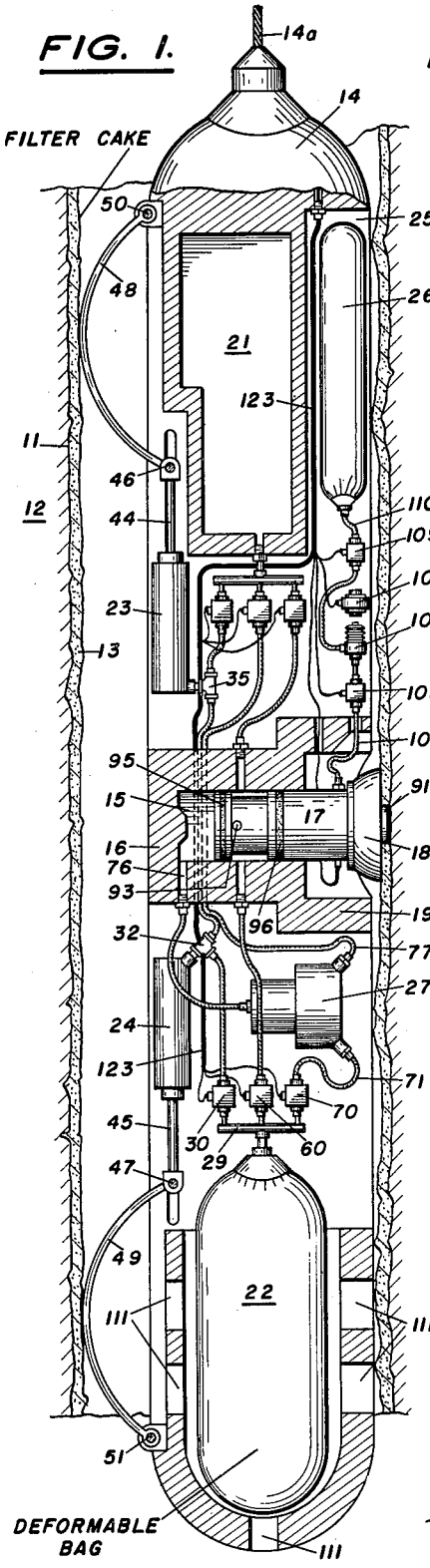
Nov. 29, 1955 W. D. MOUNCE ET AL 2,725,283

APPARATUS FOR LOGGING WELL BORES

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FIG. 1.



