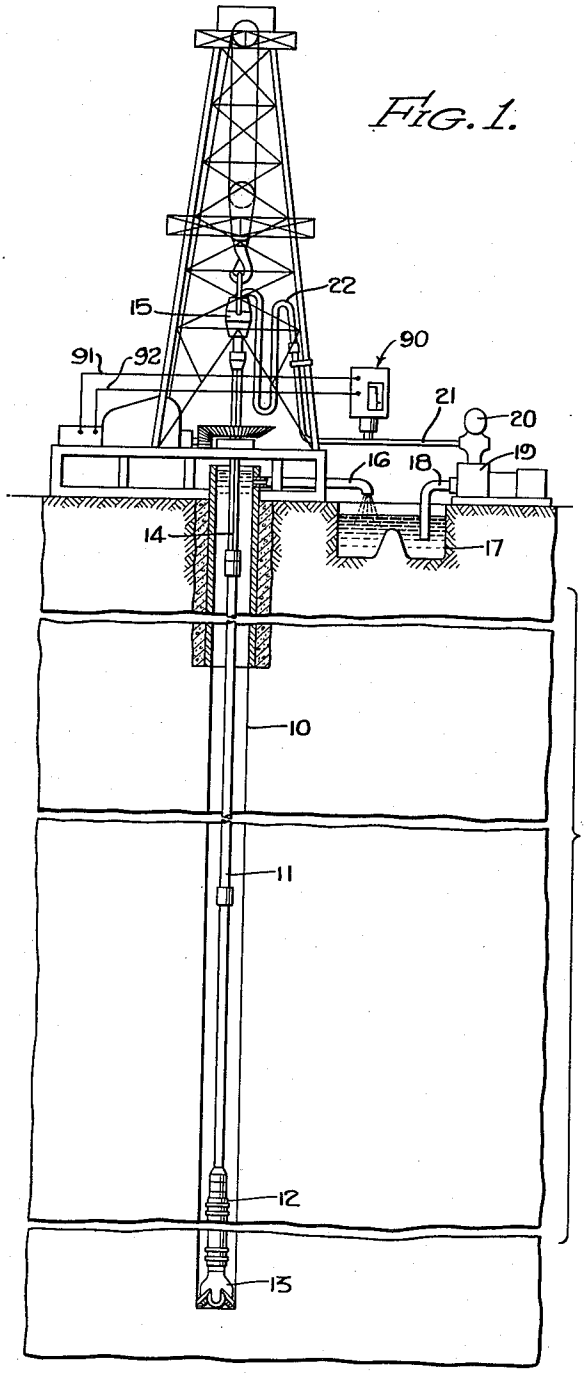
Aug. 14, 1956 J. J. ARPS 2,759,143

EARTH BOREHOLE INVESTIGATION-SIGNALING SYSTEM

Filed July 14, 1954

2 Sheets-Sheet 1

FIG. 1.



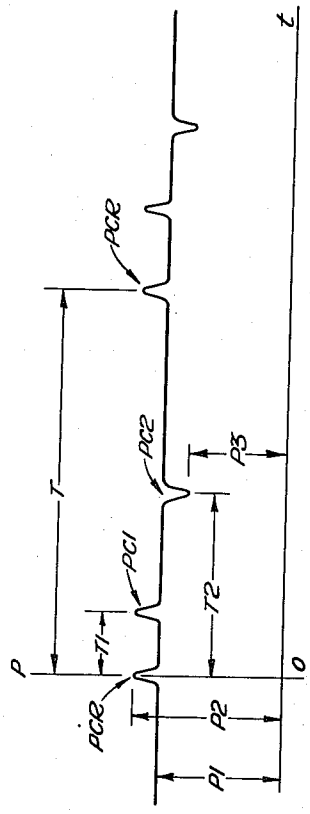


FIG. 6.

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EARTH BOREHOLE INVESTIGATION-SIGNALING SYSTEM

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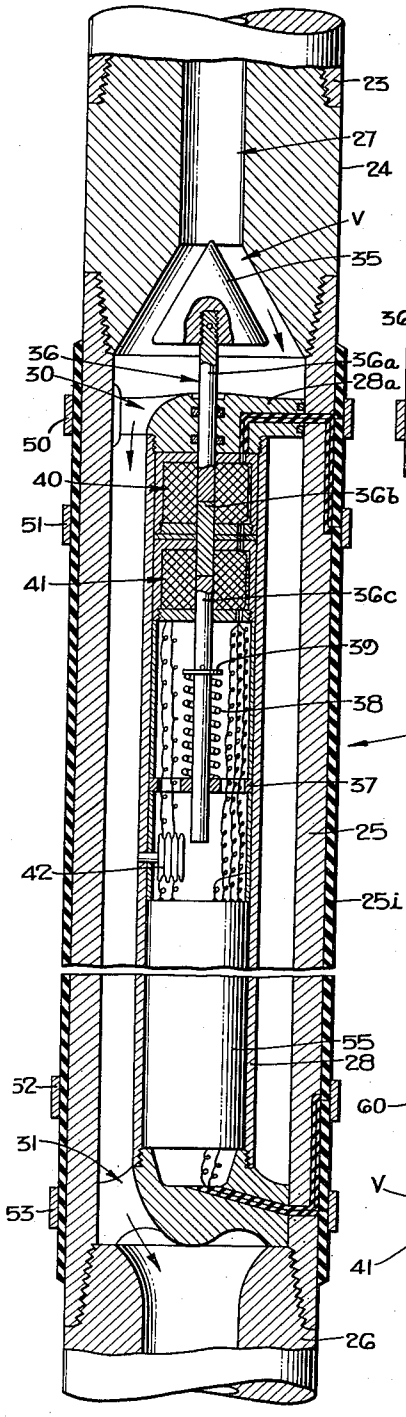

FIG. 2.

