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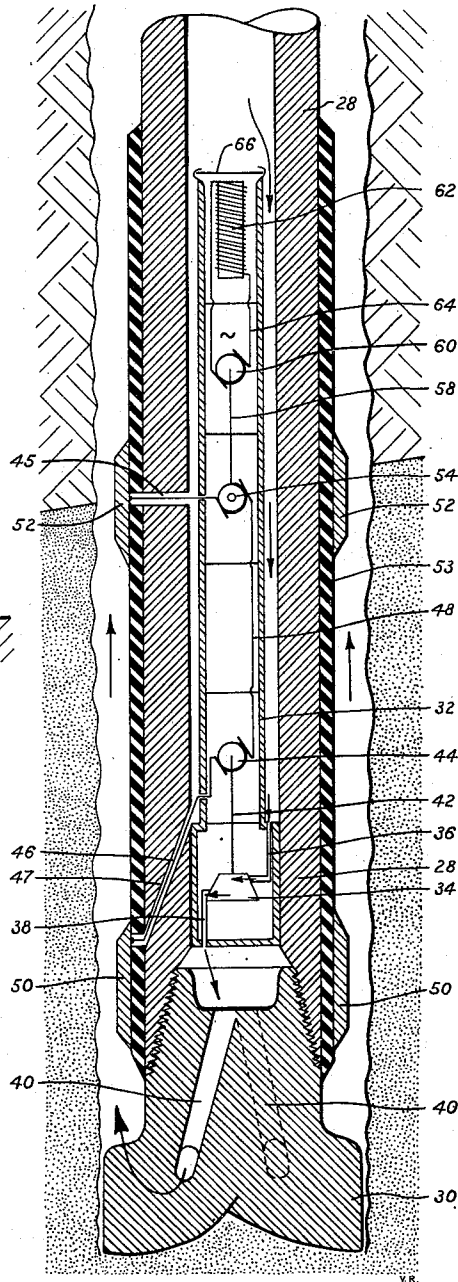
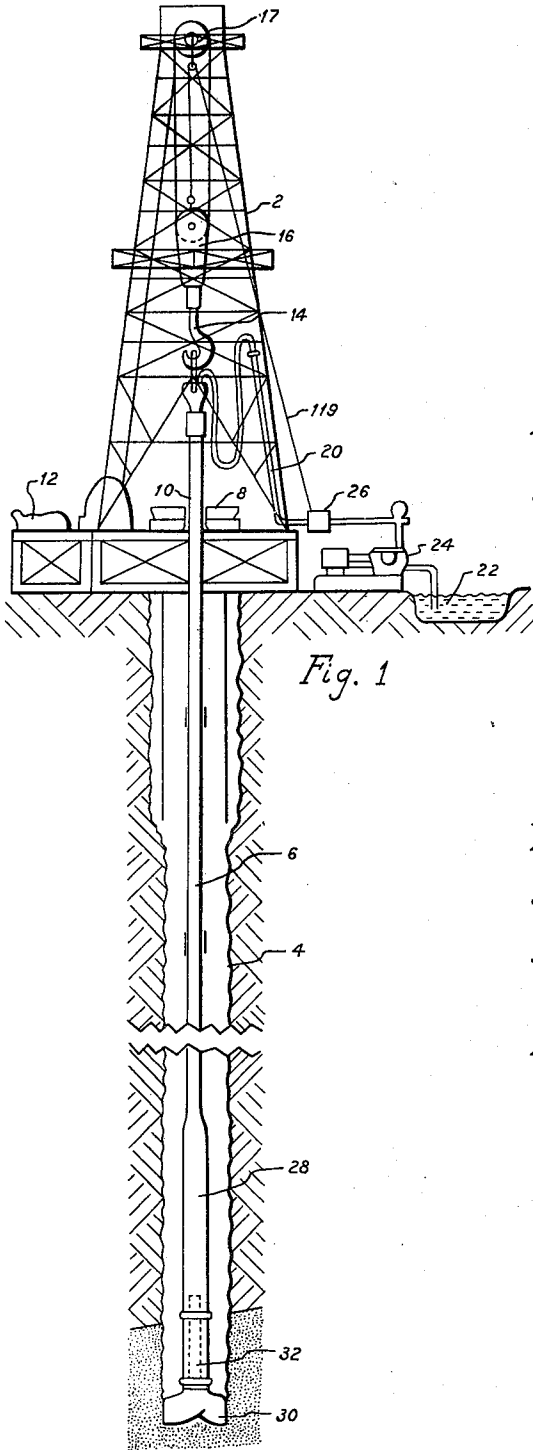
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2,524,031

