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April 27, 1943.

L. C. MILLER

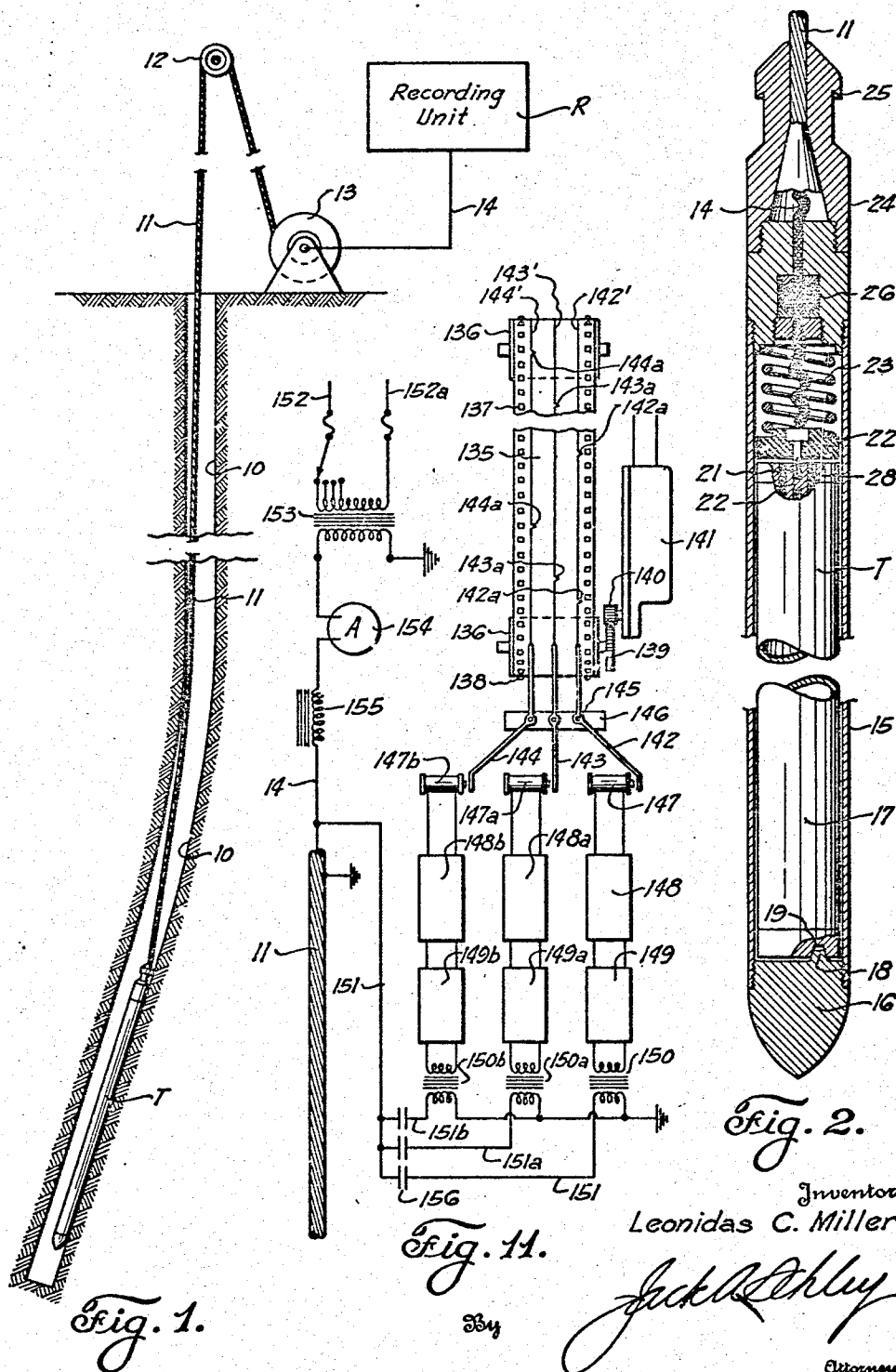
2,317,632

SUBSTITUTE FOR MISSING XR

MEANS FOR SURVEYING WELL BORES

Filed July 20, 1939

9 Sheets-Sheet 1

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April 27, 1943.

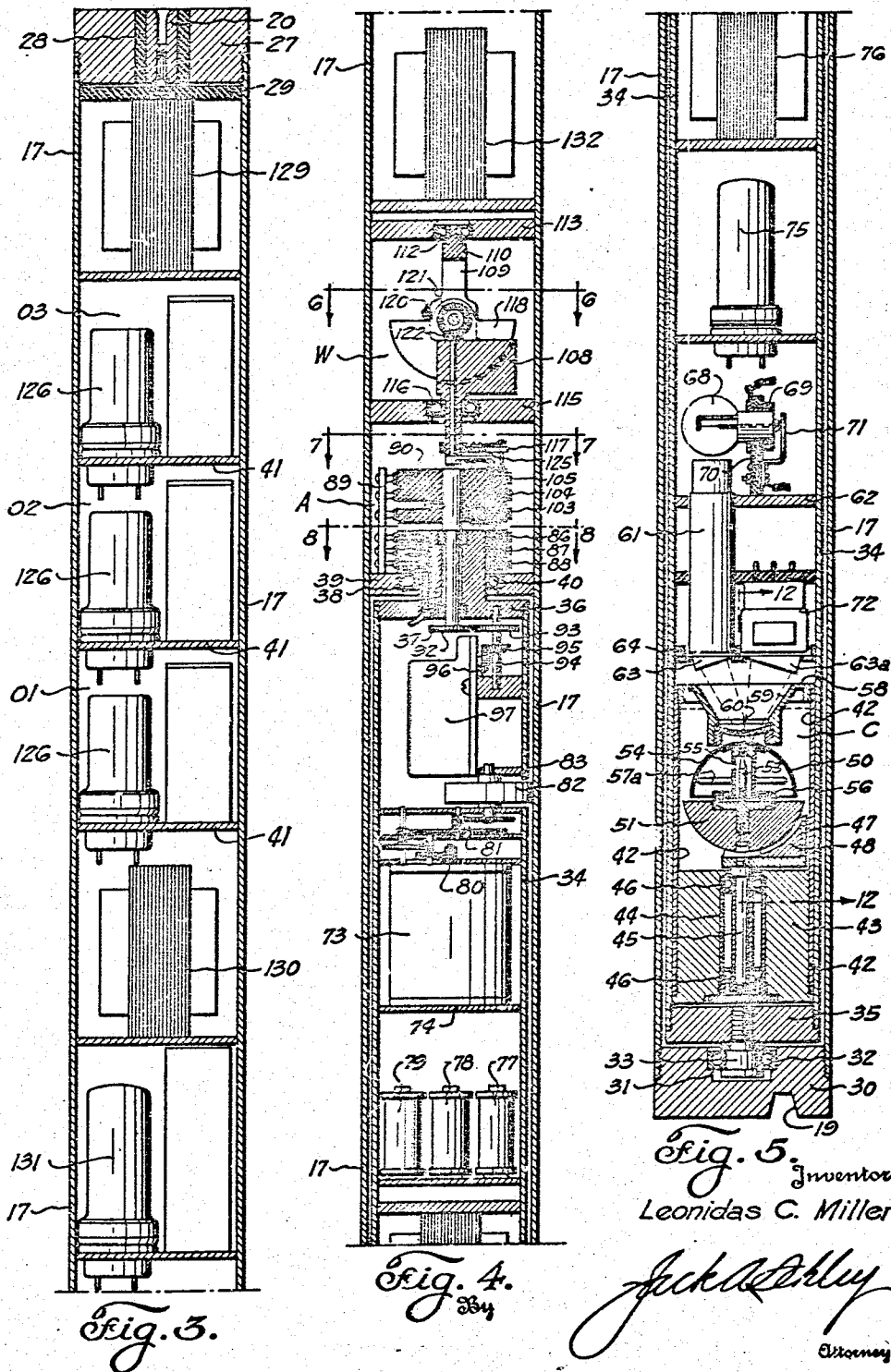
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MEANS FOR SURVEYING WELL BORES

Filed July 20, 1939

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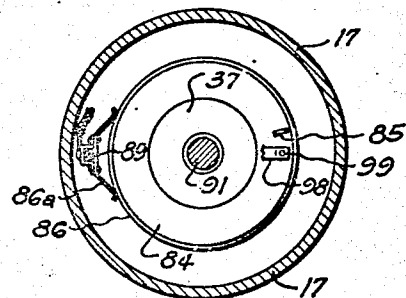
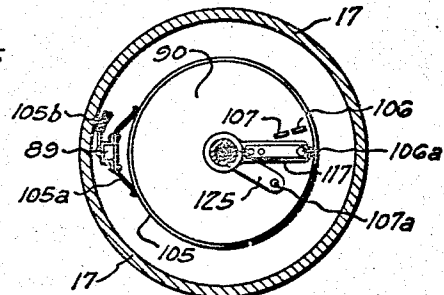
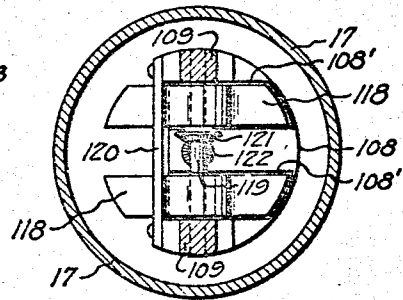
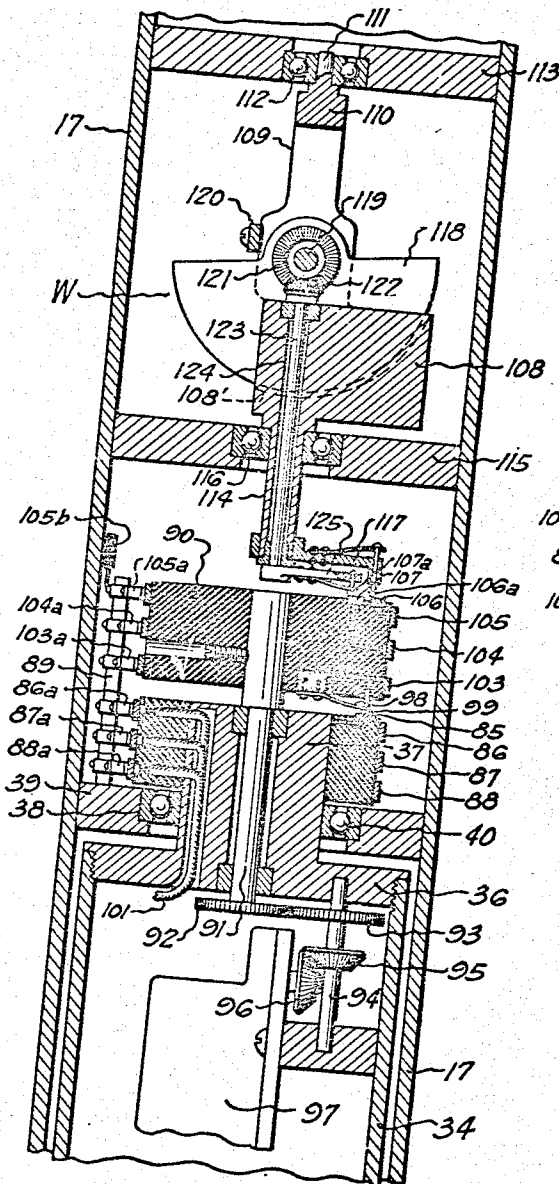
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2,317,632

