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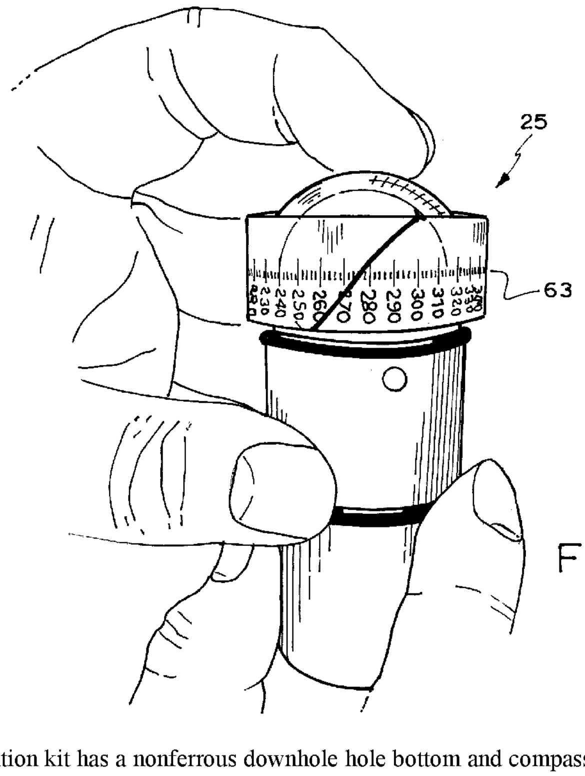

FIG.28

(57) **Abstract:** A core orientation kit has a nonferrous downhole hole bottom and compass unit assembled from two parts and above ground components employing manually operable measurement scales. Assembled parts form a chamber holding a free floating eccentrically weighted compass ball with hole bottom indicator spot (23) and North/South line (24). An applicator is used to assemble the parts to trap the ball in a chamber and floating in a liquid. The parts are axially shiftable at the hole bottom to lock the ball. Upon retrieval the unit is taken apart and measurements may be taken off the ball. There are two scales employed with measurement of azimuth using the azimuth lens (25) by aligning the lowest point on a ladder scale (62) with the spot (23) and then reading off the azimuth at the intersection of line (24) with scale (63).

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A TOOL ASSEMBLY AND RELATED KIT FOR IN-SITU BOREHOLE ORIENTATION

TECHNICAL FIELD

[0001] THIS INVENTION relates to borehole orientation and to a tool assembly and related kit for in-situ orientation of a borehole bottom and more particularly but not limited to a tool assembly and related kit for orientation of a core sample face and borehole bottom using the tool assembly.

BACKGROUND

[0002] The usual terms for orientation are “hole orientation” and “core orientation”. Core samples are used to examine the structure of a formation being drilled. The geographical location of the core sample must be determined. It is known to orient an upper face of a core prior to it being drilled. Various tools have been devised. It is also known to orient the bottom of the hole prior to the core being drilled. The position of the core relative to each tool may be reproduced at the surface. Furthermore, core samples are kept and it is desirable to record the core orientation with the core sample. Core orientation is conventionally recorded on wooden blocks held in core trays adjacent the stored core samples. Core orientation is different from simply obtaining a drill hole profile as may have been done in the past using some moldable form or fingered device. See for example US Patent 2,824,378 to Stokes.

[0003] It will be appreciated that the orientation of a borehole and positioning of the core is critical in many applications of drilling and failure to identify the correct position can be very costly both financially and from a safety point of view if, for example, fault lines are not properly located and these later give rise to unexpected slippage and rock falls.

[0004] Situations where drilling can be performed is for water wells, resource exploration, resource blasting, burying civil infrastructure and securing overhead rocks. If a drill hole is 1° misaligned over 1,000 meters to plan it could result in a 30 meter error, 15 meters either side of the target. This may mean misidentification of dangerous and unstable ground or the location of earth resources.

[0005] Hole orientation consists of two bearings, “Azimuth” bearing which is the direction to which the hole is pointing for example, North and “Dip” bearing which is the angle the hole proceeds into the earth for example, 20° down or up for holes in underground mines. Core orientation consists of capturing the exact position of the core in relation to its natural position in the earth. One side of the core is marked and used as a reference point, this mark is normally the bottom of the core.

[0006] International Patent Application Publication No. WO2003/038232 to 2iC Australia Pty Ltd describes an orienting device for providing an indication of the orientation of a ground core sample cut by a core drill. This device employs at one end a shroud having a plurality of slidable pins which contact a core face and by relative displacement of the pins provides a contour of the core face. This is described as a “face orientator”. The device also employs what is described as a “bottom orientator”. The bottom orientator has three axially spaced ball races each having a ball freely travelling in the respective race so they remain in a line at the bottom of the device under the influence of gravity. As the face orientator completes its profiling of the core face, the shroud around it is moved in the uphole direction, this action releases a spring which in turn causes the ball races to clamp the balls. This identifies the borehole bottom. Three balls are used to improve accuracy. Thus relative to the face profile the clamped position of the balls provides the bottom of the hole. Upon removal of the core the device may be used to orient the core. A line may then be drawn along the core to give the reference line on the core corresponding to the bottom of the hole.

[0007] An inclinometer is mounted in the device. The inclinometer employs a calibrated graduated wheel. It is mounted to rotate about its own axis and also about the central axis of the device so that it remains vertical. The wheel has its centre of gravity offset so that it reads 0° on the horizontal when the device is horizontal. At the same time as the ball races lock the balls, a locking pin locks the inclinometer wheel which gives the inclination just before the core is cut. The device is then released from the core drill and the core may be cut. Since the device is carried by the core drill, core orientation and core cutting is part of the one process rather than having to go down the hole twice.

[0008] International Patent Application Publication No. WO2005/078232 is a modified version of the device of WO2003/038232 in so far as it retains the face orientator and hole bottom orientator but now employs a disc mounted with the face orientator which may be marked with a face mark corresponding to a mark on the core face and with a second mark applied manually when the device is returned to the surface. This also corresponds to a line applied to the core sample corresponding to the hole bottom. This disc so marked is used as a permanent record of the core orientation. The disc is stored with the core sample.

[0009] International Patent Application Publication No WO2007/109848 describes a further development where a vernier scale is used to facilitate making of the core sample.

[0010] Devices of this type have been widely used. The inventor(s) of the above applications are in common. These devices are quite complex mechanical devices but it is important to appreciate that they are mechanical and do not employ any electronics.

[0011] International Patent Application Publication Nos WO2007/137356 and WO2008/113127 also sharing common inventor(s) marks a departure from their prior art mechanical devices in so far as it employs electronics. A gyroscope logs orientation and azimuth may be determined based on the entry position of the bore, drill depth and the gyroscope readings.

[0012] In addition to electronic readings the device retains the mechanical face and hole bottom orientation as secondary checks. The face orientator has a scale marked on its barrel. The hole bottom position is manually transferred by pen as a line to the barrel of the face orientator and to the core sample. The face orientator is single use and is stored with the core sample as a record.

[0013] Another device is described in US Patent 3,115,196 to Roxtrom also employs a face orientator having slidable pins which upon being slid, under load, to match the contour of the core face uses extra load for the release of a spring and then a second spring comes into play to retract the face orientator into a shroud. The bottom of the hole relative to the face orientator is marked by a small ball which is free in an annular space and positions itself under gravity, as the orientator is being loaded at the bottom of the hole, the ball, now located at its bottom position makes an imprint on a soft coating upstream of the face orientator. Other arrangements that separately involve the use of an inclinometer but in a completely different arrangement to those described above include for example US Patent 5,957,221 to Hay. There is no description as to how the inclinometer is employed. US 2009/0071716 to Van Ruth describes the use of a ball to read azimuth off scale on the ball. The device relies on the ball floating in a chamber in liquid from the bore hole entering into the device. This effectively makes it an open system. The sphere has a scale and there is a clear annulus around it so that supposedly azimuth may be read from the scale. It is doubtful that this device actually works. According to the examination file on this application there is no actual enabling disclosure as to how the liquid from the well bore enters the chamber or how this operates in practice. The application also suffers on a number of other enablement grounds raised in subsequent reports.