APPARATUS FOR LOGGING WELLS

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3 Sheets-Sheet 1



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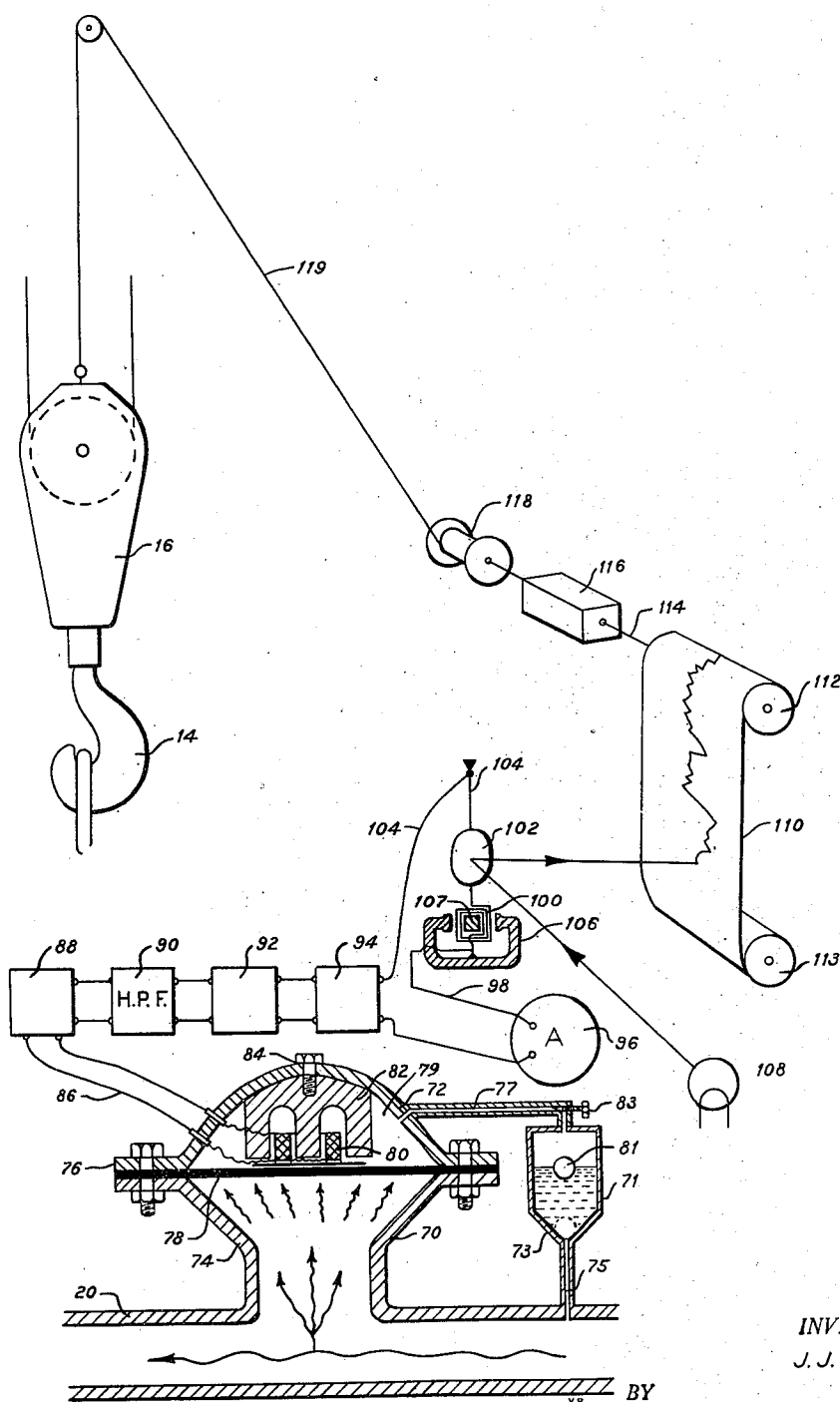
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APPARATUS FOR LOGGING WELLS

