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DRILL HOLE INDICATOR

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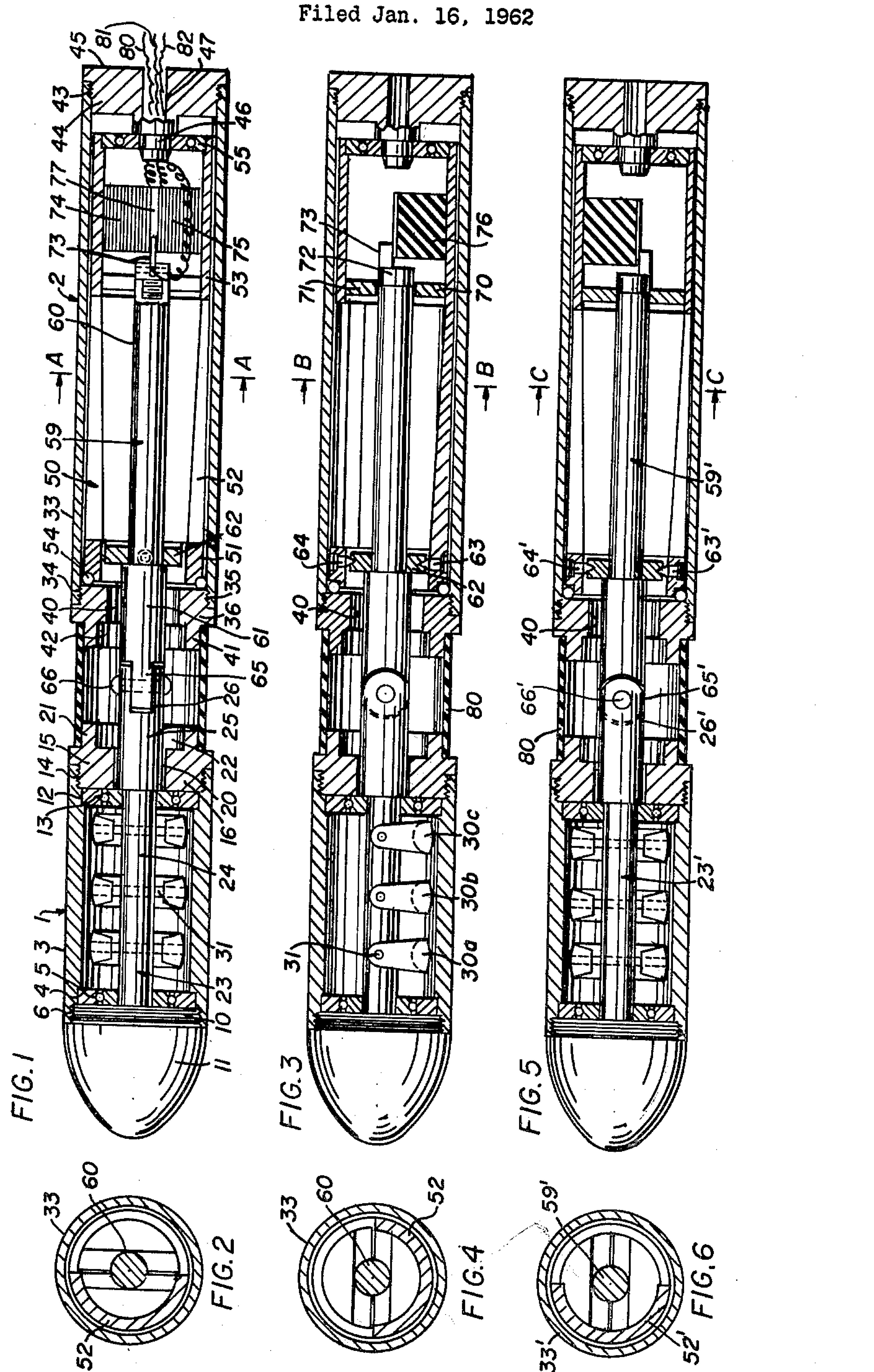

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DRILL HOLE INDICATOR

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This invention relates to surveying instruments for measuring variations in the direction of drill holes.