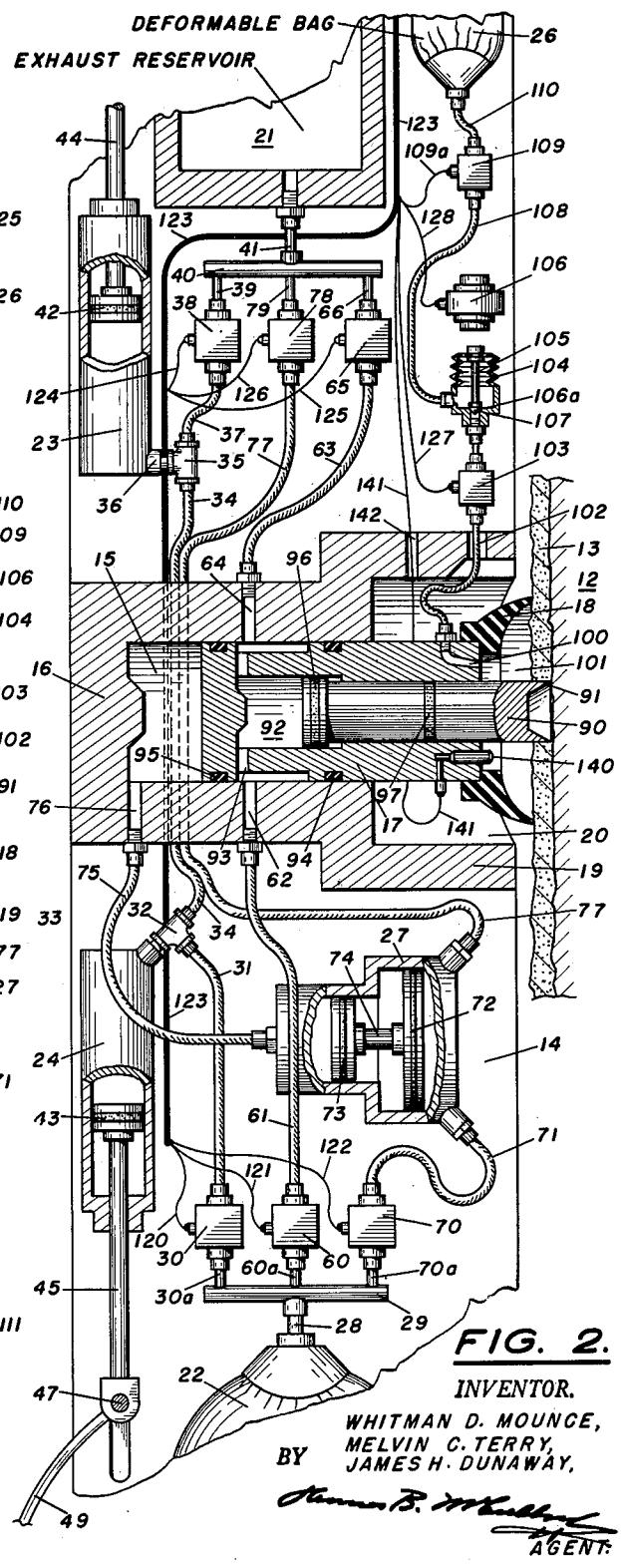


FIG. 2.

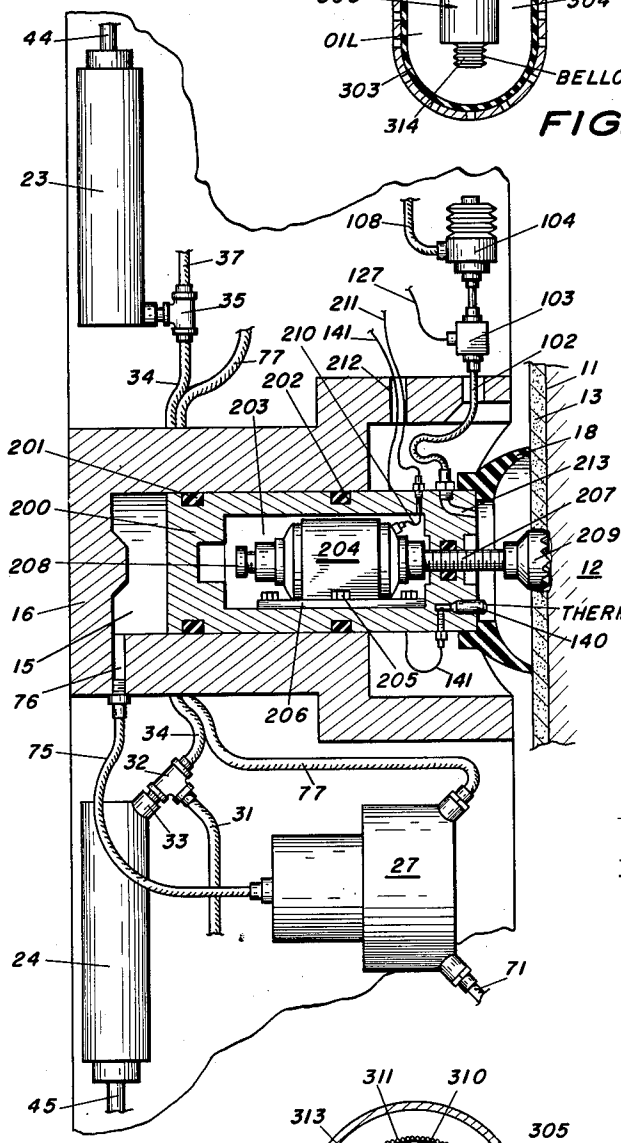
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APPARATUS FOR LOGGING WELL BORES

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FIG. 3.



