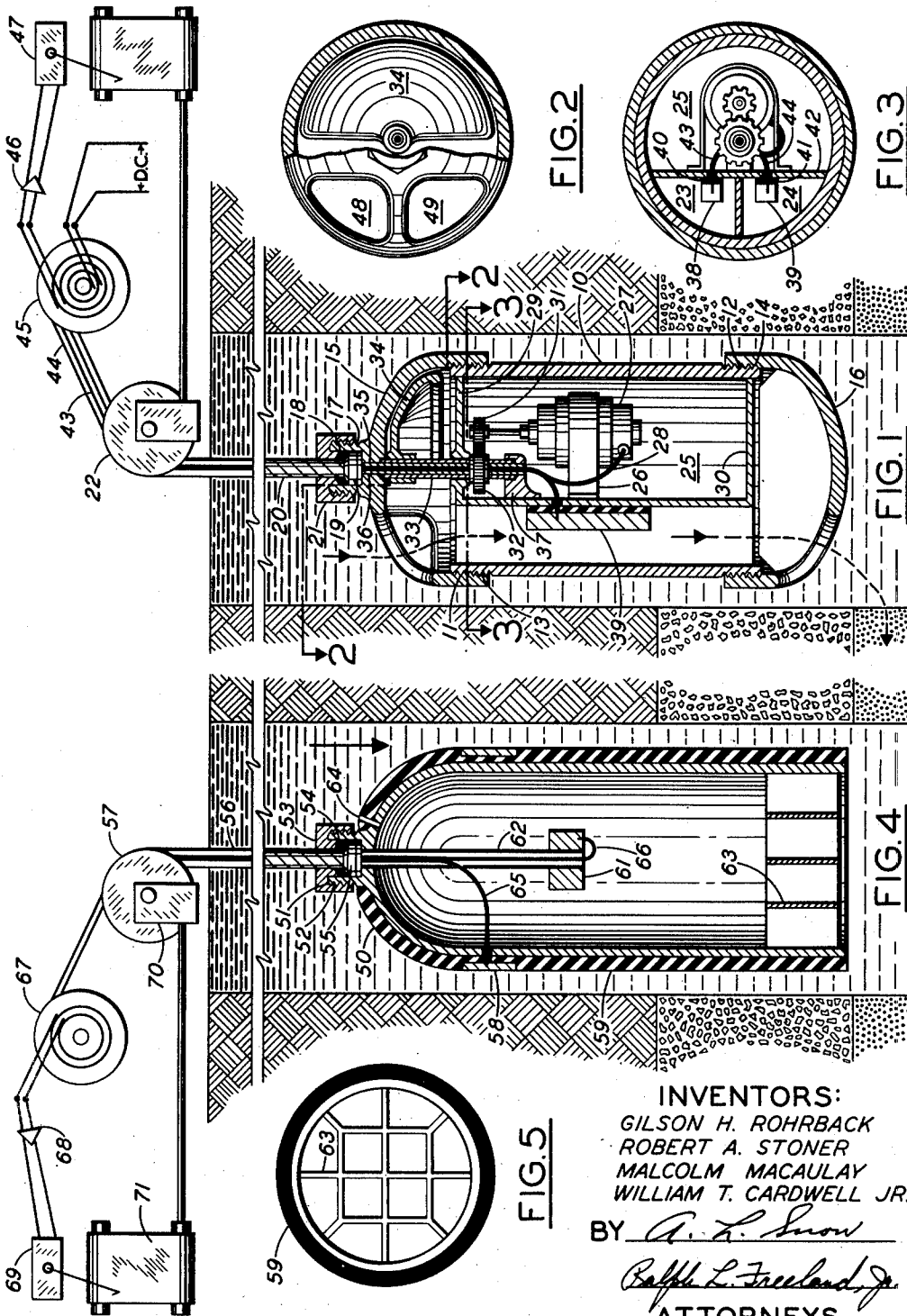


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FLUID MOVEMENT IN WELL BORES
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METHOD AND APPARATUS FOR DETECTING
FLUID MOVEMENT IN WELL BORES

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The present invention relates to method and apparatus for detecting the movement of fluids in a well bore, and more particularly relates to determination of the direction of fluid flow in a well bore, whether said flow is due to the entrance of contaminating fluids into the well or due to the loss of well fluid to an earth formation through which the well bore passes.