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3 Sheets-Sheet 2



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APPARATUS FOR LOGGING WELLS

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3 Sheets-Sheet 3

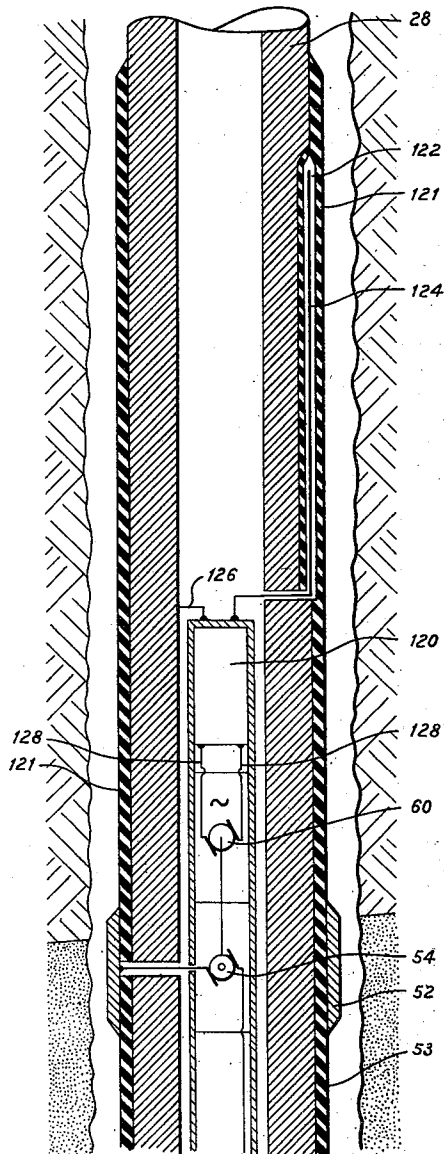
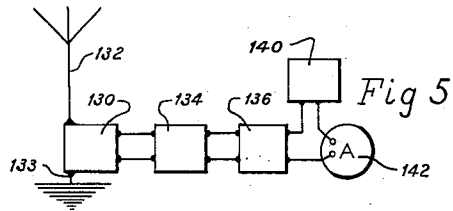


Fig 4

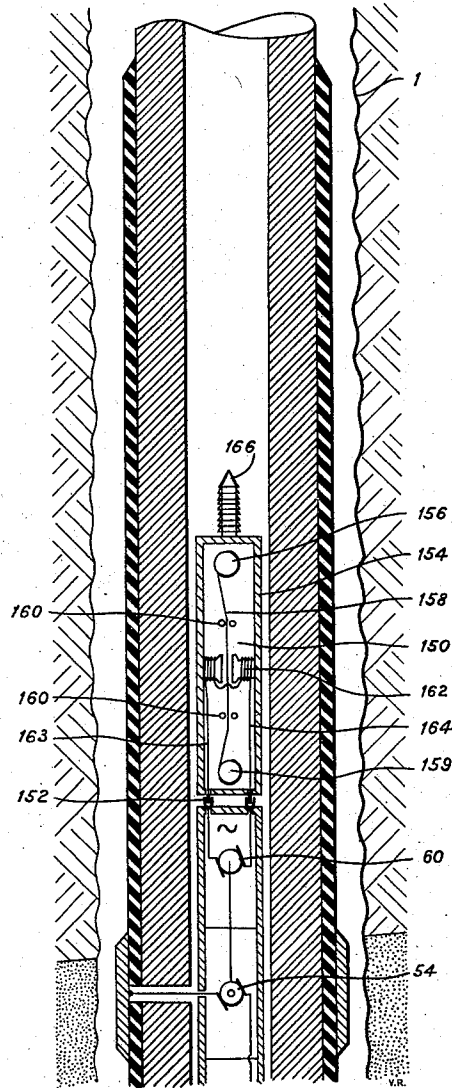


Fig 6

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UNITED STATES PATENT OFFICE

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APPARATUS FOR LOGGING WELLS

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3 Claims. (Cl. 255—1)

