

July 31, 1962

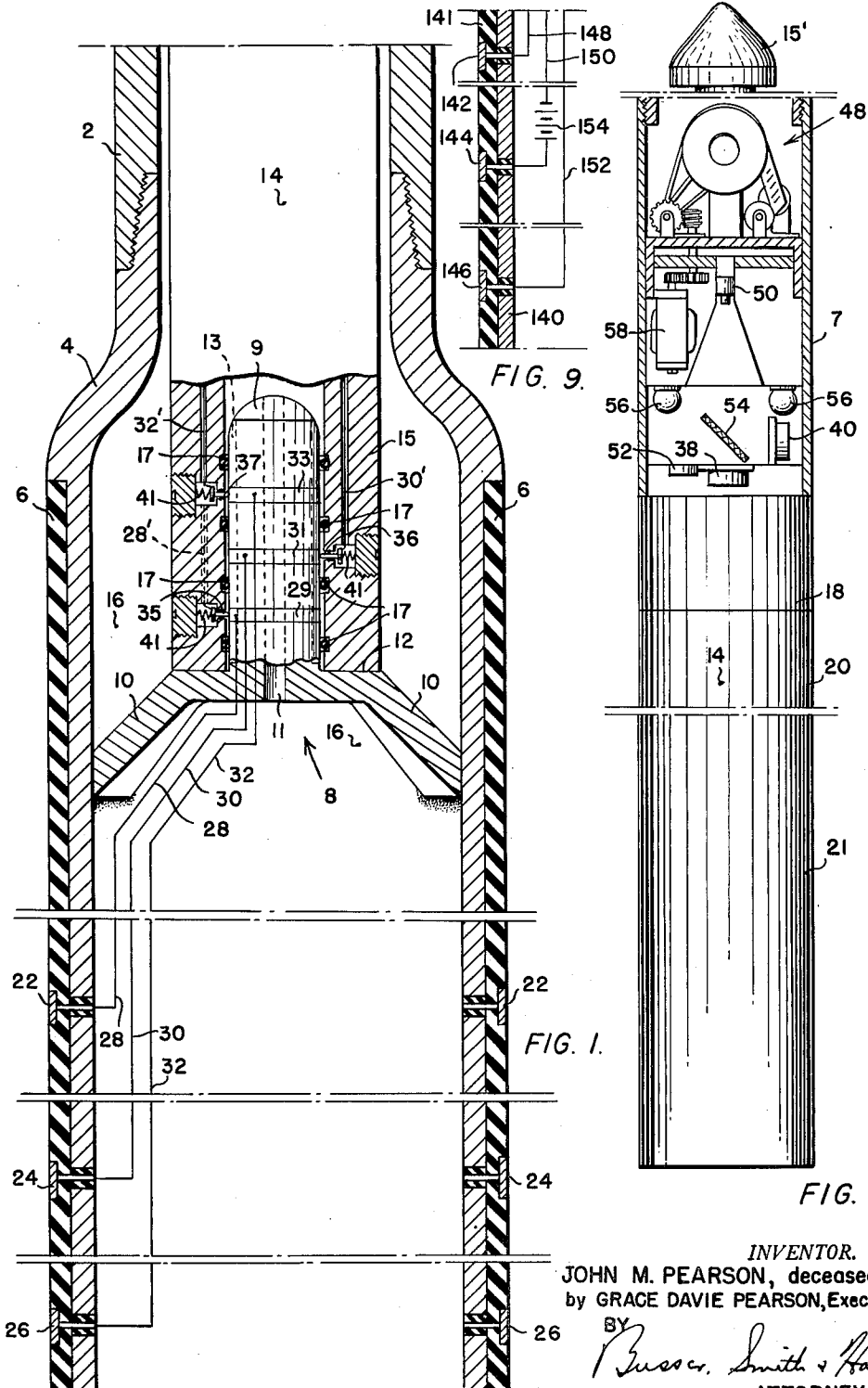
J. M. PEARSON

3,047,795

BORE HOLE LOGGING METHODS AND APPARATUS

Filed Jan. 17, 1958

3 Sheets-Sheet 1



INVENTOR.
JOHN M. PEARSON, deceased,
by GRACE DAVIE PEARSON, Executrix
BY *Bussac, Smith & Hardy*
ATTORNEYS

July 31, 1962

J. M. PEARSON

3,047,795

BORE HOLE LOGGING METHODS AND APPARATUS

Filed Jan. 17, 1958

3 Sheets-Sheet 2

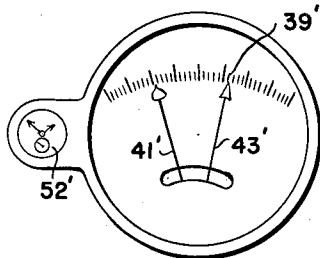


FIG. 3.