MEANS FOR SURVEYING WELL BORES

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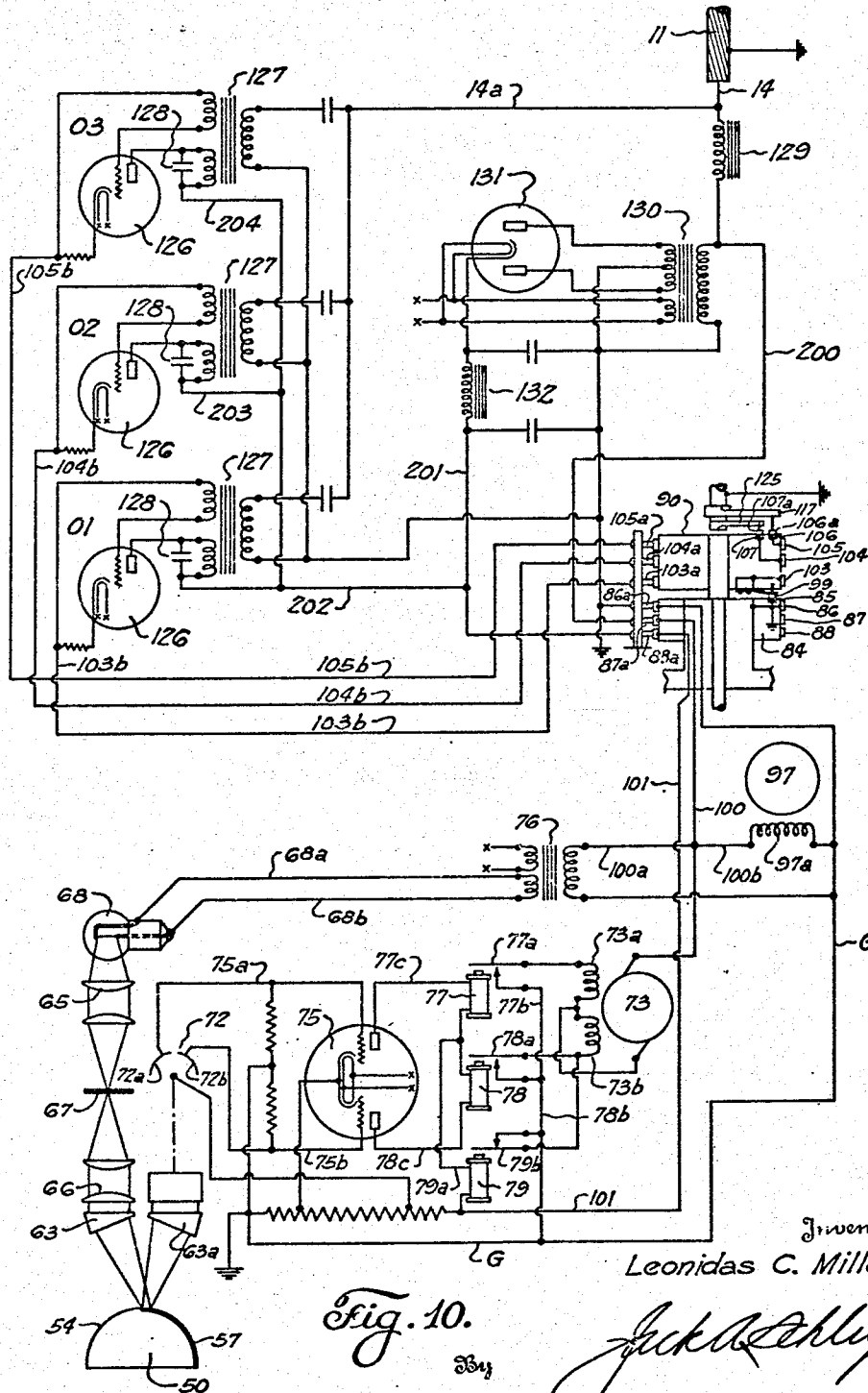
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MEANS FOR SURVEYING WELL BORES

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MEANS FOR SURVEYING WELL BORES

Filed July 20, 1939

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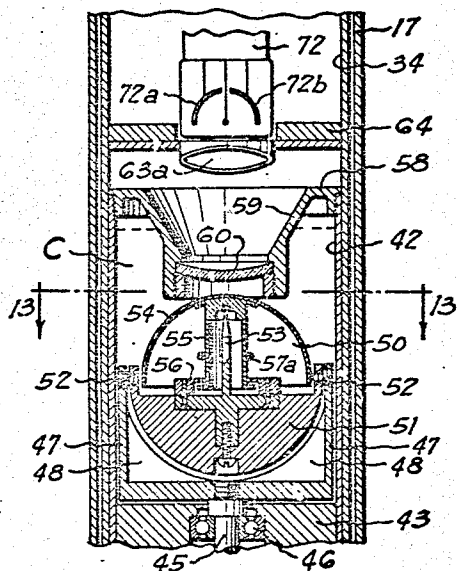


Fig. 12.

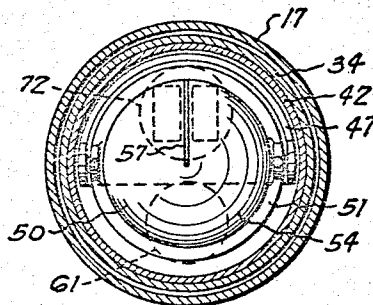


Fig. 13.

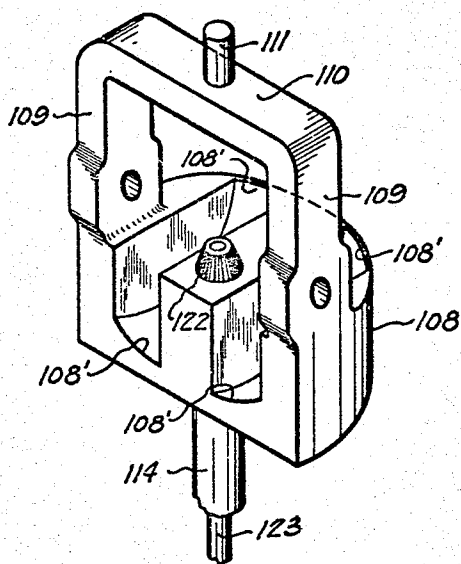


Fig. 14.

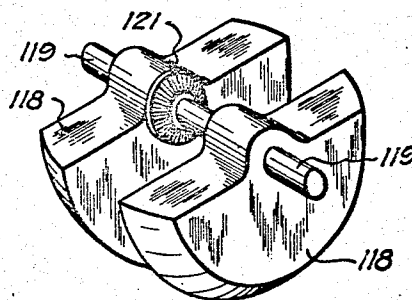


Fig. 15.

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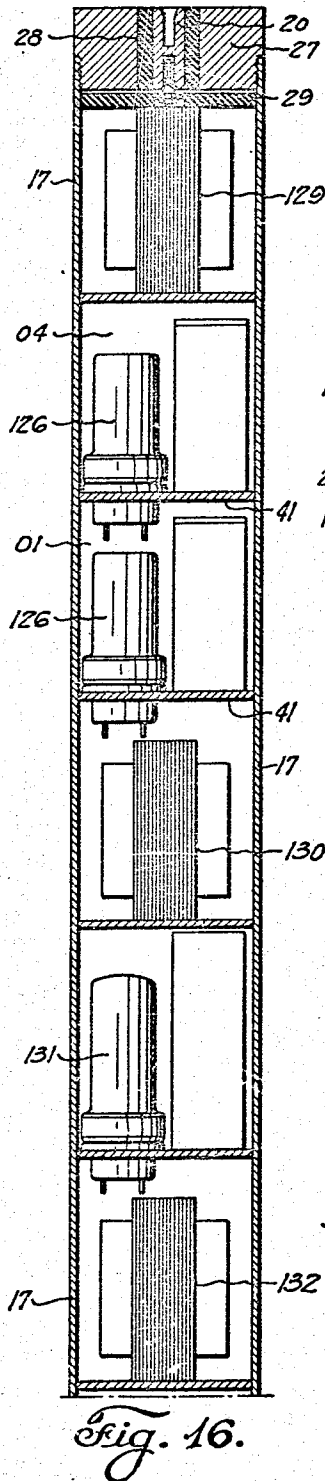


Fig. 16.

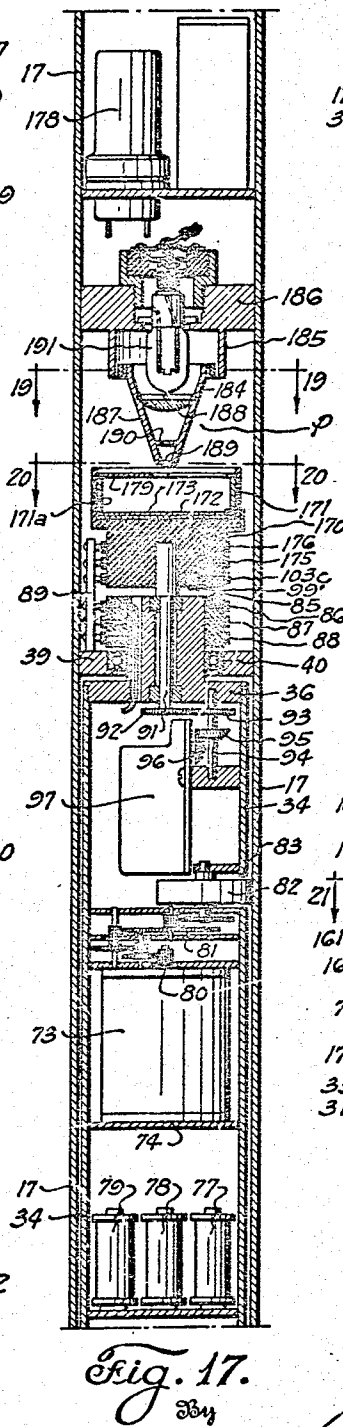


Fig. 17.

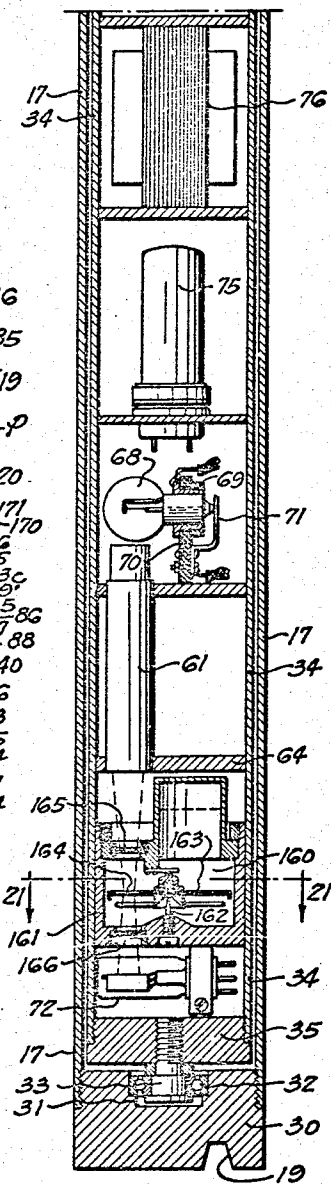


Fig. 18.

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MEANS FOR SURVEYING WELL BORES

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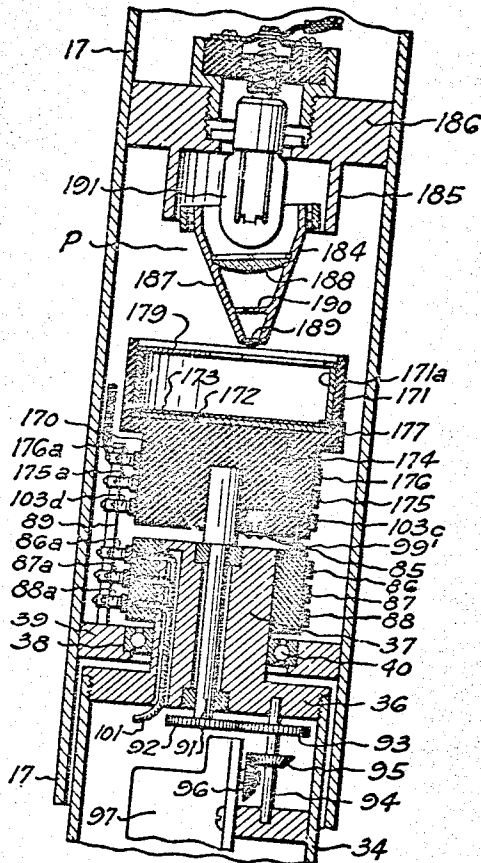


Fig. 22.

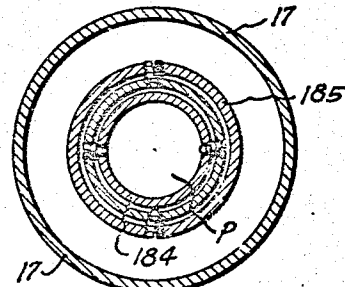


Fig. 19.

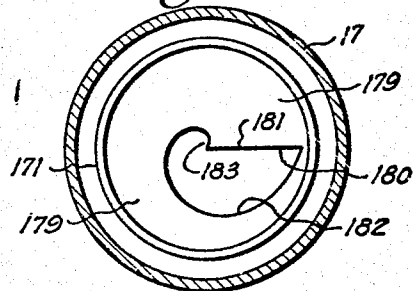


Fig. 20.

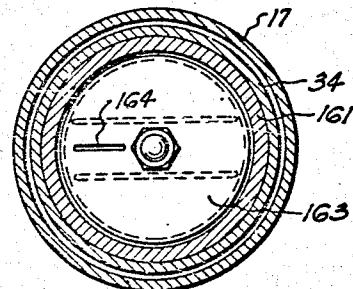


Fig. 21.