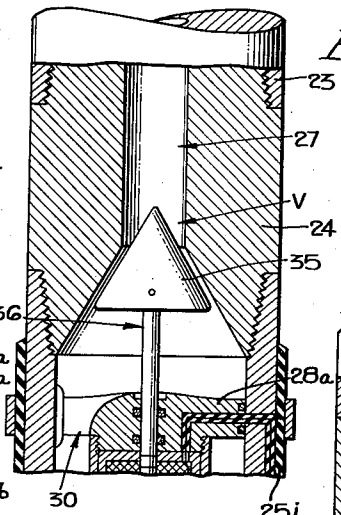

FIG. 3.

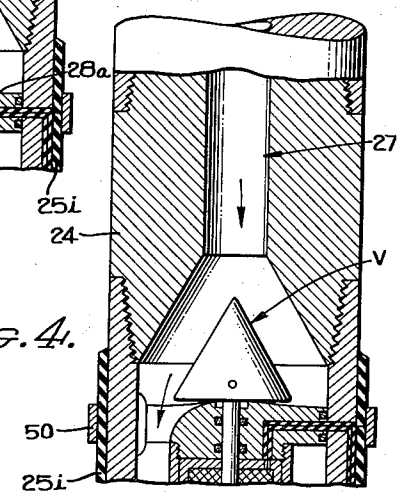

FIG. 4.

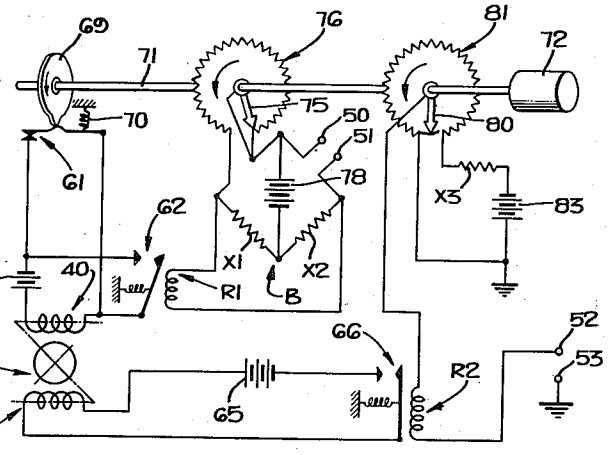

FIG. 5.

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2,759,143

EARTH BOREHOLE INVESTIGATION-SIGNALING SYSTEM

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Application July 14, 1954, Serial No. 443,308

14 Claims. (Cl. 324—1)

This invention relates to a system for communicating or signaling information from a relatively inaccessible location in an earth borehole to a location outside the borehole at the earth's surface. More particularly, the invention relates to such a system adapted for operation during drilling of the borehole as well as during periods of suspension of the drilling. Still more specifically, the present invention relates to such a system wherein there are no electrical connections between the inaccessible location in the borehole and the location exterior of the borehole, all of the electrical apparatus being located at either of said locations.

Previously proposed systems of earth borehole investigation or logging and capable of operation during drilling of the borehole have utilized a pressurized downwardly flowing stream of drilling fluid within the drill string as a communication medium for the transmission of intelligence from an inaccessible location within the borehole to the surface of the earth; see, for example, applications Serial Nos. 346,457 and 295,982, filed April 2, 1953, and June 27, 1952, respectively. In such previously known systems signals were created in the drilling fluid stream in the vicinity of the lower end of the drill string by valve means which when operated electromagnetically or otherwise, produced an increase in pressure in the fluid of the stream which signal was quickly transmitted to the exterior of the borehole and translated and recorded by transducer and recording means of suitable design. Further, such systems utilized various arrangements of time-spaced pressure changes to represent information concerning items of interest investigated in the vicinity of the bottom of the borehole. With such systems of time-spaced pressure increases confusion of intelligence is apt to occur unless the system is restricted to but one type of intelligence, or unless excessively long periods of time are allocated to each type of information or intelligence. The present invention provides a system wherein such disadvantages and defects of the previously known systems are obviated, and has as a principal object the provision of a system of the type mentioned in which two types of intelligence or information may be concurrently transmitted or signaled on the common single communication medium of the drilling fluid, without any likelihood of the two types of intelligence becoming confused or mixed.

It is another object of the invention to provide a simple and efficacious system for rapidly and surely transmitting two different types of intelligence or information from a relatively inaccessible point within an earth borehole to a location outside the borehole.

Other objects and advantages of the present invention will hereinafter be made apparent in connection with a description of a preferred embodiment of apparatus according to the system of the invention.