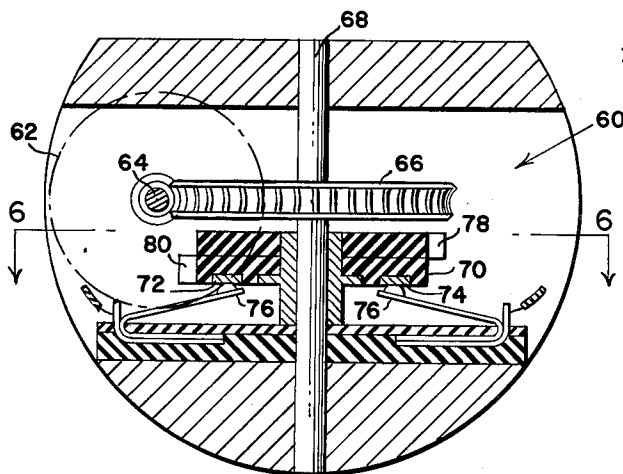


FIG. 5.

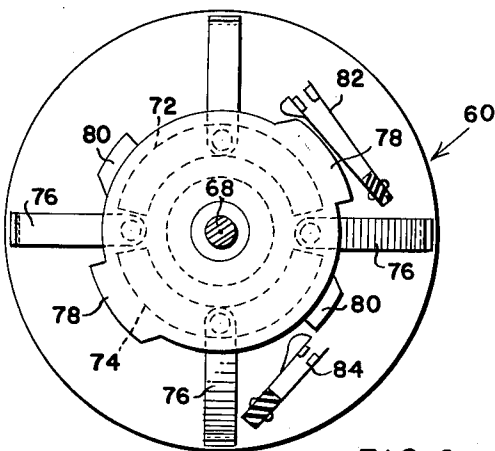


FIG. 6.

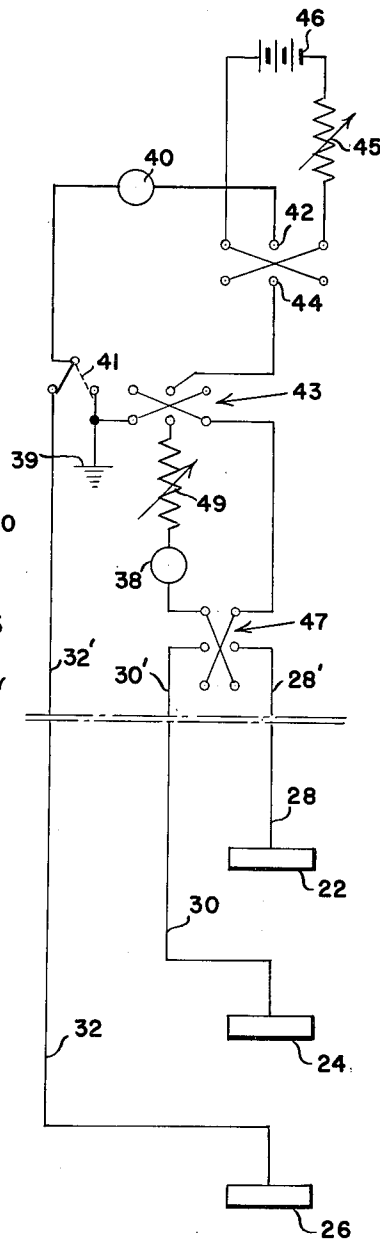


FIG. 4.

INVENTOR.
JOHN M. PEARSON, deceased,
by GRACE DAVIE PEARSON, Executrix
BY
Bussco, Smith & Harding
ATTORNEYS