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This invention relates to a method and means for determining the electrical resistance or impedance of the various subsurface geological formations penetrated by a drilling well and more particularly, but not by way of limitation, for determining the possibilities of oil, gas or water production in such formations during the continuous drilling operation or at drilling intervals thereof. The electrical resistance or impedance, being typical of the various strata penetrated, are also essential for correlation between wells in order to determine their relative geologic position on the structure.

Many prior methods have been proposed for measuring the various characteristics of a bore hole and a common practice is to employ a conductor cable for supplying electrical energy from the surface to the well logging or investigation apparatus in the bore hole, and a separate conductor for transmitting the response of the investigation apparatus to an indicating means at the surface of the well. Such a logging apparatus can only be run at intervals after the drill pipe is removed from the hole and in many cases it is found that possible productive horizons unknowingly have been passed up during the drilling, which makes subsequent completion difficult and costly. Also it is known that during the process of drilling through a prospective producing formation fresh water from the drilling mud invades such formation and this flooding action changes the natural electric resistivity of the formation thereby confusing the proper interpretation of its producing possibilities if too much time expires between the time of drilling and the time the electric survey is made. These disadvantages are overcome by the present invention because the natural electric resistivity is immediately available when the formation is being drilled into and before flooding by fresh water takes place.

Generally the present invention provides for a method and apparatus which will log the formation characteristics of a well hole during a continuous drilling operation or at an interval thereof wherein the source of electrical energy for the investigation apparatus is created at the bottom of the well and the signals related to the electrical resistance or impedance of the adjacent strata are transmitted to the top of the well without the use of any auxiliary conductors, cables or the like and the values of the electrical resistance or impedance are picked up by a surface indicating apparatus and are constantly available to the drilling operator.

More specifically, but not by way of limitation, this invention utilizes the circulation of the drilling fluid in the drill stem to actuate means for creating electrical energy utilized by the investigating apparatus. Furthermore, the drilling fluid is utilized as a transmission medium for transmitting the pulsations of the investigation apparatus to the top of the well.

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It is an important object of the present invention to provide a method and means for continuously indicating the electrical resistance or impedance of the sub-surface geological formations penetrated by a bore hole and which can be continuously transmitted to the surface of the bore hole without the necessity of employing cumbersome electrical connecting cables.

It is a further object of this invention to provide a method and means of logging a well during the process of drilling in which variations in the physical properties of the penetrated strata will produce variations in an electrical investigation apparatus located opposite the strata, and are then transmitted to the surface to provide a continuous indication at the surface of the electrical resistance or impedance of the strata.

And still another object of this invention is to provide a method and means of logging wells wherein the energy of the circulating drilling fluid is utilized to create a source of electricity adjacent the portion of the strata being drilled so that a continuous logging of the electrical resistance or impedance of the freshly drilled strata may be provided at all times.

And still another object of this invention is to provide a method and means for logging the electrical resistance or impedance of freshly drilled sub-surface formations whereby a high frequency pulsating device is utilized in the drilling string to transmit the electrical resistance or impedance of the freshly drilled formation as high frequency vibrations through the drilling fluid to the surface of the well.

And another object of this invention is to provide a method and means for continuously logging a well during the drilling operation thereof which consists in utilizing the drilling fluid as a transmission medium for created pressure pulsations in accordance with the electrical resistance or impedance of the freshly drilled formation to a detecting device communicating with the drilling fluid circuit at the surface of the well whereby the pressure pulsations are converted into electrical current which can be amplified, filtered and rectified as a source of continuous measurement of the resistivity or impedance of the formation as it is penetrated by the drilling bit.

And still a further object of this invention is to provide a method and means for logging the electrical resistance or impedance of the freshly drilled sub-surface formation which is simple in construction and operation, inexpensive to manufacture and efficient and durable in use.