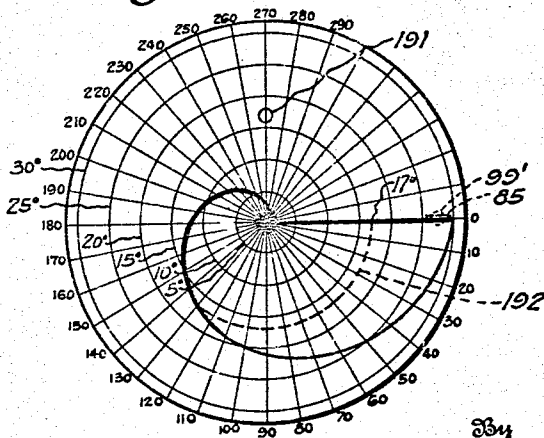


Fig. 23.

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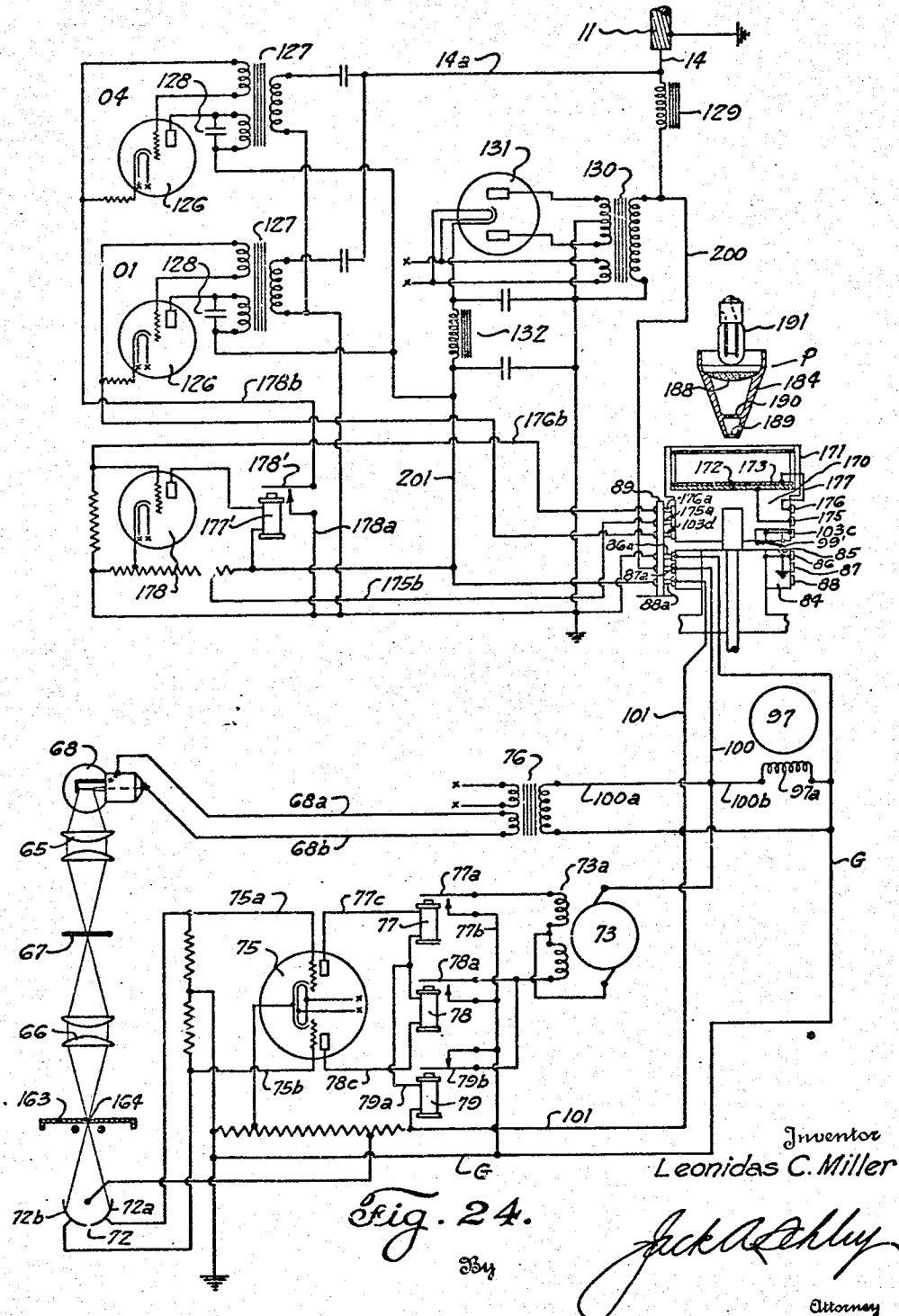
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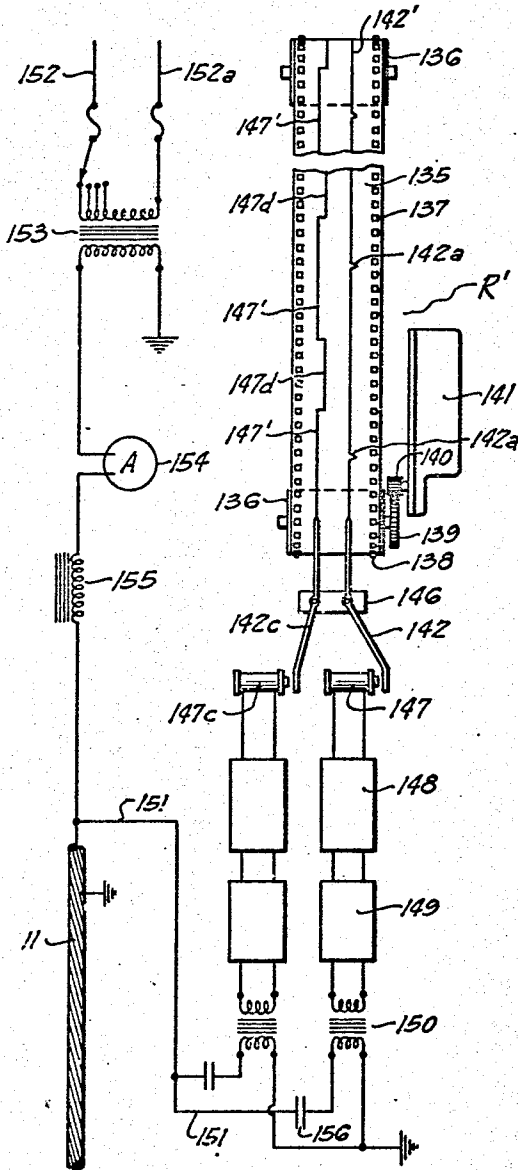


Fig. 25.

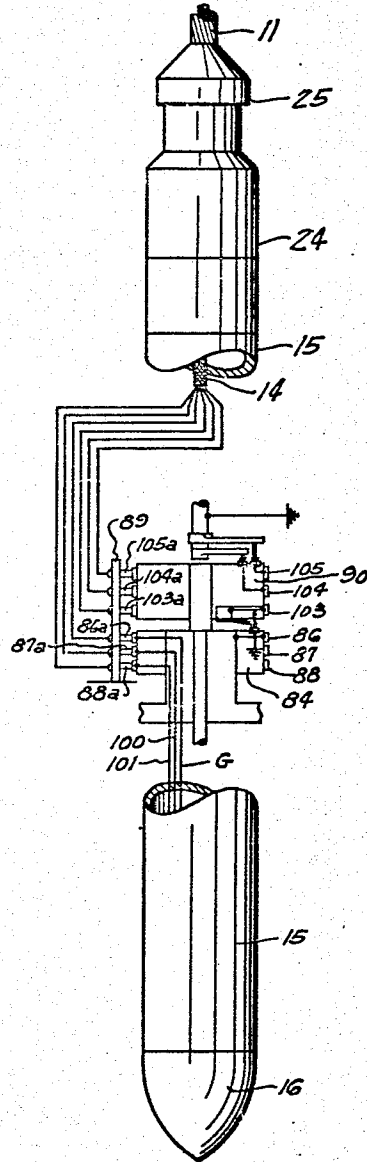


Fig. 26.

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UNITED STATES PATENT OFFICE

2,317,632

MEANS FOR SURVEYING WELL BORES

Leonidas C. Miller, Dallas, Tex., assignor, by direct and mesne assignments, of one-half to Eastman Oil Well Survey Company, Dallas, Tex., a corporation of Delaware, and one-half to Eastman Oil Well Survey Corporation, Long Beach, Calif., a corporation of California

Application July 20, 1939, Serial No. 285,597

22 Claims. (Cl. 33-205.5)

This invention relates to new and useful improvements in methods of and means for surveying well bores.

In the drilling of wells, and particularly in drilling to greater depths, it is not only desirable and advantageous, but substantially essential that the drilling operator be advised of the direction and inclination from the vertical of the bore hole, as the drilling proceeds. Such information makes it possible to accurately drill the hole in the desired manner, that is, in the proper direction and at the proper angle or inclination. Particularly in angular drilling, which has come into more extensive use, is such information regarding the trend of the bore hole especially valuable for, without it, accurate angular drilling cannot be accomplished.

It is one object of the invention to provide an improved method of surveying a bore hole wherein electrical impulses are transmitted to the surface, such impulse being in accordance with the direction and inclination of the bore hole, whereby said impulses are indicative of the trend of said hole.

Another object of the invention is to provide an improved well surveying method by which electrical impulses of varying frequencies are generated and transmitted to the surface in accordance with the direction and deviation of the well bore, said impulses being received at the surface and transposed into visible indications to indicate the trend of the bore; the method involving a minimum length of time, whereby surveying of the bore is facilitated.

It is another object of this invention to provide an improved electrical well survey apparatus for surveying a bore hole, whereby both the direction of inclination and the degree or angle of inclination from the vertical may be readily determined at various or successive points in the bore hole to indicate the trend of said bore; the apparatus being unaffected by voltage fluctuation and temperature changes and the measurements or readings being taken being based solely on time, whereby accuracy of the measurements is assured.

An important object of the invention is to provide an improved apparatus for surveying a well bore which is constructed so that the direction and degree of inclination of the bore will be indicated and recorded at the surface of said bore, whereby a permanent record of the trend of the bore is made as the well is surveyed.

Another object of the invention is to provide an improved well survey apparatus including an

orienting and transmitting unit which is arranged to be lowered into the well bore on a flexible line and which has means for transmitting electrical impulses, representative of the direction and degree of inclination of the bore, to the surface, such impulses actuating an indicating unit at the surface to transpose said impulses into visible indications to visibly record the direction and deviation of the bore.

A further object of the invention is to provide an improved apparatus, of the character described, wherein a compass is associated with a light responsive cell, the latter controlling the position of a directional indicating mechanism, whereby the mechanism is maintained in a fixed position or direction, so that a basis is established from which readings, as to direction and angle or deviation from the vertical of the bore, may be taken.

A particular object of the invention is to provide an improved well survey apparatus having an electrical contact, the position of which is controlled by a compass so as to maintain said contact in a fixed position, the apparatus also including a pair of movable electrical contacts which are controlled by weight elements and which indicate the direction and angle of inclination of the well bore, respectively, together with a master rotatable contact disk arranged to engage the trio of contacts to close electrical circuits to an indicating mechanism located at a point remote from said contacts, whereby the direction and angle of inclination of the bore may be accurately indicated at the surface.

Still another object of the invention is to provide an improved compass unit which will accurately maintain a fixed point in a predetermined direction, whereby such point provides a basis from which indications and readings may be obtained.

A still further object of the invention is to provide an electrically operated survey apparatus which is arranged so that the electrical power for operating the apparatus, as well as the generated indicating impulses, may be transmitted over the same conductor, whereby lowering of the device through the well bore is facilitated.

Another important object of the invention is to provide an improved indicating and recording unit wherein the indications are recorded on a tape, or other element, which permits a continuous, as well as a permanent, record to be made.

A construction designed to carry out the in-

vention will be hereinafter described, together with other features of the invention.

The invention will be more readily understood from a reading of the following specification and by reference to the accompanying drawings, in which an example of the invention is shown, and wherein:

Figure 1 is a transverse, vertical, sectional view of a well bore, showing the transmitting unit of the apparatus lowered therein.

Figure 2 is a transverse, vertical, sectional view of the outer housing and illustrating the unit mounted within said housing.

Figure 3 is an enlarged transverse, vertical, sectional view of the upper portion of the transmitting unit.

Figure 4 is a similar view of the intermediate portion of said unit.

Figure 5 is a similar view of the lower portion of said unit.

Figure 6 is a horizontal, cross-sectional view taken on the line 6—6 of Figure 4.

Figure 7 is a horizontal, cross-sectional view taken on the line 7—7 of Figure 4.

Figure 8 is a horizontal, cross-sectional view taken on the line 8—8 of Figure 4.

Figure 9 is an enlarged transverse, vertical, sectional view of the contact assembly and also of the weight assembly, the same being illustrated in an inclined position.