While a wide variety of types of intelligence or information concerning items of interest to be investigated in the vicinity of the bottom of the borehole may be handled with equal facility by the system of the present invention, for purposes of illustration two items of interest commonly forming the subject of investigation of ordinary electrical logging systems; namely, earth current path resistance and natural potential of the earth, are arbitrarily selected to illustrate operation of the invention.

Generally, the system of the present invention utilizes as a signal transmission medium the downwardly flowing pressurized stream of drilling fluid within the hollow interior of the drill string, but differs from the previously proposed systems in utilizing two different types of pressure changes within the drilling fluid stream to form signals representing two different channels of information. The pressure changes comprised in the signals according to the system of the present invention are, as stated, of two types, the first type being in the nature of a pressure increase, and hereinafter referred to as "positive," and the second type being in the nature of a pressure decrease and hereinafter referred to as "negative," both such changes in pressure being measured from an average or normal prevailing pressure in the drilling fluid stream. The pressure change producing device may assume a wide variety of forms within the spirit of the invention, but as hereinafter illustrated and described by way of example, comprises an electromagnetically operated drilling fluid valve arranged to assume three different operating positions. In the normal position of this valve, which is assumed when neither of its two operating electromagnets is energized, the valve offers a certain amount of resistance to flow of the drilling fluid therethrough or therepast, thereby producing a detectable pressure differential between a point in the drilling fluid stream above the valve, and a point in the drilling fluid stream below the valve. A positive or pressure rise producing position is assumed as a result of energization of a first of the valve electromagnets, and results in an increased resistance to flow of drilling fluid therethrough or therepast; and a negative or extreme open position is assumed as a result of energization of a second of the actuating electromagnets, in which latter position the valve offers substantially no, or very little, resistance to flow of drilling fluid therethrough or therepast. The means for investigating various items of interest within the borehole and for formulating signals indicative of such information may, within the spirit of the invention, assume a wide variety of forms. It is only necessary that such means be capable of reducing each type of information or intelligence to respective time-spaced electrical current pulses in individual circuits, the time intervals between the pulses being indicative of, or representing, the information or intelligence. In the preferred embodiments of a system according to the invention as hereinafter illustrated and described, a time clock controlled structure including a periodically acting set of cam actuated contacts and power supply means is arranged to energize one of the valve actuating electromagnets in such a manner that the valve produces a series of regularly time-spaced reference pressure-change signal elements in the drilling fluid stream. Also included are two information registering or measuring devices cyclically operated by the time-clock means of said structure and each effective to energize a respective one of the actuating electromagnets of the valve to produce a pressure change signal element in the drilling fluid stream. The polarities, or "conditions" of the two pressure change signal elements produced by the action of the two devices will be opposite, that is, one positive and the other negative. The two pressure-change signal elements produced by action of the mentioned devices are each spaced in time following the reference pressure change signal element, the individual time-spacing being a measure of, or otherwise representative of, the particular information or intelligence being conveyed by the respective positive or negative element of the signal. The time-spacing of the reference signal elements of a series of signals is automatically effected by

the cam actuated contacts as hereinabove noted, and the time spacing of the information representing positive and negative signal elements is also automatically adjusted, by means hereinafter more specifically disclosed, so that the time interval between a reference signal element and a next following positive signal element represents one measurement or registration of one type of information and so that the time interval between the reference signal element and the next following negative signal element similarly represents the other information.

A preferred embodiment of apparatus operable to perform the method of the invention and otherwise conforming to the system of the invention is illustrated in the accompanying drawings, in which:

Figure 1 is a diagrammatic illustration, partly in vertical section, of a typical earth borehole and earth borehole drilling rig with a system according to the present invention applied thereto;

Figure 2 is a view, partly in longitudinal section and to an exaggerated scale, of a portion of the structure shown at the lower end of Figure 1;

Figure 3 is a diagrammatic view, partly in longitudinal section, similar to a portion of Figure 2 but showing parts of the valve mechanism in a pressure increase producing position;

Figure 4 is a view similar to Figure 3 but showing portions of the valve mechanism in a pressure decrease producing position;

Figure 5 is a schematic and electrical circuit diagram of apparatus contained in a drill collar of the drill string adjacent the lower part of Figure 1; and

Figure 6 is a graphical representation of a record provided by signal receiving and translating apparatus located exteriorly of the borehole at the surface of the earth.

Referring now to the drawings and to Figure 1 in particular, there is depicted in section and in somewhat simplified form a typical earth borehole **10** which may penetrate the earth in any desired direction, but which is shown extending generally downwardly, and being drilled by drilling means which comprises a sectional string of drill pipe **11** connected at its lower end to a sectional drill collar **12** to the lower end of which is in turn secured a rotary drill bit **13** which upon rotation produces an extension of the borehole **10**. The upper end of the string of drill pipe **11** is suspended from a Kelly bar **14** which is in turn suspended from a rotary swivel **15**. The rotary swivel is supported for vertical movement by conventional means including a traveling block and a crown block and wire rope operated by a drawworks as is usual and well known in the art. As the drill string comprising Kelly bar **14**, drill pipe **11**, drill collar **12** and drill bit **13** is slowly lowered as drilling proceeds, the earth borings or chips removed by bit **13** are carried to the surface in a stream of drilling fluid or mud which flows in the free space within the borehole surrounding the outside of the drill string; the drilling fluid and chips being discharged from an upper cased portion of the borehole through a side discharge pipe **16** into a settling pit or other conventional fluid recovering means **17**. From a suitable portion of the means **17** the relatively free or cleaned drilling fluid is withdrawn through an intake pipe **18** into a drilling fluid pump **19** from which it is discharged under considerable pressure past a surge tank **20** into a conduit **21**. The stream of drilling fluid supplied to conduit **21** is delivered through a rotary hose **22** to the aforementioned rotary swivel **15** through which it is delivered in turn to the interior of hollow Kelly bar **14** from which it flows downwardly through the interior of the drill string to orifices in the drill bit **13**. The purpose of surge tank **20**, which may be conventional, is to dampen or remove to the greatest possible extent pressure fluctuations in the drilling fluid stream caused by action of pump **19** and other actions incident to the drilling. The thus far enumerated structure, with the exception of drill collar **12**, is or may be such as is used in conventional drilling practice and is depicted and thus briefly described to portray an environment of the present invention.

