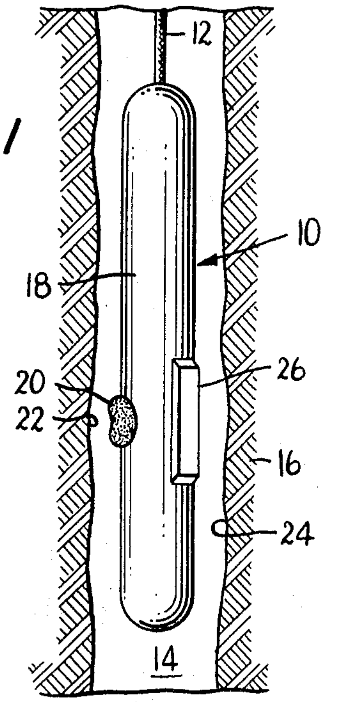
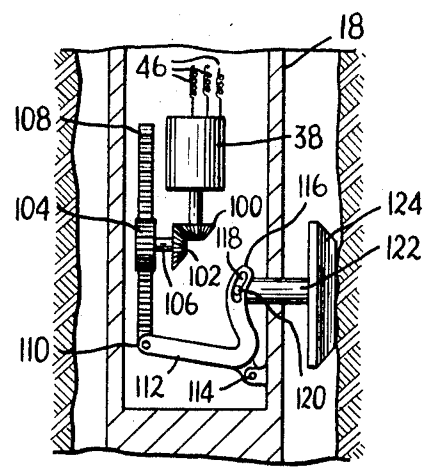


FIG. 3



INVENTORS
MAURICE P. LEBOURG &
ROGER Q. FIELDS
BY
Brumbaugh, Graves, Donohue & Raymond
their ATTORNEYS

FIG. 4

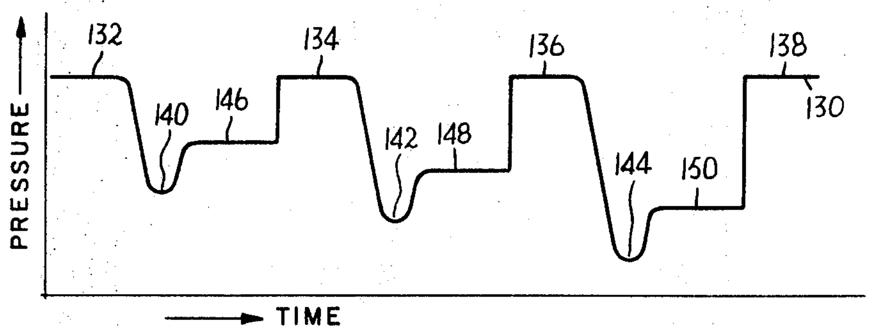


FIG. 5

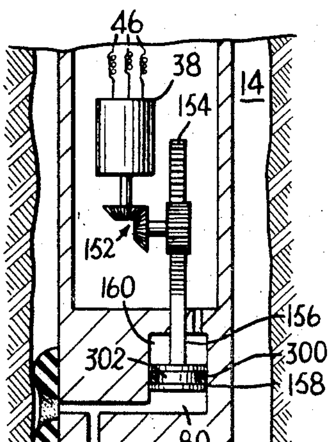


FIG. 6

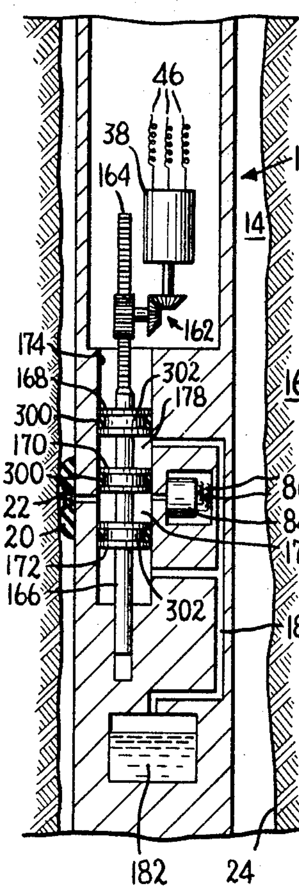
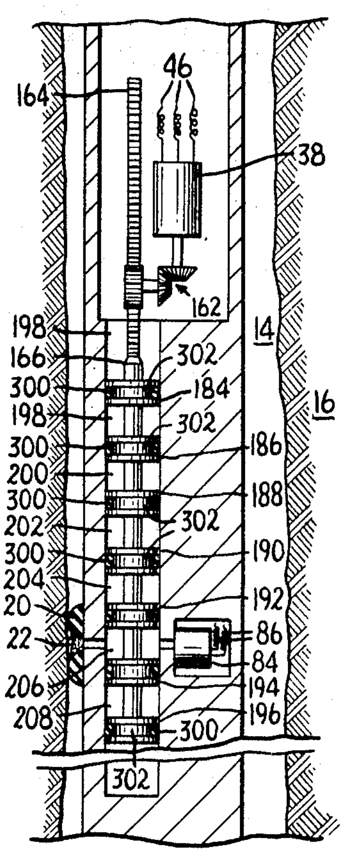