When drilling into the ground, and particularly in the case of diamond drilling, it has frequently been found that drill holes deviate from their initial path considerably both as to direction and inclination, i.e. both in horizontal and vertical planes. Individual deviations will be referred to throughout the specification as changes in direction in a horizontal plane or in a vertical plane. Such changes in direction of the drill hole may be brought about by any one of a number of reasons, some of which may be controlled by the driller, such as worn drill rods, and some of which are unavoidable such as variations in the composition of the strata through which the drilling is being conducted. Such changes in direction are possible due to the fact that a long length of steel tube, such as a series of connected drill rods, is quite flexible and may be bent through a curve approaching a semi-circle and yet be freely rotatable within the close confines of a drill hole. The fact that such changes in direction do occur has, on occasion, caused drill holes to entirely miss their objectives and has rendered the reliability of some drilling operations open to question. It is therefore desirable to determine changes in the direction of drill holes both in a horizontal and vertical plane so that corrective measures may be taken.

In order to determine if any change in the direction of a drill hole has occurred as well as the extent of such change in direction, apparatus capable of yielding this information has been developed and is presently in use. One of such apparatus is disclosed in U.S. Patent No. 830,730 issued September 11, 1906, to H. S. Marriott, and comprises a device having an outer casing adapted to traverse a bore hole, an inner casing, weighted at one side and adapted to revolve about the longitudinal axis of the outer casing whereby to orient the inner casing such that a plumb-bob pivoted therein will swing freely, relative to the inner casing, in a vertical plane. Attached to the upper extremity of the plumb-bob is a switch arm which traverses a variable resistance which is fixed with respect to the inner casing such that the current in a circuit including the variable resistance and passing through the pendulum and contact arm will vary in accordance with the change in the inclination of the drill hole as recorded by the plumb-bob. In this apparatus the electric circuit may be extended to the earth's surface and the inclination read directly from a suitable instrument such as a galvanometer.

Another type of drill hole surveying apparatus is disclosed in U.S. Patent No. 2,791,035, issued May 7, 1957, to E. B. Roxstrom. In this apparatus a pendulum is pivotally mounted in a casing which is adapted to traverse a drill hole, the lower tip of the pendulum acting as a contact adapted to close an electric circuit on coming into contact wtih a second contact located on the side wall of the casing. A electromagnet is so situated in the casing that when a switch is closed current passes through the electromagnet to produce a magnetic field adapted to force the pendulum contact tip towards the contact on the wall of the casing. In operation, the pendulum normally hangs in a vertical direction so that when the external casing is situated veritcally the longitudinal axis of the pendulum is coaxial with the longitudinal axis of the casing. When the casing is lowered into a drill hole by

means of a non-tortional tubular member, the casing will follow any change in direction of the drill hole, however, the pendulum will continue to hang in a vertical direction. If the inclination of the hole varies in one direction the casing and thus the contact on the wall of the casing will move towards the contact tip of the pendulum whereas if the inclination of the hole varies in an opposite direction the contact on the wall of the casing will move away from the contact tip of the pendulum. In the former case when the electromagnet is actuated a smaller current will be required to move the contact tip of the pendulum into contact with the contact on the wall of the casing than the current required in the latter case and it is the magnitude of this current which indicates the amount of deviation in the inclination of the drill hole. The deviation can be measured directly in degrees through a suitable current measuring device at the earth's surface.

While the aforementioned apparatus makes it possible to take slope and directional measurements at various depths in a drill hole without returning the measuring apparatus to the surface after each measurement, they both depend on the use of a free-swinging pendulum which may be materially affected by the magnetic properties of the ore body through which the drill hole and the measuring apparatus pass. This renders the apparatus unsuitable for measurements in drill holes which pass through magnetic ore bodies. In addition, the apparatus in each case is of a fairly complex and delicate nature and is subject to damage through shock and impact.

