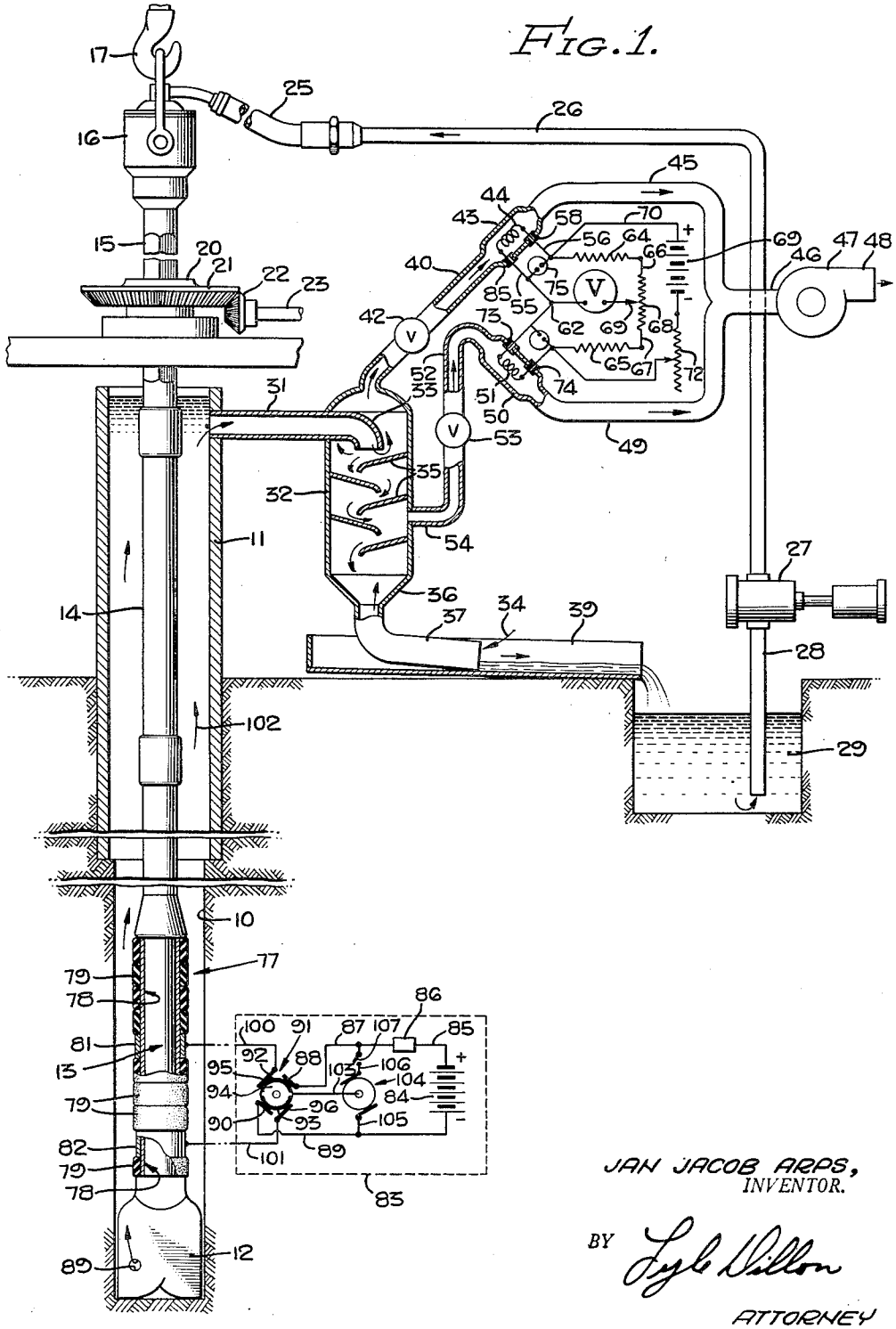
Feb. 1, 1955 J. J. ARPS 2,700,897

CONTINUOUS ELECTRICAL LOGGING

Filed Sept. 20, 1950 2 Sheets-Sheet 1

FIG. 1.