[0014] Purely electronic borehole survey tools are available. For example, the GyroPath (Gyro Path is a Registered Trade Mark) produced by Icefield Tools of Canada is a borehole surveying tool utilising gyroscopic and inclination sensors which amongst other capabilities can measure and record core sample orientation. The trend has been toward electronics but of course with the addition of electronics comes high cost. The purpose of reviewing the above prior art is merely to illustrate this trend and the inclusion herein of these documents should not be considered an admission that any one or part thereof is part of the common general knowledge.

[0015] It should be appreciated that the prior art mechanical arrangements all attempt to provide, in general, for either face orientation or dip or both, sometimes employing pin type face orientators as well as gravity to mark the hole bottom. There is usually some form of lockable and/or rotating parts. However, these features where they might be generally held in common, the specific solution in each case is varied. Each mechanical arrangement has its own advantages and disadvantages and generally operate in combination with none of the parts of any one device being interchangeable with or compatible with another. Many are very complex and possibly unworkable. With this in mind it is an object of the present invention to provide an alternative to the prior art which Applicant considers is simpler and much less expensive. Moverover, with the concept of the present invention as set out in the kit according to claim 1, involving separate and manually applied scales, in a preferred form applicant’s invention is able to record orientation including taking a core face profile, record the hole bottom as well as measurements of azimuth and dip angle.

OUTLINE

[0016] In one aspect there is provided a kit for borehole orientation comprising:

a. a borehole orientation device having a hole bottom indicator carried by a carrier including a lockable gravity follower; and

b. at least one read out device having a scale to be applied manually to the orientation device, after the follower is locked, to read orientation data from a scale. The scale typically includes azimuth and/or dip angle.

[0017] Preferably, the follower is locked by being axially shiftable. Locking preferably takes place by resilient engagement with an arrestor. The arrester may comprise two or more resilient tangs. The follower may also include a compass function by employing a magnet. The magnet may also serve as a centre of gravity offset to follow gravity. Preferably, there is a separate scale for each of azimuth and dip angle.

[0018] In another aspect there is provided a borehole orientation device having a lockable gravity follower, the gravity follower carrier having a hole bottom indicator. The borehole bottom indicator may be at a lower position on the device so that it is truly lower or at a position that may be related to the borehole bottom. In the case of downhill drilling the indicator may be at 180° from the borehole bottom. In the case of uphill drilling it may coincide with the downhill bottom.

[0019] Preferably, the follower is a rotatable element, typically an orientation ball and the hole bottom indicator is a spot on the surface of the ball. The gravity following feature is usually provided by an offset centre of gravity. This may be provided by an eccentric weight. This may be a magnet. The spot may be opposite the weight. The spot position is selected so that it may be visible when the ball is locked. The opposite position is typically used for “downhill” drilling. A different spot position relative to the weight is usually employed for substantially “horizontal” drilling and a still further position for “uphill” drilling. Separate balls may be used or different spot colours.

[0020] Preferably, azimuth is read from a manually applied scale after the ball has been locked and the device retrieved. As an example in dowhill drilling, the first step involves locating the spot on the ball intersecting with a first scale, with a line from the spot intersecting with a second scale, the line being on the surface of the ball in a radial plane and terminating at or adjacent the hole bottom indicator. In this case the line will always point due north. The azimuth reading is taken from the second scale, the first and second scales being on a see through “azimuth” hemispherical dome, manually applied to the ball. The see through dome has an inner surface complementary to the ball so that it may rotate on the locked ball, the second scale being a 360° scale along an “equatorial” circumference with the first scale set at 90° to the second scale. Using the same or a second see through dome, being a dip angle dome, dip angle is read from a dip angle scale rotatably placed over the ball, the see through dip angle dome operating as a hemispherical protractor placed over the ball with a central 90° mark at the top of the dome and typically a spiral scale marking. Rotation of the dome on the ball such that the spot is located by a user on the spiral scale enable a user to read off dip angle.

[0021] In order that the ball may be free and then locked, in a preferred form, there is a non-ferrous device body which is adapted to hold the orientation ball in two positions. In a first position the ball is free to rotate in any direction under the influence of gravity due to the offset weight. In the second position it is locked or arrested against any rotation. In another form the ball also operates as a compass where the weight is also a magnet causing the magnet to shift North in a substantially horizontal plane while at the same time retaining the vertical set due to gravity. This means the ball is locked with both compass and hole bottom orientation function.

[0022] In addition and in combination with the orientation ball, at one end, being the downhole end, the device body may carry a face orientator comprising axially slidable pins and at the other end, being the uphole end, house the orientation ball. The orientation ball may be in an orientation ball chamber formed when first and second chamber portions are assembled about the ball. In this regard the kit may include an applicator to manually "set" the ball in a free moving position.

[0023] In one preferred form the chamber portions comprise a downhole wall portion with resilient axial tangs about a dome-like wall, each tang having an orientation ball arrestor rib, arranged such that the chamber portions expel air from the chamber during assembly. Grooves are provided either side of the chamber and these have o-ring seals used to seal the chamber with the ball in the first position, uphole of the arrestor ribs. Thus, the portions are assembled, after being progressively vented. Relative axial movement of the portions locks the ball by reason of its engagement with the ribs. While this arrangement is preferred in order to arrest movement of the ball, it will be appreciated that any means may be used to stop rotation of the ball.

[0024] In another aspect there is provided a method of setting a device according to the invention, the method including the steps of:

> loading the orientation ball into a second body part having a second ball chamber portion;
> before or after loading the ball, pouring liquid into the second body part;
> inserting a first body part having a first ball chamber portion into the second part; and
> progressively venting air and then liquid from the ball chamber; and
> subsequently sealing the ball chamber such that the ball is in the first position.

[0025] Preferably, the second body part has a hollow formed by a tapered wall used to vent air and some liquid and then seal the orientation ball chamber when a o-ring held in one of the parts between the parts becomes located in a groove in the other part.

[0026] In order to move the ball to the locked position under further axial pressure the o-ring may move axially out of the groove, so that the ball is shifted slightly over-centre and locked in place by the arrestor ribs on the tangs.

[0027] As a further step in the method and as further elements of the kit, an azimuth lens having a dome section matching the ball may be placed over the ball and the method further comprises the measurement of azimuth using the azimuth lens by aligning a ladder scale with the spot and then reading off the azimuth at the intersection of a line with an azimuth scale set at 90° to the ladder scale.

[0028] As a further step in the method and as further elements of the kit a dip angle lens having a dome section matching the ball may be placed over the ball and the method further comprises the reading of dip angle using the dip angle lens, the dip angle lens being equipped with a calibrated spiral scale and dip angle may read off by rotating the lens until the spot intersects with the scale.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] In order that the present invention and improvements may be more readily understood and put into practical effect reference will now be made to the accompanying drawings which illustrate preferred embodiments of the invention and wherein:-

Figure 1 is a schematic drawing illustrating the mistaken belief that a particular ore body is located on a 45° line;

Figure 2 illustrates a formation of two fault lines;

Figure 3 illustrates in phantom an anticipated open cut removal of an ore body and surrounding material;

Figure 4 illustrates the prospective hazard that might arise from removal as illustrated in Figure 3;

Figure 5 illustrates the hazardous landslip that might occur;

Figures 6 through 9 are component parts of a tool according to the present invention;

Figures 12 through 15 are measurement devices applicable to a kit according to the present invention;

Figure 17 is a drawing illustrating the method by which the orientator ball is located in its free moving position;

Figure 18 is a removal tool which is used to remove the tool according to the present invention from the position illustrated in Figure 17;

Figures 19 to 21 are a cap that may be inserted over the pins and may be marked so that the tool according to the present invention may be stored with an associated core sample;

Figure 22 illustrates operation of the present invention at the bottom of a borehole;

Figure 23 illustrates the removal of a core sample with the core sample shown in Figure 24;

Figures 25 and 26 is a core cradle used to reorient the core and a tool according to the present invention at the surface for measurement purposes and marking of the core;

Figures 27 and 28 illustrate measurement of azimuth;

Figures 29 and 30 illustrate measurement of dip angle;

Figure 31 illustrates storage of core samples in core trays and the capped unit according to the present invention;

Figures 32A to 32E illustrate an orientation ball, azimuth and dip angle lenses for use in upward drilling; and

Figures 33A to 33E illustrate an orientation ball, azimuth and dip angle lenses for use in substantially horizontal drilling.