I have found that the disadvantages of the prior art devices may be overcome by providing a drill hole surveying instrument comprising first and second axially spaced units of cross-section approximating that of a drill hole to be surveyed and adapted to be slidingly received in said drill hole and means connecting said first and second units whereby to permit pivotal movement of said first unit relative to the second unit in one plane only. An indicating means is operatively connected with the connecting means to indicate the extent of the change in direction of that portion of the drill hole between the units in a plane perpendicular to the aforementioned plane. The operation of this apparatus depends upon the forced deviation of the first unit with respect to the second unit and is entirely independent of the magnetic influence of any ore body through which the apparatus passes. Such apparatus is of robust construction, simple in design and therefore relatively easy to manufacture, assemble and use.

In drawings which illustrate embodiments of the invention,

FIGURE 1 is a plan view of a drill hole surveying instrument according to the invention,

FIGURE 2 is a cross-section of the drill hole surveying instrument taken along the line A—A of FIGURE 1,

FIGURE 3 is a side elevation view of the drill hole surveying instrument of FIGURE 1,

FIGURE 4 is a cross-section of the drill hole surveying instrument taken along the line B—B of FIGURE 3,

FIGURE 5 is a plan view of a drill hole surveying instrument adapted to indicate deviation of the direction of a drill hole in a plane perpendicular to that for which the apparatus of FIGURE 1 provides indications, and

FIGURE 6 is a cross-section of the drill hole surveying instrument taken along the line C—C in FIGURE 5.

The embodiment disclosed in FIGURES 1, 2, 3 and 4 comprises a first unit 1 and a second unit 2 which are separate from one another. Unit 1 is the front unit and unit 2 is the rear unit in the completed assembly. The first unit 1 consists of a cylindrical casing 3 of diameter slightly less than the drill hole to be surveyed, which has, at its front end, a smooth counter-bore 4 for the receipt of a roller-bearing 5 and a threaded counter-bore 6 for receipt of the threaded shank 10 of a nose cone 11. In its rear end, the cylindrical casing 3 has a smooth counter-bore 12 for the receipt of a roller bearing 13 and a threaded counter-bore 14 for the receipt of the threaded shank 15 of a rear end plug 16. The end plug 16 has an axial bore 20 therein and a smooth rearwardly extending shank 21 which is counter-bored at 22. Mounted in the bearings 5 and 12 and co-axial with the longitudinal axis of cylindrical casing 3 is a shaft 23 of circular cross-section, having a front section 24 of reduced diameter and a rear section 25 of greater diameter. The rear section of shaft 23 extends through the bore 20 of end plug 16 to the exterior of unit 1. Shaft 23, at its rear end, has a slot 26.

By reason of being mounted in roller bearings 5 and 13 the shaft 23 is freely rotatable; however, to prevent rotation of the shaft 23 and to maintain the slot 26 in a determined plane, pendulum weights 30*a*, 30*b* and 30*c* are provided. These weights are pivoted on pins 31 which pass transversely through the longitudinal axis of shaft 23. Thus the weights by reason of gravitational forces will always act in a direction such as to maintain the slot 26 in the said determined plane.

Unit 2 consists of an external cylindrical casing 33 of the same outer diameter as casing 3 of unit 1 and has an internal thread 34 at its front end which is adapted to receive the threaded shank 35 of end plug 36. The end plug 36 has an axial bore 40 and at its front face has a smooth shank 41 which has the same external diameter as the smooth shank 21 of end plug 16 in unit 1. The shank 41 has a smooth counter bore 42 therein. The rear end of external cylindrical casing 33 has an internal thread 43 adapted to receive the threaded shank 44 of an end plug 45. The end plug 45 has a stub axle 46 extending inwardly from the front face thereof and an axial bore 47 extending through the end plug and the stub axle for the entry of electrical conductors into the interior of casing 33.

Within the confines of the external cylindrical casing 33 and end plugs 36 and 45 is an inner casing 50 having a cylindrical front portion 51, a rearwardly tapering semi-cylindrical middle portion 52 and a cylindrical rear portion 53. The front portion of inner casing 50 is rotatably mounted in external casing 33 by means of bearing race 54 whereas the rear portion of inner casing 50 is rotatably mounted in external casing 33 by means of roller bearing 55 which is seated on stub axle 46.