Figure 10 is a wiring diagram of the transmitting unit.

Figure 11 is a schematic view and wiring diagram of the recording unit, which is located at the surface of the well.

Figure 12 is an enlarged transverse, vertical, sectional view taken on the line 12—12 of Figure 5.

Figure 13 is a horizontal, cross-sectional view taken on the line 13—13 of Figure 12, and illustrating the position of the photoelectric cells in dotted lines.

Figure 14 is an isometric view of the weight assembly which controls the direction contact.

Figure 15 is an isometric view of the pendulous weights.

Figures 16, 17 and 18 are views similar to Figures 3, 4 and 5 and illustrating a modified form of the invention.

Figure 19 is a horizontal, cross-sectional view taken on the line 19—19 of Figure 17.

Figure 20 is a horizontal, cross-sectional view taken on the line 20—20 of Figure 17.

Figure 21 is a horizontal, cross-sectional view taken on the line 21—21 of Figure 18.

Figure 22 is an enlarged transverse, sectional view of the contact assembly and control means of the modified form.

Figure 23 is a diagram illustrating the operation of the parts shown in Figure 22.

Figure 24 is a wiring diagram of the transmitting unit of the modified form.

Figure 25 is a schematic view and wiring diagram of the recording unit employed in the modified form, and

Figure 26 is a schematic view and partial wiring diagram illustrating the hook-up when the oscillators and their associate parts are eliminated.

The general assembly

In the drawings, the numeral 10 designates a well bore which has been illustrated as curving or inclining from the vertical. In surveying the bore, it is essential that the direction in which

said bore inclines, as well as the angle or inclination, in degrees, from the vertical, be ascertained. Successive readings are taken at various elevations or points throughout the well bore and a correlation of such readings provides accurate information as to the direction and degree of inclination of said bore.

In carrying out the invention, an orienting and transmitting unit T is adapted to be lowered through the well bore 10 on a flexible line or cable 11. The upper end of the cable extends from the well bore and passes over a pulley 12, after which the cable is wound around a drum 13 located at the surface, whereby lowering and raising of the unit T is facilitated. A lead wire or conductor 14 extends upwardly from the unit T through the cable and has connection with a suitable indicating and recording unit R which is mounted at the surface of the well. The wire or conductor 14 is utilized to conduct the electrical current, which is necessary for operation of the unit T, downwardly to said unit, and is also employed for carrying the transmitted electrical impulses from said unit to the recording unit R, as will be hereinafter explained.

The orienting and transmitting unit T includes an outer shell or housing 15 (Figure 2) which has its lower end closed by a plug or closure 16, which is threaded thereto. An inner housing 17 is mounted within the outer shell and the operating apparatus and equipment of the unit is contained in this inner housing. The housing is held against rotation within the shell by an upstanding, transversely extending key 18 which is formed on the plug or closure 16 and which engages a groove 19 in the underside of said housing. A metallic contact 20 is axially mounted within the top of the inner housing and is recessed to receive a contact prong 21 which depends from the center of an insulating disk 22. The lower end of the wire or conductor 14 is electrically connected with the prong 21. The prong is urged into engagement with the contact by a coiled spring 23 which is confined between the disk 22 and the underside of a cable or line socket 24, the latter being constructed in two sections and being threaded into the upper end of the shell 15. The lower end of the cable 11 is secured within the socket and a fishing neck 25 which is threaded onto the upper end of the socket surrounds the cable. A suitable packing 26 is confined within the socket and packs off around the conductor which extends from the lower end of the cable.

The unit T is lowered to successive positions in the well bore 10 and at each position, the unit T is operated. As will be explained, the operation of the unit transmits a plurality of electrical impulses to the indicating and recording unit R at the surface, said impulses being transmitted over the conductor 14. The impulses are representations of the direction in which the bore 10 inclines and also of the degree or angle of such inclination and the indicating and recording unit R transposes these representations into visible indications. By taking the readings at successive elevations or points in the bore, the direction and degree of inclination is accurately indicated.

The orienting and transmitting unit

The orienting and transmitting unit is clearly shown in Figures 3 to 5 and, as explained, includes the housing 17 which is incapable of rotation within the shell 15. The housing is of

a constant diameter, slightly less than the inner diameter of the shell, and the upper end thereof is closed by a cap 27 which is threaded thereto. The metallic contact 26 is mounted within the cap and is insulated therefrom by an insulating collar 28 which surrounds said contact and by an insulating disk 29 which underlies the cap. The lower end of the housing 17 is closed by a plug 30, which has threaded connection therewith, and the underside of this plug is provided with the groove 18 which receives the upstanding key 18 of the closure 16. The upper end of the plug 30 is formed with an axial recess 31, which is countersunk to receive a bearing assembly 32. A pivot pin 33 which depends from the lower end of a rotatable casing 34 is confined within the bearing assembly and is freely rotatable therein.

The rotatable casing 34 houses that portion of the apparatus, which will hereinafter be referred to as the compass unit C, and said casing has an outer diameter less than the inner diameter of the housing 17 so as to be freely rotatable therein. The casing is within the lower portion of the housing and has its lower end closed by a plug 35 into which the pivot pin 33 is threaded (Figure 5). The upper end of the casing has a cap 36 (Figure 4) threaded thereto and said cap has an upwardly extending, tubular shank or sleeve 37, preferably made integral therewith. The shank projects through an axial opening 38 formed in a transverse partition 39, which is provided within the housing 17. Suitable bearings 40 surround the shank and, manifestly, the inner casing 34 is mounted so as to be freely rotatable within the housing 17.

The compass unit C, which will be hereinafter described, is housed within the rotatable casing 34 which is mounted within the lower portion of the housing 17. Immediately above the casing, a contact assembly A, which is actuated to close electrical circuits to a transmitting apparatus, is mounted. A weight assembly W, which controls the position of certain of the contacts in the assembly A, is disposed above said assembly and in the upper portion of the housing 17, is the transmitting apparatus. This apparatus includes a trio of oscillators 01, 02 and 03, which are supported on transverse partitions or decks 41. The various transformers, filter reactors and other necessary electrical equipment, are also mounted within the housing 17, as will be more fully explained.

The compass unit C within the rotatable casing 34 is arranged to control the position of the casing with relation to north, or any other desired azimuth. This casing has connection with the contact assembly and the position of the casing, which is, in effect, the position of the compass, is transmitted to the surface through the oscillator 01. The weight assembly W also has connection with the contact assembly A and the positions of the weights of said assembly are transmitted to the surface through the oscillators 02 and 03 of the transmitting apparatus. The weights of the assembly W assume a position in accordance with the direction and degree of inclination and, therefore, by transmitting the positions of said weights to the indicating and recording unit R at the surface, the trend of the bore is indicated, as will be hereinafter described in detail.

The compass unit

The compass unit C is mounted within the

lower portion of the rotatable casing 34 and includes a tubular shell or sleeve 42 (Figure 5), which is secured within the casing immediately above the plug 35 which closes the lower end thereof. A block 43 is disposed within the lower portion of the shell, preferably having threaded engagement therewith, and this block is formed with an axial bore or opening 44. A shaft 45 extends axially of the bore, being supported on bearings 46, and the upper end of said shaft projects above the block. An arcuate supporting bracket or collar 47 is secured to the upper end of the shaft and, manifestly, said bracket or collar is freely rotatable within the casing. A weight 48 is fastened within the bracket at one side thereof and when the casing 34 is inclined as, for example, as it is lowered through an inclined bore, this weight always finds the low side, the bracket being rotated to allow said weight to move to such low side.

A magnetic compass 50 is mounted within the supporting bracket or collar 47 and includes a semi-spherical base 51 (Figures 5 and 12). The base is weighted and is pivotally secured to the bracket, the pivot points 52 being located diametrically opposite each other and being misaligned substantially ninety degrees from the weight 48 of said bracket. With such arrangement, when the casing 34 is inclined, the weight 48 finds the low side, rotating the bracket 47 accordingly. At such time the bracket is inclined, that is, its side walls are off the vertical, but the weighted base 51 of the compass swings on its pivots 52 to maintain the upper surface of said base in a true horizontal plane.

The usual suspension pivot 53 extends upwardly from the base 51 and a semi-spherical shell 54 is mounted on the upper pointed end of said pin. Upward displacement of the shell is prevented by a sleeve 55 which depends axially from the shell and which has its lower flanged end engaged beneath a keeper 56 mounted on the base 51. The usual magnets 57a are suitably secured within the shell 54. The upper surface of the shell is of a dull non-reflecting surface except for a narrow strip or bar of light reflecting material 57. This strip or bar extends from the center of the shell (Figure 13) to the outer edge thereof and is disposed on the shell so as to constantly point in a predetermined direction. For the purposes of this description, it will be presumed that the reflecting bar or strip 57 is always pointing north, although it could be arranged on the upper surface of the shell to point in other directions. From the foregoing, it will be obvious that when the unit T is lowered into a well bore, said unit will incline in accordance with the inclination of the bore. Also, since said housing is carried by the flexible line 11, it may rotate as it is lowered. However, regardless of the rotation of the unit or of the inclination thereof, the compass 50 maintains the reflecting strip or bar 57 on the upper surface of the semi-spherical shell 54 in a position or direction pointing north.

The upper end of the tubular shell 42 which houses the compass is closed by a cap member 58 which is threaded into said upper end. This cap member has a downwardly extending, conical sleeve 59 formed integral therewith and located axially thereof. The sleeve is reduced toward its lower end and has a suitable curved window 60 mounted therein. The window provides a closure to retain a suitable damping fluid for the compass within the casing 42, the fluid being

maintained at the level indicated in Figure 5. Manifestly, the light rays pass through the window and strike the light reflecting strip or surface 57 of the semispherical shell 54 of the compass.

A tubular lens-carrying sleeve or casing 61 is mounted above the shell 42 within the casing 34. This sleeve is disposed at one side of the casing 34 and has its upper end extending through and supported within a transversely extending plate or deck 62. The lower end of the sleeve terminates adjacent a prism 63 which is mounted in a transverse partition 64 and light rays which pass through the sleeve strike the prism and are directed through the window 60 above the compass. As is schematically shown in Figure 10, the sleeve 61 has a pair of condensing lenses 65 at its upper end with a pair of projecting lenses 66 at its lower end. A gate 67, of the usual construction, is interposed between the lenses 65 and 66. Manifestly, light rays from a source of light above the tubular sleeve 61 pass downwardly through the lenses which concentrate said rays on the prism 63, which prism directs the same through the window 60 and onto the light reflecting strip 57 of the compass shell 54.

As a source of light, an electric lamp 68, having a straight wire filament, is mounted above the tubular sleeve 61. The lamp is insertable within a socket 69 which is carried by an insulated support 70 extending upwardly from the deck 62. A spring contact 71 engages the base of the lamp and serves to conduct electrical current thereto. When the lamp is illuminated, light rays are directed downwardly through the lenses and prism and are concentrated on the light reflecting strip 57 of the compass shell; actually, an image of the lamp filament is projected onto the reflecting strip.

The light rays which strike the light reflecting strip 57 are reflected upwardly therefrom and onto a twin light sensitive element, such as a twin photo tube 72, which includes photoelectric cells 72a and 72b (Figure 10). A prism 63a is interposed between the compass and the twin photo tube. The twin photo tube 72 is adapted to control a follow-up electric motor 73 which is mounted on a transverse support 74 within the casing 34 near the upper portion thereof. The motor has a double winding 73a and 73b so that its shaft may be rotated in either direction. The electrical circuit, in which the twin photo tube and motor 73 are connected, includes a twin amplifying tube 75, a power transformer 76, and a trio of relays 77, 78 and 79, these elements being mounted within the casing 34 on suitable transverse supports which are disposed between the twin photo tube 72 and follow-up motor 73. The details of the electrical circuit of the motor 73 will be hereinafter described in detail, but it is noted that, at this time, the photoelectric cell 72a is arranged to close the circuit through the relay 77 to the winding 73a of the motor to rotate the motor shaft in one direction, while the other photoelectric cell 72b is adapted to close the circuit to the other winding 73b of the motor through the relay 78. Thus, if the cell 72a is receiving more light, as reflected by the light reflecting strip 57 of the compass, then the winding 73a is energized to rotate the shaft of the motor 73 in one direction; if the cell 72b is receiving more light, then the motor shaft is rotated in an opposite direction. As is clearly shown in Figure 12, the light responsive cells 72a

and 72b are normally located, one on each side of the light reflecting strip 57. When the compass is at rest with the strip 57 pointing north, then the light rays from said strip are directed between the photoelectric cells 72a and 72b, with each cell receiving an equal amount of light, such amount being insufficient to actuate the relays controlling the motor windings 73a and 73b. If the shell 50 of the compass moves, with relation to the photo tube, so as to cause more light to strike one cell, then the motor winding controlled by that cell is actuated and such actuation, as will be hereinafter explained, results in a rotation of the casing 34 to automatically cause alignment of the cells 72a and 72b with the strip 57. In other words, the follow-up motor 73 rotates the casing in one direction or the other so that the relative position of the casing 34 to the compass 50 is maintained.