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CONTINUOUS ELECTRICAL LOGGING

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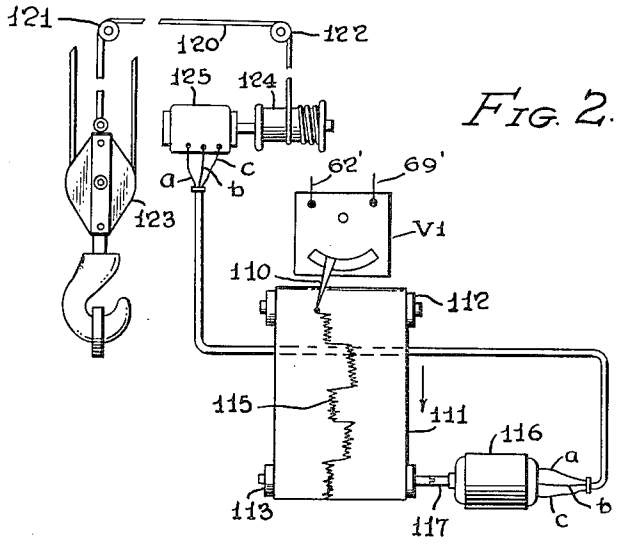


FIG. 2.

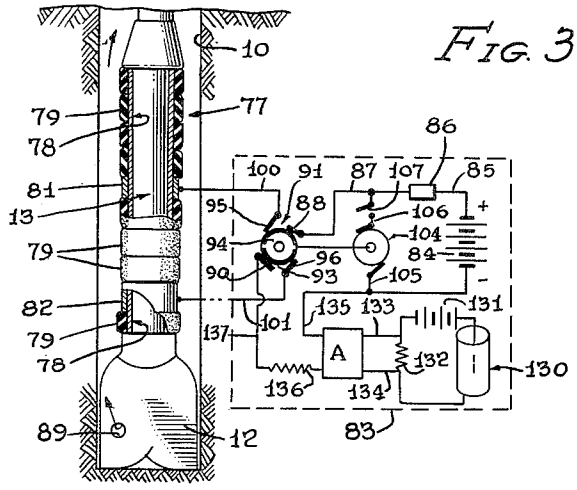


FIG. 3.

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CONTINUOUS ELECTRICAL LOGGING

Jan J. Arps, Tulsa, Okla.

Application September 20, 1950, Serial No. 185,849

8 Claims. (Cl. 73—152)

This invention relates in general to electrical exploration of the geological strata traversed by earth boreholes and more particularly to methods and apparatus for the simultaneous electrical logging and drilling of well boreholes.

In the conventional methods of electrical logging of earth boreholes as heretofore usually practiced, a source of electric current has been located at the surface of the earth outside of the borehole and a current therefrom has been applied, through an insulated cable lowered into the borehole, to a portion of the penetrated geological strata to be explored, and the results of such exploration transmitted back up the borehole to the earth surface through the same or separate insulated conductors in the cable. The provision of insulated conductors in a drilling well together with the drill pipe in such manner that drilling and electrical logging operations can be carried on simultaneously, has been found to be of doubtful practicability. Therefore, the usual practice has been to interrupt the drilling operation at intervals to permit the removal of the drill pipe from the borehole and the running of the logging apparatus suspended from a conductor cable in the borehole in the absence of the drill pipe.

This has the disadvantage that the precise control of the depth of drilling with respect to certain formations is difficult, with the result that in many cases the desired shale body or the possible productive formation may have been drilled through or passed up, possibly necessitating subsequent time consuming and expensive corrective measures before the next intended steps in the process of continued drilling or completion of the well can be undertaken.

Another disadvantage in the before described usual method of electrical logging resides in the well known fact that the liquid from the drilling fluid invades the penetrated formations surrounding the borehole, thereby changing the electrical characteristics of such formations for a substantial distance laterally from the borehole axis. Such invasion is progressive with time and if permitted to continue for an appreciable length of time, results in sufficient contamination of the formations to cause possible confusion in the correct interpretation of the electrical characteristics of the formations thus measured.

The before described difficulties are largely overcome by the present invention which does not require insulated conductors in the borehole at any time but provides for the transfer of the results of the electrical logging operations or other similar operations within the borehole to the earth surface without employing the usual interconnecting insulated conductors, and this can be accomplished while the drill pipe is in the well borehole and during drilling operations. The system of the present invention furthermore permits the electrical logging apparatus to be embodied in or contained within the drilling tools, and the process of electrical logging to be carried on simultaneously with the drilling of the borehole whereby the electrical logging measurements can be made of the freshly penetrated formations before excessive invasion of drilling fluid into the formation takes place.