FIG. 7



INVENTORS
MAURICE P. LEBOURG &
ROGER Q. FIELDS
BY
Brumbaugh, Graves, Donohue & Raymond
their *ATTORNEYS*

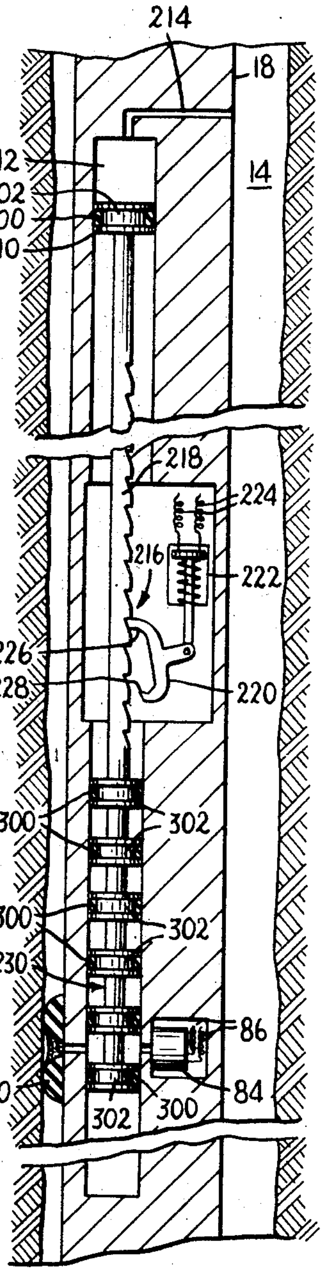


FIG. 8

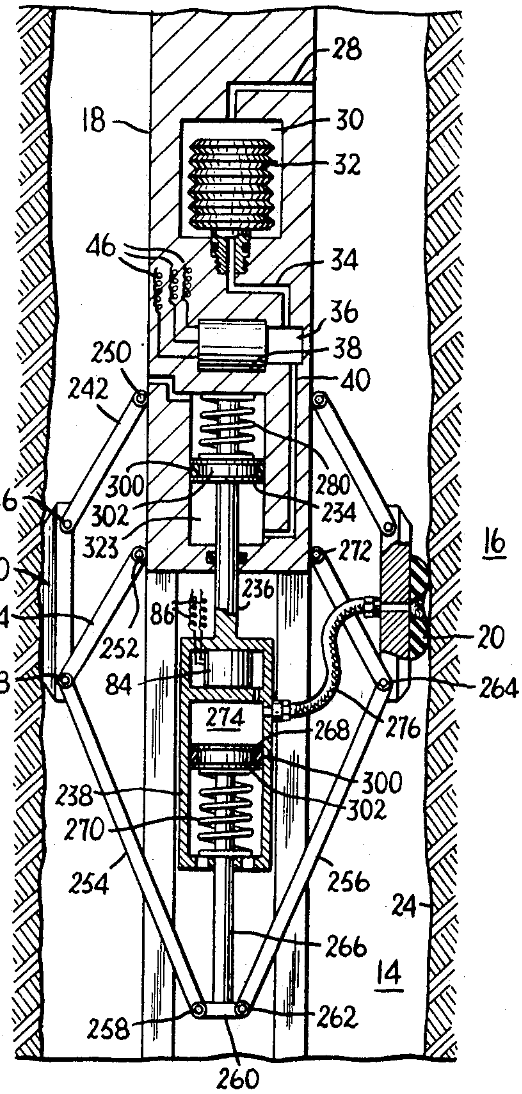


FIG. 9

INVENTORS
MAURICE P. LEBOURG &
ROGER Q. FIELDS
BY
Brumbaugh, Graves, Donohue & Raymond
their ATTORNEYS