With these and other objects in view there has been illustrated on the accompanying drawings several forms in which the invention may be conveniently embodied and practiced.

In the drawings:

Fig. 1 is a diagrammatic elevational view of the well showing the bore hole in section.

Fig. 2 is a sectional elevational view of the lower portion of the bore hole showing the logging apparatus arranged schematically in the lower part of the drill collar.

Fig. 3 is a schematic view partly in section showing the arrangement of the surface detecting apparatus in the mud stream as well as the apparatus for correlating the depth of the bore hole with the recording means.

Fig. 4 is a sectional elevational view of the bore hole showing a modified form of the investigation apparatus disposed in the drill collar.

Fig. 5 is a schematic detail view of a receiving means for the investigating apparatus in Fig. 4.

Fig. 6 is a sectional elevational view showing another modification of the investigating means disposed in the lower portion of the drill column.

Referring now to the drawings in detail and more particularly to Figs. 1 to 3 inclusive, reference character 2 indicates a well derrick disposed over a bore 4 in which is located a string of drill pipe 6 extending through a rotary table 8 on the derrick floor. The upper end of the drill stem 6 is attached to a kelly 10 grasped by the table 8 which in turn is rotated by a source of motive power such as the engine 12. The drill string is supported by a hook 14 of a traveling block 16 supported by crown block 17. A mud line 20 discharges into the drill string 6 and receives mud from a sump 22 through a mud pump 24. Interposed in the mud line 20 is a surface detecting device 26 which will be hereinafter explained in detail. The lower end of the drill stem is provided with a drill collar 28 of an increased outside diameter having the usual drill bit 30 connected thereto.

The logging apparatus to be hereinafter referred to is disposed in the drill collar immediately above the drill bit 30 and is preferably housed in a cylindrical housing unit 32 completely sealed in with the exception of inlet and outlet ports as will be hereinafter explained.

Referring now to the investigation or logging apparatus in detail and more particularly Fig. 2, a vertical turbine 34 is arranged inside the housing 32 disposed immediately above the rotary bit 30 and comprises an inlet flow passageway 36 in communication with the drilling fluid or mud present in the drill string 6. The velocity of the drilling fluid flowing downward through the drill string toward the drilling bit and into the passageway 36 drives the turbine 34 and then is discharged through an outlet passageway 38 which in turn communicates with passageways 40 of the bit 30. The turbine 34 activated by the drilling mud is directly coupled by means of shaft 42 (shown schematically) with a direct current generator 44. The generator 44 is equipped with a voltage regulator (not shown) in order to maintain the output voltage therefrom at a constant value independent of variations in the revolutions per minute of the turbine 34, which would normally be caused by the fluctuations in the velocity of the mud stream flowing downward in the drill string. The electrical output or current from the generator 44 is transmitted by conductors 46 and 48 extending through apertures 45 and 47 in the collar to two metal electrode bands 50 and 52 respectively. These annular electrodes are disposed around the drill collar 28 in vertical spaced relationship. The periphery of the drill collar is provided with an insulating sleeve 53 interposed between the electrodes and the collar. In the electrical circuit emitting through con-

ductor 48 to the electrode 52 is a direct current electric motor 54 in series therewith, and of such type that the speed of rotation varies directly with the magnitude of the current flowing there-through.

From the foregoing it will be apparent that the complete circuit activated by the direct current voltage generator 44 includes in series the direct current variable speed motor 54 a portion of the drilling fluid in the annular space in the borehole surrounding the electrodes and the formation strata extending between the electrodes 50 and 52. The electrical resistance of the formation in the space between the two electrodes and also to some extent that of the drilling mud passing through this space will thus determine the amount of current flowing through the circuit which in turn will determine the speed or velocity of the motor 54.