For imparting rotation to the casing 34 by means of the follow-up motor 73, the motor shaft is provided with a drive pinion 80, which has a driving connection through a reduction gearing 81, with a friction drive wheel 82. The wheel is mounted at one side of the casing 34 and has one side extending outwardly through an opening 83 formed in said casing. The periphery of the drive wheel rides on the wall of the outer housing 17 of the unit T and has frictional engagement therewith. Manifestly, when the motor 73 is actuated to rotate the wheel in one direction or the other, said wheel imparts a rotation to the inner casing 34, such rotation being relative to the outer housing 17. Therefore, regardless of the position of the outer housing 17, the position of the inner casing 34 is maintained fixed with relation to the compass 50 and with relation to the point north.

The tubular shank 37 at the upper end of the casing 34 extends through the supporting partition 39, as has been explained, and has an insulating collar or disk 84 secured thereon so as to be rotatable therewith (Figures 4 and 9). This disk has a contact 85 embedded in its upper surface near the periphery thereof and this contact will be hereinafter referred to as the "north" contact. The north contact is so located radially on the insulating disk that when the light reflecting strip 57 on the compass 50 is properly aligned with the twin photo tube 72 and the casing 34 is stationary, said north contact is aligned vertically with the strip 57, whereby both the strip and the contact 85 are at all times pointing north. If the unit T is rotated on its supporting cable, the compass shell 54 will naturally rotate with relation to the casing 34 so as to maintain its reflecting strip 57 pointing north. Such movement of the shell 54 results in misalignment of the strip 57 with the photoelectric cells 72a and 72b, whereby one or the other of the cells operates one of the motor windings 73a or 73b to actuate the motor and impart sufficient rotation to the casing 34 to again align the cells with the strip. Since the north contact 85 is secured to the casing, the contact is moved therewith to maintain it in vertical alignment with the strip. Thus, it is manifest that the compass unit and its associate parts serve to hold the contact 85 pointing north at all times, regardless of the rotation or inclination of the outer housing 17 of the unit T. This north contact establishes a basis from which readings can be taken and calculations made to determine the direction and degree of inclination of the bore hole.

The compass unit wiring diagram

The electrical circuit, in which the twin photo tube 72 and the electric follow-up motor 73 are connected, is, of course, subject to variation and one form of hook-up is illustrated in Figure 10. In this figure, alternating current is supplied to the motor windings 73a and 73b by a supply wire 100. The relay 77 controls relay contacts 77a which, when closed, completes the circuit through a wire 77b and through the winding 73a, to a common ground G; similarly, the relay 78 controls relay contacts 78a which, when closed, completes a circuit through a wire 78b and through the winding 73b to the common ground G. Obviously, when the relay 77 is energized, the winding 73a is energized to operate the motor shaft in one direction, while energization of the relay 78 operates the motor in an opposite direction. The windings of the relays 77 and 78 are supplied with direct current by a supply wire 101 through the plate circuit of the twin tube 75.

The relay 77 is connected by a wire 77c with one plate of the twin amplifying tube 75, the grid of which is, in turn, electrically connected through a wire 75a with the photoelectric cell 72a. When sufficient light is striking the cell, the relay is energized to close the contacts 77a and energize the winding 73a. The relay 78 is similarly connected to the plate of the tube 75 through a wire 78c and a wire 75b connects the grid of the tube to the cell 72b, whereby when sufficient light is directed onto this cell, the relay 78 is energized to complete the circuit to the winding 73b of the motor 73. When the compass shell is in a normal position, the light rays reflected from the strip 57 are directed between the cells so that neither receives sufficient light to actuate its relay. However, when the compass shell rotates relative to the cells, one cell receives more light and actuates its relay to rotate the casing 34 and re-align the cells with the strip. In this manner, the casing 34 is maintained in the same position relative to the strip 57 of the compass and the north contact 85, which is carried by the insulating disk 84 secured to the casing, is always maintained in a position pointing north.

It might occur, in some instances, that the housing 17 and casing 34 will be rotated very rapidly, in which case the compass shell, in finding north, will move the reflecting strip 57 completely from beneath both cells 72a and 72b, with the result that neither could operate its relay to re-align said cells with the strip. For rotating the casing 34 to again align the cells with the strip 57 in the event the above occurs, the emergency relay 79 is provided. As shown in Figure 10, the relay is connected by a wire 79a to the relays 77 and 78 and is arranged to control relay contacts 79b. These contacts are adapted to complete the circuit to the winding 73b of the motor 73. The relay 79 is so connected in the circuit that when both cells 72a and 72b are receiving light, at which time their relays 77 and 78 are inoperative, the relay 79 is energized since it is, in fact, connected to both cells. Energization of the relay 79 holds its relay contacts 79b open and so long as either or both cells are receiving light, the circuit through these contacts is open. However, in the event no light strikes either cell, the relay 79 is de-energized, allowing the contacts 79b to close the circuit to the motor winding 73b, whereby the motor shaft is rotated in one direction to impart

rotation to the casing. Such rotation continues until one of the cells 72a or 72b again receives the reflected light, at which time the cells actuate their relays to again align the strip 57 with the tube 72. As soon as the light again strikes one or both cells, the relay 79 is again energized to open the contacts 79b. Thus, the relay 79 is an auxiliary relay to assure alignment of the photo tube 72 with the reflecting area or strip 57 in the event no light rays are striking either cell.

The electric lamp 68, which provides the light rays which are directed onto the reflecting surface of the compass, is supplied with current from one of the secondary windings of the transformer 76, being connected thereto by wires 68a and 68b. The other secondary winding of said transformer has connection with the heater or filament of the twin amplifying tube 75. The primary winding of said transformer is supplied with A. C. through a wire 100a, which leads from the main supply wire 100.

The contact assembly

The insulating collar 84 which is mounted on the tubular shank 37 at the upper end of the casing 34 forms a part of the contact assembly A. As has been explained, this collar has the contact 85 embedded in its top and said contact is maintained in a position pointing north by means of the compass unit C. A trio of contact rings 86, 87 and 88 are secured to the periphery of the insulating collar 84 (Figure 9) and the former, 86, is connected with the common ground G, while the latter two rings, 87 and 88, are connected to the supply wires 100 and 101 which supply current to the compass unit C. The rings are engaged by contact brushes 86a, 87a and 88a, respectively, which are mounted on a vertical post 89 which extends upwardly from the transverse partition 39. Manifestly, the brushes and rings provide a means whereby current may be conducted through the rotatable member or collar 84.

Above the insulating collar 84, which carries the north contact 85, a rotatable disk 90 is mounted. This disk is constructed of electrical insulating material and is secured to the upper end of a rotatable shaft 91. The shaft extends downwardly through the tubular shank 37 of the casing, being rotatable on bearings therein, and the lower end of said shaft projects into the upper portion of the casing 34. This projecting lower end of the shaft has a drive gear 92 thereon and said gear is in constant mesh with another gear 93, the latter being secured on a shaft 94. Bevel gears or pinions 95 and 96 establish a driving connection with the shaft of an electric motor 97 which is supported on a transverse partition within the upper portion of a casing 34. Alternating current is supplied to the winding 97a (Figure 10) of the motor 97 through a wire 100b which leads from the main supply line 100. The motor 97 is arranged to be actuated at a fixed or predetermined speed, whereby the disk 90 is rotated at a predetermined speed, as for example, 5 R. P. M.

A spring contact arm 98, having a contact 99 at its outer end, is mounted on the underside of the disk and is arranged to ride on the upper surface of the insulating collar 84. The contact 99 is disposed in the same concentric plane as the north contact 85, whereby the contacts engage each other once during each revolution of the disk. The contact arm is electrically con-

nected with a collector ring 103 which surrounds the periphery of the disk. Above the ring 103, two additional rings 104 and 105 are secured to said disk and the three rings are engaged by spring brushes 103a, 104a and 105a, which brushes are carried by the vertical post 89. The brush 103a is connected to the oscillator O1 of the transmitting apparatus, while the brushes 104a and 105a are connected to the oscillators O2 and O3 of said apparatus, as will be more fully explained. Since the brush 103a, which engages the ring 103, has electrical connection with the oscillator O1, the engagement of the contact 99 on the arm 98 with the north contact 85 closes an electrical circuit to the oscillator O1, whereby said oscillator is actuated to set up and transmit an electrical impulse to the surface, as will be described. Therefore, each time the contact 99 engages the north contact 85, which is once during each revolution of the disk, the electrical circuit to the oscillator O1 is closed and an electrical impulse is transmitted to the surface.

The collector rings 104 and 105 are electrically connected to a pair of contacts 106 and 107, respectively, and these latter contacts are mounted on the upper surface of the disk 90. The contacts 106 and 107 are located adjacent each other and are aligned vertically with the contact 99 on the underside of the disk; manifestly, since these contacts are mounted on the disk, they rotate simultaneously therewith. The contact 106 is arranged to engage a contact plunger 106a, which is supported by a flat spring, while the contact 107 is adapted to engage a similar contact element 107a, said elements overlying the disk 90. It is preferable that the contacts 106 and 107 have their upper surfaces slightly above the top of the disk, whereby the contacts 106a and 107a may be engaged thereby, without said contacts 106a and 107a riding on the top of said ring. This arrangement reduces friction and obviates the danger of the disk causing movement of the contacts 106a and 107a to produce an inaccurate reading. When the contacts 106 and 106a engage each other, an electrical circuit to the oscillator O3 of the transmitting apparatus is closed, whereby an electrical impulse is generated and transmitted to the surface. Such impulse is representative of the direction of inclination of the bore 10, as will be explained. Engagement of the contacts 107 and 107a closes an electrical circuit to the oscillator O2, whereby an electrical impulse is transmitted to the surface and this impulse is representative of the angle or degree of inclination.

The weight assembly

For controlling the position of the contacts 106a and 107a, so as to indicate the direction and degree of inclination, the weight assembly W is provided and is mounted within the housing 17 above the contact assembly. This assembly includes a weight member 108 which has a pair of upwardly extending arms 109 preferably made integral therewith. The upper end of the arms are connected by a crossbar 110 (Figures 9 and 14) which has a central upstanding pivot pin 111. The pin is mounted in suitable bearings 112 which are disposed within a transverse supporting partition 113. As is clearly shown in Figure 9, the weight is off-center with relation to the interior of the housing and has a depending tubular sleeve 114 which extends through a transverse deck 115. Suitable bearings 116 sur-

round the sleeve and, manifestly, by means of said sleeve and the pivot pin, the weight is rotatable within the housing. Due to the fact that the weight 108 is off-center of its pivot points, it is obvious that when the housing 17 is inclined, the weight will find the low side. Such movement of the weight will impart a rotation to the sleeve 114, the rotation being in accordance with the amount of movement of the weight.

The lower end of the sleeve 114 has a radially extending arm 117 secured thereto and the contact 106a is mounted in the outer end of said arm. When the housing is in a vertical position, the arm 117 and contact 106a are aligned vertically with the north contact 85 in the collar 84. In such position, the contact 106 on the disk would engage the contact 106a simultaneously with the engagement of the contact 99 with the north contact 85. This would result in a simultaneous actuation of the oscillators O1 and O3 and such actuation would indicate true vertical, as will be explained. However, if the outer housing 17 were inclined, then the weight 108, in moving to the low side, rotates the arm 117 and misaligns the contact 106a relative to the north contact 85. The number of degrees of this misalignment is representative of the number of degrees from north that the bore inclines, thereby indicating the direction of inclination.

For indicating the degree or angle of inclination, a second weight member 118 is provided. This member includes a pair of arcuate weights which are secured together by a shaft 119. The ends of the shaft are journaled in the arms 109 of the first weight (Figure 9), and the weight 108 is recessed at 108' to permit the arcuate weights to move therethrough. Obviously, the weights 118 form a pendulum and remain in a vertical position, regardless of the inclination of the housing 17. An adjustable stop 120 may be provided for limiting the swing of the weights 118.