TOOL TO TAKE MULTIPLE FORMATION FLUID PRESSURES

BACKGROUND OF THE INVENTION

This invention relates to the gathering of information with respect to fluids in earth formations and, more particularly, to novel and highly effective methods and apparatus facilitating the making 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 art of gathering information regarding earth formations is developed to a high state, as evidenced by a U.S. Pat. No. 3,011,554, to Desbrandes et al. U.S. Pat. Nos. 3,104,712 and No. 3,261,402, to Whitten and a U.S. Pat. No. 3,329,208 to Voetter. 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 time lost 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 improve prior methods and apparatus relating to the obtaining of readings with respect to fluids in earth formations. In particular, an object of the invention is to facilitate the obtaining of a plurality of readings with respect to fluids in earth formations at a plurality of spaced-apart locations without withdrawing the tool between successive readings. 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 attained, in representative apparatus constructed in accordance with the invention, by the provision of a housing, annular sealing means mounted on the housing for sealing off an area of the wall of a well bore from fluid within the well bore, and formation-fluid-sample-receiving chamber means within the housing in communication with the sealed-off area of the wall. Gauge means is provided for obtaining a reading with respect to formation fluid within the chamber means, and motive means is provided for bringing the chamber means into cooperation with discrete samples of formation fluid collected at spaced-apart locations in the well bore. In this way, a plurality of readings with respect to fluid in the formations is obtainable in a single traverse of the well bore by the apparatus.

BRIEF DESCRIPTION OF THE DRAWING

An understanding of additional aspects of the invention may be gained from a consideration of the following detailed description of several representative embodiments thereof, taken in conjunction with the accompanying FIGS. of the drawing, in which:

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

FIG. 2 is a detailed view in elevation, partly sectioned and on a scale larger than that of FIG. 1, of a first representative embodiment of apparatus constructed in accordance with the invention;

FIG. 3 is a fragmentary view in elevation, partly sectioned, of an alternate embodiment of a portion of the apparatus of FIG. 1;

FIG. 4 is a graph showing typical pressure readings as a function of time obtained in accordance with the invention; and

FIGS. 5—9 are elevational views, partly sectioned, of five additional embodiments of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows apparatus 10 constructed in accordance with the invention. The apparatus 10 is a tool or instrument suspended by a cable 12 in a well bore 14 that traverses earth formations 16. The well bore 14 typically contains a fluid such as a low-consistency mud, and the tool 10 includes a housing 18 at least a part of which is watertight.

Annular sealing means 20 is mounted on the housing 18 for sealing off an area 22 of the wall 24 of the well bore 14, and positioning means such as a shoe 26 is also mounted on the housing 18 for pressing against the wall 24 of the well bore 14 and thereby urging the sealing means 20 against the wall to facilitate the sealing off of the area 22.

The cable 12 is connected to means (not shown) at the well head for raising and lowering the tool 10 in the well bore 14 so that a plurality of areas such as the area 22 may be selected for withdrawing sample fluid from the formations. When the sealing means 20 firmly engages the wall 24 at any selected area, fluid in the formation can penetrate the wall 24 of the well bore 14 at the selected area, inasmuch as the sealing means 20 is annular and isolates the selected area of the wall 24 from the hydrostatic pressure of the fluid in the well bore 14. A formation-fluid-receiving chamber means is provided within the housing 18 and is under low pressure—i.e., a pressure lower than that of the formation fluid—to facilitate the flow of formation fluid into the chamber means.

FIG. 2 shows in detail the structure of a first representative embodiment of apparatus constructed in accordance with the invention. A channel 28 formed in the housing 18 provides communication between the mud in the well bore 14 and a chamber 30 within the housing 18. A diaphragm 32 is mounted within the chamber 30 and serves as an oil reservoir.

A channel 34 connects the reservoir within the diaphragm 32 to a reversible pump 36 powered by a reversible electric motor 38.

The diaphragm 32 is adapted to expand and contract in response to supply of oil to the oil reservoir or withdrawal of oil from the oil reservoir by the pump 36. In order to set the shoe 26 and thereby force the annular sealing means 20 against a selected area 22 of the well bore 24, the pump 36 withdraws oil from the reservoir within the diaphragm 32 and discharges the oil through a line 40.

The line or channel 40 branches into a line or channel 42 facilitating actuation of the shoe 26 and a line or channel 44 facilitating collection of a sample of fluid from the earth formation.