Heretofore, in the art of detecting the influx or ingress of contaminating fluids into a well bore, such as the entrance of water into a producing oil well at an unknown level, it has been common practice to provide a pair of electrodes in the well bore with at least one electrode at the level to be investigated. The electrical resistance between that pair of electrodes is then measured by the application of an external current source of either A. C. or D. C. potential. Changes in the electrical resistance are then correlated with the depth of the electrodes to locate the elevation at which water is entering the well. In some instances it has been proposed that the fluid in the well be entirely replaced by a test solution prior to making these resistance measurements. Another method proposed in the prior art is that of introducing an electrolyte solution into the well to create a voltaic cell between a pair of electrodes of dissimilar materials to generate a potential. Movement of well fluid may then displace the electrolyte to vary the potential measured between the electrodes.

While the foregoing apparatus and methods have been fairly satisfactory in detecting water ingress into a producing oil well, each of these systems requires either the application of an external source of current or the introduction of modifying fluids into the well bore. Accordingly each requires the use of quite complex equipment in the well bore. Additionally, apparatus constructed in accordance with the prior art has not been directly applicable to the problem of detecting the level at which drilling fluid is lost during the drilling of oil wells by conventional rotary methods. One satisfactory type of apparatus which has been useful in locating the position in a well bore where fluid is being lost is disclosed in the copending application of Marshall B. Standing, Harry S. Yaplee and Malcolm Macaulay, Serial No. 105,354, filed July 18, 1949, now Patent No. 2,581,979. However, this apparatus likewise requires means for introducing an electrolyte fluid capable of changing the resistance characteristics of the drilling fluid.

It is an object of the present invention to provide a method of detecting fluid movement in a

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well bore without the necessity of introducing electrolyte solutions to change the electrical characteristics of the well fluid.

It is another object of the invention to provide a method of detecting fluid movement in a well bore wherein it is unnecessary to externally energize a set of test electrodes.

It is a further object of this invention to provide a method and apparatus which is capable of detecting movement of fluid either into or out of a bore hole.

Still a further object of the invention is to provide means for detecting the direction of movement of well fluids to determine the elevation in a well bore where fluid within the borehole is either being contaminated by the influx of water from a formation or the well fluid is being lost to such a formation.

Still another object of the invention is to provide a simplified method and apparatus for determining the fluid flow at a pre-determined level in a well bore utilizing a minimum number of electrical cable leads between the testing unit and the earth's surface.

Briefly, the present invention contemplates a method of detecting relative movement of fluid in a well bore by measuring the potential between a pair of electrodes positioned in the well bore and correlating the direction of movement with the location of the electrode pair in the well bore.

Further objects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawing which forms an integral part of the specification.

In the drawing:

Fig. 1 is a schematic representation of one form of apparatus useful in performing the method of the present invention;

Fig. 2 is a cross-sectional view of a portion of the down-hole apparatus shown in Fig. 1, taken in the direction of arrows 2—2;

Fig. 3 is a cross-sectional view of the apparatus of Fig. 1 taken in the direction of arrows 3—3;

Fig. 4 illustrates another form of apparatus which may be used in carrying out the method of the present invention; and

Fig. 5 is a bottom-plan view of the down-hole test instrument shown in Fig. 4.

Referring now to the drawing, and in particular to Fig. 1, an elongated housing or casing means, designated generally as 10, which may be an elongated cylinder or pipe, is preferably provided with threaded ends 11 and 12 which are

adapted to engage threaded portions 13 and 14 respectively on upper and lower end closure members 15 and 16.

For the purpose of positioning housing 10 at any desired level in the well bore, end member 15 may be provided with a threaded flange portion 17 which has a bore 18 therein adapted to receive an expanded end 19 of a conventional well-logging cable 20. Cap nut 21 is adapted to engage the threads on flange 17 to secure expanded portion 19 of cable 20 to end closure 15.