Referring now to Figure 2, drill collar **12** is shown as comprising an upper section **23**, an upper sub **24**, a special section **25** whose construction will hereinafter be more fully explained, and a lower section **26** to which drill bit **13** is secured. The downwardly flowing stream of drilling fluid is delivered by upper section **23** of the drill collar to the specially shaped internal bore **27** of sub **24**, in which bore the aforementioned pressure changes in the drilling fluid stream are adapted to be effected. Bore **27** at its upper portion is of substantially uniform diameter, but diverges at its lower portion in a section of increasing diameter, reaching a maximum diameter in the region where the interior bore of special section **25** joins the bore of sub **24**. Special drill collar section **25** is, as depicted, of relatively large internal diameter, whereby there may be positioned and supported in the drilling fluid stream a generally cylindrical apparatus case **28** provided with upper and lower sets of supporting legs **30** and **31**, respectively, which legs are suitably formed to snugly engage the interior wall of section **25**. The respective supporting legs are circumferentially spaced apart around the exterior periphery of the apparatus case and are preferably of smooth streamlined form, whereby the stream of drilling fluid may flow therepast without undue interference. Further, two or more of such legs may be formed of special cross-sectional shape as hereinafter more fully explained, whereby electric conductors may be led from the interior of case **28** and through suitable apertures in special drill collar section **25**. The drilling fluid stream passing downwardly around the exterior periphery of apparatus case **28** flows in the direction indicated generally by the streamlined arrow pointed lines, into the bore of lower sub **26**, from which it is delivered to the drill bit **13**. Apparatus case **28** is employed to house means for investigating items of interest adjacent the lower end of the drill string, a power supply means, valve means, and subsidiary equipment whose function is, with other means which may be conventional, to actuate a three-position valve means at proper times and in the proper manner to produce the aforementioned pressure change signal elements.

The valve means utilized to produce the pressure changes in the drilling fluid stream may assume any of a variety of physical forms. That chosen to illustrate the preferred embodiment of apparatus according to the invention, comprises a lower shaped portion of the wall of bore **27** of the sub **24** and a complementarily formed shaped valve head **35** fixedly mounted on the upper end of a valve rod **36** mounted as indicated for vertical reciprocation in the upper and cap piece **28*a*** of apparatus case **28**. Valve rod **36** is of three-piece construction and comprises an upper section **36*a*** and a lower section **36*c***, both of nonmagnetic material and both rigidly secured to a central section **36*b*** of ferromagnetic material. Upper section **36*a*** is adapted to be guided by suitable bearing and packing means formed in the upper cap piece **28*a*** of case **28**; while lower section **36*c*** is arranged to be guided in conventional bearing means provided in a suitable valve rod guide disc **37** secured in the interior of case **28** as indicated. The lower end of rod section **36*c*** is surrounded by a compression spring **38** abutting against disc **37** and pressing against a disc **39** suitably affixed to section **36*c***, spring **38** serving to hold the valve rod **36** and valve head **35** in approximately the position illustrated in Figure 2 with a normal stream of drilling fluid flowing, and with neither of the hereinafter described valve electromagnets energized. Secured in the upper interior of the casing **28** and encircling valve rod **36** are two valve actuating electromagnets **40** and **41**, each comprising a ferromagnetic outer case and a coil or winding within the case; the two magnets sharing in common the ferromagnetic section **36*b*** of valve rod **36** as a readily slidable core piece. The otherwise un-

occupied space in the interior of case 28 is preferably filled with a suitable damping fluid such as oil, and provision such as bellows means 42 communicating with the drilling fluid stream and located in the interior of case 28 may be provided to allow for reciprocatory movement of rod 36 into and out of the case. The aforedescribed arrangement of valve structure is such that with neither of electromagnets 40 and 41 energized, spring 38 and the drilling fluid stream act to position valve head 36 to provide a medium degree of restriction of the drilling fluid stream therepast, and such that when the upper electromagnet 40 is energized, valve rod section 36*b* is drawn upwardly, forcing valve head 35 upwardly to increasingly restrict flow of drilling fluid therepast to cause a pressure increase in the drilling fluid stream thereabove; and further such that upon energization of electromagnet 41, valve rod section 36*b* is drawn downwardly to draw valve head 35 down against or closely adjacent the upper face of end cap 28*a* of casing 28, thereby substantially removing all restriction offered by the valve head to the moving drilling fluid stream. The normal or neutral position of valve head 35 is depicted in Figure 2; the upper position wherein a pressure increase is produced is indicated in Figure 3 and the lower position in which a negative pressure change is created in the drilling fluid stream is indicated in Figure 4.