When the pendulous weights swing they impart a rotation to the shaft 119 to which they are secured. This shaft has a bevel gear 121 thereon and said gear is in constant mesh with a bevel pinion 122, the latter being secured to the upper end of a shaft 123. The shaft 123 extends through a vertical bore 124 formed in the weight 108 and also through the sleeve 114, the lower end of said shaft projecting from the lower end of the sleeve. The projecting end of the shaft has an arm 125 secured thereto and the outer end of this arm has the contact 107a mounted therein. When the housing 17 is in a vertical position, the pendulous weights 118 are centered in the housing and, in such position, the contact 107a is aligned vertically with the north contact 85 and is also aligned with the contact 106a. However, when the housing is inclined, the pendulous weights 118 swing with relation to the weight 108 and through the medium of the gears 121 and 122 and the shaft 123, the arm 125 and contact 107a are swung out of alignment with the arm 117 and contact 106a. The amount of such misalignment is representative of the degree of inclination from the vertical of the housing 17 and of the bore 10, in which the housing is located. As explained, the contact 107a is adapted to be engaged by the contact 107 to close an electrical circuit to the oscillator O2 of the transmitting apparatus to generate and transmit an electrical impulse as to the recorder R at the surface.

The transmitting unit

As has been explained, the transmitting apparatus includes a trio of oscillators 01, 02 and 03. Each oscillator, as is clearly shown in the wiring diagram in Figure 10, includes a triode tube 128, oscillation coupler 127 and condenser 126. The electrical hook-up of each oscillator is well known in the electrical art and it is not believed necessary to give a detailed description thereof. The oscillator 01 is connected by a wire 103b with the contact brush 103a, which is in engagement with the collector ring 103 on the rotating disk 80. The oscillator 02 is connected by a wire 104b with the brush 104a, which brush is in engagement with the collector ring 104 of said disk, while the third oscillator 03 is connected through a wire 105b with the brush 105a engaging the collector ring 105 of said disk. The current is supplied to the transmitting unit through the wire 14 which extends downwardly through the flexible cable or line 11. A filter reactor 129 is connected in the wire 14a prior to the connection of said wire to a power transformer 130. A direct lead wire 200 connects the line 14 with the brush 87a, which brush engages the collector ring 87 on the insulating collar 84. As has been explained, the ring 87 is connected with the supply wire 100 and, thus, it will be seen that alternating current flowing downwardly from the wire 14 will pass downwardly through the wire 200, then through the ring 87 and finally to the wire 100.

The primary winding of the transformer 130 is supplied with the alternating current from the wire 14. The low voltage secondary winding of the transformer 130 supplies the heater current to a rectifying tube 131 and also to the triode tubes 128 of the oscillators. The high voltage secondary output is rectified by the rectifier tube and is changed to direct current. This direct current is filtered by a filter condenser 132 and is then conducted by means of a wire 201 to the contact brush 88a. This brush is in constant engagement with the contact ring 88 of the insulating collar 84. The ring 88 is directly connected with the direct current supply wire 101 and, thus, it will be seen that a flow of direct current is conducted to the compass unit C. The direct current is fed to the oscillators 01 to 03 by means of wires 202, 203 and 204, which wires have connection with the main supply wire 201.

When the cathode circuit to any one of the oscillators is closed through the action of the contact assembly, as has been explained, that oscillator generates a carrier frequency or an electrical impulse, which impulse is transmitted over a wire 14a, which is connected to the wire 14 in advance of the filter reactor 129. This electrical impulse is carried to the surface by the wire 14 and is then conducted to the recording unit R, as will be hereinafter explained. From the foregoing, it will be obvious that, as the contact assembly operates, the oscillators are operated to transmit electrical impulses to the surface. It is pointed out that each oscillator transmits an electrical impulse of a different frequency, that is, the oscillator 01 may generate a carrier frequency of 350 cycles, while the oscillator 02 may generate a frequency of 450 cycles, while the oscillator 03 may generate a frequency of 600 cycles. Thus, it will be possible to transmit the impulses simultaneously over the same wire. It is pointed out that the figures given

herein with respect to the cycles are illustrative only and the invention is not to be limited to the same, as the frequency of the impulses generated by the oscillators is subject to variation.

The indicating and recording unit

Any suitable type of indicating and recording unit R may be employed and one type which has been found suitable has been illustrated; however, the invention is not to be limited to the type shown. The indicating and recording unit R which is illustrated in Figure 11 includes the movable tape 135, which is mounted on suitable rollers 136. The tape is preferably formed with perforations 137 along its edges, which perforations are adapted to be engaged by radially extending pins 138 formed on the rollers. One of the rollers 136 has its shaft extended and provided with a drive gear 139, which meshes with a pinion 140. The pinion is secured to the outer end of the shaft of an electric motor 141, whereby the tape 135 may be driven at a constant speed.

A trio of styluses 142, 143 and 144 are arranged to ride on the tape 135 and, as said tape moves beneath said styluses, the latter form or imprint a trio of longitudinal, parallel lines on said tape. Each stylus is pivotally mounted on a pin 145 which is secured to a suitable support 146.

The stylus 142 imprints or forms the parallel line 142' on the tape and the outer end of said stylus is adjacent an electromagnetic relay 147. When the relay 147 is energized, a lateral movement is imparted to the inner or marking end of the stylus 142, whereby an offset 142a is formed in the line 142'. The relay 147 is connected in an electrical circuit which includes an amplifier 148 and a suitable filter 149, as well as a transformer 150. The transformer is connected by a wire 151 with the wire 14, whereby an electrical impulse transmitted upwardly along the wire 14 will pass over the wire 151 and to the relay 147 to energize the same.

It is pointed out that the filter 149 is so constructed as to receive impulses of the frequency generated by the oscillator 01 and, therefore, each time that the oscillator 01 is operated, the electrical impulse generated thereby is transmitted to the surface and energizes the relay 147 to swing the stylus 142 and form one of the offsets 142a in the line 142'. The line 142', as will be hereinafter explained, represents the azimuth or north point.

The stylus 143 forms or imprints a line 143' which is located centrally on the tape 135. The outer end of the stylus 143 is adjacent a relay 147a, which is similar to the relay 147 in the circuit of the stylus 142. The circuit for the stylus 143 is substantially the same as that hereinbefore described for the stylus 142, and includes the amplifier 148a, filter 149a and transformer 150a. The transformer is connected to the wire 151 by a wire 151a. The filter 149a for the stylus 143 is arranged to pass impulses of the frequency which are generated by the oscillator 03. As explained, the oscillator 03 transmits impulses which represent the direction of the drift or inclination of the bore hole and each time this oscillator is operated the relay 147a is energized to swing the inner or marking end of the stylus 143, whereby an offset 143c is formed in the line 143'.

The stylus 144 forms a line 144' on the tape and has its outer end adjacent a relay 147b. When the relay is energized, the inner or marking end of the stylus is moved laterally to form an offset 144a in the line 144'. The circuit in which the

relay 147b is mounted includes an amplifier 148b, a filter 149b and a transformer 150b. A lead wire 151b connects the transformer to the wire 151, whereby the impulses travelling upwardly over the wires 14 and 151 will pass to said transformer. The filter 149b which is connected in the circuit controlling the relay 147b is constructed so as to receive the impulses of a frequency which are generated by the oscillator O2. This oscillator, as has been explained, transmits impulses representative of the angle or degree of inclination and each time said oscillator is actuated, the relay 147b is energized. Such energization of the relay swings the stylus 144 so as to form one of the offsets 144a in the line 144'.

From the above, it will be seen that the first stylus 142 is controlled in its operation by the oscillator O1 and the line 142' which is formed by this stylus is representative of the azimuth or north point. The second stylus 143 is controlled in its operation by the oscillator O3 and the line 143' formed by this stylus is representative of the direction of the inclination of the bore hole. The third stylus 144 is controlled in its operation by the oscillator O2 and the line 144' formed by the stylus 144 is representative of the angle or degree of inclination.

The operation

In the operation of the apparatus, the unit T is assembled as shown in Figures 1 and 2 and is lowered to successive positions within the bore 10 by means of the cable 11. The recording unit R is located at the surface of the well, being electrically connected through the wire 151 with the main lead or conductor 14. The electrical power necessary for operating the various parts is conducted through wires 152 and 152a, which lead from a suitable source of supply. An insulating transformer and voltage control 153 is connected to the power lines 152 and 152a and is also connected to the line 14. A suitable ammeter 154 may be connected in the wire 14 in advance of the transformer. A filter reactor 155 is also connected in the wire 14 to prevent the electrical impulses, which are travelling upwardly along the wire, from passing to the transformer. Also condensers 156 are connected in the wires 151, 151a and 151b to prevent the current flowing downwardly to the compass unit through the wire 14 from passing to the indicating and recording unit R.

Assuming that the device is lowered to the position shown in Figure 1 and a reading is to be taken at this position, it will be seen that the bore is inclined, whereby the transmitting unit T is also inclined in accordance with said bore. In such position, the outer housing of the unit T is inclined. At this time, no current is flowing downwardly through the unit T, and the device is permitted to remain for a brief period to permit the magnetic compass 50 to adjust itself and align the reflecting strip 57 on the compass shell 54 in a direction pointing north. After the compass 50 has adjusted itself, the reflecting strip 57 may or may not be aligned with the twin photo tube 72, depending on whether or not the casing 34 has been rotated during the lowering operation.

At the same time that the compass 50 is adjusting itself, the weight assembly W automatically operates to swing the contacts 106a and 107a into their positions in accordance with the inclination of the housing 17. The weight 100, which controls the contact 106, swings on its pivot

to the low side and such swinging of the weight 100 rotates the arm 117 which carries the contact 106a, thereby resulting in an adjustment or movement of the contact relative to the rotating disk 90. At the same time, the pendulous weights 113, which control the position of the contact 107a, are swung, whereby the contact 107a is adjusted or moved with relation to the contact 106a and also with relation to the disk 90. After sufficient time has elapsed for the weights and compass to adjust themselves, the device is in readiness for the reading to be taken.

In taking the reading, a manual switch at the surface is closed so that electrical current flows from the power lines 152 and 152a and downwardly through the wire or conductor 14. This electrical current is alternating current and flows through the wire 200, then through the contact ring 87 of the insulating collar 84 (Figure 10) and then to the wire 100, and finally to the timing motor 97, follow-up motor 73 and power transformer 76, as has been explained. The current is rectified by the tube 131 and is conducted through the wire 201, through the collector ring 88 of the collar 84 and then through the wire 101 which leads to the relays 77, 78, 79 and to the tube 75. The rectified current is also conducted to the oscillator units O1, O2 and O3 through the wire 202, as has been explained. The leads to the common ground G connect with the third contact ring 86.

As soon as the switch at the surface is closed and the current is conducted downwardly to the compass unit C, the electric lamp 68 is illuminated and the light rays therefrom are projected downwardly through the lenses 65 and 66 and then through the prism 63 onto the reflecting surface 57 of the compass shell 54. These light rays are reflected from the surface or strip 57 upwardly through a prism 63a and onto the photoelectric cells 72a and 72b. If the photo tube 72 is in proper alignment with the reflecting surface 57, then these reflected light rays will partially strike each tube, with the result that the follow-up motor 73 will not be operated. However, if the casing 34 is misaligned so that more light strikes one or the other of the photoelectric cells, then that cell is actuated to energize one winding of the motor 73. Such energization of the motor winding, as has been explained, rotates the casing 24 until it is properly aligned with the reflecting strip 57. When the photo tube 72 is aligned with such reflecting strip, which indicates the north point, then the contact 85 on the insulating collar 84 is also aligned with said reflecting strip, whereby said contact is also pointing north. The provision of the photo tube 72, together with the projection and reflection of the light rays, provides a positive means to assure that the contact 85 is maintained in a direction pointing north.

When the electrical current was conducted downwardly to the unit T, the timing motor 97 was operated to start rotation of the rotating disk 90. As explained, this motor operates at a fixed speed whereby the disk rotates a predetermined number of revolutions over a given period. As the disk 90 is rotated, the contact 99 on its underside engages the contact 85 on the insulating collar one time during each revolution of the disk. As the contact 99 moves into engagement with the contact 85, the electrical circuit is closed to the oscillator O1, whereby said oscillator is actuated to generate an electrical impulse of a predetermined frequency.

This impulse is transmitted upwardly over the wire 14 and then over the wire 151 to the relay 147 of the recording unit R. When the relay 147 is energized, the stylus 142 is swung to provide or form an offset 142a in the line 142' formed by said stylus. Since the contact 85 is pointing north and also since said contact is engaged by the contact 99 one time upon each revolution of the disk 90, it will be manifest that each offset 142a in the line 142' is representative of the position or direction north. The distance between the two offsets 142a in the line 142' is 360 degrees, since the disk 90 revolves one complete revolution after the contacts 99 and 85 are engaged. Since each offset 142a represents the direction north, it will be seen that halfway between said offsets represents south, and from these representations any given direction along the line 142' may be determined.