[0030] Please Note: the drawings are for illustrative purpose only and are not to be taken as scale drawings nor are they intended to be working engineering drawings.

METHOD OF PERFORMANCE

[0031] Referring to the drawings and initially to Figure 1 there is illustrated in schematic a drilling operation employing a drilling rig 11 and showing two hypothetical drill bores 12 and 13, the bore 12 represents an intended 45° bore. Core samples are taken at intervals, these intervals are represented by the small circles. The hatched area represents the real resource. The real bore line is at 13 and the “phantom” resource is represented at 15 in phantom.

[0032] It should be appreciated that even a small deviation can result in serious and expensive errors and the importance of accurate mapping of the real borehole is vital.

Thus at each core sample an accurate borehole orientation, for example, which may be relative to the bore entry at 17 or any relative position can be employed for correlating the core samples to the actual underground location of that sample.

[0033] Figures 2 to 5 illustrate another example of the possible consequences of incorrect borehole mapping. In these Figures it is proposed to excavate the area shown bounded by the broken line 18 in Figure 3. However, there are two fault lines at 19 and 20 which could result in a safety risk due to slippage along fault line 19 and rock fall 21 putting workers at risk. Accurate orientation of exploratory boreholes enable the fault lines 19 and 20 to be properly mapped and alternate measures taken to mine the area and eliminate this risk.

[0034] The angles illustrated in Figure 1 represent the inclination of the borehole, this is usually referred to as dip, then there is the deviation to the left or right represented by the angle of horizontal deviation which is referred to as azimuth. These may be recorded as absolute figures relative to the Earth. Thus the location of the core may be mapped by the physically measured depth using drill rod length, usually in 3 meter units, the dip angle and the azimuth which as will be described below, may be measured using the present invention.

[0035] The kit has a nonferrous downhole hole bottom compass unit and above ground components. There are two main components of the downhole unit, an indicator and an indicator carrier. These two components are operated within a body which typically comprises an assembly of two parts. The assembled parts form a chamber holding the carrier. An applicator is used to assemble the parts. The parts are axially shiftable and the carrier is axially shiftable in concert therewith to lock the indicator. In this example, the indicator is typically part of a carrier in the form of a compass ball. The indicator may be one or more markings on the surface of the ball.

[0036] The relationship between these parts is such that the indicator may freely move under the influence of gravity and then be locked where it is required to correlate with the borehole bottom at that point.

[0037] In terms of the present kit there is provided at least one measuring unit that may be manually loaded or placed in juxtaposition with the device to read off a coordinate.

[0038] The indicator and carrier combination according to the present example is illustrated in Figure 16 which, in this example, is an orientation ball 22 having an offset centre of gravity, and the indicator is a spot 23 or a line 24 or a combination of the two. The measuring unit may be an azimuth lens 25 as illustrated in Figures 12 and 13 or a dip angle lens 26 as illustrated in Figures 14 and 15 each of which has a dome section 27 matched to the orientation ball 22. The operation of these will be described in greater detail below.

[0039] Returning to Figures 6 through 9 there is illustrated an example of a device body 28 which is adapted to hold the orientation ball 22 in two positions. In a first position the ball is free to rotate in any direction under the influence of gravity. In the second position it is locked or arrested against any rotation. Thus the indicator spot 23 corresponds to the lowermost point that the ball would adopt under the influence of gravity. This means it can be locked when the device is in the bottom of the borehole and the spot 23 will correspond or be related to the lowermost part of the borehole just uphole from what will be the upper face of the core sample. Where the ball has magnetic weight on the outside of the ball, the line is arranged to always point to magnetic North.

[0040] End 29 carries the known type of face orientator comprising axially slidable pins 30 and an axially slidable marking pencil 31. Thus the present invention may orient what will be the core top face in a customary way.

[0041] The other end 32 has an orientation ball chamber wall portion 33 with resilient tangs 34, 35 and 36, each tang having an orientation ball arrestor rib 37, 38, and 39 respectively. The chamber wall portion 33 is dome-like and has vents at 40, the function of which will be described further below. Grooves for o-ring seals are provided at 41 and 42.

[0042] As will be appreciated the orientation ball 22 is separated from the body 28 in this embodiment and is loaded as part of an assembly process depicted in Figure 17 but this need not be the case. The ball may be in a preformed assembly and encapsulated inside a sealed membrane. The membrane may be transparent or single use and removed for reading purposes in order to achieve the objects as set out in this example.

[0043] Figure 17 illustrates how the orientation ball 22 is loaded into the first position. The body 29 is connected to a second body part 43 which includes a second dome-like chamber wall 44 which together with portion 33 form an orientation ball chamber 45 at a first position where o-ring 46 locates in groove 47. The body 43 has a hollow formed by tapered wall 48. As the parts move axially, this tapered wall is used to progressively vent air and some liquid and then seal the orientation ball chamber when the o-ring 46 is located in the groove 47.

[0044] As will be appreciated from Figure 17 the body 43 is initially placed upright and an incompressible liquid is poured in before the ball 22 and body 28 are in turn loaded.

[0045] As downward manual pressure is applied using applicator 50, which impinges on the body 28 at 51, any air and in turn some liquid will be vented through vents 40 and by reason of taper 48 air and some liquid will pass by the ring 49, the ring 49 will compress and seal the ball chamber, air free. In this position the ball will freely rotate under the influence of gravity.

[0046] The applicator 50 is removed and the pins 30 and pencil 31 all extended to an even position and the body 43 being equipped with an internal connector end 52 may be connected as shown in Figure 22 to a suitable downhole carrier 53.

[0047] Once down at the bottom of the hole the pins 30 profile the bottom of the hole and the pencil 31 marks it and by further downward pressure the body 28 and o-ring 49 moves axially so that the ball 22 is shifted slightly over-centre and locked in place by the locking ribs 37, 38 and 39 on the tangs. The movement of the o-ring is exaggerated in this drawing. Since an incompressible fluid is employed some fluid is expelled.

[0048] The assembled and locked device is then removed from the borehole. The core sample is cut and broken away and removed from the hole as depicted by Figure 23 and as to be analysed in Figure 24.

[0049] In order to remove the body 28 and locked ball 22 from the body 43 a removal tool 55 shown in Figure 18 is employed. This fits over the pins 30 in similar fashion to applicator 50 and a threaded extraction tool is inserted into threaded axial bore 56 and the parts 28 and 43 are pushed apart thereby releasing them from each other. The body 28 and locked ball 22 may be capped with a suitable cap of the type depicted in Figures 19-21 with the measured record recorded on the cap and this may be stored with the core sample in a storage tray as shown in Figure 31. Thus the ball 22 spot 23 records the borehole bottom.

[0050] In order to record face orientation the core sample may be placed in a core tray 57 as depicted in Figure 26 (Figure 25 is an insert 58 for a smaller core size) and the body 28 placed in the tray section 59 on mounts 60 and 61 so that the in hole position is reproduced according to the face profile taken with pins 30 and marker pencil 31. A line may then be drawn along the core sample opposite the spot 23 to mark the hole bottom on the core sample.

[0051] Figures 27 and 28 illustrate the measurement of azimuth using the azimuth lens 25 by aligning the lowest point on the ladder scale 62 with the spot 23 and then reading off the azimuth at the intersection of line 24 with scale 63.

[0052] Figures 29 and 30 illustrate reading of dip angle using dip angle lens 26. Dip angle lens 26 is equipped with a calibrated spiral scale 64 and dip angle may read off by rotating the lens until the spot 23 intersects with the scale.