Extending into the interior of the external casing 33 and internal casing 50 through bore 40 of end plug 36 is a shaft 59 having a rear section 60 of reduced diameter and a front section 61 of greater diameter. At the junction of section 60 and 61 shaft 59 has a circular collar 62 rigidly affixed thereto and pivoted in portion 51 of internal casing 50 about aligned pivot pins 63 and 64 which may be seen more clearly in FIGURE 3. The front end of shaft 59 is equipped with an ear 65 which is adapted to fit snugly within slot 26 of rod 23 and to be pivotally retained therein by pivot pin 66 which is at a right angle to aligned pivot pins 63 and 64. Section 60 of shaft 59 passes through guide members 70 and 71 which project from the inner surface of portion 53 of inner casing 50 and which limit movement of rod 59 to a plane perpendicular to the plane of slot 26 and terminates in a contact carrying insulating plug 72 which is threaded into the rear end of rod 59.

The plug 72, which may be constructed of ebonite, carries a projecting electrical contact 73 which is made of a suitable conducting material such as silver. Contact 73 is adapted to traverse two resistance coils 74 and 75 which are wound about an insulating block 76 which may be of fibre or ebonite and which is affixed to portion 53 of inner casing 50. The two resistance coils 74 and 75 are separated by a space 77 which is of approximately the same width as contact 73 and which provides a neutral position for the contact. The resistance coil 74 consists of a length of wire 80 wound around insulating block 76 and extending outwardly through axial bore 47 to the exterior of unit 2 and resistance coil 75 consists of a similar winding of the wire 81. The turns of wires 80 and 81 are wound equidistant from each other to provide a definite equal ohmic resistance therebetween.

A third wire 82 extends through axial bore 47 to electrical contact 73. The three wires 80, 81 and 82 form part of a suitable electrical circuit, which is not shown, whereby current may flow through wire 82 and through that portion of either coil 74 or 75 which has been traversed by contact 73. That is, movement of the contact 73 towards the top of the page in FIGURE 1 will create an increased resistance in a part of the circuit which may be measured on a suiable resistance measuring device at the surface of the earth and movement of the contact arm toward the bottom of the page in FIGURE 1 will cause an increased resistance in another part of the circuit which again may be measured on a suitable resistance measuring device. In its normal position as indicated in FIGURE 1, electrical contact 73 rests on insulating block 76 at neutral position 77 and no current will flow in the circuit.

The connection of unit 1 and unit 2 is completed by providing a waterproof, flexible cover 80 to seal the pivoted joint 26, 65, 66 from the corrosive effect of water. Cover 80 may be made of any suitable material such as thin rubber.

In operation the initial orientation of the drill hole in both horizontal and vertical planes is obtained by known surveying methods and, units 1 and 2 are lowered into a drill hole by means of any suitable connecting cable or rod and, if the hole is inclined to the vertical the weights 30*a*, 30*b* and 30*c* will cause the two rods 23 and 59 to assume a position such that the hinge joint 26, 65, 66 will permit pivotal movement of one rod and unit relative to the other rod and unit in the vertical plane. If the hole is vertical then the weights 30*a*, 30*b* and 30*c* will produce an inertial force which prevents the rod from rotating about its longitudinal axis. As the rod 23 is freely rotatable in unit 1 and the rod 59 is firmly secured in inner casing 50 which in turn is freely rotatable in outer casing 33, it will be seen that any action of the walls of the drill hole on the external casings of units 1 and 2 tending to cause rotation of these outer casings will have no such effect upon rods 23 and 59 and inner casing 50 as the rotation of these elements is resisted by the inertia of weights 30*a*, 30*b* and 30*c*. Therefore, as the apparatus is lowered through a drill hole the inner components of the apparatus will not rotate about their axes and the orientation of hinge joint 26, 65, 66 will remain constant.

Upon any change in direction of the drill hole in a horizontal or vertical plane from the initial orientation of the drill hole the leading unit 1 will be forced to follow this change and it will be seen that for changes in direction in a vertical plane or for changes in direction having a component in a vertical plane the hinge joint 26, 65, 66 will permit shaft 23 to pivot with respect to shaft 59 and the electrical contact 73 positioned at the free end of shaft 59 will not be affected by the vertical component of the change in direction. However, for changes in direction in a horizontal plane or having a component in a horizontal plane the hinge joint 26, 65, 66 will prevent movement of shaft 23 relative to shaft 59 for the component of the change in direction in a horizontal plane and shaft 59 will be forced to pivot about pivot pins 63 and 64 and electrical contact 73 will be moved accordingly to indicate the extent of the change in direction in a horizontal plane. Pivoting of shaft 59 is permitted by reason of axial bore 40 and counterbore 42 being of substantially larger diameter than that of shaft 59.