July 31, 1962

J. M. PEARSON

3,047,795

BORE HOLE LOGGING METHODS AND APPARATUS

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3 Sheets-Sheet 3

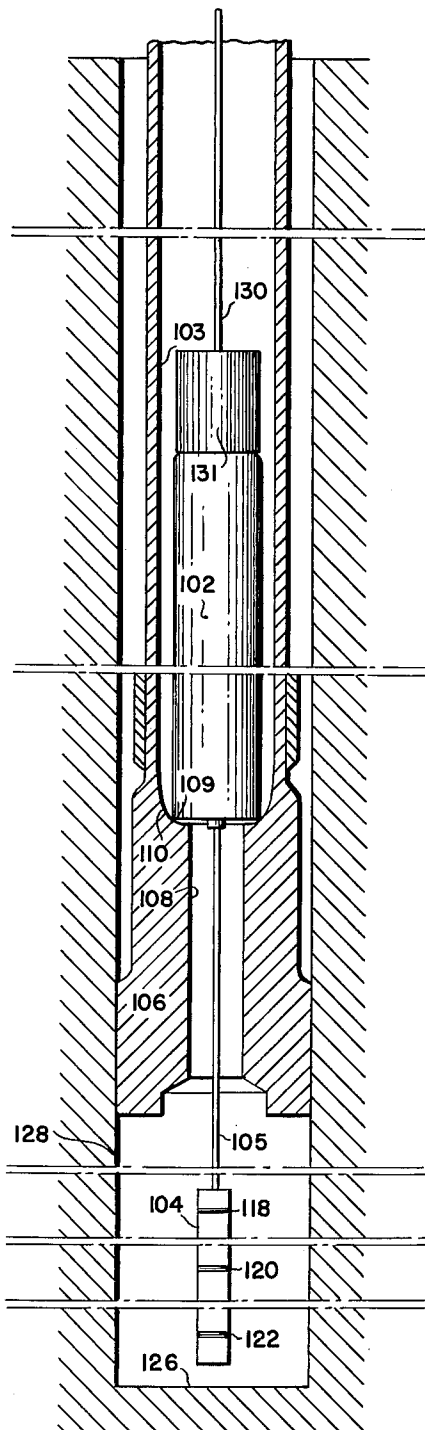


FIG. 7.

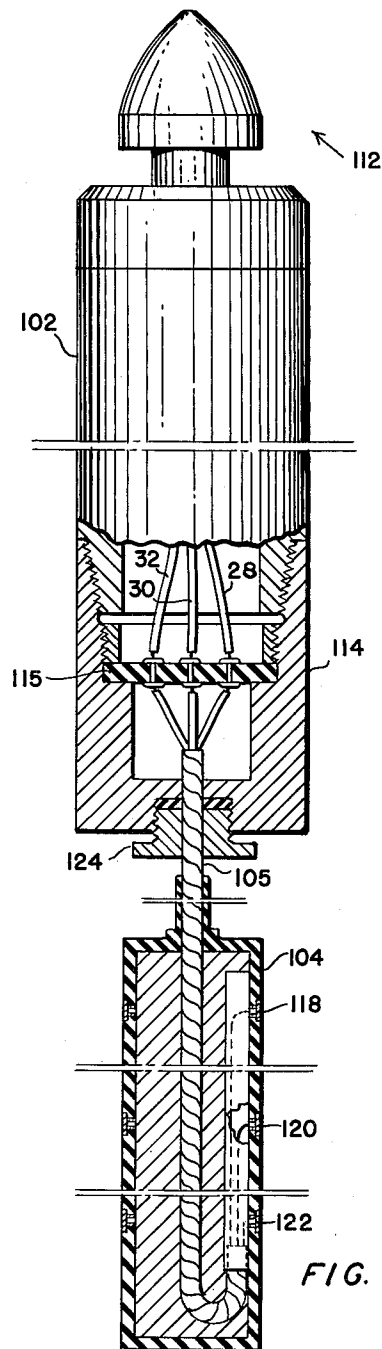


FIG. 8.

INVENTOR.
JOHN M. PEARSON, deceased,
by GRACE DAVIE PEARSON, Executrix
BY
Buss, Smith & Hardy
ATTORNEYS

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3,047,795

BORE HOLE LOGGING METHODS AND
APPARATUS

John M. Pearson, deceased, late of Swarthmore, Pa., by
Grace Davie Pearson, executrix, Swarthmore, Pa., as-
signor to Sun Oil Company, Philadelphia, Pa., a cor-
poration of New Jersey

Filed Jan. 17, 1958, Ser. No. 709,710

4 Claims. (Cl. 324—10)

This invention relates to bore hole logging methods and
apparatus and particularly to methods which involve the
location of recording apparatus within a hole and which,
during its operation, is independent of surface connection.

This application is in part a continuation of the applica-
tion of John M. Pearson, deceased, Serial No. 361,362,
filed June 12, 1953, now abandoned.

Conventional methods of electrical well logging involve
the absence of the drill stem during the logging operation.
This has two serious drawbacks in that not only must
special time be consumed in running the well log, during
which time the drill stem must be out of the hole, but
after a period of drilling, due to the fact that the drill
stem must be removed, there is inevitably a delay before
the new part of the hole may be logged, during which delay
there occurs invasion of the formation by drilling liquid.
Since the drilling liquid has physical properties of its own,
it may, by penetration of porous layers, greatly change
their properties so as to interfere with their detection.
In particular, the conductivity of the liquid will effect
changes in the apparent conductivity of the formations.

Proposals have been made to effect electrical logging
by using the drill bit or one or more other parts of the
drill stem as logging electrodes. In line with this, it has
been proposed to supply special drill stem tubing contain-
ing one or more conductors which are electrically con-
nected in the assembly of the drill stem and extend to
recording apparatus at the surface. The use of such an
arrangement has been found to be impractical because
of high cost and wear.