Another advantage of the present invention resides in the substantially simultaneous drilling and logging of a formation which it provides, thereby permitting a continuous and more accurate determination of the depth of the borehole relative to the formations penetrated thereby, than is possible by the intermittent, alternate

drilling and logging operations heretofore usually employed. In other words, by employment of the method and apparatus of the present invention an electrical log may be made and observed while drilling operations are in progress and the drilling operations modified as desired or stopped immediately at the time the electrical log being recorded indicates the desirability of such modification or stoppage.

Accordingly, an object of this invention is to provide a method and apparatus for electrical logging of geological strata traversed by a borehole in which the necessity of using an insulated conductor extending into the borehole to the logging apparatus within the borehole is avoided.

Another object of this invention is to provide an electrical logging system which permits the conducting of electrical logging operations and drilling operations simultaneously.

Another object of this invention is to provide a system for transmitting information from a point within a well borehole to a point outside of the borehole during drilling and while the drilling tools are present in the borehole.

The objects of this invention are attained, in brief, by utilizing the circulating drilling fluid to carry hydrogen tracer gas to the top of the borehole. This hydrogen tracer gas is generated by electrolysis of the liquid portion of the drilling fluid at the exploring electrode, by the action of and in proportion to the exploring current which flows between such electrode and the adjacent surrounding borehole formations. Upon arrival of the thus generated hydrogen at the top of the borehole as conveyed in the circulating drilling fluid, it is separated and measured by means of a suitable hydrogen gas detector. Measurements thus obtained provide indirect continuous measurements of the exploring electrode current and therefore are indicative of the conductivity or resistivity of the formations opposite the electrode within the borehole.

Other objects, advantages and features of novelty will be evident hereinafter in the more detailed description of the invention.

In the drawings which illustrate a preferred embodiment and mode of operation of the invention and in which like reference characters designate the same or similar parts throughout the several views:

Figure 1 illustrates the general arrangement of the apparatus of the invention as applied to a drilling well borehole.

Figure 2 illustrates alternative apparatus to be employed in connection with the apparatus of Figure 1.

Figure 3 illustrates a modified form of the apparatus of Figure 1.

The apparatus is as follows:

Referring primarily to Figure 1, a longitudinal section of a typical well borehole is shown, by way of example, having a lower uncased portion **10** and an upper portion in which a surface string of casing **11** has been set. Within the borehole is shown conventional rotary drilling apparatus comprising a drill bit **12**, a drill collar **13** and a drill stem or drill pipe **14** connected at its upper end through a square kelly **15** to a swivel **16**, which is in turn supported by a hook **17** suspended from a suitable drilling line traveling block **123** and from well derrick apparatus thereabove (not shown). The square kelly **15** passes through conventional gripping means in a rotary table **20** which is adapted to be rotated by means of the usual beveled gear and pinion drive illustrated at **21** and **22** respectively. The pinion **22** is arranged to be driven, in accordance with usual practice, through shaft **23** by a suitable prime mover.

The circulation passage through the drill stem and swivel **16** is connected through flexible hose coupling **25** and piping **26** to a suitable drilling fluid circulating pump **27**, the suction of which is taken, through suction inlet pipe **28**, from a mud settling pit **29**. The upper end of the surface casing **11** which provides a return path for circulating drilling fluid from the borehole, is provided with a lateral outlet pipe **31** which extends into the upper end portion of a closed separator chamber **32**. The said

lateral pipe 31 is provided inside of the separator chamber with a downwardly curved elbow 33. Below the elbow 33 and within the separating chamber 32 are provided a plurality of oppositely positioned, inwardly sloping baffles 35. The lower end of the separating chamber 32 is provided with a conical bottom 36 which leads into an outlet pipe 37 which in turn extends downwardly and laterally into a trough 39 leading to the top of the settling pit 29.

The separator chamber 32 is connected to suitable hydrogen detecting and measuring apparatus as hereinafter described. Chamber 32 is connected at the top end by way of pipe 40 and through a valve 42 to a chamber 43, containing an electrically conductive heater filament 44, and thence through connecting piping 45 to the inlet 46 of a suitable exhaust fan or blower 47 having a discharge or outlet connection 48. The beforementioned inlet 46 of the blower 47 is also connected through another branch pipe connection 49 to a chamber 50, similar to chamber 43, containing an electrically conducting heater filament 51 similar to filament 44, and thence the connection extends through connection 52 and valve 53 into a lower portion of the separator chamber 32 at 54.

