Nov. 26, 1946. D. SILVERMAN ET AL 2,411,696

WELL SIGNALING SYSTEM

Filed April 26, 1944 2 Sheets-Sheet 1

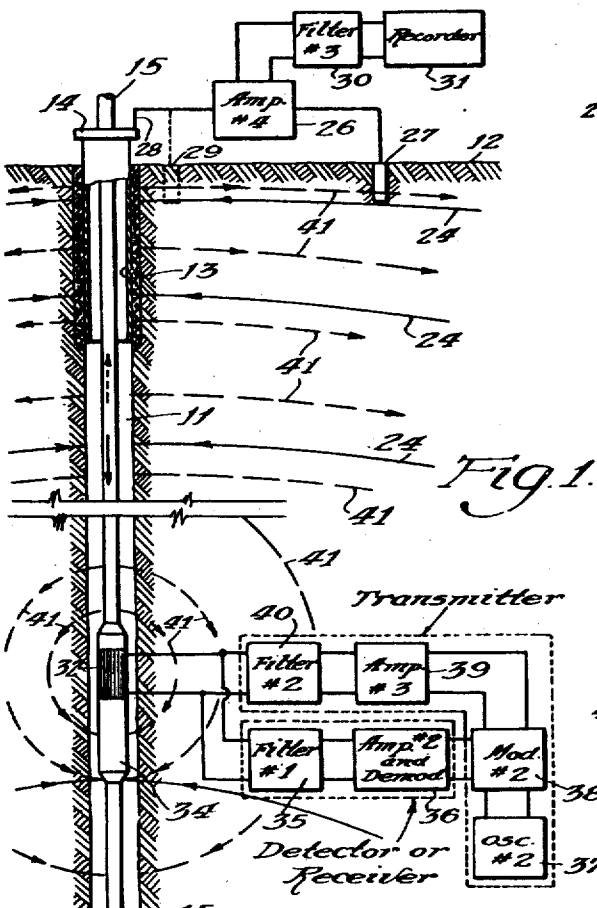


Fig. 1.

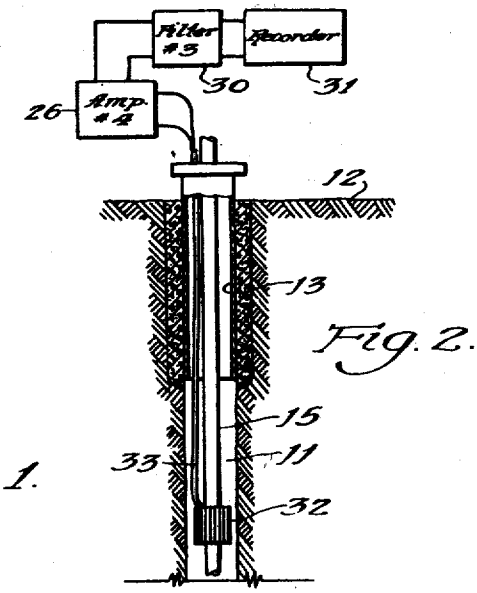
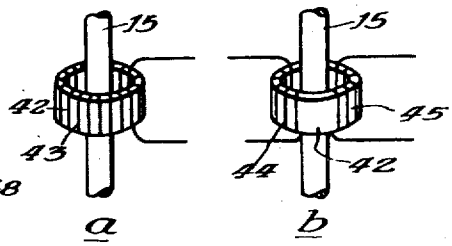
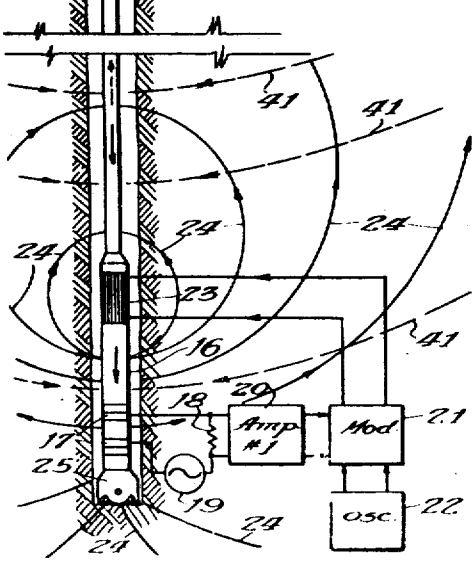


Fig. 2.



a b

Fig. 3.



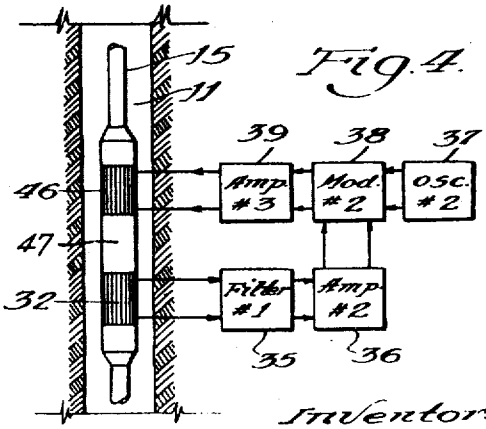


Fig. 4.