[0053] While the above description has been primarily in relation vertical or downhill (vertical down) drilling the invention may be utilised for drilling upward (vertical up) and substantially horizontal directions using the balls and lenses depicted in Figures 32A to 32E and Figures 33A to 33E respectively noting the following in relation to those drawings.

1) Vertical up ball is different to the vertical ball down as the line and dot are at the same end of the ball as the magnet and the ball will be captured looking up and gravity will keep this side of the ball facing down. The ball will be captured on the non-visible side of the ball so the opposite side of the ball can be sighted in the device for noting the hole / core orientation.

Secondly the vertical azimuth lens up increments are etched in reverse to the vertical azimuth lens down.

The vertical down lenses are operated in the same way as for the vertical ball down.

2) The horizontal ball has the magnet located 90° to both the vertical balls and

horizontal balls as it is looking along the horizontal axis.

3) To identify azimuth using the horizontal ball, place the azimuth target lens horizontal over the horizontal ball and look where the target crosshairs intersect with the longitude lines, follow this line to the number that indicates the azimuth. The reading is taken from the ball.

4) To identify dip using the horizontal ball place the dip spiral lens horizontal over the horizontal ball and rotate the lense until the horizon line lines up with the arc of the spiral line and then take the reading.

[0054] Whilst the above has been given by way of illustrative example many variations and modifications will be apparent to those skilled in the art without departing from the broad ambit and scope of the invention as herein set forth in the appended claims.

Claims

1. A kit for borehole orientation comprising:

a. a borehole orientation device adapted to be fed down a borehole and having a hole bottom indicator carried by a carrier including a lockable gravity follower, the follower being lockable upon the orientation device engaging a core face adjacent the hole bottom; and

b. at least one read out device separate of the borehole orientation device having a scale to be applied manually in a predetermined position, to the follower of the orientation device, after the borehole orientation device has been removed from the borehole and disassembled to expose the locked follower, to thereby read orientation data from the scale.

2. A kit according to claim 1 wherein the follower is locked by being axially shiftable after the orientation device engages the core face.

3. A kit according to claim 1 wherein the orientation device includes a follower arrestor and the follower is locked by being axially shiftable and by resilient engagement with the arrestor.

4. A kit according to claim 1 wherein the orientation device includes a follower arrestor and the follower is locked by being axially shiftable and by resilient engagement with the arrestor comprising two or more resilient tangs.

5. A kit according to any one of the preceding claims wherein the follower includes a compass function.

6. A kit according to any one of the preceding claims wherein there is a separate scale for each of azimuth and dip angle and both may be separately read in accordance

with claim 1 integer b.

7. A kit according to any one of the preceding claims wherein the follower is an orientation ball and the hole bottom indicator is a spot on the surface of the ball, the ball having an offset centre of gravity.

8. A kit according to claim 7 wherein the scale is an azimuth scale and azimuth is read from a manually applied scale applied to the ball after the ball has been locked and the orientation device retrieved.

9. A method for taking a measurement using the kit according to claim 7 or claim 8 after the orientation device has been retrieved from a borehole and after the follower has been locked, the follower being a ball and having a hole bottom indicator being an indicator spot and there being an adjoining line extending from the spot, the spot and line being in predetermined position for measurement of azimuth and dip, wherein a first step involves locating the spot, intersecting with a first said scale, with the line from the spot intersecting with a second scale, the line being in a radial plane and terminating at or adjacent the spot, the follower being arranged so that the line always points due north, the azimuth reading is taken from the second scale, the first and second scales being on a see through "azimuth" hemispherical dome, manually applied to the follower.

10. A method for taking a measurement using the kit according to claim 9 wherein the see through dome has an inner surface complementary to the ball so that it may rotate on the locked ball, the second scale being a 360° scale along an "equatorial" circumference with the first scale set at 90° to the second scale, dip angle is read from a dip angle scale rotatably placed over the ball, the see through dip angle dome operating as a hemispherical protractor placed over the ball with a central 90° mark at the top of the dome and a spiral scale marking, rotation of the dome on the ball such that the spot is located by a user on the spiral scale enables a user to read off dip angle.

11. A method for taking a measurement using the kit according to claim 9 after the orientation device has been retrieved from a borehole and after the follower has been locked, the follower being a ball and having a hole bottom indicator being an indicator spot and there being an adjoining line extending from the spot, the spot and line being in predetermined position for measurement of azimuth and dip, wherein a first step involves locating the spot, intersecting with a first said scale, with the line from the spot intersecting with a second scale, the line being in a radial plane and terminating at or adjacent the spot, the follower being arranged so that the line always points due north, the azimuth reading is taken from the second scale, the first and second scales being on a see through "azimuth" hemispherical dome, manually applied to the follower, dip angle is read from a separate see through dip dome with an angle scale rotatably placed over the ball, the see through dip angle dome operating as a hemispherical protractor placed over the ball with a central 90° mark at the top of the dome and a spiral scale marking, rotation of the dome on the ball such that the spot is located by a user on the spiral scale enables a user to read off dip angle.

12. A borehole orientation device adapted to be assembled in an assembly step to set the device before being passed down a borehole and then disassembled in order to take a measurement the orientation device having a hole bottom indicator carried by a lockable compass and gravity follower in the form of an orientation ball, the device having a downhole end and an uphole end, the downhole end carrying a face orientator comprising axially slidable pins and at or adjacent the uphole end, a chamber holding the orientation ball, the chamber being formed when first and second chamber portions are assembled in the assembly step about the ball where the ball is free to move within the chamber, the ball being lockable in the chamber by axial relative axial movement of the chamber portions to clamp the ball.

13. A borehole orientation device according to claim 12 wherein the ball is free to rotate in any direction under the influence of gravity due to an offset weight and the ball also operates as a compass where the weight is also a magnet causing the magnet to shift North in a substantially horizontal plane while at the same time retaining the vertical set due to gravity so that the ball is locked with both compass and hole bottom orientation function.

14. A borehole orientation device according to claim 12 wherein the chamber portions comprise a downhole wall portion with resilient axial tangs about a dome-like wall, each tang having an orientation ball arrestor rib, arranged such that the chamber portions expel air from the chamber during the assembly step.

15. A borehole orientation device according to claim 14 wherein grooves are provided either side of the chamber and these have o-ring seals used to seal the chamber with the ball in a first position, uphole of the arrestor ribs.

16. A borehole orientation device according to claim 12 wherein the portions are assembled, after being progressively vented.

17. A method of setting a borehole orientation device according to any one of the preceding claims having an orientation ball, the method including the steps of:

loading the orientation ball into a second body part having a second ball chamber portion;
before or after loading the ball, pouring liquid into the second body part;
inserting a first body part having a first ball chamber portion into the second part; and
progressively venting air and then liquid from the ball chamber; and
subsequently sealing the ball chamber such that the ball is in a first freely

moving position.

18. The method of claim 17 wherein the second body part has a hollow formed by a tapered wall used to vent air and some of the said liquid and then seal the orientation ball chamber, there being a sealing o-ring, wherein the o-ring held in one of the parts between the parts becomes located in a groove in the other part.

19. The method of claim 18 wherein in order to move the ball to a locked position under further axial pressure, the o-ring may move axially out of the groove, so that the ball is shifted slightly over-centre and locked in place by arrestor ribs.

20. The kit according to claim 1 as a further element of the kit, an azimuth lens having an azimuth scale.

21. The kit according to claim 1 as a further element of the kit, an azimuth lens having a dome section matching a ball, the dome section having an azimuth scale and may be placed over the ball and the measurement of azimuth using the azimuth lens by aligning the scale in a predetermined position on the ball and then reading off the azimuth on the scale.

22. The kit according to claim 1 as a further element of the kit, a dip angle lens having a dip angle scale.

23. The kit according to claim 1 as a further element of the kit, a dip angle lens having a dome section that may be placed over a ball and comprises the reading of dip angle using the dip angle lens, the dip angle lens being equipped with a calibrated spiral scale and dip angle may read off by rotating the lens until a predefined position of the ball intersects with the scale.