The reversible electric motor 38 (and hence the reversible pump 36) is controlled remotely (for example, from the well head) by electrical leads 46 extending from the motor 38 to the remote location. Similarly, a valve 48 is controlled remotely, preferably, from the same location as the location from which the motor 38 is controlled, by means of electrical leads 50 extending from the valve 48 to the remote location. Upon the initial actuation of the reversible electric motor 38 to cause the reversible pump 36 to withdraw oil from the reservoir within the diaphragm 32 and discharge the oil into the line 40, the valve 48 is maintained closed, so that the oil discharged into the line or channel 40 flows into the branch 42 but not into the branch 44.

The branch 42 in turn divides into a line or branch 52 and a line or branch 54 communicating, respectively, with cylinders 56 and 58 formed in the housing 18. The cylinders 56 and 58 are fitted, respectively, with pistons 60 and 62 integral, respectively, with ram extensions 64 and 66. The ram extensions 64 and 66 are in turn integral with the shoe 26.

The discharge of oil by the pump 36 into the line 40 is therefore effective to set the shoe 26: i.e., move the shoe outwardly with respect to the housing 18 and 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, thereby sealing off the area 22 from fluid within the well bore 14.

At this point, the valve 48 is opened by the application of an appropriate signal to the electrical leads 50, and the pump 36 then not only maintains the shoe 26 set but also supplies oil through the line 44. The line 44 communicates with a cylinder 68 formed in the housing 18. The cylinder 68 is provided with a piston 70 which is forced downwardly (as seen in FIG. 2) by the admission of oil through the line 44. The piston 70 is connected by a ram extension 72 to a second piston 74 within a second cylinder 76.

The pistons 70 and 74 are able to move downwardly (as seen in FIG. 2) in response to the supply of oil from the line or channel 44 into the cylinder 68 because of channels 78 and 79 establishing communication between the cylinders 76 and 68, respectively, and the exterior of the housing 18. The downward movement of the piston 74 lowers the pressure within a chamber 80 formed above the piston 74, defined in part by the piston 74 and the cylinder 76, and communicating with the sealed-off area 22 of the wall 24 of the well bore 14.

A gauge 84 is operatively associated with the chamber means 80. The gauge 84 is adapted to obtain a reading with respect to the sample fluid withdrawn from the formation. The gauge 84 may measure temperature, radioactivity, or any other property of interest of the fluid. In a representative embodiment of the invention, the gauge 84 measures the pressure of the fluid. The reading obtained by the gauge 84 may be determined upon recovery of the tool 10 or may be read immediately at a remote location, for example the location from which the motor 38 and valve 48 are controlled. To this end, electrical leads 86 extend from the gauge 84 to the remote location.

In operation, after the annular sealing means 20 is firmly positioned against the wall 24 of the well bore 14 and the pressure within the chamber 80 is reduced by lowering the piston 74 within the cylinder 76, the fluid, if present, within the formation 16 readily flows into the chamber 80, provided the permeability of the formation is not too low. In formations of low permeability, any conventional means such as shaped charges may be employed to facilitate flow of formation fluid. Such means are not illustrated here, inasmuch as they are well understood by those skilled in the art. Similarly, the use of snorkels and other devices is within the scope of the invention.

After a sample has been obtained and the pressure thereof recorded within the tool itself or at a remote location, the collected sample is ejected from the chamber 80 and the shoe 26 is withdrawn from the position illustrated in FIG. 2 to the position illustrated in FIG. 1. This is accomplished by reversing the reversible electric motor 38 and hence the reversible pump 36 to withdraw oil from the line 40 and discharge it into the line 34 and the reservoir within the diaphragm 32. The hydrostatic pressure of the fluid within the well bore 14 acting across the area of the ram extensions 64 and 66 forces the shoe 26 inwardly against the housing 18. With the valve 48 open, oil can also be withdrawn from the branch 44 and the portion of the cylinder 68 above the piston 70. A compression coil spring 88 within the cylinder 76 assists the upward movement of the piston 74 and therefore the piston 70. The upward movement of the piston 74 reduces the volume of the chamber 80 and expels the sample collected therewithin to the exterior of the housing 18.

The tool 10 is then moved to another selected area of the well bore 14, and the sequence of operation described above is repeated to collect a separate sample of formation fluid and make a pressure measurement or another desired measurement with respect thereto.

Seals 94, 96, and 98 respectively, prevent leakage of mud or oil, as the case may be, around the portions of the ram extensions 64, 66, and 72 that are slidably engaged by the housing 18.