The electrically conducting heater filament 44 is supported within chamber 43 by means of conductors 55 and 56 which pass through suitable sealed lead-in insulators 57 and 58 in the walls thereof, and the electrically conducting heating filament 51 is similarly supported within chamber 50 by means of conductors 60 and 61 which pass through sealed lead-in insulators 73 and 74. Conductors 55 and 61 leading from the filaments 44 and 51, respectively, make common connection at 62, and conductors 56 and 69 leading from the opposite ends of the filaments make connection with substantially identical resistors 64 and 65 which in turn are connected through conductors 66 and 67, respectively, to opposite ends of resistor 68. A conventional voltmeter or galvanometer V is connected between connection 62 and a contactor 69 which makes sliding contact with the resistor 68. The circuit thus formed is, in effect, that of a conventional Wheatstone bridge arrangement. Current is supplied to the bridge circuit, from a suitable battery 69, through conductors 70, 71 and a variable resistor 72. Voltmeters 75 and 76 may be connected across the filaments 44 and 51, respectively. Filaments 44 and 51 are preferably made of a material which has a high temperature coefficient so that small changes in temperature will cause comparatively large changes in the electrical resistance thereof. Suitable materials for these filaments are preferably those not subject to oxidation and may be, for example, a noble metal such as platinum, gold, nickel or alloys thereof.

Referring now to the lower end of the drill stem, the drill collar 13 is provided with an outside insulating covering 77 which may be composed of an inner insulating sleeve or tubing member 78 fitting snugly over the full length of the drill collar from the top of the drill bit 12 to the upper end of the drill collar. A pair of spaced-apart electrode rings 81 and 82 are carried by the insulating sleeve 78 and are insulated from the drill collar 13 thereby, said electrodes being normally exposed to contact with surrounding drilling fluid. These electrode rings may be made of platinum or a similar noble metal. The insulating sleeve 78 is covered above, below and between the electrode rings 81 and 82 by a plurality of protective insulating ring members placed end-to-end as shown at 79. Such rings are preferably made of rubber or the like material and are of such thickness as to protect the recessed electrodes 81 and 82 and the insulating sleeve 79 from abrasion by the borehole walls. Conventional casing protector rings may be here employed. The drill collar 13 is provided on its interior with a suitable fluid tight container or cavity schematically designated at 83 for containing a battery 84 and switching apparatus as hereinafter described.

The battery 84 has its positive terminal connected through conductor 85, fluid circulation pressure operated switch 86 and conductor 87 with a brush 88. The negative terminal of the battery 84 is connected through conductor 89 with a brush 90. Brushes 88 and 90 are positioned to make electrical contact at diametrally opposite points with a reversing commutator 91 having a pair of opposite, conductive commutator segments 92 and 93 insulated from one another and each of which extend around slightly less than half the circumference of the insulating commutator disc 94. A pair of diametrally opposite brushes 95 and 96 are positioned to make contact with the commutator 91 at right angles to the diametral line of contact of brushes 88 and 90, said brushes 95 and 96 being connected through conductor 100 and 101 respectively with the beforementioned ring electrodes 81 and 82.

The commutator 91 is coupled for rotation, through a shaft 103 to a motor 104. The motor 104 is adapted to be supplied with current from battery 84 through conductors 105 and 106 from conductors 89 and 87 respectively when switch 107 is closed. The fluid circulation pressure operated switch 86 may be constructed in a manner similar to that disclosed in copending Arps application, Serial No. 68,930, now Patent No. 2,658,284.

Referring now primarily to Figure 2, recording apparatus is there illustrated employing a voltmeter or galvanometer V_1 which may be the same or similar to the galvanometer or voltmeter shown at V in Figure 1, the conductors 62' and 69' being adapted to make connection at junction point 62 and movable contact 69 respectively, in the hydrogen detection and measuring apparatus of Figure 1. The hand 110 of the voltmeter or galvanometer V_1 carries at its outer end a pen which bears upon a chart or strip of graph paper 111 adapted to be moved between rollers 112 and 113 for the purpose of tracing a curve or making a graph as illustrated at 115. The chart 111 may be driven by a suitable motor 116 coupled through shaft 117 to one of the rollers such as the roller 113. The rate of drive of the roller 113 may be such that the chart 111 is moved at a given constant rate with respect to time or preferably at a rate or having a motion proportional to the longitudinal motion of the drill stem 13 and accompanying electrodes 81, 82, into or out of the well borehole. This proportional motion may be accomplished by various suitable means such as, for example, employing a line 120 passing over pulleys 121 and 122 and extending between the traveling block 123 and a drum 124, said drum being coupled to a Selsyn generator 125 and the Selsyn generator in turn being coupled through suitable electrical connections, as shown at *a*, *b* and *c*, to a Selsyn motor at 116. Another apparatus suitable for this purpose is illustrated in Figure 2 of copending Arps applications Serial No. 619,629, filed October 1, 1945, now Patent No. 2,524,031, and Serial No. 269,568, filed Feb. 1, 1952.