As the disk 90 revolves, it also causes the engagement of the contact 106 with the contact 106a and such engagement of these contacts closes an electrical circuit to the oscillator 93, whereby that oscillator generates and transmits an electrical impulse to the surface. Such impulse energizes the relay 147a so as to actuate the stylus 143, whereby offsets 143a are formed in the line 143'. These offsets will be spaced apart 360 degrees and are representative of the direction of the inclination of the bore 10. That these offsets represent the direction will be readily seen for, as explained, when the contact 106a is aligned with the fixed north contact 85, the housing 17 is in a vertical position. Whenever the housing 17 is inclined, it follows that the contact 106a is swung or moved circumferentially with relation to the disk 90 because of the weight 108, which always finds the low side. The amount of inclination of the housing 17 will, of course, control how many degrees the contact 106a is moved relative to the fixed north contact 85. Therefore, when the position of the contact 106a is changed with relation to the fixed contact 85, the contact 106a will be engaged by its contact 106 either before or after the contact 99 engages the north contact 85. The difference in the time of engagement of the contact 106a with relation to the engagement of the contact 85 will be indicated by the offsets 143a and 142a. As shown in Figure 11, the stylus 142 was actuated upon the engagement of the contacts 99 and 85. Due to the inclination of the housing 17, the contact 106 did not engage its contact 106a until several degrees later and this number of degrees can readily be determined by comparing the offsets 143a in the line 143' with the offsets 142a in the line 142'. As illustrated, the offset 143a is substantially northeast because it lies between the point north and the point east on the tape. Thus, the offset 143a immediately indicates the direction in which the bore hole 10 is inclined.

As the disk 90 rotates, it also brings about the engagement of the contact 107 with the contact 107a. The latter contact is controlled by the pendulous weights 118 and has been explained hereinbefore. The degree or angle of inclination of the bore 10 and the housing 17 is represented by the position of the weights 118 which always hang vertically from their shaft 119. When the housing is in a true vertical position, the contact 107a is aligned vertically with the contact 106a and lies in the same vertical plane. However, upon the inclination of the housing, the weights 118 swing so as to rotate the arm

125 which carries the contact 107a, thereby varying the radial position of said arm and contact with relation to the contact 106a, as is clearly shown in Figure 7. The number of degrees or the amount of this misalignment is of course controlled by the amount of inclination of the bore hole and, as illustrated, the contact 106a is engaged by its contact 106 in advance of the contact 107 engaging the contact 107a.

As soon as the contact 107a is engaged by its contact 107, an electrical circuit to the third oscillator 92 is closed, whereby an electrical impulse is transmitted to the surface. This impulse actuates the relay 147b, whereby the stylus 144 is swung to form the offset 144a in the line 144'. By comparing the point at which the offset 144a occurs with the offset 143a in the line 143', it is possible to determine the number of degrees difference between the contacts 106a and 107a. This difference in degrees is representative of the number of degrees that the housing is off true vertical and, thus, it is readily determined at what degree or angle the bore hole 10 inclines.

Successive readings may be taken throughout the entire length of the bore hole 10, whereby an accurate survey of the same is had. The device is accurate and positive in its operation and may be quickly lowered and raised through the bore on the flexible line. It is pointed out that the provision of the tape 135 provides a means whereby the indications may be quickly interpreted and also whereby a permanent record is had. The first line 142' establishes a basis from which the other readings may be taken. That is, the line 142' provides a means whereby the north point may be definitely determined. The second line 143' is indicative of the direction in which the bore hole 10 inclines and, by comparing the offset 143a in this line with the offsets 142a in the line 142', the exact direction of the bore hole inclination is had. The third line 144' provides a means for indicating the degree or angle of the inclination and, by comparing the position of the offsets 144a with the offsets 143a, such inclination, in the exact number of degrees, may be determined. The device is compact in construction and is mounted within the outer shell 15 which is sealed against fluids, whereby any fluids which may be present in the bore 10 will not interfere with the operation.

The arrangement herein described permits the operating current to be conducted to the unit T over the wire 14 and also allows the impulses generated by the oscillators to be transmitted over the same single wire. In some cases, it may be more desirable to eliminate oscillators and various filters, in which instance separate conductors, or wires, are employed (Figure 26) to connect the contact assembly C directly with the recording unit. With this arrangement, the engagement of contact 99 with the azimuth or "north" contact 85, results in closing the circuit to the relay 147, whereby the stylus 142 is actuated. Similarly, the engagement of contact 106a with the contact 106 closes the circuit to relay 147a of the stylus 143 and engagement of the contacts 107 and 107a closes the circuit to the relay 147b of the stylus 144. The same measurements and readings would be accomplished without the oscillators and filters. However, a multiple wire cable is substituted for the single wire or conductor 14 but the results obtained are the same.

The modified form

In Figures 16 to 25, a slightly modified form of

the invention is shown. This form of the invention is substantially the same as the first form, with the exception that another type of compass is illustrated in place of the compass 50 and also the weight assembly W is omitted, the direction and degree of inclination being indicated by other means. In this form, only two oscillators, instead of three, are employed.

In place of the compass 50, a compass 160 is substituted therefor and is mounted in the lower portion of the casing 34, as is clearly shown in Figure 18. This compass includes an outer casing 161 which has the tapered supporting pin 162 secured axially thereof. A circular compass card or disk 163 is mounted on the pin 162 and is provided with an elongate, radial slot 164 (Figure 21) therein. The slot 164 is arranged so as to point north at all times. The slot is disposed beneath an opening 165 formed in the top of the housing or casing 161 and this opening is located beneath the lens-carrying sleeve 61, whereby light rays may be projected downwardly through the opening and through the slot 164. The lower end of the casing 161 is provided with an opening 166 whereby the light rays passing through the slot 164 may be projected downwardly onto the twin photo tube 72. Instead of being mounted above the compass and adjacent the lens-carrying sleeve 61, as in the first form, the twin photo tube 72 is located below the compass and is arranged to receive the direct light rays rather than reflected light rays as in the first form. Manifestly, when the light rays are passing through the openings 165 and 166, as well as through the slot 164, an equal amount of light is striking the photoelectric cells 72a and 72b. However, if the casing 34 becomes misaligned with the slot 164 in the compass card 163, then one or the other of the photoelectric cells receive more light to actuate one or the other of the motor windings of the motor 73. The operation of the motor 73, as has been explained, results in an adjustment of the casing 34, whereby the contact 85, which is mounted in the upper end of the insulating collar 84 carried by said casing, is maintained in a direction pointing north at all times. The results obtained by this construction are exactly the same as that of the first form, the main difference being that direct light rays, rather than reflected light rays, are utilized to actuate the photoelectric cells 72a and 72b. In both instances, the contact 85 is held in a position pointing north at all times.

As has been pointed out, the weight assembly W, together with its associated parts, as shown in the first form, has been omitted and, in place thereof, a plumb bob assembly P substituted therefor. This latter assembly includes a rotating disk 170, which is somewhat similar to the disk 90 and which is mounted on the upper end of the shaft 91 which is controlled in its rotation by the timing motor 97. The disk 170 has a collector ring 103c secured thereon, which ring is engaged by a brush 103d mounted on the post 89. The brush 103d is similar to the brush 103a illustrated in the first form and is connected to the oscillator O1, which generates and transmits an electrical impulse to the surface to indicate the azimuth or north point. The contact ring 103c is electrically connected with a contact 99', which is similar to the contact 99 in the first form (Figure 22). Manifestly, as the disk 170 rotates, the contact 99' engages the contact 85 to close an electrical circuit to the oscillator O1. This oscillator generates and transmits an electrical impulse upwardly to the surface and energizes the

relay 147 of the stylus 142, as has been explained. Thus, it will be seen that as the disk 170 rotates and causes the engagement of the contacts 89' and the fixed north contact 85, the stylus 142 is actuated to form the offset 142a in the line 142'. This operation is exactly the same as has been described in the first form.

For indicating the direction and degree of inclination, the upper portion of the disk 170 is formed with an upwardly extending collar 171. This collar is preferably made of insulating material and is integral with the disk. Disposed within the collar and resting on the upper surface of the disk is a metallic plate 172 which has its upper surface suitably coated with a light responsive material 173, whereby the plate 172, in effect, forms a selenium or photoelectric cell. The plate 172 has its underside electrically connected through a contact bar 174 with a contact ring 175, which surrounds the disk 170 above the contact ring 103c. A similar contact ring 176 is disposed above the ring 175 and has connection through a bar 177 with the upper surface or with the coating material 173. The selenium cell acts as a resistance in the circuit and the amount of light striking the same varies its resistance. When light rays are projected onto the plate 172, the resistance of the cell is changed.

The collector rings 175 and 176 are engaged by spring brushes 175a and 176a, which brushes are electrically connected through wires 175b and 176b with an operating relay 177'. A suitable amplifying tube 178 is connected in the relay circuit. When light is projected onto the selenium cell formed by the plate 172, the change in resistance results in a change in the grid circuit of the tube 178, whereby the relay 177' is energized. When the relay is energized, the relay contact 178 closes the circuit through wires 178a and 178b to the cathode circuit of an oscillator 94, whereby said oscillator is energized to transmit a carrier frequency to the surface and to the recording unit R', as will be hereinafter explained. So long as the relay 177' is energized, the oscillator is maintained in operation and it is only when said relay is de-energized to open the switch 178' that the oscillator 94 ceases to operate.

Overlying the plate 172 and disposed within the upstanding collar 171 is an opaque plate 179. This plate is clearly shown in Figures 20 and 23 and has an opening 180 formed therein. The opening is of a predetermined shape and has one side 181 extending from the center of the plate to the outer portion thereof. From the outer end of this straight side, the opening is curved gradually inward as shown by the numeral 182. Adjacent the inner end of the straight side, the opening is abruptly curved as indicated at 183. An annular mirror 171a is inserted within the collar and covers the inner surface thereof.

For projecting light rays downwardly through the opening 180 onto the selenium cell formed by the plate 172, a plumb bob 184 is universally mounted within a depending collar 185 which is formed integral with a partition or support 186 located within the housing 17. The plumb bob is clearly shown in Figure 22 and includes a conical or tapered sleeve 187 which is reduced toward its lower end. A lens 188 is mounted in the upper portion of the sleeve 187, while a projecting lens 189 is secured across the lower reduced end. Interposed between the lenses is a gate 190, whereby a pinpoint or very small beam of light is projected from the sleeve.

The light rays are provided by an electric lamp 191, which is suitably mounted in the partition 186.

When the housing 17 is in a true vertical position, the plumb bob 184 is hanging vertically, as shown in Figure 17. At this time, the light rays which are projected downwardly through the sleeve 187 strike the center of the plate 172. These light rays serve to close the electrical circuit between the contact rings 175 and 176, whereby the relay 177' is energized to operate the oscillator 04. So long as the parts remain in this position and the light rays continue to strike the plate 172, the oscillator would continue to operate and to transmit its carrier frequency to the surface.

It is preferable that the point north or the contact 85 be vertically aligned with the straight side 181 of the opening 180. However, this is not absolutely essential but it is necessary that the operator know the relative position of the contact 85 with relation to the contact 99' which engages such north point. When the housing 17 is tilted or inclined, it follows that the plumb bob 184, which is universally mounted, will remain in a true vertical position, as is clearly shown in Figure 22. In such position, the light rays passing through the plumb bob will not be directed exactly on the center of the plate or disk 179, with the result that they may be projected onto the flat surface of said disk or plate and will not reach the selenium cells or plate 172 at all times. Manifestly, when the light rays are not striking the plate 172, the oscillator 04 is not actuated.

In explaining the operation of the light rays as acting on the plate 172 through the opening 180, reference is made to Figure 23. In this figure, the position of the light rays projected from the plumb bob are indicated by the numeral 191, while the position of the contact 99' is illustrated by the dotted line. Assuming that the disk is rotating in a counterclockwise direction, it will be seen that the contact 99' will engage the north contact 85 prior to the time that the light rays are permitted to pass through the opening 180. As explained, the engagement of the contacts 99' and 85 will actuate the oscillator 04 and stylus 142 of the recording unit R'. Such operation of the oscillator and the stylus will result in the formation of one of the offsets 142a in the line 142'. During this time, the light rays are not striking the plate 172 and the oscillator 04 is inactive. As the disk continues to rotate, the straight side 181 of the opening approaches the light rays striking the top surface of said disk and, after the disk has travelled approximately 90 degrees (as illustrated in Figure 23), the opening 180 moves beneath the projected light rays. As soon as this occurs, the circuit is closed to the oscillator 04, whereby said oscillator is operated.

The oscillator 04 is arranged to energize a relay 147c which is similar to the relays 147 to 147b hereinbefore described. Associated with the relay 147c is a stylus 142c, which rides on the tape 135. This stylus is arranged to form a line 147' on the tape and, when the stylus is actuated, an offset 147d is formed in said line.