Proposals have also been made to support one or more
electrodes on cables to be dropped through a bit into the
lower portion of a hole from which the bit has been raised.
In such case currents are conducted through the cable to
recording apparatus at the surface. It has also been
proposed to provide on the lower portion of a drill stem,
for example a drill collar, electrodes which may be cou-
pled to apparatus lowered through the drill stem by a
cable to afford pick up of signals from the electrodes and
conduct the signals to recording apparatus at the surface.
Both of the last proposals are impractical since logging,
effected by movements of the drill stem, is limited to the
relatively short length of hole corresponding to the rise
of the drill stem which may be accomplished before the
removal of a section thereof in the derrick must be ef-
fected. This, then, required, after such limited extent of
logging, the complete removal of the cable and any ele-
ments which is carried, so that the uppermost drill stem
section could be removed. Continuation of logging
through another section length then required another
lowering of the cable to connect the apparatus in the
vicinity of the bit with the recording apparatus at the sur-
face. In the case of holes of ordinary depths, the lowering
and raising of the cable require an expenditure of time
which was very costly in view of the consequent inter-
ruption of the drilling operation.

It is the general object of the present invention to pro-
vide bore hole logging methods and apparatus whereby
the hole may not only be logged immediately following
the drilling of a predetermined portion thereof but with-
out a limitation as to the length of the hole which may
be logged, this logging being effected either when the bit
is raised for substitution of a new bit or merely to provide

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a logging traverse of a portion of the hole to be immedi-
ately followed by a lowering of the drill stem and con-
tinuation of drilling.

In brief, this result is accomplished in either of two
ways. The lower portion of the drill stem may have elec-
trodes associated therewith with electrical connections to
a coupling element which may be permanently associated
with a lower section of a drill stem. When logging is to
be accomplished there may then be dropped into the
drill stem in go-devil fashion a completely self-contained
energizing and recording apparatus which, when it reaches
the lower end of the drill stem will engage the coupling
element to complete electrical connections thereto. Log-
ging may then be accomplished by raising of the drill stem
to any desired extent with or without removal of upper
sections, the recording apparatus making automatically
the desired records. When the logging is completed, the
recording apparatus may then be removed either immedi-
ately by the use of an overshot lowered on a wire line or
at a later time when the drill stem is completely removed
for changing of the bit. This form of apparatus may be
used for logging during drilling as well as subsequent there-
to without interference with the drilling operation and
without interference with the addition of other sections to
the drill stem.

In an alternative form of the invention, upon the ces-
sation of drilling there may be dropped in go-devil fash-
ion through the drill stem a completely self-contained
energizing and recording apparatus comprising an ener-
gizing and recording assembly and also an electrode as-
sembly associated therewith and supported thereby, the
electrode assembly being of a size to pass through an
opening in the bit so that, if the drill stem is somewhat
raised to provide a clear portion of the hole below the
bit the electrode assembly will be located sufficiently below
the bit to permit its operation within an open portion of
the hole. Logging may then be accomplished by raising
the drill stem, with or without the removal of upper sec-
tions thereof. Following completion of the logging the
self-contained assembly, including the electrodes, may be
withdrawn from the drill stem by means of an overshot
or may be removed by withdrawal of the entire drill stem
if that is desired for change of the bit. If the withdrawal
is accomplished by an overshot, drilling may be resumed
promptly following the logging operation. It will be evi-
dent that in either of the forms of the invention just men-
tioned logging may be accomplished promptly after drill-
ing is interrupted so that substantial invasion of porous
formations by the drilling liquid will not have occurred
at the time of logging.

It will also be evident that there is no interference
whatever with removal or addition of drill stem sections
so that there is avoided any delay in progress of the
normal drilling operation.

The further objects of the present invention relate to
details of apparatus and method and will be apparent from
the following description, when read in conjunction with
the accompanying drawings, in which:

FIGURE 1 is a vertical section through a portion of
a drill stem;

FIGURE 2 is an elevation partly in section showing
apparatus adapted to be go-devilled into the drill stem;

FIGURE 3 is a view illustrating a type of photographic
record made during the operation of the apparatus;

FIGURE 4 is a wiring diagram showing the electrical
connections involved;

FIGURE 5 is a transverse section showing certain tim-
ing elements used for control of the recording means;

FIGURE 6 is a section taken on the plane indicated
at 6—6 in FIGURE 5;

FIGURE 7 is a vertical section through a drill stem

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in a bore hole showing an alternate form of the present invention;

FIGURE 8 is a vertical section showing the electrode assembly and the recording apparatus shown in FIGURE 7; and

FIGURE 9 is a fragmentary showing of FIGURE 1 showing a modification of the form of the invention of FIGURES 1-6.

Referring to FIGURES 1 and 2 there is shown at 2 a section of a conventional drill stem. Coupled to this drill stem is a lower drill stem section, or drill collar, 4 which is adapted to have attached to its lower end a conventional drill bit. Inserted into the outer surface of the lower drill stem section 4 is a sleeve of insulating material 6.