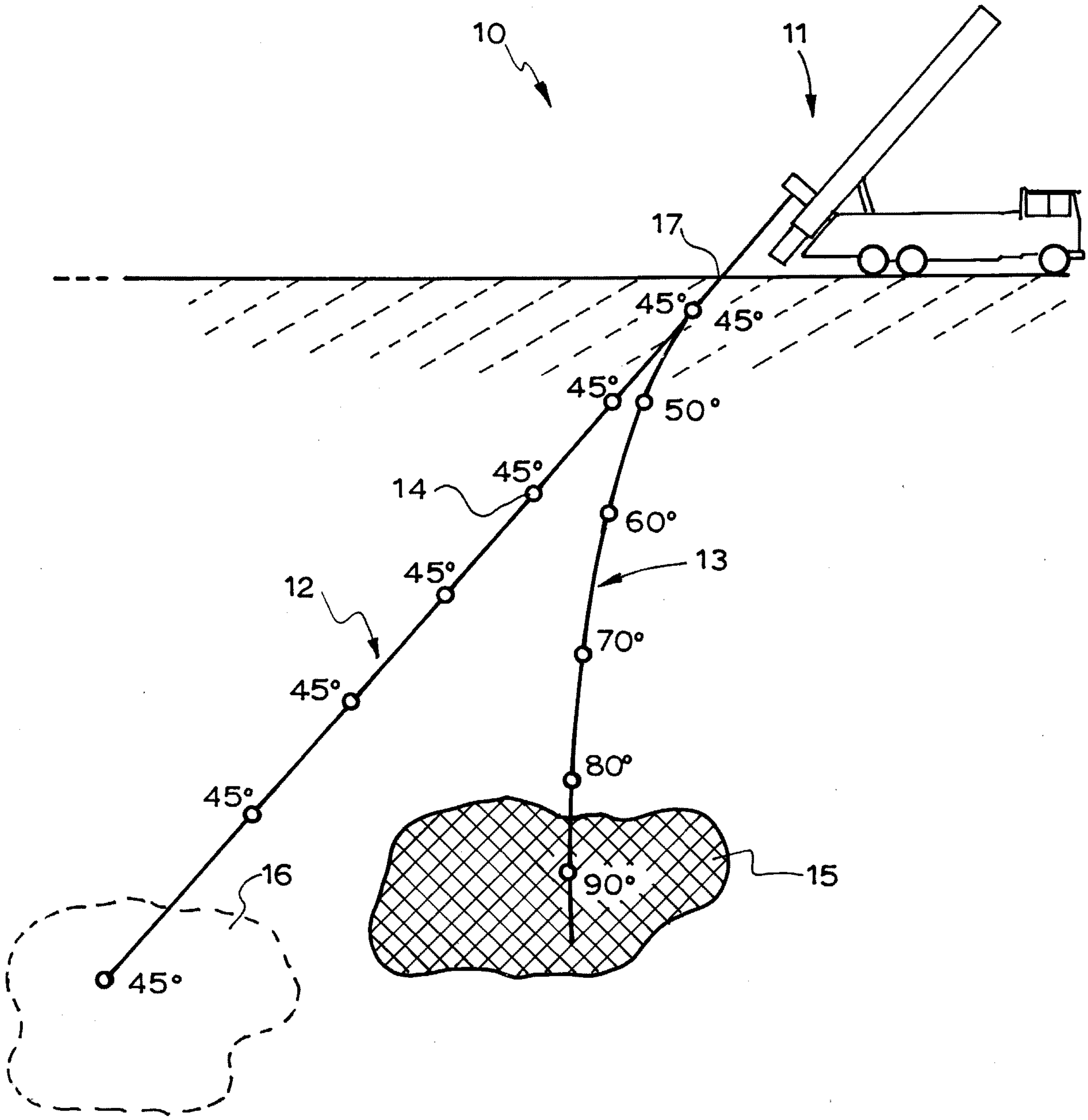

FIG.1

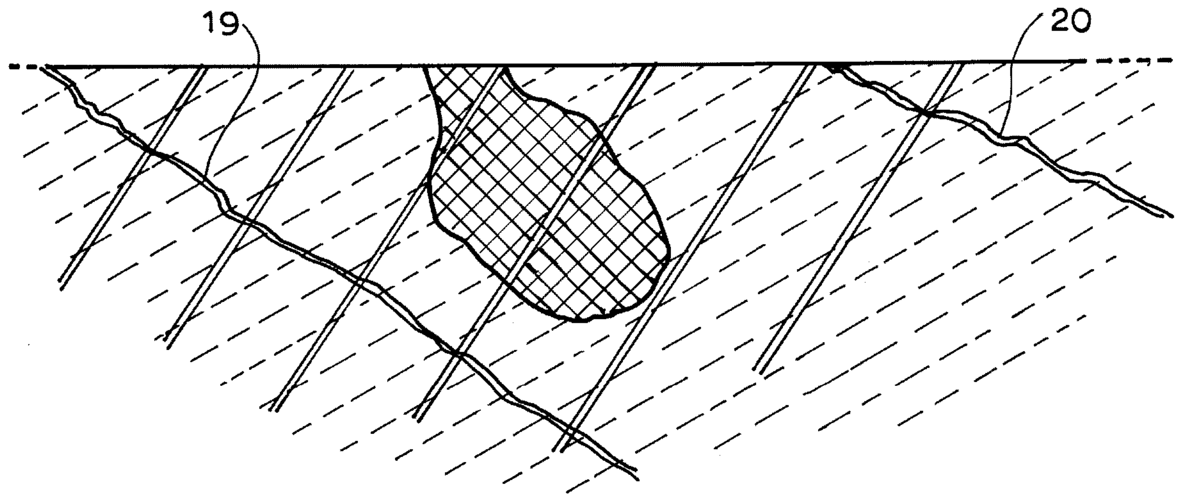

FIG. 2

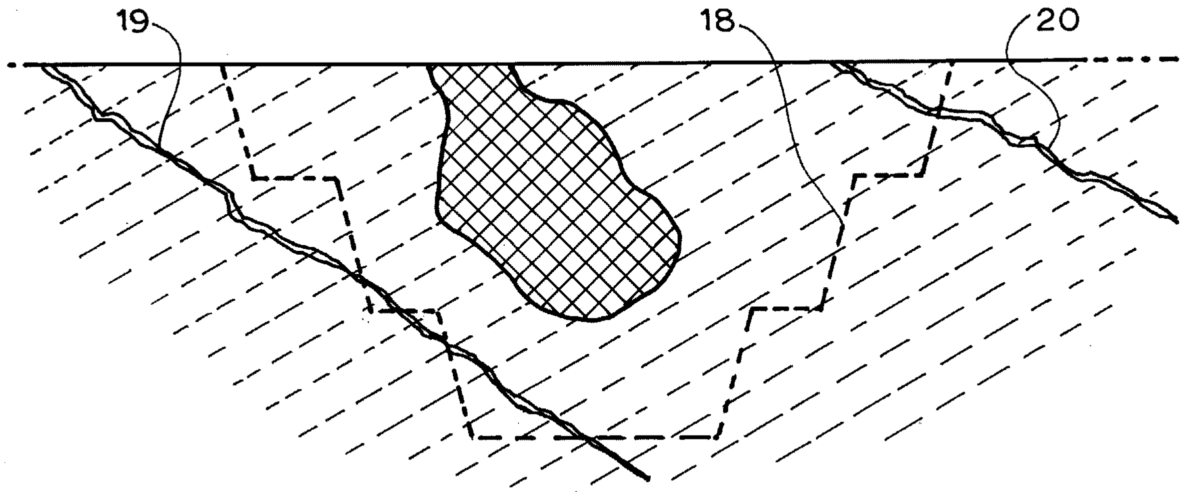

FIG. 3

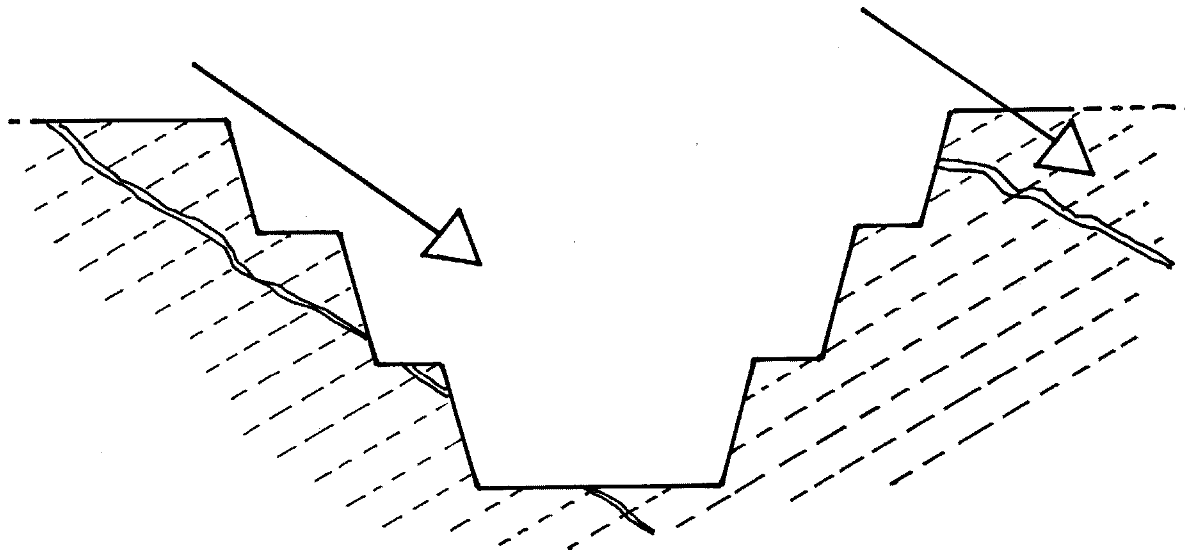

FIG.4

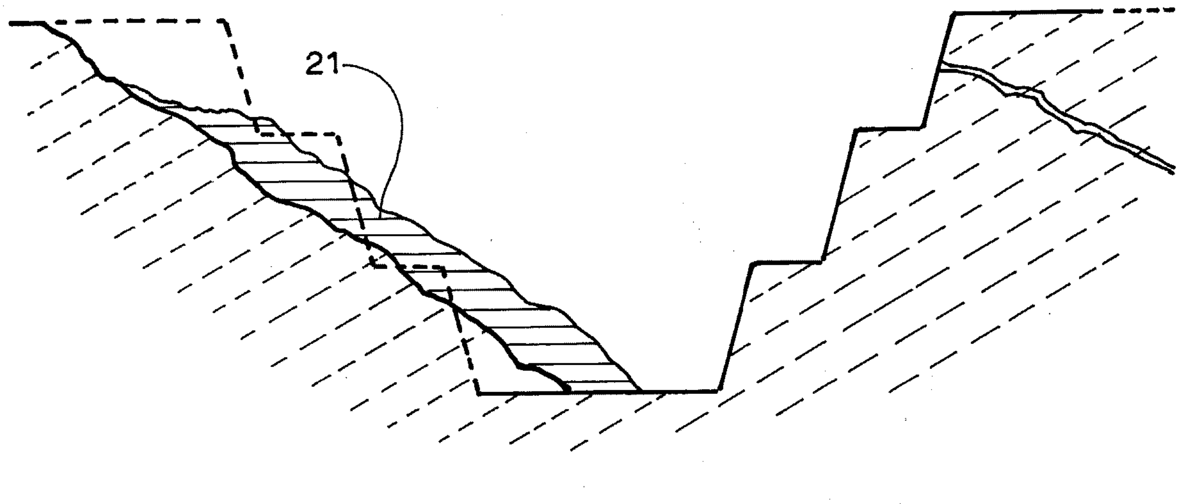

FIG.5

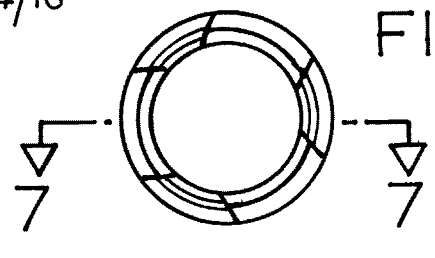