Inventors:
Daniel Silverman
Thomas Gilmartin
By: Paul F Hawley
Patent Agent

Nov. 26, 1946. D. SILVERMAN ET AL 2,411,696

WELL SIGNALING SYSTEM

Filed April 26, 1944 2 Sheets-Sheet 2

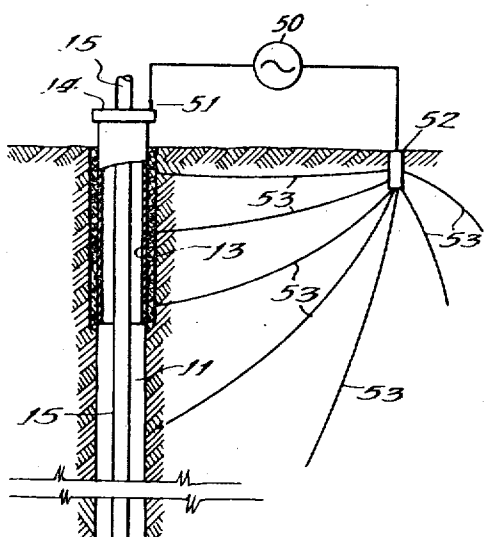


Fig. 6.

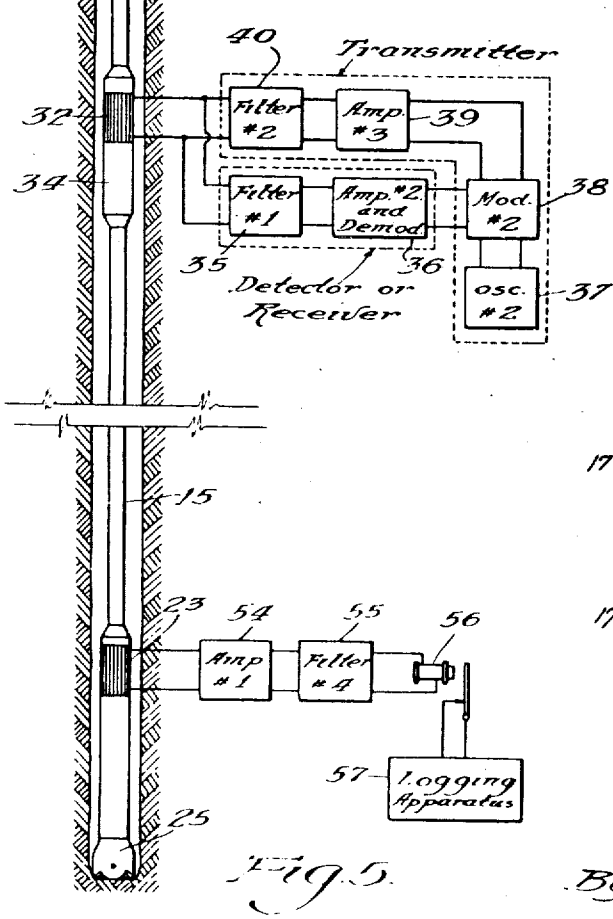


Fig. 5.

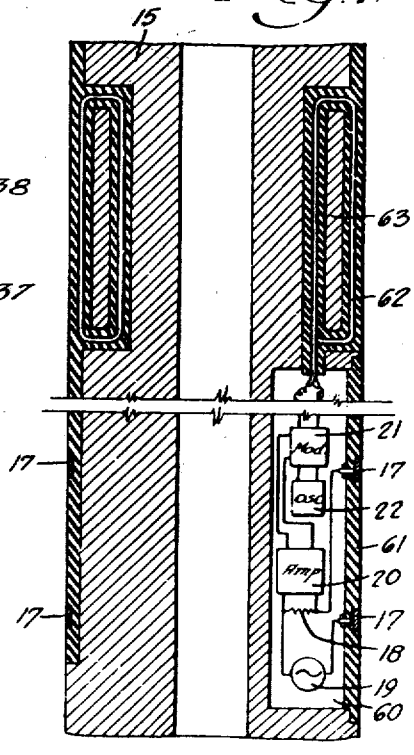


Fig. 7.

Inventors:
Daniel Silverman
Thomas Gilmartin
By Paul H Hawley
Patent Agent

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UNITED STATES PATENT OFFICE

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WELL SIGNALING SYSTEM

Daniel Silverman and Thomas Gilmartin, Tulsa, Okla., assignors to Stanolind Oil and Gas Company, Tulsa, Okla., a corporation of Delaware

Application April 26, 1944, Serial No. 532,756

15 Claims. (Cl. 177—352)

1

This invention relates to the art of well signaling and more particularly finds very useful application in well logging.

In a prior United States Patent 2,354,887, dated August 1, 1944, of Daniel Silverman and Robert E. Fearon, it has been pointed out that it is possible to signal in a well by making use of a single uninsulated conductor which extends into the well from the top to a point at or near the bottom thereof by employing the conductor as part of a single electric circuit, the electric signals flowing through the conductor in one direction and back through the conducting fluids in the well and the earth formations immediately adjacent the well, in the other direction. While other investigators had attempted to utilize this system, they had all found it necessary to employ in some fashion or another an insulated section along the drill pipe, across which the electromotive force acted, whereas in the application referred to it is pointed out that by the use of the so-called toroidal transformer (that is, a core of magnetic material surrounding the conductor, the core being wrapped with a coil of wire), it is possible either to transmit or receive along the well conductor without the need of such an insulated section.