Referring now primarily to Figure 3, radioactivity of the formations may be measured by the apparatus modification there shown. A radioactivity radiation detector 130 which may be of any conventional type such as the Geiger counter, ionization chamber or the like devices responsive to gamma rays, neutrons or the like radiations is connected through battery 131 across resistor 132. Resistor 132 is in turn connected through conducotrs 133 and 134 across the input terminals of a suitable amplifier means A. One terminal of the output of the amplifier means A is connected through conductor 135 to the battery 84 and thence through conductor 85, switch 86 and conductor 87 to the brush 88 of the commutator 91. The other output terminal of means A is connected through resistor 136 and conductor 137 to brush 90 of the commutator 91. The amplifier device A may be of conventional design and such that the current flow from battery through the output thereof bears a predetermined functional relationship to the input signal appearing across resistor 132, which in turn is representative of the radiation intercepted by the detector 130.

The operation of the apparatus is as follows:

In operation of the drilling apparatus of a drilling well, the drilling fluid which is usually an aqueous suspension of clayey materials, is withdrawn from the pit 29 through the suction pipe 28 and forced by means of pump 27 through pipe 26 and coupling 25 into the top of the swivel 16 and thence down through the interior of the kelly 15, drill pipe 14, drill collar 13 and out through suitable discharge holes, as illustrated at 89, in the drill bit 12. The circulating drilling fluid then flows upwardly in the annular space formed between the borehole walls and the drill stem as indicated by arrow 88, and up through the surface casing 11, from the top of which it is finally discharged through the lateral discharge pipe 31 into the top of the separator 32. In the

separator 32 the drilling fluid passes or falls downward over the baffle plates 35 to the bottom of the chamber from where it is finally discharged through pipe 37 into the trough 39 from which it flows into the top of the settling pit 29 to complete the cycle of circulation.

Meanwhile, during circulation of the drilling fluid as hereinbefore described, the drill stem comprising the kelly 15, drill pipe 14, drill collar 13 and drill bit 12, may be rotated by means of the rotary table 20 which is driven by the bevel gear and pinion 21 and 22 respectively, the pinion 22 being driven through the shaft 23 as beforementioned. Drilling operations in the borehole may thus be maintained.

During drilling operations or any other operations, when the drill collar 13 is maintained in electrical contact with the drilling fluid within the borehole, and under conditions where the drilling fluid is being circulated, the fluid operated switch 86 is operated to close the circuit between conductors 85 and 87. A closed circuit is thereby formed across the battery 84 permitting a continuous flow of current from the negative terminal of the battery 84 through conductor 89, brush 90, commutator segment 93, brush 96 and conductor 101, to electrode 82 and thence through the drilling fluid and through a portion of the adjacent formation and return through the drilling fluid to the electrode 81, conductor 100, brush 95, commutator segment 92, brush 88, conductor 87, fluid operated switch 86 and conductor 85, to the positive terminal of the battery 84. Since a portion of the formation surrounding the borehole adjacent the electrodes 81 and 82 forms a part of the electrical circuit across the battery 84, as before described, the current flowing in this circuit will consequently be directly proportional to or at least representative of the formation conductivity.

The passage of the direct current between the electrodes 81 and 82 while immersed in the aqueous drilling fluid will cause hydrogen gas to be generated by electrolysis and liberated at the cathode electrode 81. At the same time oxygen gas will be generated by electrolysis and liberated at the anode electrode 82. As is well known two volumes of hydrogen will be liberated at the electrode 81 for each volume of oxygen liberated at the electrode 82. The amount of hydrogen gas which will be released at the cathode 81, per unit of time will be, in accordance with Faraday's Law, proportional to the current passing between electrodes 81 and 82, and consequently the amount of hydrogen released at electrode 81 will be representative or indicative of the conductivity of the adjacent formation.