FIG.8

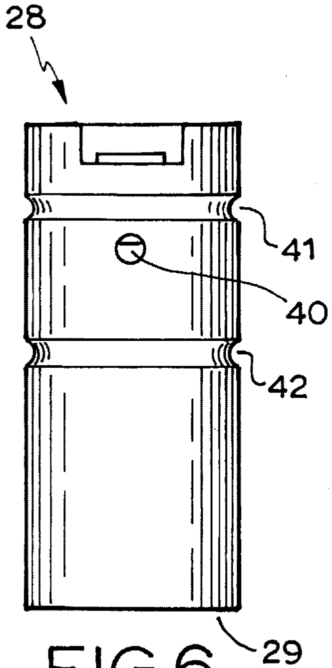

FIG.6

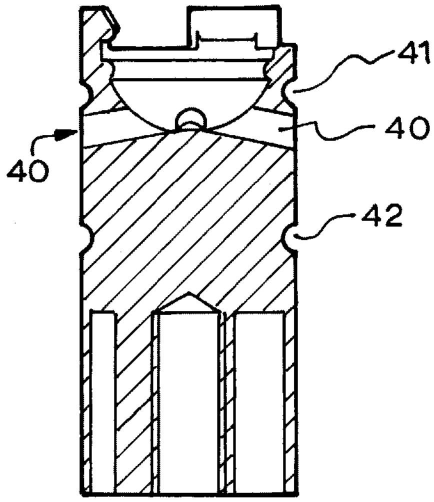

FIG.7

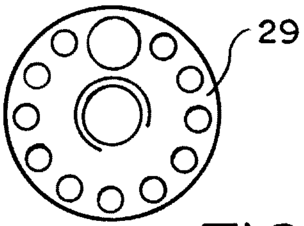

FIG.10

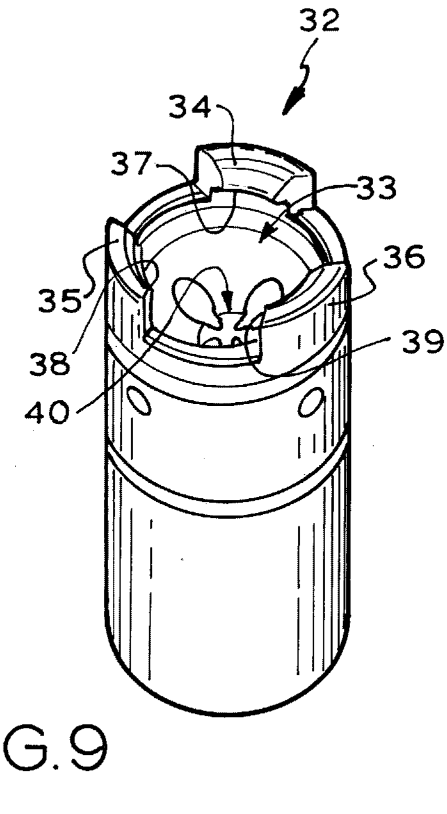

FIG.9

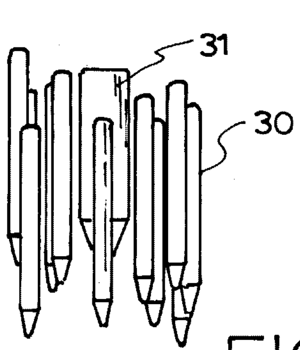

FIG.11