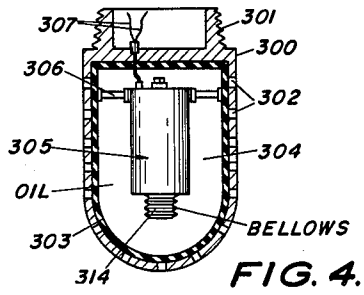


FIG. 4.

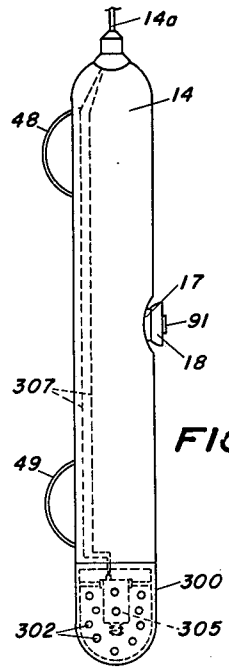


FIG. 7.

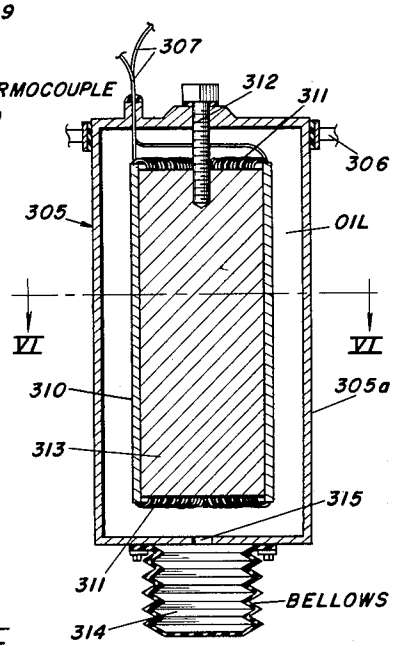


FIG. 5.

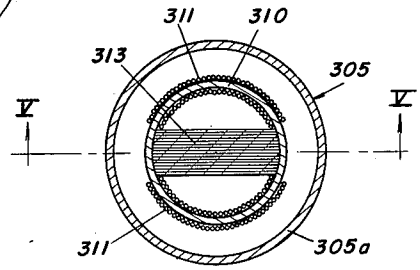


FIG. 6.

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APPARATUS FOR LOGGING WELL BORES

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Application April 30, 1952, Serial No. 285,224

7 Claims. (Cl. 23—253)

The present invention is directed to apparatus for logging a borehole in an earth formation. More particularly, the invention is directed to apparatus for indicating directly the presence of petroliferous substances in a well bore penetrating an earth formation containing petroliferous substances.

The invention may be described briefly as involving apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises a body member adapted to be lowered and raised in a well bore. The body member defines a cylinder in which is arranged a piston having a free end provided with a cutting edge adapted to cut through a filter cake on a wall of the well bore and to contact an earth formation. A reservoir is provided which may be a deformable bag member and is adapted to contain a fluid oxidizing agent. This reservoir is arranged in a cavity in the body member which may be exposed to well pressure, if desired. A conduit connects the deformable bag member with the piston cylinder adjacent the free end of the piston. The body member has arranged therein actuating means for moving the piston into and out of contact with said formation to close and open said conduit and to release oxidizing agent into contact with the formation. A detection means such as a thermocouple to detect a reaction effect of the oxidizing agent with petroliferous substances in the formation is arranged adjacent a free end of the piston; the detection means may be carried by the body member directly.

The invention will be further illustrated by reference to the drawing in which

Fig. 1 is an illustration of a preferred embodiment of our invention in partial section;

Fig. 2 is an enlarged view in partial section of a detail of Fig. 1;

Fig. 3 is a modification of the device of Figs. 1 and 2;

Fig. 4 is a partial sectional view of a pressure responsive means which may be used in the apparatus of Figs. 1 to 3;

Fig. 5 is a sectional view of the pressure responsive means of Fig. 4;

Fig. 6 is a view taken along the lines VI—VI of Fig. 5; and

Fig. 7 shows an arrangement of our apparatus with the pressure responsive means arranged on a lower end thereof.

In the several figures of the drawing, identical numerals will be employed to designate identical parts.