Mounted within the drill stem portion 4 is an instrument receiver assembly indicated generally at 8. The receiver assembly includes a vertically extending stem 9 which is supported by webs 10 from the wall of the drill stem portion 4. The stem 9 is provided with three contact bands 29-33 which are bedded into an insulating sleeve 13 mounted on the surface of the stem 9. The stem is provided with an internal bore 11 which extends longitudinally through the stem to permit the flow of mud therethrough. The webs 10 adjacent to the base of the stem 9 form a shoulder 12 which is adapted to receive the lower end of an instrument 14 which may be go-devilled down a drill stem or lowered on a wire line.

During normal drilling operations, the instrument 14 will be removed from the drill stem and the normal flow of drilling mud will pass down through the inside of the drill stem 2 and into the interior of the drill stem section 4, there being provided outside of the receiver assembly 8 the passages 16 to permit the free flow of fluid. The webs 10, supporting the receiver 8, afford only a minimum of resistance to the flow. Thus it will be evident that, during normal drilling operations, the lower portion of drill stem 4, which may constitute the drill collar, mounts the drill bit and provides for an unrestricted flow of drilling mud to the drill bit.

Mounted in the insulating sleeve 6 are the electrodes 22, 24 and 26. These electrodes are in the form of bands or rings and are connected by means of insulated conductors 28, 30 and 32 to the contact bands 29, 31 and 33, respectively, mounted on the stem 9.

The instrument 14 comprises a plurality of sections including an upper section 7 containing photographic recording apparatus, an upper intermediate section 13 containing timing apparatus, shown more particularly in FIGURES 5 and 6, a lower intermediate section 20 containing batteries which serve to supply current, and a lower end 21 which is adapted to engage the receiver assembly 8 and to be positioned thereby. The lower portion of the instrument 14 is in the form of an annular wall 15 in which there are mounted contact points 35, 36 and 37 so spaced as to engage the contact bands 29, 31 and 33, respectively, when the instrument 14 is resting upon the shoulder 12. The contact points 35, 36 and 37 are each provided with a spring 41 or other suitable means in order to insure proper contact between the contact points and their respective contact bands. Connected to the contact points 35, 36 and 37, respectively, are the insulated conductors 28', 30' and 32' which pass upwardly into the instrument.

O rings 17 are mounted on the inside surface of the annular portion 15 of the instrument and are spaced above, below and between the contact points 35, 36 and 37. These O rings serve to clean the mud and other foreign matter from the surface of the contact bands and the stem on which they are mounted as the instrument slides down thereover. The central bore 11 provided through the stem 9 provides for the discharge of mud which would otherwise be trapped within the bore within the annular lower portion of the instrument 14.

The upper cap of the instrument is provided with

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conventional overshot coupling means 15' to which a wire line may be attached for lowering the apparatus into the drill stem or, alternately, after the apparatus is go-devilled into the drill stem, to provide means to be engaged by an overshot device lowered on a wire line if the apparatus is to be withdrawn from the drill stem independently of the withdrawal of the drill stem from the bore hole.

The instrument casing 14, together with the drill stem or wire line, forms a fourth electrode which may serve either as a reference electrode, in which case, it should be remote from electrodes 22, 24 and 26 so as to influence to a minimum degree the readings obtained, or as a current electrode, in fashions referred to herein-after. In FIGURE 4 there is shown the electrical circuit involved including a number of switches which make it possible to use various electrode combinations. A battery 46, which is desirably of a storage type so as to supply relatively heavy currents for long periods without substantial decrease in its terminal potential, is connected through a resistance 45 to a reversing switch, which is indicated diagrammatically at 42-44, this switch being preferably a rotary one, illustrated in greater detail in FIGS. 5 and 6. If switch 41 is thrown to its left-hand position and the double pole, double throw switch 43 is also in its left-hand position, the battery furnishes current through an ammeter 40, the wire 32 and the electrode 26, and may, through the reversing switch 47, be connected to either electrode 22 or 24 to complete the current circuit. If the reversing switch 47 is in such position as to make electrode 22 a current electrode, then 24 becomes a potential electrode connected through galvanometer 38 to the casing, which is indicated at 39 as a ground. This casing is, of course, actually an electrode and with the circuit arrangement just indicated forms a reference datum for the potential. It may be remarked that the galvanometer 38 should be of high resistance relative to other resistances in the circuit so as to draw a minimum of current, since, as the drain of current through the electrode 24 increases, the results would become increasingly uninformative without the application of special corrections based on the known electrical constants of the circuit. The galvanometer 38 is provided with a multiplying resistance 49 which may be so adjusted as to conform with the particular configuration used, since some configurations will require a sensitive galvanometer and others an insensitive one which will not be injured by comparatively heavy currents.

If the reversing switch 47 is thrown to its alternative position, then the electrode 22 becomes the exploratory or potential electrode and electrode 24 becomes a current electrode. Again, the casing acts as the datum electrode.