Since the contact 99' engages the contact 85 once during each revolution, the distance between the offsets 142a represent 360 degrees. Also, as explained, the disk or plate 179 rotates 90 degrees after the engagement of the contacts 99' and 85 before the light rays strike the plate 172, because it is this length of time before the opening 180

moves beneath the projected light rays. Thus, when the oscillator 04 is operated, the stylus 142c forms its offset 147d 90 degrees later on the tape 135. This indicates that the direction of inclination of the hole is 90 degrees from north, which in this instance would be substantially due east.

As the disk continues to rotate, the opening 180 moves beneath the projecting light rays and the length of time that the opening remains beneath these projected rays controls the length of time that the stylus 142c is held inwardly toward the relay 147c. Therefore, the length of the offset 147d formed by said stylus indicates the number of degrees during which the opening has remained below the projecting light rays. In the position illustrated in Figure 23, the opening 180 remains below the projecting light rays through approximately 130 degrees as indicated by the line 192. If the inclination of the housing was greater, the plumb bob would move outwardly or further from the center of the plate 179. In such case, the opening would not remain below the projecting light rays as long, with the result that the line or offset 147d formed by the stylus 142c would not be as long on the tape 135. By determining the length of the line 147d in degrees, it is possible to determine the position of the plumb bob with relation to the plate 179 and, therefore, it is possible to determine the degree of inclination of the housing 17. The provision of the mirror 171a makes it possible to reduce the diameter of the collar 171, while increasing the effective area which receives the light rays. For example, when the plumb bob swings to maximum inclination, the rays are directed onto the mirror and are then reflected onto the selenium cell. If the mirror were not provided, the light rays would miss the cell at maximum inclination of the plumb bob. It is pointed out that the invention is not to be limited to the particular shape of the opening 180, as illustrated, as, obviously, said opening may be varied in shape.

From the foregoing, it will be obvious that the direction in which the bore 10 inclines is indicated by the relative positions of the offsets 142a and the beginning of the offset 147d. This difference in degrees indicates the direction in which the bore is inclining. The length of the offset 147d illustrates, in degrees, the length of time that the opening 180 has remained beneath the projecting light rays and this indicates the position of the plumb bob with relation to the housing and the plate 179. In this manner, the angle or the degree of inclination of the bore hole is definitely and accurately indicated. This form of the invention is particularly adapted for use in determining the inclination of a bore hole, where such inclination is relatively slight, that is, under 30 degrees. Less structure is necessary than in the first form because only two oscillators and two styluses are employed instead of three as shown in the first form. In both forms, the direction of the inclination of the bore, as well as the angle or degree of such inclination, is accurately indicated. Although a magnetic compass has been illustrated, a gyro-compass, or other type of compass, may be employed.

The foregoing description of the invention is explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made, within the scope of the appended claims, without departing from the spirit of the invention.

What I claim and desire to secure by Letters Patent is:

1. An apparatus for surveying a bore hole including, means for generating electrical impulses of various frequencies, means for controlling the generation of certain of said impulses in response to directional positions for the purpose of orientation, means for transmitting said impulses to the surface along a wave of predetermined frequency, means for further controlling the generation of the remaining impulses in response to inclinational conditions, means for transmitting said remaining impulses to the surface along a wave of frequency different from the frequency wave of the first mentioned impulses and means at the surface for transposing said impulses into visible indications.

2. A well survey instrument including, a housing adapted to be lowered into the well, a movable azimuth contact, a compass unit remote from the contact and associated with said contact to maintain the same in a predetermined position, means for indicating the position of said contact at the surface, means within the housing responsive to variations from the vertical, and means at the surface for indicating the position of said last named means with relation to the azimuth contact, whereby the direction of inclination of the instrument may be determined.

3. A well survey instrument including, a housing adapted to be lowered into the well, a movable azimuth contact, a compass unit remote from the contact and associated with said contact to maintain the same in a predetermined position, means for indicating the position of said contact at the surface, means within the housing responsive to variations from the vertical, means at the surface for indicating the position of said last named means with relation to the azimuth contact, whereby the direction of inclination of the instrument may be determined, gravity operated means also responsive to variations from the vertical, and means at the surface for indicating the position of said gravity operated means, whereby the degree of inclination of said instrument may be determined.

4. A well survey instrument including, a housing adapted to be lowered into the well, an azimuth contact, a compass unit, an electric motor for moving the contact, light responsive means connected in the electrical circuit of the motor and associated with the compass unit, whereby the compass unit controls the motor to maintain the contact in a predetermined position, means for indicating the position of said contact at the surface, means within the housing responsive to variations from the vertical, and means at the surface for indicating the position of said last named means with relation to the azimuth contact, whereby the direction of inclination of the instrument may be determined.

5. A well survey instrument including, a housing adapted to be lowered into the well bore, an inner rotatable casing within said housing, an azimuth contact carried by the casing, an electric motor for imparting rotation to the casing, a twin photo tube mounted in the casing connected in the electrical motor circuit for controlling the operation of the motor, a compass unit, and means for projecting light onto the photo tube in accordance with the position of the compass, whereby the motor is actuated to rotate the casing and thereby maintain the azimuth contact in a predetermined position.

6. A well survey instrument including, a hous-

ing adapted to be lowered into the well bore, an inner rotatable casing within said housing, an azimuth contact carried by the casing, an electric motor for imparting rotation to the casing, a twin photo tube mounted in the casing connected in the electrical motor circuit for controlling the operation of the motor, a light source, a compass unit for controlling the projection of light rays from the light source to the twin photo tube to control the position of the azimuth contact in accordance with the position of the compass unit, and means connected in the motor circuit for actuating said motor in the event no light rays are striking said tube, whereby said tube is brought back into the field of the projected light rays.

7. As a sub-combination in a well survey apparatus, a contact assembly including, an azimuth contact which is maintained in a predetermined position and direction, a rotating disk having a contact adapted to engage the azimuth contact once during each revolution to close an electrical circuit to a suitable indicating instrument, additional electrical contacts responsive to the inclination of the apparatus overlying the disk, and contacts carried by the disk for engaging such additional contacts to close electrical circuits to said indicating instrument.

8. As a sub-combination in a well survey instrument, a weight assembly including, a vertically extending rotatable shaft, a weight rotatably mounted on said shaft and adapted to always find the low side when the instrument is inclined from the vertical, an extension on said weight having a radial arm thereon, a contact carried by said arm, the position of said contact being controlled by the position of the weight and in accordance with the inclination of the instrument, a pendulous weight pivotally suspended within the instrument, means for connecting said weight with the rotatable shaft, and a second contact carried by the shaft and controlled in its position by the pendulous weight, the relative positions of the two contacts indicating the degree of inclination of the instrument.

9. As a sub-combination in a well survey apparatus, a contact assembly including, an azimuth contact which is maintained in a predetermined position and direction, a rotating disk having a contact adapted to engage the azimuth contact once during each revolution to close an electrical circuit to a suitable indicating instrument, light responsive means carried by the disk for effecting the operation of a suitable indicating apparatus, a light source, and gravity operated means for controlling the projection of light rays onto the light responsive means in accordance with the inclination of the apparatus.

10. A well survey instrument including, a housing adapted to be lowered into the well bore, an inner rotatable casing within said housing, an azimuth contact carried by the casing, an electric motor for imparting rotation to the casing, a twin photo tube mounted in the casing connected in the electrical motor circuit for controlling the operation of the motor, a light source mounted in the casing adjacent the twin photo tube, a compass unit below the light source and photo tube and including a hemispherical compass card having a radial reflecting strip thereon, said strip being located to receive light rays from the light source and reflect them onto the twin photo tube to control the position of the azimuth contact in accordance with the position of the compass unit, and means connected in the motor circuit

for actuating said motor in the event no light rays are striking said tube, whereby said tube is brought back into the field of the projected light rays.

11. A well survey apparatus including, an instrument adapted to be lowered into a bore hole, means to indicate inclination of the instrument from the vertical, a compass, means to indicate the compass position, electrical oscillators controlled in their operation by the indicating means, whereby electrical impulses representative of the position and inclination of the instrument are generated, each oscillator generating and transmitting electrical impulses along a wave of different frequency than that of the impulses of the other oscillators, a single conductor cable connecting the surface receiving and transposing means with the electrical oscillators in the instrument, and a filter arrangement connected in the conductor, whereby said conductor may be utilized for conducting electrical power to the instrument to operate said oscillators and also for transmitting the electrical impulses of different frequencies from said oscillators to the surface receiving and transposing means.

12. An apparatus for surveying a bore hole including, an instrument adapted to be lowered into the bore hole, said instrument comprising an orienting means, means associated with said orienting means for generating and transmitting electrical impulses to the surface, certain of said impulses being transmitted along a wave of different frequency than that of the other impulses, a single electrical conductor connecting the impulse generating and transmitting means in the instrument with the surface receiving and recording means, and an electrical filter arrangement connected in said conductor, whereby electrical power may be supplied to the instrument by means of the conductor and also whereby said conductor may be utilized to carry the electrical impulses of different frequencies from the instrument to the surface receiving and transposing means.

13. A well survey instrument including, a housing adapted to be lowered into the well, an azimuth contact rotatably mounted within the housing and movable circumferentially around the axis of said housing, operating means for rotating said contact, a compass unit associated with said operating means for maintaining the contact in a predetermined azimuthal position, a rotating contact element adapted to engage the contact once during each revolution to generate an electrical impulse representative of the position of the azimuth contact, an inclinometer within said housing, an electrical circuit associated with said inclinometer and with the rotating contact element and normally open, and means controlled by the position of the inclinometer for closing said electrical circuit at some point in each revolution of the element for generating an electrical impulse which is representative of the position of inclination of the housing with respect to the vertical.

14. A well survey instrument including, a housing, an azimuth contact which is maintained in a predetermined azimuthal position within the housing, a revolving contact element adapted to engage the azimuth contact once during each revolution thereof for generating an electrical impulse, a light sensitive medium carried by the revolving element and having a predetermined portion exposed, and an inclinometer above said medium for projecting light onto said element, whereby as the element revolves the exposed portion will receive light in accordance with the position of the inclinometer, and means associated with the light sensitive medium for generating an electrical impulse when said medium is receiving light projected by the inclinometer.

15. An apparatus for surveying a bore hole including, an instrument adapted to be lowered into the bore hole, said instrument including a casing, rotatable contact arms mounted within the casing and movable to various circumferential positions therein, a compass unit associated with one of the contact arms for maintaining said arm in a predetermined azimuthal position, means responsive to inclination from the vertical associated with the other contact arms to move said arms into positions in accordance with the direction and degree of inclination of the casing, a single rotatable circuit closing element adapted to engage the various contact arms, each such engagement closing an electrical circuit, and means within the casing actuated by the engagement of the element with the contact arms for transmitting electrical impulses to the surface, said impulses being indicative of the circumferential positions of the contact arms and representative of the direction and degree of inclination of the bore hole.

16. An apparatus as set forth in claim 15, with means at the surface for receiving said electrical impulses and transposing the same into visible indications.

17. An apparatus as set forth in claim 15, wherein the means responsive to inclination is gravity actuated and is directly connected with the contact arms with which it is associated so as to accurately control rotation of said contact arms.

18. An apparatus for surveying a bore hole including an instrument adapted to be lowered into the bore hole, said instrument having a movable orienting element therein, compass means independent of and connected with the element for controlling the movement and position of said element, an electrical circuit associated with said orienting means, means for making and breaking said electrical circuit to generate electrical impulses, means for transmitting said impulses to the surface, and means at the surface for receiving and transposing said impulses into visible indications.

19. A well survey apparatus including, an instrument adapted to be lowered into a bore hole, movable electrical contacts to indicate inclination of the instrument from the vertical, a compass, a movable electrical contact controlled by the compass to indicate the compass position, a rotating contact element for engaging said contacts to close electrical circuits therethrough, and electrical oscillators controlled in their operation by the closing of such circuits, whereby electrical impulses representative of the positions of the contacts are generated.

20. A well survey apparatus as set forth in claim 19, with means for transmitting the impulses to the surface, and means at the surface for receiving the impulses and transposing the same into visible indications.

21. A well survey instrument including, a housing adapted to be lowered in a well, a circumferentially movable azimuth contact, a compass unit independent of and connected with the contact for maintaining the same in a predetermined position, gravity operated means within the housing responsive to variations from the vertical

tical, circumferentially movable electrical contacts controlled by the gravity operated means and movable to predetermined circumferential positions in accordance with the position of said means, electrically operated devices arranged to be actuated when electrical circuits are closed through the movable contacts to generate and transmit electrical impulses representative of the

position of the contacts to the surface, and time controlled means for periodically closing the circuits through said contacts.

22. An instrument as set forth in claim 21, with an indicating and recording unit at the surface for receiving said impulses and transposing the same into correlated visible indications.

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