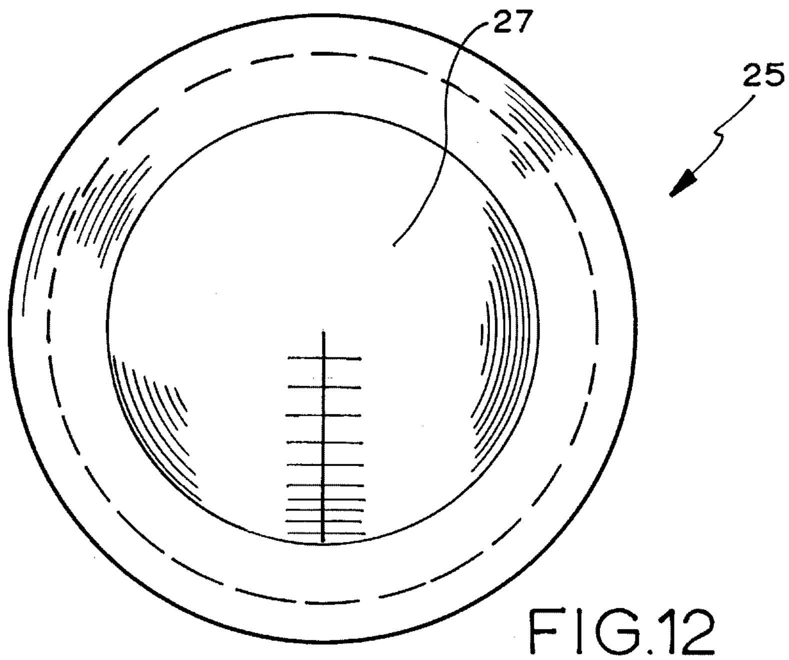

FIG.12

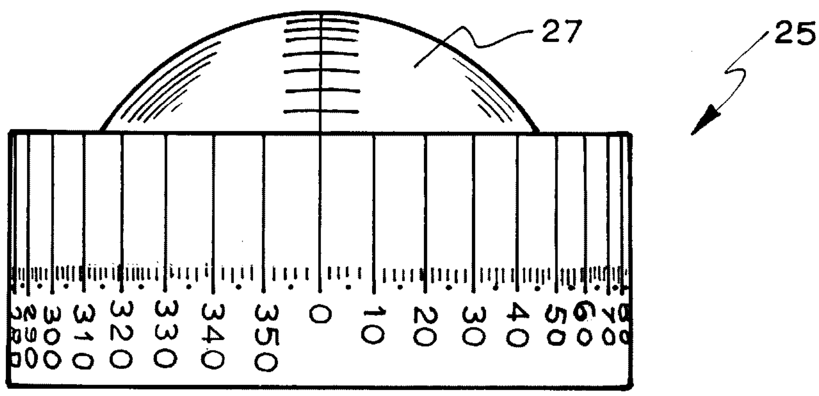

FIG.13

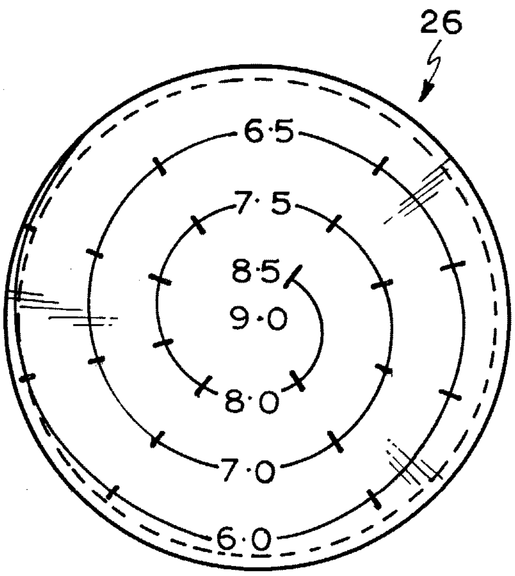

FIG.14

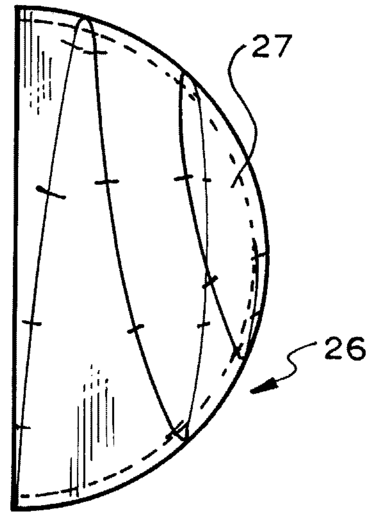

FIG.15

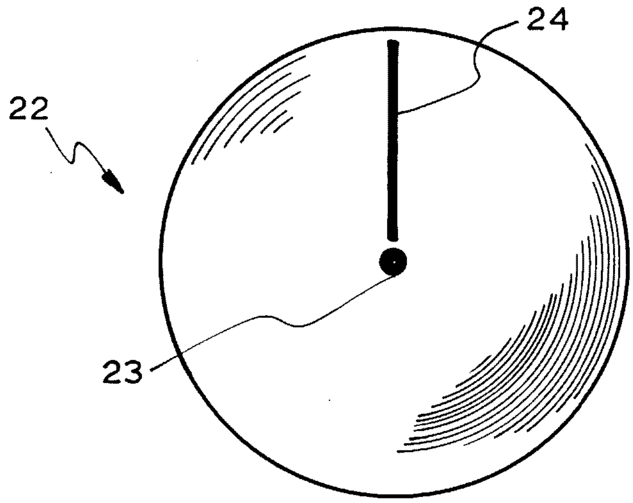

FIG.16

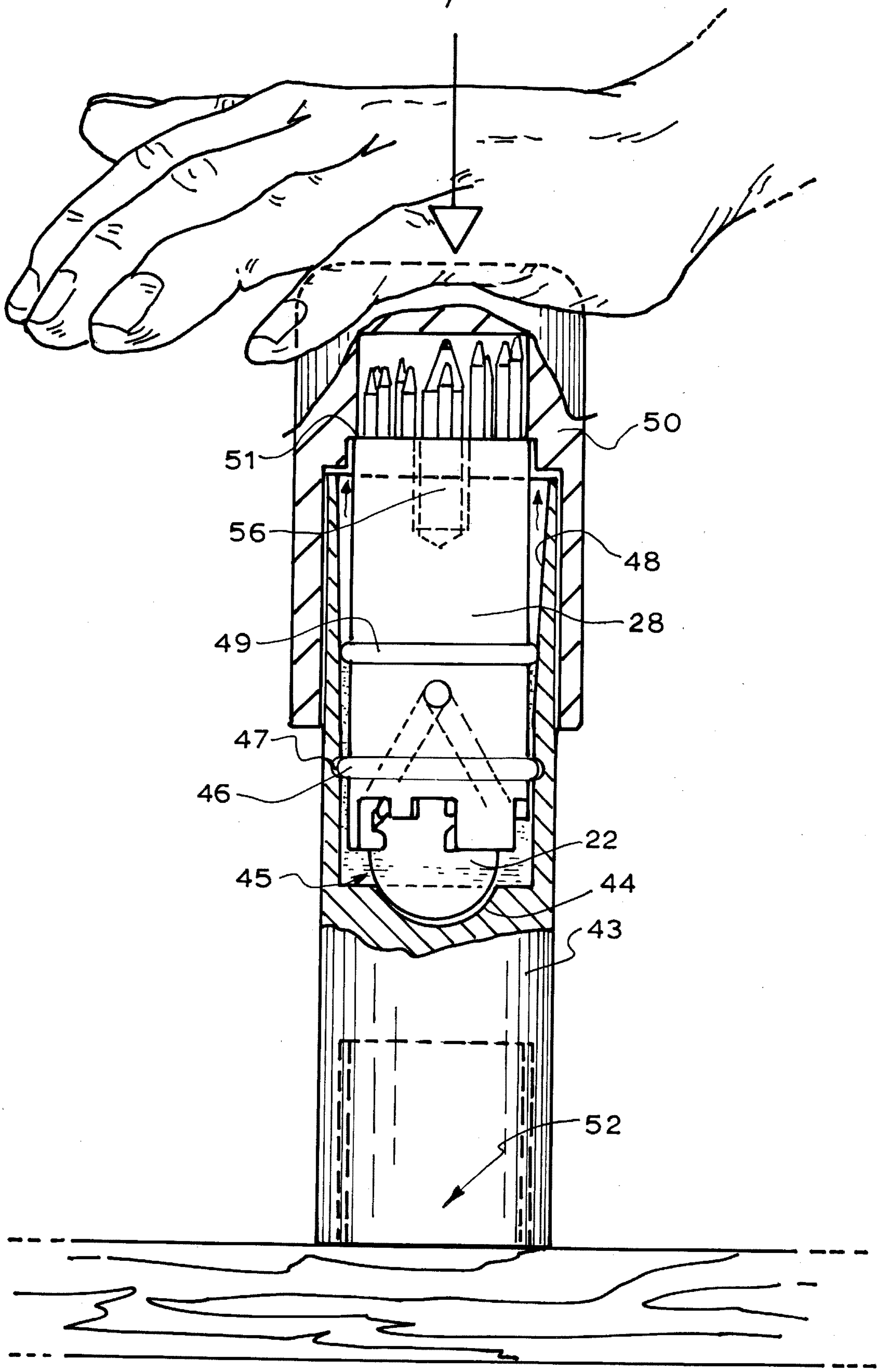