From the aforedescribed operation of the valve means interposed in the drilling fluid stream it is seen that a pressure change of either positive or negative character may be produced in the stream above the valve, by selective operation of one or the other of electromagnets 40 and 41. Means for selectively energizing the electromagnets will now be described.

Referring again to Figure 2, special section 25 of drill collar 12 has secured thereto, as by vulcanization, an insulating jacket 25*i* upon which are mounted a plurality of electrically conducting sleeves or electrodes 50, 51, 52 and 53, which may be of conventional form and spacing and such as are used in conventional earth borehole logging operations employed in obtaining information concerning earth path resistances and the natural potential of earth formations adjacent the borehole. The nature and arrangement of the insulating jacket and the electrode system are not per se of the present invention, may be of conventional arrangement and construction, and are depicted solely as one form of suitable means of obtaining information concerning items of interest within the borehole for transmission from within the bore hole to the surface of the earth by a system according to the present invention.

Referring now to Figure 5 of the drawings, a schematic circuit diagram is shown of apparatus comprised in a capsule 55 contained within apparatus case 28 in the interior of the drill collar. The circuit diagram also indicates diagrammatically the aforementioned electrodes 50, 51, 52 and 53. The electromagnets 40 and 41 are indicated in position to selectively operate the aforedescribed valve, here identified by the reference character V. Electromagnet 40 is indicated as having its coil connected in series with a suitable source of electric power such as a battery 60 and to parallel-connected circuit-closing sets of contacts including a set 61 regularly and periodically closed by cam means, and a second set 62 operable by a relay R1, closures of these sets of contacts being effected at times as hereinafter more fully described. Electromagnet 41 is connected in series with a suitable source of electric power such as battery 65 and a set of normally open contacts 66 forming part of a relay R2, whose coil when energized is adapted to close said contacts against the force exerted by a relay spring. Contacts 61 are adapted to be periodically closed by a regularly operated cam 69 and opened by a spring 70 as indicated to provide reference pressure-change signal elements. Cam 69 is carried on a rotating shaft 71 which is rotated at a slow uniform rate of speed of the order of one revolution each three minutes by a suitable time clock or time clock controlled means 72, the arrangement preferably being such that the rate of rotation of shaft 71 is definitely known. Thus positive pressure change signal elements are created. Mounted on shaft 71 and electrically insulated therefrom is a wiper arm 75 of a rheostat 76 whose resistance element is connected as one leg of a bridge B as indicated. Other legs of bridge B are comprised of resistance units X1, X2, and the resistance presented by the drilling fluid and the earth formation between electrodes 50 and 51, all as indicated. A battery 78 is connected across a diagonal of the bridge, as indicated. The circuit elements comprising bridge B and appurtenant electrical apparatus have values so chosen that as wiper 75 rotates in the direction indicated around the resistance element of rheostat 76 and sweeps through a resistance value that is equal to or indicative of the electrical resistance presented between electrodes 50 and 51, and thus brings the bridge momentarily into balance at some point in each revolution of wiper 75, the current normally energizing the coil of relay R1 will at such point drop to zero value, permitting the relay spring to close contacts 62 and thus cause energization of electromagnet 40 and the production of a second positive pressure change signal element in the drilling fluid stream. Also mounted on shaft 71 and electrically insulated therefrom is a wiper 80 of a potentiometer 81 whose resistance is connected in series across a battery 83 and resistor X3 as indicated. Battery 83 has one of its poles grounded and wiper 80 is connected as indicated to the coil of relay R2 in series with electrodes 52 and 53, the latter also being connected to ground as indicated. Thus, as wiper 80 rotates in the direction indicated it applies across the coil of relay R2 a gradually decreasing potential which, when it reaches a value equal to and of polarity opposite to the natural potential applied thereto from electrodes 52 and 53, results in drop of the current through coil R2 to zero value, thereby permitting the contacts 85 to close under influence of the relay spring, thereby energizing electromagnet 41 to produce a pressure decrease or negative pressure change signal element in the drilling fluid stream above the valve. It is evident that movement of wiper arms 75 and 80 beyond the positions at which bridge and potentiometer balances are attained, results in the reenergization respectively of relays R1, R2 and the return of the valve head 35 to normal or neutral position.

It is evident from the preceding explanation and description relating to the circuit diagram of Figure 5 that the apparatus therein diagrammatically depicted operates through the medium of cam 69 and cam operated contact 61 to cause valve V to produce in the drilling fluid stream a periodic reference pressure change (which pressure change is herein indicated as positive in nature but which could readily be made negative by connecting contacts 61 in series with battery 65 and electromagnet 41 rather than as indicated), and further operates to produce, following each such reference pressure change, an information-representing pressure change of a first polarity after an elapsed time following the respective reference pressure change indicative of or proportional to the resistance between electrodes 50 and 51, and another information-representing pressure change of different polarity after an elapsed time interval following the respective reference pressure change proportional to or otherwise indicative of natural potential as reflected on electrodes 52 and 53. It is obvious that it is immaterial which pressure polarity is employed for the reference pressure change. Further, it is evident that the two information-representing pressure changes, being of opposite polarity, cannot be confused. Polarity of the reference, or time-marking pressure changes, if not known beforehand may easily be ascertained by examination of a graphical record of the received signals on which such reference pressure changes are indicated, as those pips,

marks or other indications occurring at regularly spaced intervals. The spacing of the information-representing pips or marks vary as the values they represent vary.