As shown, the upper end of cable 20 desirably passes over a pulley member 22 at the earth's surface. Pulley 22 may be driven by any conventional means such as an electrical motor (not shown), and is preferably inter-connected to an elevation, or level, recording means to be described hereinafter.

In the embodiment shown in Fig. 1, casing means 10 is preferably divided into three compartments designated generally as electrode compartments 23 and 24 and shutter-drive compartment 25. Since shutter-drive compartment 25 provides a mounting means 26 for an electric motor 27, a pair of end wall members 29 and 30 are arranged to seal off compartment 25 from the fluid present in the remainder of housing 10 during the operation of the equipment. As shown, motor 27 may be energized from the surface through cable 20 and lines 28. It will be noted that the shaft of motor 27 is provided with a spur gear 31 which is adapted to drivably engage gear 32. Gear 32 is mounted upon shaft 33 which has a semi-circular shutter member 34 positioned at the opposite end which is adapted to rotate in the hemispherical space defined by end member 15. Shaft 33 is rotatably mounted upon a concentric, hollow, tubular shaft 35 which interconnects bore 18 of flange 17 with compartment 25 so that the electrical leads 28 of cable 20 may be connected to motor 27. One end of shaft 35 is supported in bore 36 in end member 15, while the opposite end is supported by a mounting bracket 37 suitably positioned in chamber 25.

Motor means 27 is shown to be connected through leads 28, cable 20 and slip ring means 45 to a source of D. C. potential. By this arrangement, motor 27 is adapted to continuously drive shutter means 34 in the same direction. However, it will be apparent that switch means (not shown) may be provided so that motor means 27 may be selectively reversed or stopped. In this way, the shutter means may be positioned in any desired location. Another means for accomplishing this positioning control of the shutter would be to employ a selsyn-type motor in place of motor 27 for the driving of shutter means 34.

As best seen in Fig. 3, a pair of metal electrodes 38 and 39 which are preferably, but not necessarily, formed of the same material, are respectively positioned in compartments 23 and 24. These electrodes in turn are insulated from housing 10 and transverse wall 42 by rubber, Bakelite or similar mounting strips 40 and 41. Electrodes 38 and 39 are connected to surface indicating means through cable leads 43 and 44 which pass through wall 42 into compartment 25 and then through hollow shaft 35 to cable 20. Cable leads 43 and 44 are then connected through slip-ring assembly 45 to potential, or current, responsive means, such as amplifier 46 and recording millivolt meter 47.

It will be noted that the upper end closure member 15 is preferably provided with a pair of openings designated generally as 48 and 49 which

are positioned to directly overlie compartments 23 and 24 in housing 10. Likewise a similar pair of openings are provided in the lower end closure member 16. In this way, fluid entering through passageway 48 may pass downwardly through chamber 23 and out of housing 10 through the corresponding opening in lower end member 16. Similarly, fluid may enter through opening 49, pass through chamber 24 and thus through the test instrument.

In the operation of the embodiment shown in Figs. 1 to 3, it will be apparent that housing 10 may be lowered by means of cable 20 and pulley 22 into a well bore in which it is desired to detect the movement of fluid. As contemplated by the present invention, the testing of the direction of fluid movement is normally conducted with the well "shut in," that is, when fluid is neither being added nor withdrawn from the well, and only the normal hydrostatic pressure, or head, exists at the top of the well. However, under these conditions there may be a displacement of normal well fluid due to the pressure existing in a formation traversed by the bore hole being either higher or lower than the pressure in the well opposite that formation. When the condition to be remedied is that of lost circulation, the well fluid will move downwardly from the top of the well to the lower pressure formation to which fluid is being lost. At the same time, there will be virtually no movement of fluid in the bore below that level.

Conversely, when water is entering a producing well or a bore hole either through a break in the casing or from a higher pressure formation in an uncased portion of the well bore, the water so entering, being of greater specific gravity than the oil, may tend to migrate downwardly through the oil from the level at which the fluid enters. Accordingly, in either case it is desirable to locate the level where relative movement of well fluids originates under such static or "shut in" well conditions.