Referring now to Figs. 1 and 2, numeral **11** designates a well bore in an earth formation **12** which is lined with a filter cake **13** resulting from the drilling operations employing a conventional type of drilling mud. Arranged in the well bore **11** is a body member **14** which is suspended from a wellhead, not shown, by a cable **14*a*** which may be, and in this particular instance is, an electrical conductor cable. The body member **14** may be positioned adjacent a wall of the well bore as is shown in the drawing.

The body member **14** is provided with a piston cylinder **15** which may be formed integrally with the body member **14** but preferably is bored in a block member **16**. Arranged within the piston cylinder **15** is a piston **17** which is provided on a free end thereof with a deformable sealing member **18**, the function of which will be described in more detail hereinafter. It will be noted that the block **16** is provided with an enlarged portion **19** and that a cavity **20** is defined by the enlarged portion **19** to accommodate the deformable sealing member **18** as the piston member **17** moves into the piston cylinder **15**.

The body member **14** has arranged within it an exhaust reservoir **21**, a hydraulic fluid reservoir **22**, a first piston cylinder **23** and a second piston cylinder **24**. The body member **14** also has arranged within it in a cavity **25** a chamber **26** which is adapted to contain a fluid oxidizing agent.

Arranged in the body member **14** above the hydraulic fluid reservoir **22** and below the block member **16** is a piston cylinder **27** which allows the piston **17** to be moved by the effect of the drilling mud pressure on the hydraulic fluid reservoir **22**.

The piston cylinders **23** and **24** are connected to the hydraulic fluid reservoir **22** through a conduit **28** and a manifold **29**. Connected to manifold **29** by conduit **30*a*** is a first solenoid valve **30** which has a conduit **31** connecting into a T-shaped connection means **32** which serves to connect the piston cylinder **24** by a connection means **33** with the conduit **31** and the manifold **29**. The T-shaped member **32** has a conduit **34** connected thereto which, in turn, is connected to a second T-shaped member **35** which allows hydraulic fluid to be transmitted to piston cylinder **23** by connection **36**. The T-shaped member **35**, in turn, is connected by a still further conduit **37** to a second solenoid valve **38** which connects by conduit **39** to manifold **40** which, in turn, connects by conduit **41** to exhaust reservoir **21**.

Arranged within the piston cylinders **23** and **24**, respectively, are pistons **42** and **43** provided with piston arms or rods **44** and **45** which, in turn, are connected pivotally at points **46** and **47** with spring members **48** and **49** which are in themselves pivotally connected at points **50** and **51** with body member **14** to allow the latter to be moved to the wall of the well-bore **11** as will be described further.

The manifold **29** has connected thereto by conduit **60*a*** a third solenoid valve **60** which is connected by conduit **61** to a passageway **62** and to piston cylinder **15** in the block **16**. A conduit **63** connects into a passageway **64** in the block **16** and to piston cylinder **15** and to a fourth solenoid valve **65** which connects by conduit **66** into manifold **40**.

A fifth solenoid valve **70** is connected to manifold **29** by conduit **70*a*** and connects by conduit **71** into the piston chamber **27** as will be seen in the sectional view of Fig. 2. Piston cylinder **27** has arranged in it interconnected pistons **72** and **73** which are connected by a piston rod **74**. It will be noted that piston **72** has an area substantially larger than the area of piston **73** and it will be further noted that the arrangement of conduit **71** allows the hydraulic fluid to be exerted against piston **72**. The force exerted against the exposed faces of pistons **72** and **73** is the product of the area of the piston and the pressure of the fluid system to which said face is exposed. The purpose of pistons **72** and **73** is to allow the drilling mud pressure to be used as a motivating force in actuating piston **17**. The interconnected pistons **72**, **73** and the fluid pressures of the separate hydraulic systems to which these pistons are exposed are designed so that the total force exerted on piston **72** by its hydraulic system will be greater than the total force exerted on piston **73** by its hydraulic

system. As will be seen, piston chamber 27 is connected at its smaller end to a conduit 75 which, in turn, connects with a passageway 76 in the block 16 and communicates thereby with the piston cylinder 15. The piston chamber 27 is also connected at its larger end with conduit 77 which, in turn, connects with a sixth solenoid valve 78 connecting by conduit 79 to manifold 40.