Referring again to Figure 1, the pressure change signals in the drilling fluid stream created by valve V and representing items of interest such as physical quantities or measures thereof, are quickly transmitted upwardly through the fluid in the hollow drill string and are impressed upon a receiver-recorder means indicated generally by reference numeral **90**, which serves to receive and translate the pressure change signals into sense-perceptible indications of the two types of information secured by the investigating apparatus at the bottom of the drill string. This signal receiving translating and recording apparatus may be supplied with electrical energy from a generator in the draw works through leads **91** and **92**, and may be of conventional form comprising a conventional pressure transducer whose output is preferably amplified and fed into a conventional electrical recorder mechanism. In regard to the recorder apparatus, it is essential only that it be operated at a uniform rate of speed as, for example, by a time clock mechanism, to produce a graphical or other sense perceptible indication of the pressure variations in the drilling fluid stream in conduit **21**.

Referring now to Figure 6, there is indicated diagrammatically a length of a typical graphical recording produced by the means **90** operating according to the system of the invention. The graphical recording is a record of the drilling fluid pressure, P, in conduit **21**, plotted against time, *t*. The recording includes two reference pressure change signal element marks or pips PCR, spaced apart a distance representing a time period T. Also the recording includes positive and negative pressure change signal element marks PC1 and PC2, spaced from the preceding reference mark PCR by respective distances representing time periods T1 and T2, respectively. The latter time periods, and the corresponding distances on the record, are directly proportional to the values measured in the borehole and represented by the pressure change signal elements. Thus the method of evaluating the record is obvious. The only possibility of confusion arising from operation of the system according to the invention resides in the impossibility of producing both a positive and a negative pressure change signal at the same time. This possibility of confusion is readily avoided by proper selection of the values of the circuit elements of the bridge network and of the potentiometer network so that the signal resulting from one of said networks with invariably precede, or invariably follow, that produced by the other of the networks. Further, it will be evident that even if the full range of time between reference pressure changes were to be utilized for each of the types of information or information channels, only in rare instances would any values of the information be encountered which would result in attempted formation of concurrent positive and negative pressure changes. In such rare instance, fluctuation or variation of one or both of the measured values would cause noncoincident signals to be transmitted before and after any attempted coincident signals, whereby by interpolation and/or extrapolation the values represented by the coincident signals could readily be ascertained.

Thus, it is seen that the system of the invention provides a means and method of concurrently transmitting information of two distinct types from a location within an earth borehole to a location outside the borehole, without electric connections between the two locations and without danger of mixing or confusing the types of information; and that the other stated and obvious objects of the invention are fully accomplished. While a single preferred embodiment of apparatus according to the system of the invention has been illustrated and described, it is evident to those skilled in the art that the apparatus may assume a wide variety of forms within the spirit and scope of the invention; and it accordingly is not desired to limit the invention to the specific details disclosed, but what is claimed is:

1. In a system for communicating information of two types from a relatively inaccessible location in an earth borehole to a point outside the borehole while concurrently extending the borehole by drilling with means including a hollow drill string through which a stream of drilling fluid flows under pressure, apparatus comprising: a section of such drill string; means in the section of drill string to recurrently measure each of two physical quantities and to produce in such stream pressure change signals, each comprising one of a series of regularly produced reference pressure change signal elements of a given character and two information-representing pressure change signal elements one above and the other below an average pressure value and each representing a respective measure of said physical quantities; and means outside the borehole for receiving and translating said signals.

2. In a system for communicating information of two types from a relatively inaccessible location in an earth borehole to a point outside the borehole while concurrently extending the borehole by drilling with means including a hollow drill string through which a stream of drilling fluid flows under pressure, apparatus comprising: a drill string extending from such location to such point, valve means in the drill string, interposed in the path of such stream; actuator means to selectively move the valve means to positions to produce pressure changes of opposite signs, respectively above and below normal pressure in said stream; means for recurrently securing measures of each of two physical quantities and representing two types of desired information, and for periodically causing said actuator means to move the valve means to one of said positions for producing a series of reference pressure changes in said stream and after each of said reference pressure changes to causing said actuator means to move the valve means to each of such positions for producing a pressure change of each of said opposite signs and each representing a respective one of said two types of information; and means at said point for receiving and translating such pressure changes into sense-perceptible indications of said measures.

3. In an investigation system adapted for use in an earth borehole being drilled by means including a hollow drill string having a downwardly flowing stream of drilling fluid flowing therethrough under pressure, apparatus comprising: a drill string; means to supply drilling fluid under pressure to said drill string; signal element producing means in the drill string selectively actuatable to produce in such drilling fluid stream, pressure change signal elements both of positive and of negative characteristics with respect to normal pressure; means in the drill string to measure each of two items of interest and to selectively actuate said signal element producing means to produce a reference pressure-change signal element of a selected one of said characteristics and to thereafter produce measurement-representing pressure change signal elements of each of said characteristics, each such measurement-representing signal element representing by its time spacing from the reference signal element a measurement of one of a respective said items of interest; and means outside the drill string in hydraulic communication therewith for receiving said signal elements and for therewith forming sense-perceptible indications of said measurements.