Signaling in accordance with that application might be carried out either from the surface of the earth down to responsive apparatus located adjacent the toroidal transformer near the drill bit, or in the well logging type of signaling system, the well logging impulses at the bottom of the well could be applied to the coils of the toroidal transformer, with the signal being picked up between two insulated electrodes or spaced points near the surface of the earth, one of which was adjacent the upper portion of the conductor and the other one of which was grounded and located at a greater distance from the axis of the conductor than the first-named point.

This application constitutes an improvement over that prior application, permitting a greater signal intensity to be obtained at greater depths of well than is possible in that system.

Basically two toroidal transformers are used, both of them being disposed within the well but spaced at considerable distances apart. One of the coils on one toroidal transformer is connected to a source of pulsating signals which may, for example, be a source of alternating current, varying direct current, or the like. The other of these transformers is connected to a detector of pulsating electric signals, which may and frequently does include a filter, an amplifier, and if the

2

original source of signals was a modulated source, a demodulator, in order to obtain a signal proportional to that which modulated the waves applied to the first transformer. With this arrangement, it is possible to increase greatly the signal-to-noise ratio over that possible with the signaling system outlined in United States Patent 2,354,887. This results from the fact that neither of the two toroidal transformers is disposed adjacent the surface of the earth, the shallower of the two being disposed at least 50 feet from the surface of the earth and preferably disposed at a distance of some hundreds or thousands of feet from the surface. This means that since the amount of current flowing through the conductor at the point where toroidal transformer surrounds it depends considerably upon the resistance of the section of the conductor between that point and the nearer terminals of the conductor, that by so disposing the two transformers it is possible to get a great deal better coupling between them and hence greatly increase the signal strength. On the other hand, the amount of noise picked up is not under any circumstances any greater than that described in the former system and quite often it is less due to the small gathering area for extraneous currents, so that the resultant effect is a great improvement in clarity and strength of received signals.

It is also possible to improve this signal-to-noise ratio still more by using the second toroidal transformer as at least part of an electromagnetic coupling element for a repeater station which is placed at a point in the well intermediate the signaling and ultimate receiving sources to pick up the transmitted signal, amplify it, and retransmit it on a different frequency band, so that the received signal at the second frequency is of a great deal higher intensity due to the shorter path for attenuation.

It is accordingly an object of this invention to provide a well signaling system for use in connection with an uninsulated conductor extending into a well. This uninsulated conductor can be, for example, a string of drill pipe. It is a further object of this invention to provide an improved well signaling or logging system in which the original electric signals are produced in a region adjacent the drill bit, electromagnetically coupled to the drill pipe by means of which a relatively intense current flows along the drill pipe and back through the earth's circuits so that it is possible to couple inductively a detecting system to the pipe at some distance from the surface of the earth and produce a signal substantially

duplicating the original logging signal therein.

Another object of this invention is to provide a so-called repeater station in a logging or signaling system utilizing a drill bit as one conducting path for the signals, by means of which the original signals are detected at an intermediate point and retransmitted on a different frequency band so that stronger signals are eventually picked up than could otherwise be obtained. Other objects and advantages of the invention are shown in this specification.

A series of drawings is attached hereto and made a part hereof in order to explain more easily the elements of the invention. It is not to be considered, however, that the invention is limited to the embodiments shown and described, for they are but a few of the possible embodiments which can be constructed in accordance with the invention itself.

Figure 1 shows in diagrammatic form a cross-section of the earth including a well, together with the apparatus for one desired embodiment of this invention.

Figure 2 shows an alternate receiving means to that given in the logging system shown in Figure 1.

Figure 3 illustrates in diagrammatic form two variations of the toroidal transformer coupling system.

Figure 4 illustrates a second form of repeater station useful in the signaling system.

Figure 5 illustrates a second embodiment of the invention, in which signals are applied at the surface of the earth for transmitting to a point adjacent the bit and controlling apparatus located at that point.

Figure 6 illustrates an alternative method of connecting the original transmitting system shown in Figure 5 to the conductor or drill pipe extending into the well.

Figure 7 illustrates one form of toroidal transformer and associated apparatus as disposed within the drill pipe.

Referring now to Figure 1, a well 11 is shown penetrating the earth to some distance from the surface 12 thereof. Conventionally the uppermost part of this well has been cemented with a section of casing 13 terminating in a well head 14. A string of drill pipe 15 is shown lowered into the well in order to drill it deeper, in accordance with the customary rotary drilling practice. The usual derrick and mud circulation system, etc., are not shown. It is assumed in the following discussion that at least the major part, and preferably all of the well, is filled with a conducting material such as drill mud, so that there is electrical contact between the conducting drill pipe 15 and the earth itself. In the lower end of the drill string is a section 16 of increased diameter, which is called the drill collar. This section serves to apply weight to the drill bit and to stiffen the lower section of the drill pipe so that a straighter hole may be bored. The walls of this section of drill pipe are normally quite thick compared to that of the balance of the drill pipe. A section of the wall of the drill collar has been hollowed out, as will be shown in greater detail in Figure 7, and a large part of the well logging apparatus about to be described is located therein.