Referring specifically to Fig. 2, it will be noted that the piston 17 is provided with an inner piston 90 which has on a free end thereof a cutting member 91 which is adapted to cut the filter cake 13 sheathing the wellbore 11. The piston 90 is arranged in an inner chamber 92 of the piston 17 and communicates with the piston cylinder 15 through an opening 93 in the wall of the piston 17. The piston 17 is suitably sealed by sealing means 94 and 95 while the piston 90 is also provided with seals 96 and 97 for operation thereof.

The piston 17 has adjacent a free end thereof enclosed by the seal 18 a port 100 which communicates with the space 101 also enclosed by the seal 18. The port or conduit 100 is connected by a conduit 102 to a seventh solenoid valve 103. This solenoid valve is provided with a bellows-type arrangement 104 in which is positioned an iron rod 105. Spaced above the bellows arrangement is a magnet means 106 which on energization, as will be described, serves to draw the iron rod 105 upwardly and to lift the seating means 106*a* on the end of the iron rod 105 off the seat 107 in the bellows arrangement 104. It will be noted that the bellows arrangement means 104 is connected by a conduit 108 to an eighth solenoid valve 109 which, in turn, is connected by conduit 110 to the reservoir 26 which carries the fluid oxidizing agent.

It will be noted that the cavity 25 is open to the well and that the reservoir 26 may be constructed of a deformable material to allow well pressure to be exerted directly thereon. It is to be further noted that the hydraulic fluid reservoir 22 may likewise be constructed of a deformable material and that the reservoir 22 is also exposed to the well pressure through ports 111 in the body member 14.

The solenoid valves 30, 60 and 70 are connected by electrical conducting means 120, 121 and 122 to electrical energy means not shown at the wellhead and which is carried thereto through electrical conductor 123 which, in turn, connects with the electrical conductor cable 14*a*. Similarly, the solenoid valves 38, 65 and 78 are also connected by electrical conducting means 124, 125 and 126 to electrical energizing means at the wellhead and carried thereto by electrical conductor 123 and electrical conductor cable 14*a*. Similarly, the solenoid valve 103 is connected by electrical connecting means 127 to electrical conductor 123 which, in turn, is carried to the earth's surface and connected to electrical energizing means, not shown. In a similar manner, the magnetizing means 106 is also onnected by electrical connecting means 128 to electrical conductor 123 which is then carried to the wellhead through electrical conductor cable 14*a*. Solenoid valve 109 is also connected by electrical connecting means 109*a* to conductor 123.

It will be noted that the piston 17 carries thermocouple 140 adjacent a free end thereof. The purpose of this thermocouple is to measure a temperature increase caused by reaction of fluid oxidizing agent with petroliferous or organic substances with which a fluid oxidizing agent may come into contact when it is released as will be described further. It will be noted that the thermocouple 140 is connected by electrical connecting means 141 to electrical conductor 123 and is carried to the earth's surface through electrical conductor cable 14*a*. The electrical connection means 141 passes around the piston cylinder 17 in the space 20 and through the block 16 by way of opening 142.

Referring now to Fig. 3, it will be noted that the block 16 is provided with a piston cylinder 15 in which is arranged a piston 200. Piston 200 is provided with sealing means 201 and 202. Arranged within the inner cavity 203 of piston 200 is a reversible electrical motor 204 which is clamped within the chamber by bolts 205 to plate 206 which, in turn, is connected to the piston 200. The motor 204 is provided with a threaded shaft 207 which extends therethrough and which may be moved longitudinally through the motor 204. One end of the threaded shaft 207 is provided with a stop 208 to restrict movement to the right while the other end thereof carries a cutting member 209 which may be constructed such that the cutting member 209 will penetrate the filter cake 13 and the formation 12 upon energization of the motor 204. The motor 204 is connected to a source of electrical energy through electrical connection means 210 which is connected to an electrical lead 211 which is carried through an opening 212 in the block 16 and which connects to electrical connector 123, not shown, and is carried by cable 14*a*, as shown in Fig. 1, to a source of electrical energy at the earth's surface. The piston 200 is provided with a conduit or port 213 which is similar to conduit or port 100 and serves to allow discharge of fluid oxidizing agent from the conduit 102 which connects as has been described to the reservoir chamber 26.