4. In a system adapted for concurrent investigation of two items of interest at a relatively inaccessible location in an earth borehole, and continued drilling of an extension of the borehole by means including a drill string having a drilling fluid stream flowing therethrough under pressure, apparatus comprising: a section of drill string;

a first means in the drill string selectively actuatable to produce pressure changes of opposite sign with respect to normal pressure in the drilling fluid stream; regularly operating means in the borehole for measuring the value of each of said two items and for selectively actuating said first means to successively produce a reference pressure change of a selected sign in the drilling fluid stream and thereafter at respective time intervals proportional to the measured values of said items, produce measurement-representing pressure changes of opposite signs in the drilling fluid stream each representing a measurement of a respective one of said items of interest; and means outside the borehole and in hydraulic communication with the drilling fluid stream for receiving and translating the several pressure changes into sense-perceptible indications of said measurements.

5. In a system adapted for concurrent investigation of two items of interest at a relatively inaccessible location in an earth borehole, and continued drilling of an extension of the borehole by means including a drill string having a drilling fluid stream flowing therethrough under pressure, apparatus comprising: a first means in the drill string including a valve interposed in the drilling fluid stream and selectively actuatable to produce pressure change signal elements therein of opposite sign with respect to normal pressure therein; regularly operating actuating and measuring means in the borehole for measuring the value of each of said two items and for selectively actuating said valve to successively produce a reference pressure change signal element of a selected sign in the drilling fluid stream and to thereafter at respective time intervals proportional to respective of the measured values, produce measurement-representing pressure change signal elements of such opposite signs in the drilling fluid stream, each representing a measurement of a respective one of said items of interest; and means outside the borehole and in hydraulic communication with the drilling fluid stream for receiving and recording the several pressure change signal elements in the form of a graphical record indicative of said measurements.

6. In an investigation system adapted for use in an earth borehole being drilled by means including a hollow drill string having a downwardly flowing stream of drilling fluid flowing therethrough under pressure, apparatus comprising: a drill string and means to supply a stream of drilling fluid under pressure to the upper end of the drill string; a first means in the drill string selectively actuatable to produce pressure changes of either positive or negative character with respect to normal pressure in said stream of drilling fluid; a second means in the drill string including regularly operated means for measuring values of two items of interest at a location within the borehole and for selectively actuating said first means to cause the latter to produce a reference pressure change signal element of positive character and two succeeding pressure change signal elements, one positive and one negative, at intervals following said reference pressure change indicative of and mathematically related to measured values of respective items of interest; and means including pressure transducer means in hydraulic communication with the upper end of said drill string for detecting and translating said pressure change signal elements to sense-perceptible indications of said measured values.

7. In a system for communicating information of two types from a relatively inaccessible location in an earth borehole to a point outside the borehole while concurrently extending the borehole by drilling with means including a hollow drill string through which a stream of drilling fluid flows under pressure, apparatus comprising: a drill string and means for supplying a stream of drilling fluid under pressure to the drill string; means including a valve means interposed in said stream in said drill string and selectively actuatable to first and second positions to create in said stream respective distinctive pressure change signal elements of first and second characteristics different from normal pressure characteristics; regularly operating means in said drill string to cause actuation of said valve means to one of said positions at periodic intervals; means controlled by said regularly operating means to procure information of one of said types and to cause actuation of said valve means to one of said positions in response to and in a manner representative of said information of one type; other means in said drill string controlled by said regularly operating means to procure information of the other of said two types and to cause actuation of said valve means to the second of said positions in a manner representative of said other type of information; and means at said point in hydraulic communication in said stream for detecting and translating the pressure changes produced in said stream by said valve means, into a sense-perceptible indication representing said types of information.

8. In a system for communicating information concerning physical quantities of two types from a relatively inaccessible location in an earth borehole to a point outside the borehole, while concurrently extending the borehole by drilling with means including a hollow drill string through which a stream of drilling fluid flows under pressure, apparatus comprising: a drill string and means to supply a stream of drilling fluid under pressure to the drill string; means in the drill string including a valve means interposed in said stream and actuatable in first and second directions from a normal position to create in said stream pressure changes of respective first and second characteristics different from normal pressure characteristics, each of which pressure changes constitutes a signal element; first actuator means for actuating said valve means in said first direction; second actuator means for actuating said valve means in said second direction; means including regularly operating means in the drill string to regularly energize said first actuator means, first and second mensuration means controlled by said regularly operating means for measuring each of said two physical quantities and for each energizing a respective one of said actuator means at a time interval following energization thereof by said regularly operable means proportional to its respective measurement; means outside the borehole in hydraulic communication with said stream for detecting and translating the pressure changes in said stream; and recorder means for forming a graphical record of the characteristic and reception time of each of the pressure changes detected and translated.