This apparatus consists of a pair of electrodes 17 which are connected through a resistance 18 to the output of an oscillator 19. The electrodes 17 are suitably insulated from contact with the drill collar itself as is shown in Figure 7. The

drop across resistance 18 is therefore inversely proportional to the resistance between the two electrodes 17, which is largely a function of the resistivity of the adjacent formations. Therefore the drop across resistance 18 indicates at least one characteristic of the adjacent formations which have been freshly uncovered by the drill bit. This signal is preferably amplified by an amplifier 20 which is also enclosed within the space within the drill collar and applied to a modulator or modulated amplifier 21 which is furnished with an oscillator 22. This system constitutes a means for producing pulsating electromotive force (which is usually an amplitude modulated wave), the amplitude of which depends upon the resistance between electrodes 17. However, it is well within the scope of those skilled in the art to substitute a frequency modulated transmitter for the amplitude transmitter shown and we contemplate in some cases employing this system of producing the pulsating electromotive force. The output of the modulator 21 is applied across the terminals of a coil of the toroidal transformer 23. This toroidal transformer was described in United States Patent 2,354,887 in great detail, to which reference is made. It consists of a core of magnetic material which may, for example, be silicon steel laminated sheets or other easily magnetizable material, preferably is in the form of a ring or toroid, which surrounds the conductor or drill pipe, and which is wound with one or more coils of insulated wire. Such a toroidal transformer is shown diagrammatically in Figure 3*a*. However, as shown in Figure 7, normally the outside surface of the toroidal transformer including insulation is flush with the outside surface of the conductor, which is accomplished by grooving the drill pipe or drill collar at this point so that the toroidal transformer can fit into this groove. This prevents attrition of the transformer by the passing drill mud.

It is immediately apparent that the application of a pulsating electromotive force across the terminals of the coil of the toroidal transformer 23 produces a pulsating magnetic field in the core of this transformer, which in turn generates a difference of potential between the part of the conductor above the transformer and that below it. This causes currents to flow in one direction (as shown by the solid arrows) through the conductor or drill pipe, and in the other direction through the conducting fluid in the well and the earth formations adjacent the well, along paths such as paths 24.

The toroidal transformer 23 is located at a considerable distance above the drill bit 25. This distance may be, for example, of the order of from 60 to 600 feet or more. Such distances are, of course, short compared to the total length of the drill pipe and hence the toroidal transformer can be said to be near the lower end of the drill string or conductor 15. The object in having a considerable separation between the drill bit and the toroidal transformer is to lower the impedance of the earth signaling circuit. All of the current which passes through the conductor and out along paths 24 through the earth must pass through a relatively small cross-sectional contact area between conductor and well, and accordingly the contact resistance, or resistance to flow from the drill pipe to a region a few inches into the formation, is considerably greater below the toroidal transformer than above it. The greater the distance between the toroidal transformer

and the drill bit, the greater is the total effective area through which current can flow from conductor to formation or vice versa, below the toroidal transformer, and the greater is the total earth current which will flow for a given applied electromotive force across the terminals of the coil of toroidal transformer 23.

The system so far described constitutes per se no invention over that disclosed in the prior United States Patent 2,354,887. It has been found that by using this apparatus, it is possible to cause the flow of enough current adjacent the surface of the earth to permit signals to be obtained with the desired distinctness when the drill bit is of the order of 2000 to 4000 feet below the surface. It has been found that relatively low frequencies for the oscillator 22 are more desirable than relatively high frequencies. Tests have been made from 2400 cycles down to approximately 20 cycles which indicate a decrease in attenuation of the signal current flow through the earth as the frequency decreases throughout this entire range. Using a frequency of 20 cycles per second, tests in a well with earth resistivities of the order of 2 ohm-meters showed satisfactory signaling with reliability from depths up to 4000 feet.

The apparatus used in these tests for detecting the signal at the surface of the earth is substantially that shown in Figure 1. Here an amplifier 26 or detector of pulsating electric signals is connected between two spaced points, one of which is adjacent the upper portion of said conductor 15 and the other one of which is grounded at a point 27 located at a greater distance from the axis of the conductor 15 than the first-mentioned point. This first-mentioned point may, for example, consist of a clip 28 connected on to the string of casing or (as shown by the dotted lines in this figure) the clip may be dispensed with and the first point may be in turn grounded at an electrode 29 located fairly close to the well head 14.

With the signaling system thus far described, the drop of potential adjacent the well head is due to the flow of the top filamentary currents along paths 24. Obviously the resistance to flow along these paths goes up as the toriodal transformer 23 moves farther away from the surface of the ground. Eventually the undesirable signals produced by natural earth currents or by other disturbances between the grounded electrodes produce enough electric noise in the amplifier 26 so that an undesired background intensity is produced. This can be obviated somewhat by applying a filter 30 to the output of the amplifier or contactor 26, this filter being adapted to pass currents of the frequency of oscillator 22. These signals are then demodulated and indicated by indicator 31 which preferably is in the form of a recording meter.