Referring now to Fig. 4, numeral 300 designates an attachment which may be threadedly connected to the body member 14 by threads 301. The attachment 300 is provided with ports 302 which allows the well pressure to be exerted against a rubber bag or sleeve 303 in which is arranged a body of oil 304 enclosing pressure indicating tube 305, embodying a magnetostriction device, which is mounted on spider 306 and which suitably may be constructed of nickel or Permendur. The magnetostriction device 305 is connected by electrical leads 307 to the earth's surface by electrical conductor cable 14*a* to a suitable sound or pressure indicating device, not shown.

The device of Fig. 4 is shown in more detail in Figs. 5 and 6. The pressure indicating device 305 is contained in a brass cylinder 305*a* which is filled with a suitable oil. A magnetostriction tube 310 is provided with a toroidal winding 311 and is held in the cylinder 305 by a threaded bolt 312. At its upper end the toroidal winding is connected to electrical leads 307 which carries an impulse caused by pressure to the earth's surface and to a suitable display or pressure recording instrument, not shown. The magnetostriction tube 310 is provided with a suitable laminated core 313 which is shown in more detail in Fig. 6.

It will be noted that the magnetostriction device 305 is provided on its lower end with a bellows arrangement 314 against which the pressure may be transmitted to the oil in the tube 305 through an opening 315 in the lower end thereof.

The apparatus of our invention works in the following manner with respect to Figs. 1 and 2. It may be assumed that the body member 14 is lowered in the well bore 11 to a point adjacent the formation 12 traversed by the well bore and it is desired to determine whether or not the formation 12 contains petroliferous or organic substances and the like. When the body member 14 has reached a desired point in the well bore traversing formation 12, the solenoid valve 30 is opened allowing the pressure exerted on the reservoir 22 containing hydraulic oil to cause the hydraulic oil to flow into the piston cylinders 23 and 24. Since these piston cylinders are at a lower pressure than the pressure exerted on the hydraulic reservoir 22, the hydraulic fluid causes the pistons 42 and 43 to move, respectively, upwardly and downwardly which causes spring members 48 and 49 to be compressed which positions the body member 14 against a wall of the well bore 11 as shown in Figs. 1 and 2. The solenoid valve 30 is closed after the body member 14 has been moved against the wall of the well bore. Solenoid valve 70 is then opened by energization which causes hydraulic fluid to be exerted against the piston 72. The piston 72 has an area greater than the area of piston 73 and since

the total force exerted on piston 73 by its hydraulic system is greater than the total force exerted on piston 72 by its hydraulic system, the assembly, piston 72, piston rod 74 and piston 73 is forced to the left as shown in Fig. 2 and in turn the hydraulic fluid back of piston 73 is caused to flow through conduit 75 into piston cylinder 15 exerting a force on the piston 17 and causing it to move to the right and providing a seal by the deformable member 18 with the filter cake 13. Thereafter the solenoid valve 60 is energized which allows hydraulic fluid to move into the piston cylinder 15 through conduit 61 and pass through passageway 93 into the inner chamber 92 of piston member 17. This causes a force to be exerted against the piston 90 and moves it to the right and causes the cutting edge 91 to penetrate the filter cake 13. It is possible to move the piston 90 by means of the drilling mud pressure because the cross-sectional area of the right hand end of the piston 90 is greater than the area of the left hand end of piston 90. Hence pressure exerted in cylinder 92 forces piston 90 to the right.

After the filter cake has been cut by the cutting member 91, the solenoid valve 60 is closed and the solenoid valve 65 is opened allowing the hydraulic oil in the inner chamber 92 to be released through conduit 63 by opening solenoid valve 65 into reservoir 21 through conduit 66, manifold 40 and conduit 41. As a result of the pressure being released into reservoir 21 the formation pressure is exerted against the piston 90 which causes it to be moved to the left within the chamber 92. Thus the formation 12 is now exposed and any hydrocarbons or petroliferous substances and the like contained in the formation 12 may suitably be contacted with the fluid oxidizing agent as will be described.