The motor 54 is directly connected through a shaft 58 with a single phase alternating current generator 60 disposed immediately thereabove in the housing 32. The generator 60 is preferably constructed in such a manner that the frequency of the alternating current generated thereby will vary directly with the velocity or speed of rotation of the variable motor 54 which obviously will depend directly upon the resistivity of the adjacent strata located in the space between the two electrodes 50 and 52. From the above it will be apparent that during the drilling operation, or during an interval thereof, if a strata is penetrated which contains mainly salt water, normally having a low electric resistivity, the electrical output or current through the circuit will be increased thereby causing a high frequency of the alternating current generated by the generator 60. However, when an oil or gas bearing strata is penetrated, which is normally characterized by a higher electrical resistivity, then the current through the circuit activated by generator 44 will be in accordance with the electrical resistance or impedance and therefore much smaller, which in turn will create a lower frequency of alternating current from generator 60. From the foregoing it will be apparent that the generator 44 and motor 54 are operating in a direct current circuit with the formation characteristic which is measured as the electrical resistivity. Instead of such direct current it is possible to utilize an alternating current circuit for the same purpose, without changing the basic principle of the invention. In such case the formation characteristic measured is the impedance rather than the normal resistivity. The use of alternating current may be preferable in those cases where a high content of electrolytes in the drilling fluid would cause polarization of the electrodes 50 and 52.

Disposed immediately above the generator 60 in the housing 32 is an electro-magnetic pulsator 62 connected in series with the generator 60 through the conductor 64. The pulsator 62 is preferably constructed so that it will produce vibrations with a frequency corresponding to that of the alternating current from generator 60. The pulsator 62 is provided with two elements: a vibrating magnetic disc 66, and a solenoid located underneath the disc. The magnetic disc 66 is constructed from suitable permanently magnetized steel. The magnetization of the disc 66 is perpendicular to its surface. Consequently, the disc 66 is in fact a permanent magnet provided with two permanently magnetized poles, the length of said magnet being equal to the thick-

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ness of the disc. The north pole is constituted by the upper surface of the disc and the south pole is constituted by the lower surface of the disc. The solenoid positioned underneath the disc is supplied by an alternating current of variable frequency derived from the generator 60. It is apparent that the solenoid behaves itself as a magnet the polarity of which varies in synchronism with the frequency of the current supplied by the generator 60. Consequently, the solenoid alternately attracts and repels the permanently magnetized disc 66. Thus the disc vibrates with the frequency of the alternating current from the generator 60 and transmits these vibrations to the drilling mud present in the drill string 6. The resulting high frequency pressure pulsations of disc 66 are transmitted through the mud stream in the drill pipe to the top of the well where they are picked up by a detecting device 26 shown more in detail in Fig. 3 and which will now be explained.

Referring now to Figs. 1 and 3, the detecting device indicated at 26 comprises a housing member 70 interposed in the mud line 20. The housing member is formed of two segments having an upper section 72 secured to a lower section 74 by bolted flanges 76. Interposed between the flanges is a diaphragm 78 which may be subject to gas or air pressure in the chamber 79 or spring loaded (not shown). To equalize the gas pressure with the mud pressure in line 20 a device 71 is preferably used which consists of a vertical vessel 73 communicating through line 75 with mud line 20 and through line 77 to the chamber 79 above the membrane 78. A floating ball 81 is provided to keep the gas from bleeding out when the pumps 24 are shut down, while an adjustable needle valve 83 is necessary to dampen sudden fluctuations in the mud pressure during the drilling. The diaphragm 78 is connected to a coil 80 which is adapted to vibrate in a strong magnetic field from a permanent magnet 82 secured by bolt 84 to the housing section 72. Movement of the diaphragm 78 and the coil 80 is caused by the pressure pulsations emitted from the pulsator 66 and transmitted through the mud circuit to the underface of the membrane 78. Slight movement of the diaphragm and coil will create an alternating current to flow through the coil 80 which is transmitted through conductors 86 to an amplifying unit 88 of the conventional type. The output or current created by the coil consists of a high frequency wave caused by the pulsator 66 which is superimposed upon a low frequency wave created by the normal pulsation of the mud pump 24. After amplification of the current in amplifier 88, it is transmitted to a standard or conventional high pass radio filter circuit 90 which will filter out the lower frequency wave created by the mud pump. The remaining high frequency wave from the pulsator 66 will be transmitted to an electrical transducer 92, designed to translate the frequency modulated input current into a corresponding amplitude-modulated output current. Since the frequency of the input current varies in accordance with the variation of the resistance or impedance of the strata, the amplitude modulated output current from transducer 92 will vary in a similar manner with the resistance or impedance of the strata. From the transducer 92 the amplitude modulated alternating current is transmitted to a rectifying unit 94 changing the output into a direct or unidirectional current. As shown in Fig. 3, the direct current may be transmitted to a sensitive ammeter