If the switch 41 is thrown to the right-hand position indicated in FIG. 4 while switch 43 remains in its previous left-hand position, then the instrument casing becomes a current electrode and at the same time becomes the datum of reference for the potential of either electrode 22 or 24, which may be chosen as the exploratory electrode depending upon the position of the switch 47. In this case it is essential that the galvanometer be adequately protected by the multiplying resistance 49.

Still another configuration is obtained by having switch 41 in its left-hand position and switch 43 in its right-hand position. The casing and electrode 26 then become the current electrodes and 22 and 24 become the reference electrodes.

The galvanometer 38 and the ammeter 40 are arranged to be photographed simultaneously by means of a camera, indicated generally at 48, provided with a lens 50 arranged to project images of the instruments upon a motion picture film which is fed through the camera by a motor 58. A suitable arrangement of the instruments is indicated in FIG. 2. The galvanometer 38 and the ammeter 40 may be located as shown. A half-silvered mirror 54

arranged at an angle as indicated permits the galvanometer 38 to be directly photographed and the ammeter 40 to be photographed by reflection so as to produce a superimposed image of the two meters. A timepiece 52 in the form of a watch is photographed simultaneously with the galvanometers at 52'. All of the instruments are illuminated by lamps 56. The camera may be provided either with a shutter, in which case the lamps may be continuously illuminated, or preferably no shutter need be used, the lamps 56 being intermittently illuminated whenever the exposure is to be made, these exposures being made during periods of rest of the film.

It is convenient to superpose the images of the meters 38 and 40 to facilitate reading. For such purpose only one of them need be provided with a scale, the needle of the other one being photographed in such fashion as to appear superimposed upon the scale of the other. The resulting record, for example, may be as indicated in FIG. 3. The scale, the record of which is shown at 39', for example, may be on the galvanometer 38, which may be provided with a needle the image of which is shown at 41'. The needle, pictured at 43', of the ammeter 40 may then be read against said scale. The correlations of these readings will be described hereafter. The galvanometer preferably has a scale of the zero-center type and current reversal, as provided by reversing switch 42—44, is a practical necessity to eliminate electrolytic errors. Meter readings, plus and minus, are averaged to provide a single data unit.

The apparatus is designed to be go-devilled within the drill stem at such a time that the apparatus will come to rest on the receiver 8 at about the time at which it is planned to withdraw the drill stem from the bore hole. After the instrument has come to rest, the drill stem is slowly raised within the bore hole while the recording apparatus produces numerous successive exposures which are made with sufficient frequency to insure that at least two occur while the electrodes are passing through any particular strata as to which information is desired. For this purpose, controlling apparatus indicated in FIGURES 5 and 6 is provided.

This controlling apparatus comprises a motor 62 driving a vertical shaft 64 which, through a worm and wheel arrangement indicated at 66, drives, at a lower rotary speed, a transverse shaft 68 which carries a switch an cam arrangement indicated at 70. Conducting segments 72 and 74, each having an extent slightly less than a semicircle, make electrical engagement with four contact members 76 spaced ninety degrees from each other, as indicated in FIG. 6. By connecting two opposite members 76 to the battery 46 through resistance 45 and the two others to the meter 40 and switch 43 respectively, it will be seen that there is provided the reversing switch mentioned above and indicated diagrammatically at 42—44. An element having cams 78 is arranged to close a switch 82, which is connected in the circuit of lamps 56 so that the lamps are periodically illuminated for a period corresponding to the angular extent of the cams 78. Other cams 80 are provided as indicated to effect closure of a switch 84, which is arranged in the energizing circuit of motor 58 so as to drive the latter intermittently to feed the film to such extent as to cause fresh portions to come in the field of the lens 50 every time the switch 84 is closed. It may be remarked, as indicated in FIG. 6, that the switches 82 and 84 are never closed simultaneously, with the result that exposures are made only when the film is stationary. It may also be noted that the switch 82 is not closed until after electrical connections between contacts 76 have been completed for a short period, so that the instrument needles are at rest when the exposure is made and a sharp image is thereby produced.

A cycle of operation is repeated time after time, and involves successively, movement of the film to locate an unexposed portion in the field of the lens 50, attainment of a particular condition of the reversing switch, for ex-

ample, to make the current electrode 22 positive, a slight delay sufficient to permit the needles of instruments 38 and 40 to reach a stationary condition, and the illumination of the bulbs 56 for a sufficient time to produce an exposure. Thereafter the film is again moved, the polarity of the current electrodes reversed, and another exposure made. Operation of this type of recording apparatus is more fully described in the patent to Charles R. Nichols and Samuel H. Williston, No. 2,428,034, dated September 30, 1947.

As was briefly indicated above in connection with the description of FIG. 4, numerous electrode configurations are possible which will give results of types known in the prior art and various spacings may be employed between the electrodes depending upon the type of information desired and the depth and thickness of strata encountered. The drill bit may in some cases be desirably employed as an electrode by, for example, insulating the drill bit from the drill stem and connecting the wire 32 directly to the drill bit, thus omitting the electrode 26 and substituting the drill bit in its place. While the type of recording apparatus described herein is an example of suitable measuring and recording apparatus, it will be evident that various types of measuring and recording apparatus may be used.