It will be apparent from FIGURE 1 that movement of the first unit in a direction towards the top of the page will cause a corresponding angular movement of the electrical contact 73 towards the bottom of the page across resistance coil 75 and vice versa. The greater the change in direction of the first unit with respect to the second unit, the greater will be the displacement of electrical contact 73 and as a result the greater will be the resistance which is introduced into the electrical circuit. It will thus be seen that the change in direction of unit 1 with respect to unit 2 in a horizontal plane will correspond directly to the change in direction of the drill hole at that particular point and that this change in direction will be reflected in the extent of the movement of electrical contact 73. As wires 80, 81 and 82 pass through the drill hole to the earth's surface where they are connected to suitable resistance measuring devices, the amount of resistance in the circuit may be measured and thus correlated with the change in direction of the drill hole in a horizontal sense necessary to give that resistance such that at every point at which the direction of the drill hole changes in a horizontal sense, the extent of this change may be recorded. If the total of these changes is computed the direction of the drill hole in a horizontal sense, at the bottom end thereof, may be determined by adding the total change in direction in a horizontal plane by adding the total of the individual changes in direction in a horizontal plane to the initial direction of the drill hole in a horizontal sense as the length of cable or rod on which the apparatus is lowered may be measured. The apparatus may be connected to a suitable totalizing device whereby the total change in direction of the drill hole in a horizontal plane at any particular depth may be ascertained. The apparatus may also be used by determining the changes in direction in a horizontal plane, if any, at any depth in the drill hole as they occur and plotting a survey diagram of the orientation of the drill hole in a horizontal plane throughout its length.

In holes which are vertical or near vertical, the apparatus may be used without the weights *30a*, *30b* and *30c* by lowering the apparatus on suitable non-torsional tubing, for instance a fiber tubing split to accommodate the electrical conductor. In such a case the split or opening in the tubing would also be arranged to move on a key attached to an outer casing at the mouth of the drill hole to prevent any twisting of the units about their longitudinal axes and thus ensure that all measurements of change in direction would be taken in a given plane.

The apparatus described in FIGURES 1, 2, 3 and 4 is particularly adapted to measure changes in direction in a horizontal plane. However, changes in the inclination of the drill hole or changes in direction in a vertical plane are just as readily measured by replacing the apparatus of FIGURES 1, 2, 3 and 4 by the apparatus disclosed in FIGURES 5 and 6. The apparatus is identical to that disclosed in the previous drawings with the exception that the pivot pin 66′ of the hinge joint 25′, 65′, 66′ is at right angles to the pivot pin 66 in FIGURES 1 through 4. This permits pivotal movement of shaft 23′ with respect to shaft 59′ for any changes in direction in a horizontal plane or having a component in a horizontal plane. The axis of aligned pivot pins 63′, 64′ have also been displaced 90° from the axis of aligned pivot pins 63 and 64 in FIGURES 1 to 3 so that shaft 59′ may pivot about a horizontal axis permitting pivotal movement of shaft 59′ for changes in direction in a vertical plane or having a component in a vertical plane whereby to indicate the vertical changes in direction or change in inclination of the drill hole. It may be seen that when the changes in direction recorded with the apparatus of FIGURES 1–4 are equated with the changes in direction recorded with the apparatus of FIGURES 5 and 6, a complete survey of the drill hole is obtained. Such a complete survey may be obtained with only one traversal of the drill hole by inserting the embodiment of FIGURES 1–4 and the embodiment of FIGURES 5 and 6 into the drill hole in tandem so that two sets of readings are obtained.

Although the previous description refers to apparatus adapted to measure changes in direction in a horizontal and a vertical plane it will be understood that the application of the apparatus is not limited to such planes. By varying the location of the slot 26 in the rear end of rod 23 it will be understood that changes in direction in any series of planes may be measured.