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96 from which the amount thereof can be read directly. However, as shown in Fig. 3, the ammeter 96 is in series with a coil 100 having a mirror 102 interposed in conductor 104 in turn connected with rectifier 94. Surrounding the coil 100 is a permanent magnet 106 which, upon transmission of current through the coil causes rotation thereof with a corresponding rotation of the mirror 102. A piece of soft iron 107 is preferably interposed in the coil 100 in order to concentrate the density of the magnetic field between the coil and the magnet 106. A source of light 108 is arranged to throw a light beam onto the rotating mirror 102 and the reflection from the mirror will be transmitted to a sensitized photographic film 110 disposed in the path of the reflection in order that a permanent record of the logging data may be recorded thereon.

The film 110 is disposed on rolls 112 and 113 and the supply roll 112 is directly connected through a shaft 114 to a gear box 116 which in turn is directly connected through a pulley 118 and cable 119 to the traveling block 16. From the foregoing, it will be apparent that the film 110 may be scaled to indicate the penetration of the bore hole and with the gear arrangement 116 the film 110 will show the proper electrical characteristics of the formation at the exact depth of the drilling operation.

Referring now to Fig. 4 showing a modification of the investigating apparatus, part of the apparatus such as the turbine 34 activated by the drilling fluid, the generators 44 and 60 are identical with the disclosure of the preferred embodiment, however, a conventional radio sender 120 is utilized in lieu of the electro-magnetic pulsator 62 of the preferred embodiment. This radio sender is of special rugged construction so as to withstand the shocks transmitted to it from the drilling bit 30 during the process of drilling. The insulated collar 121 encircling the drill collar 28 is provided with a recessed portion 122 in which is disposed an aerial 124, a ground 126 extends from the radio sender 120 into contact with the drill collar 28. In Fig. 5 is shown the modified apparatus for detecting the signals from radio sender 120. In operation, the apparatus shown in Fig. 4 is similar to the preferred embodiment in that an alternating current is transmitted from the generator 60 and with a frequency which will vary directly with the velocity of the variable motor 54 contingent upon the resistivity or impedance of the formation between the electrodes 50 and 52. The generator 60 is directly connected through conductors 128 to the sender 120 which in turn will send signals in the nature of high frequency radio carrier waves, modulated in a manner similar to the frequency modulated pressure pulsations relating to the electrical resistance or impedance of the formation. These signals are transmitted to the surface of the well where they are received by a conventional receiving set 130 having an aerial 132 and ground 133. From the set 130 the signals are filtered at 134, and rectified through a rectifier 136 whereafter the electrical impulses are transmitted to a recorder 140 in series with sensitive ammeter 142 similar to the arrangement shown on Fig. 3 for the preferred embodiment. From the foregoing, it will be apparent that the electrical resistance or impedance of the formation can be directly read from the ammeter 142 as well as be permanently recorded in the recorder 140.

Referring to Fig. 6, another modification is disclosed utilizing a conventional magnetic wire re-