As the toroidal transformer 23 progresses farther down the well, the signals become weaker until eventually it is impossible to successfully detect them at the surface of the ground with the apparatus shown in Figure 1. In that case, we have found that two general alternatives are available, one illustrated by Figure 1 and the other illustrated by Figure 2. A repeater station may be installed in the drill pipe itself a suitable distance from the toroidal transformer 23, which detects the signals sent out therefrom, amplifies and demodulates these signals, and modulates a transmitter located at the repeater station which in turn applies a pulsating electromotive force at a different frequency range from that due to the modulator 21 upon a toroidal transformer located in the well, thus producing signals of considerably increased intensity at the ultimate receiving station. This system will be described in greater particularity below. As an alternative, a second toroidal transformer can be employed as shown in Figure 2. This toroidal transformer 32 may be lowered down into the well on the end of a two-conductor cable 33 to a substantial depth below the surface. This is connected to a detector of pulsating electric signals which, as shown in Figure 2, can consist of an amplifier 26, filter 30 and demodulator and indicator or recorder 31. By the use of a large number of turns on the coil of the toroidal transformer 32, a relatively high impedance secondary winding is obtained so that the output voltage is fairly high. This toroidal transformer 32 detects the entire amount of current passing through the earth due to the action of the source of pulsating E. M. F. at the bottom of the well which flows to the drill pipe 15 above the level of the transformer 32. The relative effectiveness of this method of detection of the earth current is dependent upon the distance below the surface of the ground at which the transformer is placed. The greater this distance, the more current is intercepted and the greater is the output of the transformer 32. Of course, if the surface casing 13 extends into the well for a great distance, the problem of supplying a suitable cable 33 and the difficulty of keeping the toroidal transformer 32 from revolving with the drill pipe 15 increases and such a system, therefore, no longer becomes practical when this depth is too great. However, distances of the order of several hundred feet are entirely practical.

The repeater station signaling system is shown in Figure 1. An enlarged section of drill pipe 34 in the drill string 15 is supplied with a second toroidal transformer 32. This transformer, therefore, picks up a pulsating electric signal due to the output of modulator 21, and proportional in amplitude to the amount of current flowing through the earth to the drill string 15 above transformer 32. The winding of transformer 32 is connected to a first filter 35 tuned to the frequency band sent out by modulator 21. The output of this filter 35 is applied to an amplifier and demodulator 36 of conventional construction, which therefore produces an output varying in accordance with the voltage variations across resistor 18. This signal and that from a second oscillator 37 are applied to a second modulator or modulated amplifier 38. The frequency of oscillator 37 is chosen to be considerably different from that of oscillator 22, in order that subsequent filtering operations at the ultimate receiving station may be simplified, and in order that the detection system employed at this repeater station (comprising filter 35 and amplifier and demodulator 36) may be substantially unresponsive to the output of the repeater station transmitter. The output of this modulator 38 may be amplified further if desired by an amplifier 39 (which may be omitted if the output of the modulator is at a satisfactory volume) and passed through a second filter 40, the output of which comprises the output of the whole transmitting system made up of units 37 to 40 inclusive. This is applied in Figure 1 across the terminals of the toroidal transformer 32 as an electromagnetic coupling system to conductor 15.

The second filter 40 serves to isolate the output of the transmitter from the incoming signals

going to the detector unit. There is normally a band-pass filter tuned to the frequency range of the second modulator 38. There is a wide range of frequencies which can be employed for this second oscillator. Any such frequencies should differ from the band put out by modulator 21 and preferably should be in the low audio range, that is, 10,000 cycles or below. Thus, for example, if oscillator 22 is at a constant frequency of 20 cycles per second, the second oscillator 37 could be, for example, at a frequency of the order of 70 to 100 cycles per second. The output of the transmitter applied to the toroidal transformer 32 causes currents at transmitter frequency to flow through the earth along paths some of which are indicated as dotted lines 41. Since the toroidal transformer 32 is located intermediate the ends of the drill string 15, it is apparent that even for an equal intensity of output of the modulator 21 and the transmitter output through filter 40, the signals from the latter unit must be of a greatly increased intensity at the surface due to two factors; one, the lower contact resistance between the section of the drill pipe below the second toroidal transformer 32, as compared with the relatively high contact resistance in the section of drill collar below the first toroidal transformer 23, and the decrease in distance between the toroidal transformer 32 and the surface of the earth as compared with that from the surface to toroidal transformer 23. Thus, for example, with the second toroidal transformer placed, say of the order of 2000 to 4000 feet below the surface of the ground, it is not difficult to signal with a separation between the two transformers of the order of 6000 to 8000 feet so that the total depth of the well could be of the order of 8000 to 12,000 feet. Of course, it is possible to lower the upper toroidal transformer further into the earth than the example given.

It is to be observed here, as in the case of the apparatus shown in Figure 2, that the second toroidal transformer was used with a detector or receiver, but whereas in the apparatus shown in Figure 2 this is the ultimate detector, in the apparatus shown in Figure 1 this detector modulates a second transmitter which again sets up earth currents, which in turn actuate the detector connected at the ultimate receiving station.

Toroidal transformers 23 and 32 must contain the magnetic core 42 and at least one coil 43, as shown in Figure 3*a*. However, if desired, two coils with the same or a different number of turns can be wrapped around the core for use with the repeater station shown in Figure 1. Thus, in Figure 3*b*, the core 42 is shown wrapped with a first coil 44 and a second coil 45, one of which may be connected to the input to the first filter 35 and the other of which can be connected to the output of the second filter 40. A third alternative connection from conductor 15 to the repeater station is shown in Figure 4, in which two toroidal transformers 32 and 46 are employed on the drill pipe section 47. The output of the toroidal transformer 32 is connected to the first filter 35 of the detector or receiver of the repeater station. The output of the amplifier 39 is shown connected to the coil of the second toroidal transformer 46. In this illustration the second filter 40 has been eliminated. As was stated above, this is possible under some circumstances, i. e. if the feed back from the transformer 46 to the amplifier 38 causes no appreciable difficulties. If this is not the case, the second filter 40 would be interposed between the coil of transformer 46 and the amplifier 38.