FIG. 3 discloses an alternate embodiment of the invention. The reversible motor 38 drives a gear train including the peripherally engaged bevel gears 100 and 102 and a pinion gear 104. The pinion gear 104 and bevel gear 102 are both fast on a shaft 106. A movable rack 108 is driven by the pinion gear 104 and is connected to one end 110 of the lever or bellcrank 112. The lever 112 is pivotally mounted on a support 114 intermediate its ends, and the other end 116 of the lever 112 is formed with a slot 118 by which it engages a stud 120 integral with a ram 122. A shoe 124 is in turn integral with the ram 122.

The operation of the apparatus of FIG. 3 will be readily understood by those skilled in the art. The reversible electric motor 38 is adapted to raise or lower the movable rack 108, depending on the direction in which the motor 38 drives the beveled gear 100. In this way, the bellcrank or lever 112 is pivoted. When the rack 108 is moved downwardly (as seen in FIG. 3) the bellcrank 112 is pivoted counterclockwise to withdraw the shoe 24 from the set position illustrated in FIG. 3. The slot 118 provides sufficient play so that there is no binding of the ram 122 in the wall of the housing 18. When the rack 108 is moved upwardly (as seen in FIG. 3), the bellcrank or lever 112 is pivoted clockwise to set the shoe 124. The movement of the end 110 of the lever 112 is nearly in a straight vertical line, so that the provision of a slot to facilitate the connection between the movable rack 108 and the lever 112 is not absolutely essential. In certain embodiments of the invention, however, where the end 110 of the lever 112 has an appreciable component of motion at right angles to the direction of travel of the rack 108, a slotted connection may of course be provided.

FIG. 4 is a graph of pressure readings obtained by the gauge 84 of FIG. 1 as a function of time. The graph 130 includes portions 132, 134, 136, and 138 indicating the pressure read by the gauge 84 when the annular sealing means 20 is exposed to the hydrostatic pressure of the fluid in the well bore 14. The graph also includes portions 140, 142, and 144 indicative of the pressures read by the gauge 84 during the expansion of the chamber means 80. As noted above, such expansion lowers the pressure within the chamber 80, inasmuch as, during such expansion, the annular sealing means 20 is pressed tightly against the wall 24 of the well bore 14 to prevent entry of fluid from the well bore 14 into the chamber 80.

The graph 138 also contains portions of principal interest 146, 148, and 150 indicative of the pressures read for fluids within the formations. It is these pressures which yield significant information regarding the nature of the formations. While only three readings are illustrated in FIG. 4, it is obvious that any number of readings can be obtained by the apparatus of FIG. 1 without withdrawing the tool 10 from the well bore 14.

FIG. 5 shows another embodiment of the invention. In this embodiment, the reversible electric motor 38 drives a gear train 152 similar to the gear train comprising the gears 100, 102, and 104 of FIG. 3. A movable rack 154 similar to the rack 108 is connected to a ram extension 156 which is in turn integral with a piston 158 within a cylinder 160.

Movement of the rack 154 upwardly moves the piston 158 upwardly to expand the chamber means 80, thereby reducing the pressure therewithin and facilitating the withdrawal of fluid from the formation 16 in the manner indicated above. The pressure gauge 84 reads the pressure of the fluid sample, and the rack 154 is then moved downwardly (as seen in FIG. 5) to move the piston 158 downwardly and expel the collected sample into the well bore 14.

The embodiment of FIG. 2 and the embodiment of FIG. 5 are similar in that they expel sample fluid from the chamber 80 between successive samplings and in that each includes motive means for accomplishing this purpose. The motive means differ, of course, in structural detail.

FIG. 6 illustrates another representative embodiment of the invention. The motor 38 drives a mechanical linkage 162 similar to that illustrated in FIG. 5 including a rack and pinion assembly. The rack 164 is integral with a ram 166 on which are securely mounted three pistons 168, 170, and 172. All of the pistons are slidable within the same cylinder 174.

In operation, the reversible electric motor 38 is reversed in order to bring alternately (a) the space 176 between the pistons 170 and 172 into communication with the gauge 84 and the area sealed off by the annular sealing means 20 and (b) the space 178 between the pistons 168 and 170 into communication with the gauge 184 and the area sealed off by the annular sealing means 20. In the position of the apparatus illustrated in FIG. 6, the space 176 is in communication with the gauge 86 and sealed-off area 22, while the space 178 communicates with a line 180 and a dump chamber 182. Accordingly, while the gauge 86 registers the pressure of the fluid sample withdrawn from the sealed-off area 22, a previously collected sample within the compartment 178 is discharged to the dump chamber 182.