The conductivity of the drilling fluid in the vicinity of the electrodes 81 and 82 will of course also affect the total conductivity of the circuit across the battery 84 to some extent but as is well known in this art, the effect of this conductivity is usually a substantially constant factor and its effect is relatively small as compared to the conductivity of the relatively large volume of surrounding formations. Actually the conductivity of the drilling fluid is often less than that of the surrounding formations. In any event, the effect of the conductivity of the drilling fluid is substantially constant and can be corrected for. While the commutator 91 has been shown and hereinbefore described as positioned to connect the positive and negative terminals of the battery respectively to the electrodes 81 and 82 the commutator may obviously be positioned, by rotation 90° from the position shown to reverse these polarities, without affecting the mode of operation of the apparatus.

In some cases it may be desirable to apply an intermittently or periodically reversed current to the electrodes 81 and 82 in order to avoid polarization effects or the deposition of colloids upon the positive electrode. In such cases the switch 107 is closed manually prior to lowering the drill string into the borehole or by other suitable means after lowering the drill string into the borehole. Closing of the switch 107 energizes motor 104 which in turn drives the commutator 91 through the coupling shaft 103. Rotation of the commutator 91 results in periodic switching and reversal of the polarity of the potential applied from the battery 84 to the electrodes 81 and 82. The rate of rotation of the commutator and hence the frequency of reversal of the current or voltage applied to the electrodes 81 and 82 should be sufficiently low to permit the desired electrolysis and liberation of hydrogen at each electrode to take place. Suitable frequencies for this purpose may be of the order of 0.1 to 10 cycles per second. The potential applied to the electrodes by the battery may be from a few volts above the polarization potential of 1.2 to 1.7 volts, to as high as 100 volts depending upon the current density used, the geometry and arrangement of electrodes, type of drilling fluid employed and other conditions.

The hydrogen gas which is liberated at electrodes 81 or 82 in the case of the use of D.-C. or at electrodes 81 and 82 in the case of the use of intermittently or periodically reversed polarity, such liberation being in quantities representative of the conductivity of the adjacent formation as before described, is conveyed in the circulating drilling mud to the top of the well bore and up through the annular space in the surface casing 11 in the direction indicated by arrow 102 from where it passes through the lateral outlet pipe 31 and into the top of the separator chamber 32. The drilling fluid containing the hydrogen gas is directed downwardly through the separator chamber 32 by the elbow 33 from which it falls down through the chamber over the baffle plate 35 in counter-current contact with upwardly flowing air, and finally the drilling fluid from which hydrogen has been removed, is discharged from the bottom of the separator chamber through pipe 37 into the trough 39 through which it flows in return to the settling pit 29.

The air which passes upward in counter-current contact with the downwardly flowing drilling fluid within the separating chamber 32 as before described, enters at the bottom through pipe 37 which is only partially filled with the outwardly flowing drilling fluid as indicated by the arrow 34 and passes out of the top of the separating chamber, together with separated hydrogen through pipe 40 and valve 42 and thence the air-hydrogen mixture flows through the chamber 43 and in contact with the heater filament 44. The air, after passing through the chamber 43 and in contact with the filament 44, flows on through pipe 45 to the inlet 46 of the blower 47 and is finally exhausted from the blower outlet 48. At the same time a substantially equal amount of substantially hydrogen-free air is drawn into pipe 52 at a point 54 from a lower portion of the separating chamber, and flows through the chamber 50 into contact with the heater filament 51 and thence through pipe 49 to the inlet 46 of the blower 47 and is exhausted therefrom at 48 together with the air from the other branch pipe 45. By withdrawing air both from the top and from a lower portion of the separating chamber 32 as before described, the air streams passing in contact with the filaments 44 and 51 will thereby have nearly the same temperatures and humidities. These quantities of air may be equalized or otherwise adjusted as desired by means of the valves 42 and 53.

The Wheatstone bridge measuring circuit is initially adjusted by movement of the position of the contact 69 upon the resistor 68 to a condition of balance under which the voltmeter V is zeroed. The current flowing through the heater filaments 44 and 51 are then adjusted by means of the variable resistor 72 such that these filaments are heated to a temperature below the point where any hydrogen mixture or any other of the combustible gases passing over them will ignite. This temperature can be carefully controlled, as before stated, by adjusting the variable resistor 72 and checking with the voltmeters 75 and 76. The voltage applied will depend largely upon the total resistance of the heater filaments.

As before explained, filaments 44 and 51 are preferably made of a conductive material which has as high a temperature coefficient as possible so that a small difference in temperature between the filaments will cause a comparatively large difference in their electrical resistances, resulting thereby in a comparatively large unbalance of the measuring circuit which will be reflected in the meter V.