It will be apparent that various modifications may be made to this apparatus, for instance the relationship between the length of shaft 59 to the rear of the pivot point 63, 64 to the length of shaft 59 forward of these pivot points may be varied whereby to vary the sensitivity and accuracy of the measuring apparatus. It is also possible to provide units 1 and 2 without the independently rotatable characteristics of the interior components if it is possible to ensure through the use of a suitable lowering rod or tubing that twisting of the apparatus will not arise so that all measurements of change in direction may be taken in a given plane.

It will be apparent that this apparatus will produce accurate results independently of the magnetic properties of the ore body through which the apparatus passes and that the apparatus may be used to obtain accurate results throughout any degree of total change in direction of the drill hole. In addition, the apparatus may be used to obtain the changes in direction of a drill hole at various distances below the surface of the earth without withdrawing the apparatus after each independent reading is made.

What I claim as my invention is:

1. A drill hole surveying instrument comprising first and second axially spaced units of cross-section approximately that of a drill hole to be surveyed and adapted to loosely and slidingly received in said drill hole, means connecting said first and second units whereby to restrict pivotal movement of said first unit relative to said second unit to a first plane containing the longitudinal axis of the instrument and indicating means operatively connected with said connecting means whereby to indicate the extent of the change in direction of that portion of the drill hole between the units in a second plane perpendicular to said first plane, said first unit comprising a hollow cylindrical casing having a first shaft coaxial therewith and rotatably journalled therein, and said second unit comprising a hollow cylindrical outer casing, a hollow cylindrical inner casing coaxial therewith and rotatably journalled therein and a second shaft pivotally mounted in said inner casing for movement in a plane perpendicular to said first plane.

2. A drill hole surveying instrument as defined in claim 1, wherein said indicating means comprises an electrical contact element adapted to vary a parameter of an electric circuit proportionately to the change in direction of the drill hole in said second plane.

3. A drill hole surveying instrument as defined in claim 1, wherein said first and second shafts project from adjacent ends of said first and second units respectively, and are connected at their projecting ends for pivotal movement in said first plane.

4. A drill hole surveying instrument as defined in claim 3, wherein said indicating means comprises an electrical contact element adapted to vary a parameter of an electric circuit proportionately to the change in the direction of the drill hole in said second plane, and means for measuring the variation in said parameter.

5. A drill hole surveying instrument as defined in claim 3, wherein said indicating means comprises an electrical contact element on the end of said second shaft remote from its connection with said first shaft, two axially aligned resistance coils mounted in said inner casing, transversely thereof and perpendicular to the pivotal axis of said second shaft and forming a part of two electrical circuits, means urging said contact element against said coils whereby movement of said contact

element will vary the resistance in one of said circuits, and means for measuring said resistance.

6. A drill hole surveying instrument as defined in claim 5 wherein said first shaft is provided with means preventing rotation thereof.

7. A drill hole surveying instrument having first and second elongate, axially spaced casings of cross-section approximately that of the drill hole to be surveyed whereby to be loosely and slidably received therein, an inner casing coaxial with the longitudinal axis of said second casing and rotatably mounted therein, a first shaft coaxial with the longitudinal axis of said first casing, rotatably journalled therein and projecting from one end thereof, a second shaft normally coaxial with said inner casing and mounted therein, intermediate its length, for pivotal movement about a first transverse axis of said shaft, signal operating means within said inner casing one end of said shaft, within said inner casing, adapted to actuate said signal operating means in proportion to the amount of movement of said end, the other end of said shaft extending beyond said inner casing through one end of said second casing and being connected to the projecting end of said first shaft for pivotal movement about a transverse axis normal to said first transverse axis.

8. A drill hole surveying instrument as defined in claim 7, wherein the first shaft, within said first casing, is eccentrically weighted whereby to prevent rotation of said shaft during rotation of said first casing.

9. A drill hole surveying instrument as defined in claim 8, wherein said signal comprises an electric circuit having a variable resistance coil mounted within said inner casing, said one end of said second shaft carrying a movable contact adapted to vary said resistance in proportion to the movement of said one end and means external to said second casing for instantaneously measuring the resistance in said circuit.

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