It is to be appreciated that the signaling system which has been described can be equally well used to transmit signals originating at the surface of the earth, to points within the well. Thus, for example, the apparatus shown in Figure 5 can be employed to actuate equipment at the repeater station which in turn will actuate apparatus at the lower end of the drill string 15. A source of pulsating electromotive force 50 or other source of pulsating electric signals (preferably but not necessarily alternating current), is applied to the well system in such a way as to cause the pulsating currents to flow along the drill pipe. This may be done as shown in Figure 5 by connecting this source 50 between an electrode 51 at the well head and a second electrode 52 disposed at a considerable distance from the axis of conductor 15, for example of the order of several hundred feet. This causes pulsating current to flow through the earth, for example along paths such as paths 53. By placing the electrode 52 at a considerable distance from the well head, a very appreciable part of the current flowing between these electrodes passes to the conductor or drill pipe 15 at a point below the toroidal transformer 32 and will cause a corresponding voltage to be generated in the coils of this toroidal transformer. This voltage is impressed across the first filter 35 in the repeater station. The output of this first filter is amplified by the amplifier 36 which may, if desired, contain a demodulator if the source 50 is modulated, and the output is impressed on the modulator 38 which is also supplied with the output of oscillator 37. The output of the modulator 37 may, if desired, be further amplified by amplifier 39 and then passes through the second filter 40 tuned to the frequency band of the output of the modulator 38. The output from the second filter 40 is applied by inductive coupling to the conductor or drill pipe 15 either by connecting this output to the same coil of the toroidal transformer 32, as shown in Figure 5, or by applying it to a separate coil of this transformer, as shown in Figure 3*b*, or by applying it to a separate toroidal transformer as shown in Figure 4. In each of these cases, a set of signals in a different frequency band from those of the source 50 is produced which flow along the conductor 15 in one direction and back through the earth in the other direction, as already described in connection with Figure 1. The paths of current flow are omitted from Figure 5. An appreciable amount of this current flows through the second toroidal transformer 23 which surrounds the conductor 15 near the lower end thereof. This produces electromagnetically a voltage in the coil of this transformer corresponding to the output of the modulator 38. This signal is preferably amplified by an amplifier 54 which may, if desired, contain a demodulator. The output of this amplifier passes through a filter 55 and is then applied to actuate some apparatus located near the lower end of the drill string or conductor 15. The apparatus shown in Figure 5 consists of a relay 56, the coil of which is actuated by the output of the filter 55 and which serves in turn to close the relay contacts, thus actuating some type of electrical logging apparatus 57. As such logging apparatus has already been frequently described in the art, and as the equipment shown can be used to actuate any such type of apparatus requiring a switching circuit, no specific apparatus is described. It is seen that the apparatus located

near the drill bit consists of a toroidal transformer and a detector of pulsating electric signals and that the repeater station connected to the toroidal transformer 32 merely serves to detect the signals due to source 50 and to retransmit a set of pulsating electric signals in accordance with the waves received at the toroidal transformer 32, so that the detecting means at the bottom of the well responds to the output of the transmitter in the repeater station as it applies the pulsating electric signals to the conductor 15.

Instead of using the electrodes 51 and 52 in connection with the source 50, it is possible and in numerous cases highly desirable to apply this source 50 across the terminals of a toroidal transformer such as shown in Figure 6. In this drawing the toroidal transformer 58 has been lowered into the well to a considerable distance below the surface, which distance may, for example, be of the order of several hundred feet. This transformer surrounds the conductor or drill pipe 15 and therefore induces into this drill pipe and the surrounding earth pulsating electric signals due to source 50, which flow in part along the conductor and which actuate the toroidal transformer 32. As shown in Figure 5, the toroidal transformer 58 is connected to the source 50 by means of a two-conductor cable 59. Of course, if the toroidal transformer 23 is at a relatively shallow depth, i. e. of the order of a few thousand feet or less, the repeater station may be dispensed with, if desired, and the actuating apparatus shown in Figure 6 in that case energizes the toroidal transformer 23 directly.