cording apparatus operated by a timing mechanism in lieu of the electric magnetic pulsator 62 of the preferred embodiment. The magnetic wire recorder apparatus 150 is directly connected through prong connections 152 to the alternating current generator 60 as shown in the preferred embodiment. The recorder 150 is encased in a housing 154 and comprises a pair of spaced rolls 156 and 159. Supply roll 155 is provided with a steel wire 158 extending therefrom through guides 160 to be reeled upon roll 159. The steel wire 158 passes between a pair of electro-magnets 162 directly connected by conductors 163 and 164 with the alternating current generator 60. The frequency pulsations corresponding to the electrical resistance or impedance of the formation are transmitted directly to the magnets 162 from generator 60 which in turn transmits them to the steel wire 158 passing thereby. The wire 158 is then magnetized in accordance with the electrical resistance or impedance of the strata. The housing 154 is provided with a hook or serrated member 166 adapted to receive any conventional retracting means allowing removal of the unit from the drill pipe so that it may be inspected at any time during the drilling operation. By correlating the timing of the magnetized wire with the known drilling progress at the surface, a log of the electrical resistance or impedance of the formations penetrated can be prepared as soon as the apparatus is withdrawn from the hole.

From the foregoing, it is thought that the operation of the method and apparatus will be obvious. While several specific embodiments have been described, the invention is not intended to be limited thereto, but is susceptible to numerous changes in form and detail within the scope of the appended claims.

I claim:

1. In apparatus for logging a drill hole while drilling with a drill bit suspended in a drill hole upon a tubular drill stem and collar through which drilling fluid is circulated, the combination of: a turbine disposed within the drill stem and having its impeller means located in a drilling fluid circulating duct therein and thereby adapted to be driven by circulation of drilling fluid through said duct; a direct current generator in said drill stem; a mechanical drive connection between said turbine impeller and said direct current generator; a variable speed direct current motor; a pair of spaced electrode elements insulated from one another and positioned on and exteriorly of said drill stem to be in electrical communication with formation penetrated by the drill hole during drilling; and an electrical circuit connecting one of said electrodes to the other of said electrodes, said circuit including the output of said direct current generator connected in series with the input of said direct current motor; an alternating current generator mechanically connected to said direct current motor for generating an alternating current the frequency of which is a function of the speed of said motor; and an electro-magnetic signal generator in communication with the drilling fluid duct in said drill stem, the actuating windings of which are connected to the output of said alternating current generator, for converting alternating output current from said alternating current generator into signal pulsations within said drill stem.

2. In apparatus for logging a drill hole while drilling with a drill bit suspended in a drill hole upon a tubular drill stem and collar through which drilling fluid is circulated, the combina-

tion of: a turbine disposed within the drill collar and having an impeller means located in a drilling fluid circulation duct therein and thereby adapted to be driven by circulation of drilling fluid through said duct from said drill stem; a generator in said drill collar; a mechanical driving connection between said turbine impeller and said generator; a variable speed motor; a pair of spaced electrode elements insulated from one another and positioned on and exteriorly of said drill collar to be in electrical communication with formation penetrated by the drill hole during drilling; and an electrical circuit connecting one of said electrodes to the other of said electrodes, said circuit including the output of said generator connected in series with the input of said motor; an alternating current generator mechanically connected to said motor for generating an alternating current the frequency of which is a function of the speed of said motor; and an electro-magnetic pulsator in communication with the drilling fluid duct in said drill collar, the actuating windings of which are connected to the alternating current output of said alternating current generator, for converting alternating output current from said alternating current generator into mechanical pulsations in drilling fluid flowing in said drill stem.

3. In apparatus for logging a drill hole while drilling with a drill bit suspended in a drill hole upon a tubular drill stem and collar through which drilling fluid is circulated, the combination of: a turbine disposed within the drill collar and having an impeller means located in a drilling fluid circulation duct therein and thereby adapted to be driven by circulation of drilling fluid through said duct from said drill stem; a generator in said drill collar; a mechanical driving connection between said turbine impeller and said generator; a variable speed motor; a pair of spaced electrode elements insulated from one another and positioned on and exteriorly of said drill collar to be in electrical communication with formations penetrated by the drill hole during drilling, and an electrical circuit connecting one of said electrodes to the other of said electrodes, said circuit including the output of said generator connected in series with the input of said motor; an alternating current generator mechanically connected to said motor for generating an alternating current the frequency of which is a function of the speed of said motor; and an electro-magnetic signal generator in communication with the drilling fluid duct in said drill stem, the actuating means of which is connected to the alternating current output of said alternating current generator, for converting alternating output current from said alternating current generator into signal pulsations within said drill stem.

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