The dump chamber 182 is at low pressure and is of large capacity compared to the capacity of the compartments 176 and 178. Thus, the pressure of the compartment 178 is reduced to a low level. The tool 10 is moved to another selected area of the well bore 14 and the annular sealing means 20 pressed firmly against a selected area of the wall 24 of the well bore 14, whereupon the electric motor 38 is caused to lower the rack 164 and bring the compartment 178 in communication with the gauge 84 and newly selected sealed-off area. The gauge 184 then reads the pressure of the fluid sample collected at the newly selected sealed-off area, and the previously collected sample within the compartment 176 is dumped into the dump chamber 182.

The embodiment of FIG. 6 is similar to the embodiment of FIGS. 1 and 5 in that it includes chamber means 80. Whereas, however, in the embodiments of FIGS. 1 and 5, the chamber means 80 is but a single compartment, in the embodiment of FIG. 6 it comprises the two compartments 176 and 180. In the case of all of the embodiments, motive means brings chamber means into cooperation with discrete samples of formation fluid collected at spaced-apart locations in the well bore 14.

FIG. 7 discloses another representative embodiment of the invention. In this embodiment, the reversible electric motor 38 drives a gear train 162 and a rack 164 as in the embodiment of FIG. 6. The rack 164 is integral with a ram extension 166. The ram extension 166 supports a large number of pistons 184, 186, 188, 190, 192, 194 and 196, each fitting tightly within a cylinder 198. The chamber means required by the invention is divided into a number of separate compartments 198, 200, 202, 204, 206 and 208, each compartment being between a pair of adjacent pistons.

The compartment 206 is illustrated in FIG. 7 as being the compartment in communication with the gauge 84 and the area sealed off by the annular sealing means 20. A fluid sample from the formation 16 is thus collected, and its pressure measured by the gauge 84. At a later time, the compartment 204 is brought into communication with the gauge 84 and a different area of the wall of the well bore 14 sealed off by the annular sealing means 20, and a separate fluid sample is collected and the pressure thereof measured by the gauge 84. A dump chamber is not provided in the embodiment of FIG. 7, the collected samples being retained following the measurement of their pressure until the tool is recovered at the well head.

By the provision of a large number of separate compartments, it is possible to make a desired number of readings without withdrawing the tool. Motive means comprising the motor 38 gear train 162, and rack 164 is effective to bring each compartment successively in communication with the gauge 84 and successive sealed-off areas of the wall of the well bore 14.

FIG. 8 illustrates another embodiment of the invention. In this embodiment, the motive means does not comprise an electric motor but comprises, instead, a piston 210 mounted within a cylinder 212. The cylinder 212 communicates with fluid in the well bore 14 by means of a passage or duct 214 formed in the housing 18. The piston 210 is forced downwardly by the hydrostatic pressure of the fluid in the cylinder 212, but the downward movement of the piston 210 is restrained by a solenoid-operated escapement 216. The escapement 216 comprises a ratchet 218 engageable with a pawl 220 movable by a solenoid 222. Escapements are conventional per se and the construction and operation of the escapement 216 need not be disclosed in detail. Those skilled in the art will readily understand that each time the solenoid 222 is actuated by leads 224 extending to the surface or another convenient remote location, the pawl 220 moves to permit the ratchet 218 to drop downwardly. The pawl 220 includes fingers 226 and 228 one of which is always in contact with the ratchet 218, thereby preventing the ratchet 218 from dropping freely but permitting it to be lowered in stepwise fashion. In this way, a piston assembly 230 analogous to that shown in FIG. 7 is moved to bring successive compartments defined thereby in communication with the gauge 84 and the area sealed off by the annular sealing means 20.