Starting with solenoid valve 103 closed, solenoid valve 109 is opened and magnetizing device 106 is energized allowing a predetermined charge of the oxidizing agent in bag 26 to flow into bellows 104. Solenoid valve 109 is then closed. To inject the charge of oxidizing agent into the formation 12, solenoid valve 103 is opened and magnetizing means 106 is de-energized allowing bellows 104 to collapse forcing oxidzing agent out. This flow of oxidizing agent out of 104 to the formation is produced by the excess pressure of the well fluid over the formation pressure. Since drilling mud pressure is exerted against the deformable bag member 26 and since the formation pressure is less than the hydraulic pressure, the fluid oxidizing agent is caused to move through conduits 110 and 108 and thence through conduit 102 through port 100 and into the area 101 enclosed by the sealing means 18 and thence into contact with formation 12 which has been exposed by the cutting edge 91. As a result of contact of the oxidizing agent with the formation 12, a reaction ensues between the oxidizing agent and any petroliferous or organic substances in the formation 12. This reaction liberates heat which results in a temperature increase in the area adjacent the themocouple 140. This temperature increase is detected at the earth's surface and is a direct indication of the presence of petroliferous or organic substances in the formation. Thereafter when it is desired to move the device to a new location for testing formation, the pressure exerted against pistons 42 and 43 is released by opening solenoid valve 38 and releasing the pressure through manifold 40 and thence into exhaust reservoir 21. This frees the body member 14 and allows it to resume a normal position in the well. The piston member 17 may be retracted by opening solenoid valve 78 which releases hydraulic fluid from the piston chamber 27 releasing the piston 17 and allowing it to move to the left. When it is desired to test another formation or position in the well bore the sequence of operations may be repeated.

The apparatus of Fig. 3 functions in a similar manner to that of Fig. 1 and differs only in the way the filter cake is penetrated and the formation 12 is exposed for contact. The sequence of operations positioning the piston member 200 and the seal 18 into engagement with the filter cake 13 is similar to that described in Figs. 1 and 2 by virtue of the different areas of the pistons 72 and 73 in piston chamber 27, resulting in the piston 200 being moved to the right and a seal effected with the sealing member 18 and the filter cake 13. The motor 200 is then energized to cause the threaded rod 207 to rotate and to cause the cutting member 209 to penetrate the filter cake 13 and to cut into the formation 12. By reversing the motor 204, the threaded rod 207 and the cutting member 209 are pulled out of engagement with the formation 12, the stop member 208 moving into the recess 215 provided to accommodate it in the inner chamber 203. Thereafter the magneto means 104 and solenoid valve 103 as well as solenoid valve 109 are opened allowing the fluid oxidizing agent to be conducted through conduit 213 into contact with the formation 12 exposed as has been described and allowing any temperature increase caused by liberation of heat resulting from reaction of fluid oxidizing agent with any petroliferous or organic substances in the formation 12 to be registered on thermocouple 140.

The device of Figs. 4, 5, 6 and 7 functions similarly to that of Figs. 1 to 3 with the exception that a pressure or sound impulse is picked up with the magnetostriction device which has been described, the pressure or sound impulses generating in the well bore by reaction of the fluid oxidizing agent with the petroliferous or organic substances contained in the formation being transmitted through the bellows 314 to the magnetostriction device 305, the electrical impulses from which are then transmitted to the earth's surface through electrical connecting leads 307.

The oxidizing agent to be employed in the deformable bag member 26 may be any number of a large number of oxidizing agents known to react with hydrocarbons and petroliferous substances. As examples of oxidizing agents which may be employed may be mentioned chlorine, perchloric acid, liquid oxygen, air, hydrogen peroxide, chlorosulfonic acid, fluorosulfonic acid and the like. It is also possible to use the other perhalogen acids, such as perfluoric acid, per-iodic acid and perbromic acid. Other oxidizing agents which are suitable in the practice of the present invention are a mixture of nitrogen dioxide and aniline, potassium permanganate and chlorine, aqua regia, and the like. When chlorine is employed, it will be necessary to employ a catalyst therefor. For example, red phosphorus in a finely divided condition may be dispersed in the liquefied chlorine. Likewise, when the perhalogen acids are employed, it will be desirable to use a catalyst to cause the oxidation reaction to proceed spontaneously at a temperature such as that encountered in a well bore. For example, it is possible to employ perchloric acid having a strength in the range from 70% to 84% $HClO_4$ and temperatures down as low as 40° C. by using a catalyst such as ceric ammonium nitrate. Other catalysts may be employed such as, for example, ammonium vanadate and osmium tetraoxide, and the like.