One physical arrangement of the apparatus at a toroidal transformer station is shown in greater detail in Figure 7, the particular apparatus illustrated being that enclosed within the enlarged section of drill pipe above the bit 25. As shown in Figure 7, there is a slot or hollow portion 60 cut in the enlarged drill pipe or drill collar, in which is placed the resistor 18, the oscillator 19, amplifier 20, modulator or modulated amplifier 21, and oscillator 22. This slot or hollow portion 60 is closed by an insulating member 61 and, if desired, the region within this member may be filled with an insulating compound such as heavy oil in order better to withstand the pressure when the apparatus is in the well. The electrodes 17 are shown in the form of metal bands which are let into the surface of the insulating member 61 at a substantial distance from either end thereof so that the presence of the metal conductor 15 does not substantially affect the impedance between these electrodes. The electrodes are connected to the oscillator 19 and resistor 18 by means of leads which are also connected to the rings 17. The output of the modulator 21 is applied to the coil of insulated wire 62 which is wound around the toroidal core 63 which in turn surrounds the conductor 15. The toroidal core and coil arrangement are insulated by suitable insulation, which may form a part of the insulated member 61 or may be separate from it, so that well fluids may not penetrate into and short-circuit the coil 62. As previously mentioned, it is desirable that any such apparatus be let into the surface of the conductor 15 so that the outer surface thereof is smooth and of the same outside diameter as that of the balance of the section in which it is placed. The same type of apparatus shown in Figure 7 may be, and preferably is, employed in connection with the repeater station, it merely being necessary to have a larger hollow chamber to contain the increased amount of apparatus which is enclosed within the walls of the drill pipe section 34.

In general it is seen that all of the signaling and logging apparatus described contains at least two toroidal transformers, which are spaced a substantial distance apart. One of these transformers is in each case connected to a means for producing a pulsating electromotive force and the other is connected to means for detecting pulsating electric signals. In all cases the toroidal transformers are inductively coupled to the uninsulated conductor which extends into the well and which makes electric connection with the formations forming the walls thereof.

We claim:

1. A well signaling system including an uninsulated conductor extending into said well, a first core of magnetic material surrounding said conductor near the lower end thereof, a first coil of insulated wire coupling said core, a second core of magnetic material surrounding said conductor, located a substantial distance from the surface, and spaced a substantial distance from said first core, a second coil of insulated wire wound around said second core, and two separate means, one for producing pulsating electromotive signals, and the other for detecting substantially only said pulsating electric signals, one of said two separate means being connected to said first coil and the other of said two means being connected to said second coil.

2. A repeater section for signaling along a well into which extends an uninsulated conductor in which pulsating electric signals flow, including a receiver for said signals, a transmitter of signals at a different frequency band than those of said pulsating signals, said transmitter being modulated by the output of said receiver, and said receiver being so constructed and designed that it is insensitive to signals from said transmitter, and means for inductively coupling to said conductor both the input to said receiver and the output from said transmitter, said means including at least one core of magnetic material surrounding said conductor, and at least one coil of wire wound around said at least one core and connected to the input of said receiver.

3. A repeater section for signaling along a well into which extends an uninsulated conductor in which pulsating electric signals flow, including a receiver for said signals, a transmitter of signals at a different frequency band than those of said pulsating signals, said transmitter being modulated by the output of said receiver, and said receiver being so constructed and designed that it is insensitive to signals from said transmitter, and means for inductively coupling to said conductor both the input to said receiver and the output from said transmitter, said means including a core of magnetic material surrounding said conductor, a coil of wire wound around said core, and means for connecting said coil to the input of said receiver and the output of said transmitter.

4. A repeater section for signaling along a well into which extends an uninsulated conductor in which pulsating electric signals flow, including a receiver for said signals, a transmitter of signals at a different frequency band than those of said pulsating signals, said transmitter being modulated by the output of said receiver, and said receiver being so constructed and designed that it is insensitive to signals from said transmitter, and means for inductively coupling to said conductor both the input to said receiver and the output from said transmitter, said means including

a core of magnetic material surrounding said conductor, two coils of wire wound around said core, and means for connecting one of said coils to the input of said receiver and for connecting the other of said coils to the output of said transmitter.

5. A repeater section for signaling along a well into which extends an uninsulated conductor in which pulsating electric signals flow, including a receiver for said signals, a transmitter of signals at a different frequency band than those of said pulsating signals, said transmitter being modulated by the output of said receiver, and said receiver being so constructed and designed that it is insensitive to signals from said transmitter, and means for inductively coupling to said conductor both the input to said receiver and the output from said transmitter, said means including a first and a second core of magnetic material surrounding said conductor, two coils of wire each of which is wound around only one of said two cores, and means for connecting one of said two coils to the input of said receiver and for connecting the other of said coils to the output of said transmitter.

6. A repeater section for signaling along a well into which extends an uninsulated string of drill pipe including means for causing modulated alternating currents at a predetermined frequency band to flow along said drill pipe, a receiver for said modulated currents including a demodulator for said currents, a transmitter of modulated signals at a different frequency band than that of said currents, said transmitter being modulated by the demodulated output of said receiver, and said receiver being selectively tuned to said frequency band of said currents, whereby it is substantially insensitive to the output of said transmitter, means for inductively coupling to said drill pipe, both the input to said receiver and the output from said transmitter, said means including at least one core of magnetic material surrounding said drill pipe, and at least one coil of wire wound around said at least one core and connected to the input of said receiver, said receiver and said transmitter being disposed within the walls of said drill pipe and intermediate the ends of said string of drill pipe.

7. Apparatus according to claim 6 in which said receiver contains a filter tuned to said frequency band of said currents and sharply discriminating against signals of the frequency band of said transmitter and in which said transmitter includes a filter tuned to the frequency band of said transmitter and sharply discriminating against signals of the frequency band of said currents.