For the purpose of detecting this relative movement of well fluid, we have found that a pair of electrodes, such as electrodes 38 and 39, may be selectively subjected to the relative movement of the well fluids and that movement may be detected thereby when only one of the electrodes is placed in the moving fluid stream, while the other electrode is merely in conductive relation to the same fluid stream, but not subjected to the movement of fluid particles over the electrode. Accordingly, in the embodiment shown in Fig. 1, means are provided for selectively permitting well fluid to pass through chambers 23 and 24 while maintaining both chambers in communication with the well fluid so that electrodes 38 and 39 are continuously in conductive relationship to each other as well as to the well fluid. This is accomplished by energizing motor 27 which in turn rotates the shutter means 34 to successively open and close passageways, or ports, 48 and 49. With shutter 34 in the position shown in Fig. 2, it will be apparent that fluid may flow in the direction of the dotted lines in Fig. 1. Under this condition there will be substantially an equal flow of fluid through chambers 23 and 24, and consequently, there will be substantially no potential generated between the electrodes 38 and 39. However, when shutter means 34 is rotated counter-clockwise from the position shown in Fig. 2, so that port 48 will be substantially closed, then, only electrode 39 will be traversed by fluid passing through the housing 10. When this oc-

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curs, we have found that the potential of electrode 39 changes with respect to electrode 38, and accordingly a potential difference is created between the two electrodes. This potential is found to exist even when both electrodes are of substantially the same material. While we are not presently sure of the exact reason for the generation of this potential, it is believed that this electrode potential is created in the following manner. When an electrode is placed in a fluid which is at least partially conductive, i. e. containing some free ions, the electrode develops a potential dependent upon the concentration of ion species involving or affecting that electrode's reaction with the surrounding liquid. Especially is this electrode potential dependent upon the concentration of that ion species very close to the electrode surface. Accordingly, even a very low velocity flow over the electrode surface results in a change in this ion concentration and produces a change in electrode potential. The magnitude and direction of this potential change is dependent both on the nature of the liquid and the electrode metal. With such metals as zinc, brass, copper and silver as electrodes, this potential change is in the order of millivolts for a liquid velocity of a few feet per minute.

It will be apparent that when the shutter means 34 is rotated to such a position that both ports 48 and 49 are closed, there will again be substantially zero potential generated between the electrode pair. However, upon continued turning of shutter means 34, port 48 is opened so that fluid may flow through compartment 23 and hence over electrode 38. In this way, electrode 38 changes potential compared to electrode 39 and accordingly reverses the direction of the potential transmitted to indicating means 47.

Referring now to the embodiment illustrated in Figs. 4 and 5, it will be noted that an open-bottomed, bell-shaped housing 50 is provided with a flange 51 adjacent the closed end. Flange 51 in turn is provided with exterior threads 52 which are adapted to engage with a cap nut 53. Preferably flange 51 has a central bore 54 into which expanded end 55 of cable 56 is adapted to fit and thereby provide means for lowering and raising the housing 50 within a well bore. Cable 56 is supported preferably by pulley 57 which may be rotated by any conventional prime mover.

Housing 50 may be formed by deep drawing a metal blank to form the bell-shaped configuration. If housing 50 is formed in this manner, it is necessary to insulate band, or ring type electrode 58, from the housing by means of rubber sleeve 59 which may completely surround the exterior of housing 50. For the purpose of preventing ring electrode 58 from contacting the walls of the well bore or the well casing, sleeve 59 is preferably provided with a recessed portion into which electrode 58 fits.

In order to place the other electrode of the necessary pair in electrical contact with the well fluid, but not subject to contact with the flowing liquid, electrode 61 is mounted upon an elongated insulating bushing 62 inside housing 50. To further insure that electrode 61 is in a quiescent location, housing 50 is preferably provided with a side wall which is at least as long as the diameter of the housing 50. As best shown by Fig. 5, the lower or open end of housing 50 may be further protected from the possibility of eddy currents due to liquid flow over housing 50 from sweeping the interior of the housing by an eggcrate, or honey-comb, straightener 63. Since the