In order to minimize electrolytic effects due to the apparatus itself, it is desirable that the electrodes 22, 24 and 26 should be of similar materials and that the drill stem 2 and the metallic parts should be of the same material. This, of course, from a practical consideration, requires that the electrodes should be of steel. However, different materials may be used if caution is exercised in the interpretation of the results.

In carrying out this process, the recording apparatus is either go-devilled into the drill stem or lowered thereinto by means of a wire line. Upon reaching the receiver in the lower drill stem section, the instrument enters the receiver 8 and is coupled with electrodes 22, 24 and 26 which are a permanent part of the drill stem. After the coupling is accomplished, the beginning of the recording period may be determined at the surface of the earth by means of a watch which is synchronized with the watch 52. By raising the drill stem to various levels within the strata penetrated by the drill bit and by noting the time indicated by the synchronized watch at the surface of the earth, the recordings made at these various levels may be identified after the instrument is recovered. This recovery may be accomplished after the drill stem has been removed from the bore hole if the instrument were go-devilled or by withdrawal of the instrument by a wire line. By thus correlating the instrument readings with the depths at which they were made, it is possible to provide a graphic indication of the variations of the instrument readings with depth.

It will be evident that the apparatus shown in FIGURES 1 and 2 may be modified by the inclusion of the power supply in the form of batteries mounted in the drill stem section 4 of FIGURE 1 instead of in the instrument 14. This arrangement would be desirable in applications wherein the type of instrument employed requires a power supply in excess of that which can be conveniently installed in the instrument 14 which must be lowered or go-devilled through the drill stem. FIGURE 9 shows a portion of the drill stem 140 having mounted on its exterior surface the insulating sleeve 141 within which is mounted electrodes 142, 144 and 146 which are connected by means of the leads 148, 150 and 152, respectively, to recording apparatus such as is shown in FIGURE 4. The batteries 154 in this form of the invention are mounted in the drill stem before the drill stem is lowered into the bore hole and are connected to a recording apparatus, such as 14 in FIGURE 1 through connections such as 35—37 shown in FIGURE 1. In this form of the apparatus the alternate possibilities of using the various electrodes as either potential or current electrodes, as has been described in connection with the

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apparatus of FIGURES 1-6, would obviously be diminished. However, with the various permissible electrode arrangements remaining, it would be still possible to obtain sufficient number of electrode combinations to permit such potential and current measurements as would be practically required.

An alternate form of applicant's invention is shown in FIGURES 7 and 8 which includes an instrument 102 which may be either lowered or go-devilled into a drill stem 103 and which has suspended therefrom an electrode mounting element 104 by means of the cable 105. Attached to the lower end of the drill stem 103 is a drill bit 106 which is provided with a suitable opening 108 through the drill bit to permit the passage of the electrode mounting member 104. The diameter of the bore 103 is, however, substantially less than the diameter of the instrument 102 and thus the lower shoulder 109 of the instrument 102 will come to rest against the edge 110 of the upper interior portion of the drill bit.

The instrument 102 is substantially a duplicate of the instrument described in connection with the FIGURES 1-6 and is provided at its upper end with means, generally indicated at 112, to which a wire line may be attached for lowering the apparatus into the drill stem or, alternately, to provide means to be engaged by an overshot device lowered on a wire line if the apparatus is to be withdrawn from the drill stem independently of the withdrawal of the drill stem from the bore hole.

Attached to the lower portion of the instrument is the cap 114 which carries the disc 115 through which connections are made between wire lines 28, 30 and 32 entering the instrument and the leads passing downwardly through the cable 105 connecting with the electrodes 118, 120 and 122, respectively, mounted in the electrode mounting member 104. The bushing 124 is provided in the lower portion of the cap 114 in order to seal the cable 105 in the cap 114 to prevent tension from being applied to the connections in the disc 116 and to prevent the entrance of bore hole fluids into the interior of cap 114.

In the operation of this form of the invention, the instrument 102, having the electrode mounting member 104 attached to the cable 105 and suspended below the instrument, may be lowered go-devil fashion into the drill stem. Before the instrument reaches the bottom of the drill stem, the drilling is stopped and the drill stem is raised for a sufficient distance above the bottom 126 of the bore hole 128 to permit the electrode mounting element to pass through the bore 103 in the drill bit and to become suspended in the bore hole below the drill bit. It will be evident that, the length of the cable 105 and the length of the electrode mounting means 104 being known, the drill bit may be raised the proper distance above the bottom of the bore hole so that the electrode mounting will be suspended immediately above the bottom of the bore hole.