The thermal conductivities, expressed in calories per second per square centimeter per degree centigrade per centimeter, of the gases most likely to be encountered in the drilling fluid are as follows:

Air	56.8×10^{-6}
Carbon dioxide	30.7×10^{-6}
Hydrogen, 0° C	327.0×10^{-6}
Hydrogen, 100° C	369.0×10^{-6}

Methane	64.7×10^{-6}
Nitrogen	52.4×10^{-6}
Oxygen	56.3×10^{-6}

(Handbook of Chemistry and Physics, 23rd edition, page 1456.)

Since, as is apparent from the foregoing table of thermal conductivities of various gases, the thermal conductivity of hydrogen gas is relatively high as compared to air, oxygen or any other gases normally found in drilling mud and which may be liberated in the separating chamber **32**, the presence of hydrogen in the air from the drilling fluid and which passes through the chamber **43** will result in withdrawal of a greater amount of heat from filament **44** than the relatively hydrogen-free air passing through chamber **50** withdraws from filament **51**, thereby causing a greater cooling or reduction in the temperature of filament **44** than that of filament **51**. The resistance of the filament **44** will thus undergo a greater reduction than that of filament **55** with the result that the bridge measuring circuit will be unbalanced in such a way as to reflect that unbalance in the voltmeter V. The amount of unbalance thus indicated by the voltmeter V will, therefore, be indicative or representative of the hydrogen content of the gas stream flowing from the gas separator **32**.

By plotting the concentration of hydrogen gas measured in the before described manner, against or in correlation with the depth of the borehole, by means of the apparatus illustrated in Figure 2, a log as illustrated at **115** will be obtained representing the formation conductivity versus depth. In such measurements suitable precautions can be taken to correct for the distance between the bottom of the drill bit and the effective position of electrodes **81** and **82**. Also it may be necessary or desirable to adjust the drive mechanism moving the chart **111** to compensate for the time necessary for a given volume of the drilling fluid to travel from a point in the borehole opposite the electrodes **81**, **82** to the top of the well and through the gas separation chamber **32**. Typical means for so adjusting the chart drive mechanism is disclosed in the applicant's copending application Serial No. 269,568, filed February 1, 1952.

Instead of employing two separate electrodes as shown at **81** and **82** in Figure 1 the bit itself may be used as one of the electrodes and in such case the structure of the drill collar, electrode and electrode bit may, for example, be made as shown in the article by David G. Hawthorn and John E. Owen in the January 1940 issue of the Petroleum Engineer, page 71.

The principles of this invention can also, as hereinbefore described, be applied to other measurements such as natural potential, drilling weight on the bit, bottom hole temperature or pressure or radioactivity of the formation, it being only necessary in order to accomplish this to regulate the flow of current from the battery **84** to the electrodes **81** and **82** and therebetween through the drilling fluid in accordance with the beforementioned characteristics to be measured.

For example, the measurement of radioactivity within the well borehole can be accomplished by the hereinbefore described apparatus of Figure 3. The operation of this portion of the apparatus is as follows: Radioactivity radiation intercepted by the detector **130** results in a potential drop or in rapid potential pulsations across resistor **132** which are applied through conductors **133** and **134** to the input of amplifier device A. In the output circuit of amplifier device A, current, which is a predetermined function of the radiation received by detector **130**, flows from battery **84** through conductors **85** and **135** to the one output terminal of the device and thence through resistor **136**, conductor **137**, brush **99** (and with commutator positioned as shown), brush **96** and conductor **101** to electrode **82**. From electrode **82** the current flows through the fluid in the borehole to electrode **81** and returns through conductor **100**, brush **92**, brush **88**, conductor **87**, switch **86** and conductor **85** and returns to battery **84**. Resistor **136** is made relatively high so that differences in resistances of the current path between electrodes **82** and **81** through the borehole fluid and surrounding formations will have an inappreciable effect upon such current flow. When commutator **91** is turned 90° from the position shown, the current flow insofar as electrodes **81** and **82** are concerned will be reversed from that just described.

The hydrogen gas liberated at electrodes **81** and **82** in proportion to the current thus caused to flow therebetween in the operation of the apparatus of Figure 3 is carried in the drilling fluid to the top of the well where it is separated and measured as hereinbefore described in connection with the apparatus of Figure 1.