Since the oxidizing agents employed in the apparatus of the present invention are corrosive to ordinary materials of construction, it will be necessary to construct the deformable bag member 26 of a deformable material which resists attack of the more powerful of the several oxidizing agents which may be employed. Examples of suitable materials of construction for the deformable bag member 26 are: Teflon (polytetrafluoroethylene) and Kel-F (polytrifluorochloroethylene), and the like.

The deformable reservoir 22 may be constructed suitably of synthetic rubber which resists attack by hydraulic fluid, such as oil and the like.

The nature and objects of the present invention having been completely described and illustrated, what we wish to claim as new and useful and to secure by Letters Patent is:

1. Well logging apparatus for detecting the presence

of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting member adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a chamber arranged within said body member adapted to contain a fluid oxidizing agent; a conduit connecting said chamber with said piston cylinder adjacent a free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; and detection means carried by the body member to detect a reaction effect of said oxidizing agent with said petroliferous substance.

2. Well logging apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting member adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a chamber arranged within said body member adapted to contain a fluid oxidizing agent; a conduit connecting said chamber to said piston cylinder adjacent a free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; detection means carried by the body member to detect a reaction effect of said oxidizing agent with said petroliferous substance; and means for positioning said body member against a wall of the well bore.

3. Well logging apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting member adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a chamber arranged within said body member adapted to contain a fluid oxidizing agent; a conduit connecting said chamber to said piston cylinder adjacent a free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; detection means adjacent a free end of said piston to detect a reaction effect of said oxidizing agent with said petroliferous substance; means for positioning said body member against a wall of the well bore; and suspending means for lowering and raising said body member attached to an upper end of said body member.

4. Well logging apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting member adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a chamber adapted to contain a fluid oxidizing agent and arranged within said body member in a cavity thereof; a conduit connecting said chamber to said piston cylinder adjacent a free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; and a thermocouple carried by said body member adjacent the free end of said piston to detect a temperature rise caused by reaction of said oxidizing agent with said petroliferous substance.

5. Well logging apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting member adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a chamber adapted to contain a fluid oxidizing agent and arranged within said body member in a cavity thereof; a conduit connecting said chamber to said piston cylinder adjacent a free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; a thermocouple carried by body member adjacent the free end of said piston to detect a temperature rise caused by reaction of said oxidizing agent with said petroliferous substance; and means for positioning said body member against a wall of the well bore.

6. Well logging apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting member adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a deformable bag member adapted to contain a fluid oxidizing agent and arranged within said body member in a cavity thereof exposed to well pressure; a conduit connecting said bag member to said piston cylinder adjacent a free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; a thermocouple carried by the body member adjacent the free end of said piston to detect a temperature rise caused by reaction of said oxidizing agent with said petroliferous substance; means for positioning said body member against a wall of the well bore; and suspending means for lowering and raising said body member attached to an upper end of said body member.

7. Well logging apparatus for detecting the presence of a petroliferous substance in a well bore penetrating an earth formation which comprises, in combination, a body member adapted to be lowered and raised in a well bore; a piston arranged in a cylinder defined by said body member provided with a cutting edge adapted to cut a filter cake on a wall of a well bore and to contact an earth formation; a deformable annular member embracing the free end of said piston adapted to form a seal isolating said piston cylinder from the well bore; a deformable bag member adapted to contain a fluid oxidizing agent and arranged within said body member in a cavity thereof exposed to well pressure; a conduit connecting said bag member to said piston cylinder adjacent the free end of said piston; actuating means for moving said piston into and out of contact with said formation to open and close said conduit and to release oxidizing agent into contact with said formation; and a thermocouple carried by the piston adjacent the free end thereof to detect a temperature rise caused by reaction of said oxidizing agent with said petroliferous substance.

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