As recordings are made by the instrument 102 of the conditions existing in the earth formations adjacent to the electrodes 118, 120 and 122, the drill stem may be raised upwardly through the bore hole and a series of indications be thus obtained at a plurality of regions within the bore hole. After recordings have been made at the desired regions within the bore hole, a wire line, such as is shown at 130, may be lowered into the drill stem and the portion 112 of the upper end of the instrument casing may be engaged by an overshot coupling 131 attached to the lower end of the line and the instrument withdrawn from the drill stem and drilling resumed. Alternately, the instrument may be recovered from the bore hole by the removal of the drill stem as may be occasioned, for example, by the necessity of replacing the drill bit.

It will be evident that, if the apparatus is provided with a clock timer in order that relatively long time intervals may be provided between relatively short successive periods of making measurement, the apparatus may be employed to provide a succession of measure-

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ments made during drilling and thus avoid the necessity of raising the drill stem after a period of drilling has been completed in order to obtain measurements relating to strata penetrated by the drill bit. A suitable clock timer arranged to provide for intermittent operation of recording means, such as described above, is disclosed in the patent to G. L. Kothny No. 2,012,456, issued August 27, 1935. When the apparatus is employed in this manner, the time intervals between the making of the successive measurements will be such as to permit a desired period of drilling between the making of successive measurements. The measuring intervals are conventionally determined at the surface of the earth by a timer synchronized with the clock timer provided in the instrument and thus the drilling crew will know when to arrest the rotation of the drill stem in order that the apparatus may be stationary during the successive time intervals when recordings are being made. When the apparatus is used in this fashion, it may be go-devilled into the drill stem at any time during drilling and, after the desired measurements have been made, it may be removed from the drill stem by use of conventional overshot apparatus. In this manner, measurements may be made at any time or over a desired extended time without the necessity of removing the drill stem from the bore hole or otherwise materially interrupting the normal drilling operation.

It will be evident that the methods and apparatus disclosed herein provides a simple and practical means for obtaining information as to the strata penetrated by a drill bit without materially interfering with the well drilling operations. While the preferable mode of operation is to go-devil the instrument down into the drill stem immediately before the drill stem is to be removed from the bore hole and the drill bit changed, the possibility of lowering or of go-devilling the instrument at any time and recovering the instrument by a wire line after recordings are made permits obtaining information at any time during the drilling operation without necessitating the removal of the drill stem from the bore hole.

It is further noted that this method provides information relating to the formations traversed by each drill bit either during or immediately following its period of use and thus the time interval between the penetration of any particular strata and the procurement of accurate information relative thereto is only a fraction of the time of removal of a drill bit. It will be evident that this is highly advantageous over those methods in which the drill stem must be removed from the bore hole before well logging measurements can be made.

It will be evident from the foregoing that the advantages disclosed in the beginning of this specification are attained by the use of the methods and apparatus herein disclosed.

What is claimed is:

1. Bore hole logging apparatus comprising a sectional drill stem carrying at its lower end a bit provided with a mud flow passage, a bore hole logging instrument, including a housing, adapted to pass downwardly within the drill stem, means in the lower portion of the drill stem adjacent to the bit for arresting said instrument in predetermined location relative to the bit, and an electrode assembly supported by, and having electrical connections with, said instrument and adapted to pass through said mud flow passage and to occupy a position below the bit when said instrument is in said predetermined location, so that said electrode assembly is exposed to the earth formations below the bit, said instrument including means within its housing for supplying current to said electrode assembly and means within its housing connected to said electrode assembly for measuring and recording quantitatively over an extended period of time electrical conditions of earth formations at various depths in the vicinity of said electrode assembly during movements of said drill stem, said measuring and recording means operating independently of any connection to the surface.

2. Bore hole logging apparatus according to claim 1

in which said instrument also includes means for recording time concurrently with the recording of said electrical conditions.

3. The method of logging a bore hole while there is within the hole a sectional drill stem carrying at its lower end a bit provided with a mud flow passage comprising dropping freely through the drill stem a bore hole logging instrument, including a housing, and an electrode assembly supported by said instrument below the same and having electrical connection with said instrument, said instrument including means within its housing for supplying current to said electrode assembly and means within its housing connected to said electrode assembly for measuring and recording quantitatively over an extended period of time electrical conditions of earth formations in the vicinity of said electrode assembly, said dropping of the instrument and electrode assembly effecting passage of the electrode assembly through said mud flow passage and arrest of the instrument to locate the electrode assembly at a predetermined position below and relative to the bit, so that said electrode assembly is exposed to the earth formations below the bit, moving the drill stem lengthwise of the hole to cause said electrode assembly to traverse earth formations while said measuring and recording means operate independently of any connection

to the surface to measure and record said electrical conditions at various depths, and thereafter recovering said instrument from the hole.

4. The method according to claim 3 in which the recovery of said instrument is effected by lowering a line to said instrument, effecting coupling therewith, and removing said instrument by withdrawal of said line.

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