The terms measuring the quantity of hydrogen as employed herein in the specification and claims are not to be limited in meaning to actual quantitative determination of such values but are to include the actuation of any indicator or recorder means or device such as the voltmeter or galvanometer V or V_1 or the like device whereby a visual indication or graphical record of a measure of such values or an indication or graphical record of a value which is indicative of or representative of the amount of hydrogen present in the separated gases or present in the drilling fluid may be obtained.

It is to be understood that the foregoing is illustrative only and that the invention is not limited thereby but may include various modifications and changes made by those skilled in the art without distinguishing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A method of logging a well borehole comprising: applying a potential difference between a pair of spaced electrodes, vertically shiftable within said borehole and in electrical contact with aqueous fluid therein whereby hydrogen is generated in said fluid at said electrodes by electrolysis in quantities which are representative of the conductivities of the formations surrounding said borehole adjacent said electrodes; circulating said fluid containing said hydrogen to the top of the well borehole and there separating hydrogen gas therefrom; and measuring the quantity of the separated gas relative to time.

2. A method for logging a well borehole comprising: applying a D.-C. potential difference between a pair of spaced electrodes, vertically shiftable within said borehole and in electrical contact with aqueous fluid therein whereby hydrogen is generated in said fluid at one of said electrodes by electrolysis in quantities which are representative of the conductivity of the formation surrounding said borehole adjacent said electrodes; circulating said fluid containing said hydrogen to the top of the well borehole and there separating hydrogen gas therefrom; and measuring the quantity of the separated gas relative to time.

3. A method for logging a well borehole comprising: applying a D.-C. potential difference between a pair of longitudinally spaced electrodes, vertically shiftable within said borehole and in electrical contact with aqueous fluid therein whereby hydrogen is generated in said fluid at one of said electrodes by electrolysis in quantities which are representative of the conductivity of at least a portion of the formation surrounding said bore hole adjacent said electrodes; circulating said fluid containing said hydrogen to the top of the well borehole and there separating hydrogen gas therefrom; continuously measuring the quantity of the thus separated gas relative to time; and correlating the resultant measurements with the well borehole depth.

4. The method according to claim 3 including the step of periodically reversing the polarity of the potential applied to the electrodes.

5. A method for logging a well borehole comprising: applying a D.-C. potential difference between a pair of longitudinally spaced electrodes, vertically shiftable within said bore hole and in electrical contact with aqueous fluid therein whereby hydrogen is generated in said fluid at one of said electrodes by electrolysis in quantities which are representative of the conductivities of at least a portion of the formations surrounding said borehole adjacent said electrodes; circulating said fluid containing said hydrogen to the top of the well borehole and there separating hydrogen gas therefrom; continuously measuring the quantity of the separated gas relative to time; and recording said measurements relative to the well borehole depth.

6. A method of logging a well borehole comprising: passing a variable current between a pair of spaced electrodes vertically shiftable within said borehole and in electrical contact with aqueous fluid therein whereby said current flows through said fluid between said electrodes and hydrogen is generated in said fluid at at least one of said electrodes by electrolysis in quantities which are representative of the values of said current; varying said

current in response to and as a function of the values of a quantity to be measured within the borehole, circulating said fluid containing said hydrogen to the top of the well borehole, and there measuring the quantity of separated hydrogen in said fluid.

7. A method for logging a well borehole comprising: passing a variable D.-C. current between a pair of spaced electrodes vertically shiftable within said borehole and in electrical contact with aqueous fluid therein whereby said current flows through said fluid between said electrodes and hydrogen is generated in said fluid at one of said electrodes by electrolysis in quantities which are representative of the values of said current; varying said current in response to and as a function of the values of a quantity to be measured within the borehole, circulating said fluid containing said hydrogen to the top of the well borehole, and there measuring the quantity of the hydrogen in said fluid; and correlating the resultant measurements with the well borehole depth.

8. A method of logging a well borehole comprising: passing a variable current between a pair of spaced electrodes vertically shiftable within said borehole and in electrical contact with aqueous fluid therein whereby said current flows through said fluid between said electrodes and hydrogen is generated in said fluid at at least one of said electrodes by electrolysis; varying said current in response to and as a function of the values of a quantity to be measured within the borehole whereby said hydrogen is generated in said fluid in quantities which are representative of the said values of said quantity to be measured; circulating said fluid containing said hydrogen to the top of the well borehole, and there measuring the quantity of the thus separated hydrogen relative to time; and correlating the resultant measurements with the well borehole depth.

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