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housing 50 is adapted to be lowered in the well bore with the closed end of the housing in an upward position, it is essential that well fluid be permitted to enter the interior of housing 50 so that the fluid may make electrical contact with electrode 61. For this purpose, a small bleed hole, such as bore 64, is provided adjacent the upper or closed end of housing 50. However, the diameter of bore 64 is so proportioned that there will be no appreciable fluid flow through housing 50. To insure this, electrode 61 may be positioned, as shown in Fig. 4, near the center of cylinder 50, away from bleed hole 64. Alternatively, the housing may be filled with a conducting solution prior to its introduction into the well bore. Likewise, it is possible to cover the lower or open end of housing 50 with a permeable membrane, such as fritted glass or porous porcelain, and then fill the housing with an electrically conducting fluid which may or may not be of the same composition as the well fluid. As stated above, electrodes 58 and 61 may be constructed either of similar or different materials.

It will be apparent that electrodes 58 and 61 are connected through leads 65 and 66, respectively, and cable 56 to a slip ring arrangement 67 in the cable winding drum. In this manner the electrodes may be connected to an amplifying means 68 and a recording millivolt meter 69. A chart drive means for recording the output of millivolt meter 69 is provided by a reduction gearing 70 connected to the drive shaft of pulley 57. By this arrangement, a chart 71 is positioned in accordance with the position of the housing 50 within the well bore, so that changes in electrical potential between electrodes 58 and 61 at that level may be recorded and correlated with depth.

In operation of the embodiment shown in Figs. 4 and 5, it will be apparent that electrode 61 is in electrically conducting relationship to the well fluid, but in a quiescent zone. At the same time, the movement of fluid over electrode 58 creates a potential difference between the two electrodes wholly dependent upon the relative velocity of fluid passing over electrode 58, as explained hereinbefore. In this embodiment, when the housing 50 is positioned at a predetermined level in the well, any movement of well fluids over electrode 58 will produce a potential difference between the electrodes which may be indicated by meter means 69 and recorded on chart 71. While such movement of fluid over electrode 58 will not indicate the direction in which fluid is moving, this may be determined by moving the housing either upwardly or downwardly relative to the original pre-determined position and noting whether the potential difference increases or decreases when such movement of the housing is made. If the potential difference increases, it will be apparent that the direction of flow of the well fluid is opposite to the movement of the housing. On the other hand, if the potential difference decreases, the movement of the housing is in the same direction as the movement of the fluid due to the reduction in relative velocity between electrode 58 and the well fluid.

One method of operating the apparatus shown in Figs. 4 and 5 is provided by driving pulley 57 at a constant, predetermined speed to either lower or raise housing 50 through the zone of the well bore which is to be investigated. At this constant velocity, changes in direction of potential will be noted during a traverse of the well bore by housing 50. For example, in locating a zone of lost circulation, the fluid level in the well

will progressively move downwardly to that zone. Potential changes will accordingly occur at the level where the movement of fluid stops, since there will be an abrupt change in relative velocity at that point.

On the other hand, the housing 50 may be lowered through the well above a zone of lost circulation at a velocity so adjusted that there will be a minimum potential difference generated between electrodes 58 and 61. However, after the rate of lowering is adjusted so that there is no relative movement between fluid flowing downwardly and the housing, the potential will rise abruptly when housing 50 passes into a zone where there is no movement of well fluid. At that point, the depth of the formation to which fluid is being lost may be identified. Additionally, it will be apparent that by noting the rate of lowering where the potential approaches a minimum, this method of operation permits the exact determination of the velocity of the well fluid in the bore hole.

From the foregoing, it will be apparent that, broadly, there have been established different relative velocities or movements of the well fluid with respect to one electrode than to the other electrode, and the potential differences thus produced are indications of the direction and magnitude of the relative fluid velocities.

While a theory of operation of the present invention has been set forth hereinabove, it is not our intention to limit the invention to the correctness of that theory, but rather, the best methods and apparatus for carrying out the objects of the invention, irrespective of the merits of that theory, have been described in full in accordance with the patent statutes.

From the foregoing description of the two distinct embodiments of apparatus which may be employed in the practice of the method of the present invention, it will be apparent to those skilled in the art that numerous modifications and changes may be made in such apparatus without departing from the teachings of the invention. Accordingly, all such modifications and changes as fall within the scope of the appended claims are thereby intended to be included.