8. Well signaling apparatus including an uninsulated conductor extending into said well, a first core of magnetic material surrounding said conductor near the lower end thereof, a first coil of insulated wire coupling said core, two electrodes at the surface of the earth grounded at different radial distances from the axis of said conductor, two means, one for producing a pulsating electromotive force, and one for detecting pulsating electric signals, one of said two means being connected across said coil and the other of said two means being connected between said two electrodes, and means electromagnetically coupled to said conductor intermediate the ends thereof for receiving electric waves flowing along said conductor due to said producing means, and for applying to said conductor pulsating electric signals in accordance with said received waves, whereby

said detecting means responds to the output of said applying means.

9. Well logging apparatus including an uninsulated conductor extending into said well, means for producing pulsating signals flowing through a circuit including said conductor and the earth in the region surrounding said well, means for measuring a characteristic of the formations adjacent the lower end of said well, means responsive to said measuring means for modulating the output of said producing means, a receiver for said signals, a transmitter of signals at a different frequency band than those of said pulsating signals, said transmitter being modulated by the output of said receiver, and said receiver being so constructed and designed that it is insensitive to signals from said transmitter, means for inductively coupling to said conductor both the input to said receiver and the output from said transmitter, said means including at least one core of magnetic material surrounding said conductor, and at least one coil of wire wound around said at least one core and connected to the input of said receiver, said inductive coupling means being located intermediate the upper and lower ends of said conductor, a second receiver selectively responsive to the output of said transmitter, said second reeciver being located at the surface of the earth and adapted to produce an indication proportional to the modulation of the received signals, and means located near the surface of the earth and adjacent the head of said well for detecting the flow of current through the earth due to said transmitter, said detecting means being connected to the input of said second receiver.

10. Well signaling apparatus including an uninsulated conductor extending into said well, a first core of magnetic material surrounding said conductor near the lower end thereof, a first coil of insulated wire coupling said core, a second core of magnetic material surrounding said conductor located a substantial distance from the surface and spaced a substantial distance along said conductor from said first core, a second coil of insulated wire coupling said second core, a source of alternating current connected to said second coil, and a detector for alternating current signals the input to which is connected to said first coil.

11. A method of logging a characteristic of earth formations penetrated by a rotary drill in the course of drilling a well including the steps of measuring said characteristic while said drilling progresses at a region near the lower end of said drill, whereby contamination of said formations by drilling fluid is largely eliminated, producing pulsating electric signals varying in accordance with the magnitude of said measured characteristic, causing said signals to flow through a circuit including the drill string of said rotary drill in one direction and the surrounding earth formations in the opposite direction, detecting said signals at a point intermediate the ends of said drill string, producing a second set of signals a characteristic of which varies in accordance with the variation in said detected signals, causing said second set of signals to flow through a circuit including the drill string of said rotary drill in one direction and the surrounding earth formations in the opposite direction, detecting said second set of signals at the surface of the earth adjacent the head of said well, and producing a visual indication responsive to said detected second set of signals varying in amplitude with the variation

in said characteristic of said second set of signals.

12. A system for transmitting a set of signals throughout the length of a deep well comprising means at one end of said well for transmitting a set of electric signals through the earth formations surrounding the well, means for receiving said signals at a point intermediate the ends of said well, means for producing a second set of signals corresponding to said first set of signals but which do not interfere therewith, said receiving means serving as the means for transmitting said second set of signals through the earth formations surrounding the well, and means at the other end of said well for receiving and detecting said second set of signals.

13. A method of logging a characteristic of the earth formations penetrated by a rotary drill in the course of drilling a well including the steps of measuring said characteristic while said drilling progresses at a region near the lower end of said drill, whereby contamination of said formations by a treating fluid is largely eliminated, producing electric signals varying in accordance with the magnitude of said measured characteristic, causing said signals to flow through the earth formations surrounding the well, detecting said signals at a point intermediate the ends of said well, producing a second set of signals, a characteristic of which varies in accordance with the variation in said detected signals, causing said second set of signals to flow through the earth formations surrounding the well, detecting said second set of signals at the surface of the earth adjacent the head of said well and producing a visual indication responsive to said detected second set of signals.

14. A method of logging a characteristic of the earth formations penetrated by a rotary drill

in the course of drilling a well including the steps of measuring said characteristic while said drilling progresses at a region near the lower end of said drill whereby contamination of said formations by a treating fluid is largely eliminated, producing electric signals varying in accordance with the magnitude of said measured characteristic, causing said signals to flow through the earth formations surrounding the well, detecting said signals at a point intermediate the ends of said well, producing a second set of signals, a characteristic of which varies in accordance with the variation in said detected signals, transmitting said second set of signals from the point at which said first set of signals are detected so that said second set of signals flows through the earth formations surrounding said well, detecting said second set of signals at the surface of the earth adjacent the head of said well, and producing a visual indication responsive to said detected second set of signals.

15. A system for transmitting signals through the length of a deep well comprising means at one end of said well for transmitting through the earth formations surrounding the well a set of electric signals having difinite characteristics, at least one repeater station located intermediate the ends of said well, said repeater station comprising means for receiving similarly characterized signals transmitted through the earth formations and for transmitting through the earth formations a set of signals corresponding to said received signals but which do not interfere therewith and means at the other end of said well for receiving and detecting a set of corresponding signals transmitted from said repeater station.

DANIEL SILVERMAN.
THOMAS GILMARTIN.