FIG. 9 discloses another embodiment of apparatus constructed in accordance with the invention. This embodiment is similar to the embodiment of FIG. 2 in providing the passage 28 for admitting mud to a chamber 30 within which a flexible diaphragm 32 containing an oil reservoir is mounted. The reversible pump 36 powered by the reversible electric motor 38 for pumping oil selectively in opposite directions in lines 34 and 40 also characterizes this embodiment of the invention. In the embodiment of FIG. 9, however, the oil discharged from the line 40 into a first cylinder 232 is effective to force a first piston 234 upwardly (as seen in FIG. 9) thereby drawing upwardly a ram extension 236 and a second cylinder 238 integral with the ram 236. The upward movement of the second cylinder 238 sets a shoe 240 and also forces the annular sealing means 20 against the wall 24 of the well bore 14 by virtue of means including a parallelogram linkage. The shoe 240 is mounted on parallel arms 242 and 244. The arms 242 and 244 are of equal length and are pivotally connected at 246 and 248, respectively, to the shoe 240. They are also pivotally connected at 250 and 252, respectively, to the housing 18. The separation between the pivot points 250 and 252 is equal to the separation between the pivot points 246 and 248. Thus, the arms 242 and 244, the portion of the shoe 240 between the pivots 246 and 248, and the portion of the housing 18 between the pivots 250 and 242 form a parallelogram structure by virtue of which the shoe 240 may be moved inwardly and outwardly with respect to the housing 18 along an arc, while always remaining parallel to the housing 18. The mounting of the annular sealing means 20 is the same as that described for the shoe 40 and need not be set forth in detail. While only two arms 242 and 244 are shown for mounting the shoe 240 and only two corresponding arms are shown for mounting the annular sealing means 20, additional arms mounted, for example, directly behind the arms illustrated, may be provided for additional strength.

The parallelogram structures mounting the shoe 240 and annular sealing means 20 are swung outwardly by the upward movement of the second cylinder 238 because of connecting arms 254 and 256, respectively. The arm 254 is pivotally connected at 248 to the shoe 240 and arm 244 and at 258 to a bracket 260. The arm 256 is similarly connected at pivot points 262 and 264. The bracket 260 is connected to a ram extension 266 integral with a second piston 268 within the second cylinder 238.

A compression coil spring 270 urges the piston 268 upwardly within the second cylinder 238 so that, when the cylinder 238 is raised by the pumping of oil into the first cylinder 232, the second piston 268, the ram extension 266, and the bracket 260 move upwardly. This shortens the distance between the pivot points 258 and 262 on the one hand and the pivot point 252 and a corresponding pivot point 272 on the other.

In this manner, the shoe 240 is set and the annular sealing means 20 is pressed firmly against a selected area of the wall 24 of the well bore 14.

After the setting of the shoe 240 and the pressing of the annular sealing means 20 against the wall 24 of the well bore 14, additional movement of the arms 254 and 256 and of the parallelogram structures is impossible. Continued pumping of oil into the first cylinder 232 by the pump 36 is therefore effective to continue to move the second cylinder 238 upwardly notwithstanding the arrest of the second piston 268. The sample collection chamber means 274 is thus enlarged, reducing the pressure therein, and facilitating withdrawal of a fluid sample from the formation 16 through a flexible hose 276.

The sample collected within the chamber 274 is monitored by the gauge 84 in the manner described above, and the reversible electric motor 38 reverses the reversible pump 36 to evacuate oil from the first cylinder 232 through the line 40, the oil being discharged through the line 34 to the reservoir within the flexible diaphragm 32. This lowers the first piston 234 and the second cylinder 238 to reduce the volume of the chamber means 274 and expel the collected sample fluid. A compression coil spring 280 facilitates lowering of the first piston 234. The lowering of the piston 234 is ultimately effective to lower the second piston 268 and collapse the arms 254 and 256 as well as the parallelogram structures supporting the shoe 240 and the annular sealing means 20. The tool is then moved to a new location in the well bore 14 and the process described above is repeated in order to facilitate analysis of another sample of fluid from the formation 16. Clearly, any desired number of samples can be analyzed in this manner without withdrawing the tool from the well bore 14.

In all of the embodiments described above, sealing means is of course employed as necessary. In particular, O-rings 300 are mounted in grooves 302, extending around the respective peripheries of pistons 70, 74, 158, 168, 170, 172, 184, 186, 188, 190, 192, 194, 196, 210, 234, and 268 and the pistons of the assembly 230. These O-rings tightly engage the walls of the cylinders in which the respective pistons are mounted and prevent unwanted leakage around the pistons from one side to the other.

Thus there is provided in accordance with the invention novel and highly effective methods and apparatus facilitating obtaining a plurality of readings with respect to fluids in formations traversed by a well bore in a single traverse of the well bore. The apparatus of the invention is economical to manufacture and repair. More importantly, it is economical to use in that it reduces the time spent inserting a measuring tool into and withdrawing it from a well bore. The greater the depth of the well bore at which measurements are to be made, the greater the saving in time and money realized in accordance with the invention.