9. In a method of communicating two types of mensuration information from a relatively inaccessible location in an earth borehole to a point outside the borehole, while concurrently extending the borehole by continued drilling, the concurrent steps comprising: providing a downwardly flowing stream of drilling fluid under pressure as a signal transmission medium; creating in said stream at said location at regular time intervals, pressure changes of a uniform characteristic and selected from the class of pressure changes including pressure increase and pressure decrease from a normal pressure, to provide a series of signal intervals and references signal elements; creating in said stream a series of pressure-increase signal elements, substantially one for each reference signal element and each spaced from its respective reference signal element in time by an interval representing a measurement comprised in a first of said types of information; creating in said stream a series of pressure-decrease signal elements, substantially one for each reference signal element and each spaced from its respective reference signal element in time by an interval representing a measurement comprised in a second of said types of

information; detecting and translating at said point the pressure changes created in said stream; and forming a graphical record of the time spacing and characteristics of said pressure changes.

10. In an earth borehole investigation-signaling system adapted to provide at a point outside an earth borehole, measurements of first and second physical quantities at a relatively inaccessible location within the borehole, during extension of the borehole by drilling by means including a hollow drill string through which a stream of drilling fluid flows under pressure, apparatus comprising: a drill string and means to supply a stream of drilling fluid under pressure to the drill string; an electromagnetically actuated valve interposed in said stream in the drill string and operable in first and second directions from a normal position to produce pressure change signal elements of respectively opposite pressure change characteristics in said stream and comprising first and second electromagnets to operate the valve in respective of said directions; means including electric power means acting to recurrently energize said first electromagnet at regular intervals to produce in said stream a series of reference pressure change signal elements of a given one of said characteristics, and first and second measuring means to measure respective of said first and second physical quantities and energize respective of said first and second electromagnets at respective time intervals following each said reference signal element proportional to the respective measurement, to produce in said stream information-representing signal elements of opposite pressure change characteristics; means at said point in hydraulic communication with said stream for detecting and translating the pressure change signal elements created in said stream and producing a graphical record indicating the relative time spacing and characteristic of each of said detected signal elements.

11. In a system adapted for investigation of physical quantities associated with formations of the earth adjacent the interior of an earth borehole and in which the borehole is drilled by means including a tubular drill string through which drilling fluid flows downwardly under pressure, apparatus comprising: a lower end portion of such drill string; actuatable means located in said lower end portion of said drill string and capable, upon selective energization under first and second different conditions, of producing respective pressure changes of positive and negative sign respectively above and below normal pressure in said drilling fluid thereabove; means in said portion of such drill string for measuring values of said first and second of said physical quantities and for first energizing said actuatable means under the first of said different conditions to produce a pressure change of one such sign as a reference pressure change signal element, and to thereafter at respective time intervals following production of such reference signal element representing the measured values, energizing said actuatable means under each of said first and second different conditions to produce respective positive and negative pressure change signal elements to complete creation in said drilling fluid of a signal representing said measured values; and means including means in hydraulic communication with drill string, to receive said signal from the drilling fluid and to translate said signal into sense-perceptible indications indicative of said measured values.

12. Apparatus for communicating information of two types from a relatively inaccessible location in an earth borehole, comprising in combination: a section of tubular drill string adapted for use at such location and having a passageway through which drilling fluid may be forced to flow; means in said section of drill string for recurrently making measures of the value of each of two physical quantities; and means in said section of drill string for selectively increasing and decreasing the resistance of said passageway to flow of fluid therethrough above and below a normal flow resistance value, and governed by said first-mentioned means to recurrently change the said resistance of said passageway in at least one such way and after each such recurrent change, change the said resistance of said passageway in each way from said normal value at respective times following said recurrent change representing the corresponding measures of the values of said physical quantities.

13. In a method of communicating measurements of the values of two kinds of physical quantities from a relatively inaccessible location in an earth borehole to the top thereof while concurrently extending the borehole by continued drilling, the steps comprising: flowing a stream of fluid under pressure through at least a portion of said borehole between said location and an exterior point adjacent the top thereof; establishing a time reference; taking a measure adjacent said location of the value of each of said two physical quantities; producing in the said stream of fluid adjacent said location, in response to one of said measures, a pressure increase above the average pressure thereof and at a time interval following said time reference indicative of the measure of said one of said values; and producing in the said stream of fluid adjacent said location, in response to the other of said measures, a pressure decrease below the average pressure thereof and at a time interval following said time reference indicative of the measure of said other of said values, whereby said pressure increases and said pressure decreases are transmitted through said stream of fluid to a reception point exterior of said borehole, the times of arrival thereof at said reception point relative to said time reference being indicative of the values of said physical quantities.

14. In a method of communicating measurements of the values of two kinds of physical quantities from a relatively inaccessible location in an earth borehole to the top thereof while concurrently extending the borehole by continued drilling, the steps comprising: flowing a stream of fluid under pressure through at least a portion of said borehole, between said location and a point adjacent the top thereof; taking measures adjacent said location of the value of each of said two physical quantities; producing in said stream of fluid adjacent said location, pressure increases above the average pressure thereof in response to and having time distributions indicative of the said measures of the values of one of said physical quantities, and producing in the said stream of fluid adjacent said location pressure decreases below the average pressure thereof in response to and having time distributions indicative of the said measures of the values of the other of said physical quantities, whereby said pressure increases and said pressure decreases are transmitted through said stream of fluid to a reception point exterior of said borehole, the time distribution of arrival thereof at said reception point being indicative of the values of said physical quantities.

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