We claim:

1. A method of detecting the movement of fluids in a well bore comprising the steps of positioning a pair of electrodes in said well and in electrical contact with said fluids, establishing a different relative movement of said fluid with respect to one electrode than to the other electrode, and measuring the electrical potential generated between said pair of electrodes due to said relative movement as an indication of the direction of flow of said fluids in said well.

2. A method of determining the direction of fluid flow in a well bore comprising the steps of locating at least a pair of electrodes in said well bore at a zone where the direction of flow is to be determined, said electrodes being in electrically conducting relationship to the fluid in said bore, establishing a different relative movement of one of said electrodes than the other of said electrodes with respect to said fluid while said fluid and one of said electrodes are moving substantially vertically with respect to each other, and measuring the change in electrical potential between said pair of electrodes generated by said relative movement whereby the direction of flow of said fluids in said well may be determined.

3. A method of detecting the movement of electrically conductive fluid in a well bore comprising

the steps of positioning both of a pair of electrodes in conductive relation to said fluid, causing the fluid in contact with one of said electrodes to remain quiescent while permitting movement of said fluid in contact with the other electrode, and measuring the potential difference between said electrodes.

4. A method of detecting the movement of fluids in a well bore comprising the steps of positioning a pair of electrodes constructed of substantially the same material at a predetermined zone in said well and in electrical contact with said fluids, successively exposing first one and then both electrodes to well fluid moving relatively thereto, and determining the potential difference between said electrodes when only said one electrode is exposed to said flowing fluid and when both of said electrodes are so exposed to determine the direction of flow at said predetermined zone.

5. Apparatus for locating the level in a bore hole where fluid is entering or leaving said bore hole comprising an elongated housing adapted to be positioned in said bore hole, longitudinally extending wall means within said housing defining at least a pair of chambers, end closures for said housing having openings therein communicating with said chambers, shutter means for selectively opening and closing said end closures to prevent flow of fluid through one of said chambers and permit fluid flow through another of said chambers, electrode means positioned in each of said chambers, means connecting said electrodes to a potential responsive means at the surface whereby the direction of fluid flow with respect to said electrodes may be measured.

6. Apparatus for locating the level in a well bore where well fluid is being lost to an earth formation comprising casing means constructed and arranged to be positioned in said well bore, cable means for lowering and raising said casing, vertically extending passageway means within said casing, an electrode positioned within each of said passageway means, said electrodes being connected through said cable means to potential indicating means at the earth's surface, and means for selectively opening one and closing another of said passageways to permit fluid flowing downwardly in said well bore alternately to traverse said passageways and be retained therein and contact said electrodes whereby the movement of fluid flow may be detected as a potential difference between said electrodes.

7. An apparatus for detecting the movement of electrically conductive fluid in a well bore, comprising a pair of electrodes adapted to be lowered into said bore, cable means for supporting said electrodes and having a separate conductor for each electrode, one of said electrodes being exposed to well fluid moving relatively thereto, means for selectively isolating a quantity of fluid in electrical contact with the other electrode from motion relative thereto and from fluid flowing in said bore, and potential responsive means connected to said conductors for measuring potential differences between said electrodes.

8. Apparatus for locating that elevation in a well bore where well fluid is entering or leaving said bore comprising a casing having a closed end and an open end adapted to be positioned in a well bore, cable means for raising and lowering said casing in a well bore, a first electrode mounted within said casing adjacent the closed end thereof to prevent fluid flowing over said casing from flowing over said electrode, means for ad-

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mitting fluid to said casing through said open end to place said first electrode in electrical contact with said well fluid, a second electrode mounted on said casing exteriorly thereof and electrically insulated therefrom, means for lowering said cable and said casing at a predetermined rate, and indicating means connected to said electrodes whereby the potential between said electrodes may be measured when said fluid and said casing are moving relative to each other.

9. A method of detecting the movement of electrically conductive fluid in a well bore, comprising the steps of positioning both of a pair of electrodes in conductive relation to said fluid, establishing a different relative movement of said fluid with respect to one electrode than to the other

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electrode, and measuring the resultant potential difference between said electrodes.

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