Many modifications of the representative embodiments described 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. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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 and increasing the effective volume of said chamber means, 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.

2. Apparatus according to claim 1 wherein said readings are obtained successively and said motive means comprises a reversible pump for evacuating said chamber means between successive readings.

3. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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, said chamber means comprising a plurality of separate compartments and said motive means moving said compartments for successive cooperation with separate samples of formation fluid.

4. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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 formation is obtainable in a single traverse of said well bore by said apparatus, said chamber means comprising a pair of separate compartments, said annular sealing means sealing off separate areas of said wall, and said motive means moving said compartments for alternating cooperation with separate sealed-off areas of said wall to collect successive samples of formation fluid, further comprising a dump chamber within said housing, the chamber not in communication with a sealed-off area of said wall communicating with said dump chamber to dump thereinto a previously collected formation fluid sample.

5. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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, said chamber means comprising a plurality of separate compartments and said motive means comprising a piston-cylinder assembly urged by pressure of fluid in said well bore to move said compartments for successive cooperation with separate samples of formation fluid, further comprising escapement means for releasably restraining movement of said compartments and solenoid means operatively connected to said escapement means, whereby said compartments can execute a limited movement and successive ones of said compartments are arrested in cooperative relation with said gauge means.

6. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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 read-

ing 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, said readings being obtained successively and said motive means comprising a reversible pump, further comprising a cylinder to and from which said pump alternately discharges and withdraws fluid, a piston mounted within said cylinder and movable in response to discharge and withdrawal of said fluid by said pump, a ram extension integral with said piston and movable therewith, a second cylinder integral with said ram extension and movable therewith, a second piston mounted within said second cylinder for limited movement therewith, said chamber means being defined at least in part by said second cylinder and said second piston, and means for arresting movement of said second piston after the sealing off of said area notwithstanding continued movement of said second cylinder, whereby said chamber means is expanded to reduce the pressure therein and facilitate the collection of formation fluid therein.

7. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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, said readings being obtained successively and said motive means comprising a reversible pump, further comprising a cylinder to and from which said pump alternately discharges and withdraws fluid, a piston mounted within said cylinder and movable in response to discharge and withdrawal of said fluid by said pump, a ram extension integral with said piston and movable therewith, a second piston integral with said ram extension and movable therewith, a second cylinder enclosing said second piston, said chamber means being defined at least in part by said second cylinder and said second piston, whereby said chamber means is expansible to reduce the pressure therein and facilitate the collection of formation fluid therein.

8. Apparatus according to claim 1 further comprising positioning means mounted on said housing for pressing against the wall of said well bore and thereby urging said sealing means against said wall to facilitate said sealing off.

9. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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, further comprising a reversible electric motor, a pinion gear driven by said motor, a movable rack driven by said pinion gear, positioning means engageable with said wall, and lever means connecting said rack and positioning means, whereby said motor when run in one direction forces said positioning means against said wall and when run in the opposite direction withdraws said positioning means from said wall.

10. Apparatus according to claim 1 in which said gauge means reads pressure.

11. Apparatus for obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising 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-sample-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, said readings being obtained successively and said motive means comprising an electric motor, a pinion gear driven by said motor, a movable rack driven by said pinion gear, a piston integral and movable with said rack, and a cylinder enclosing said piston, said chamber means being defined at least in part by said piston and cylinder.

12. A method of obtaining a plurality of readings with respect to fluids in formations traversed by a well bore, comprising the steps of first lowering chamber means into said well bore and then (a) sealing off a first area of the wall of the well bore from fluid within said well bore, (b) exposing said first sealed-off area to said chamber means and increasing the effective volume of said chamber means to provide a pressure below the pressure of fluid in the formation behind said first sealed-off area, whereby a first sample of fluid in said formation flows from said formation to said chamber means, and (c) obtaining a reading with respect to said first sample; (a) sealing off a second area of the wall of the well bore from fluid within said well bore, and second area being spaced apart from said first area, (b) exposing said second sealed-off area to said chamber means and increasing the effective volume of said chamber means to provide a pressure below the pressure of fluid in the formation behind said second sealed-off area, whereby a second sample of fluid in said formation, separate from said first sample, flows from said formation to said chamber means, and (c) obtaining a reading with respect to said second sample; repeating steps (a), (b), and (c) at additional areas in said well bore spaced apart from said first and second areas and from each other without withdrawing said chamber means from said well bore; and finally withdrawing said chamber means from said well bore.