FIG.17

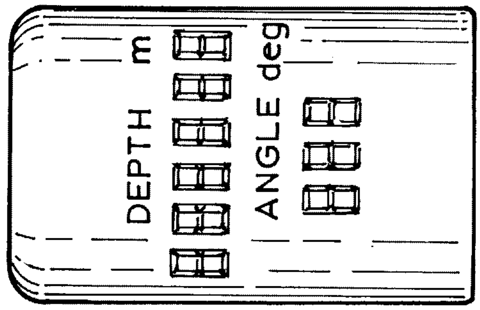

FIG.20

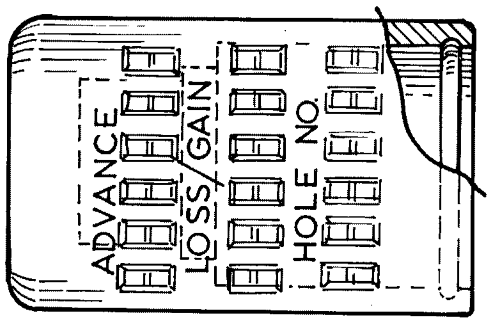

FIG.19

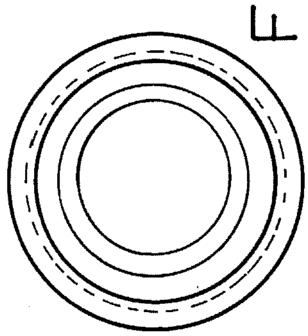

FIG.21

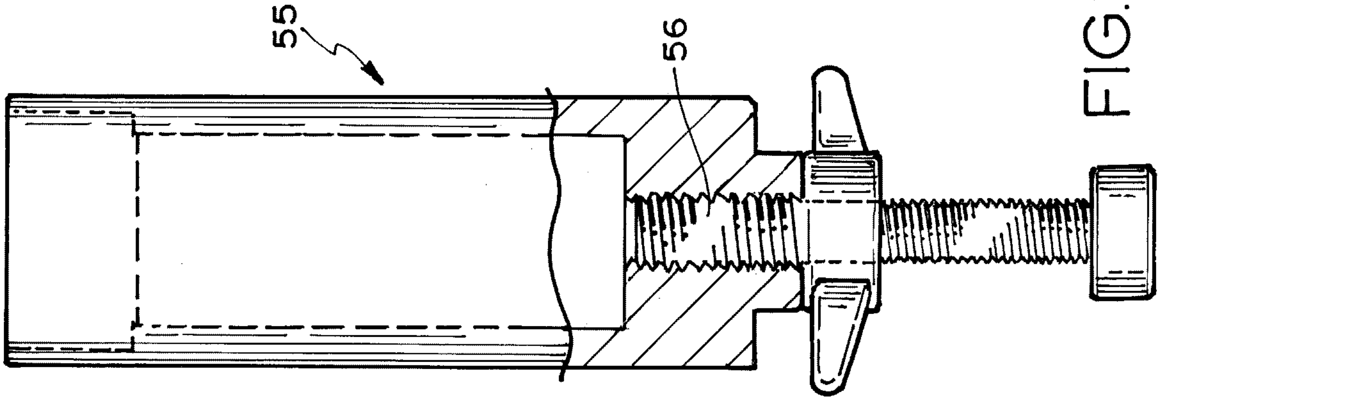

FIG.18

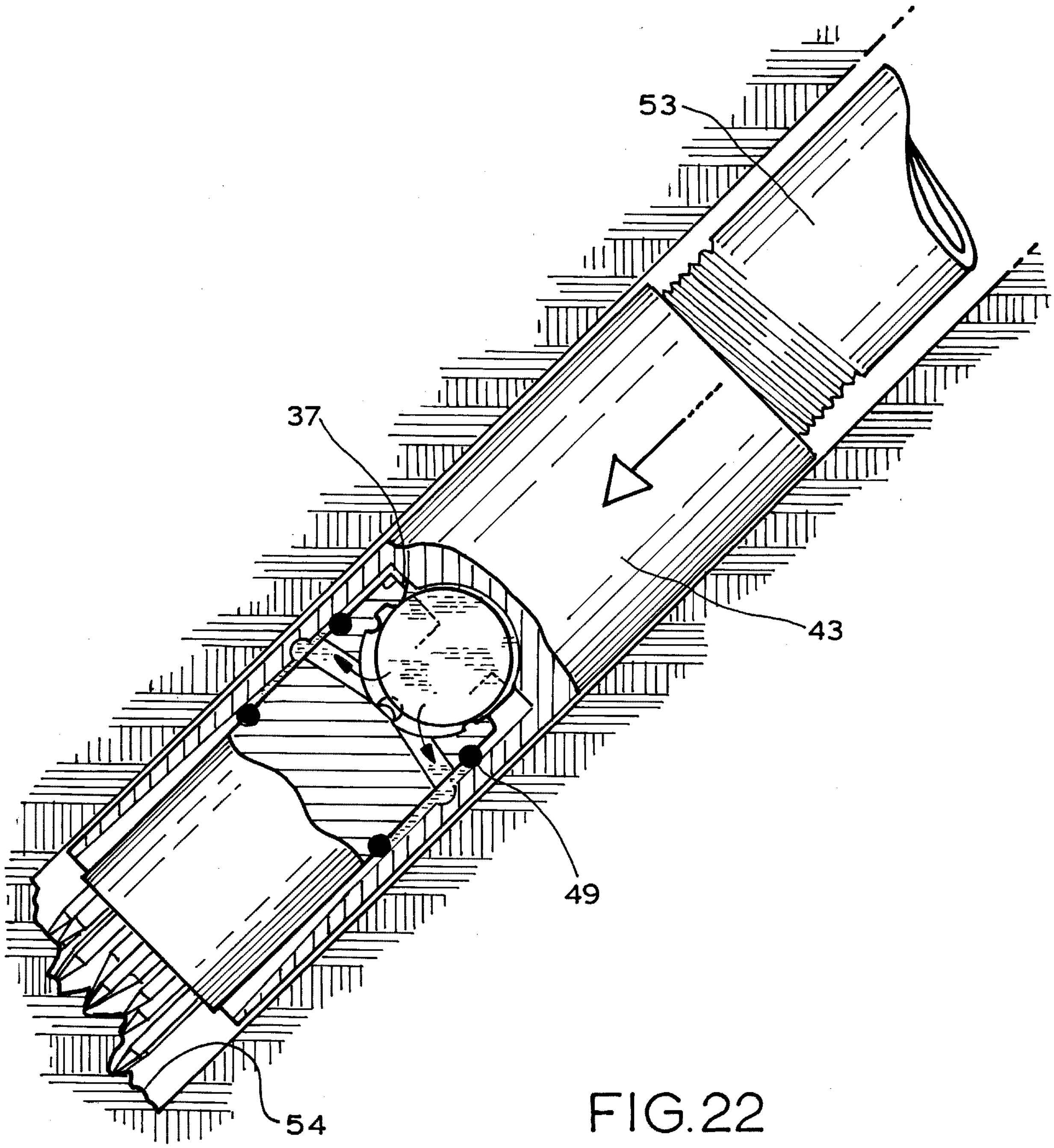

FIG.22

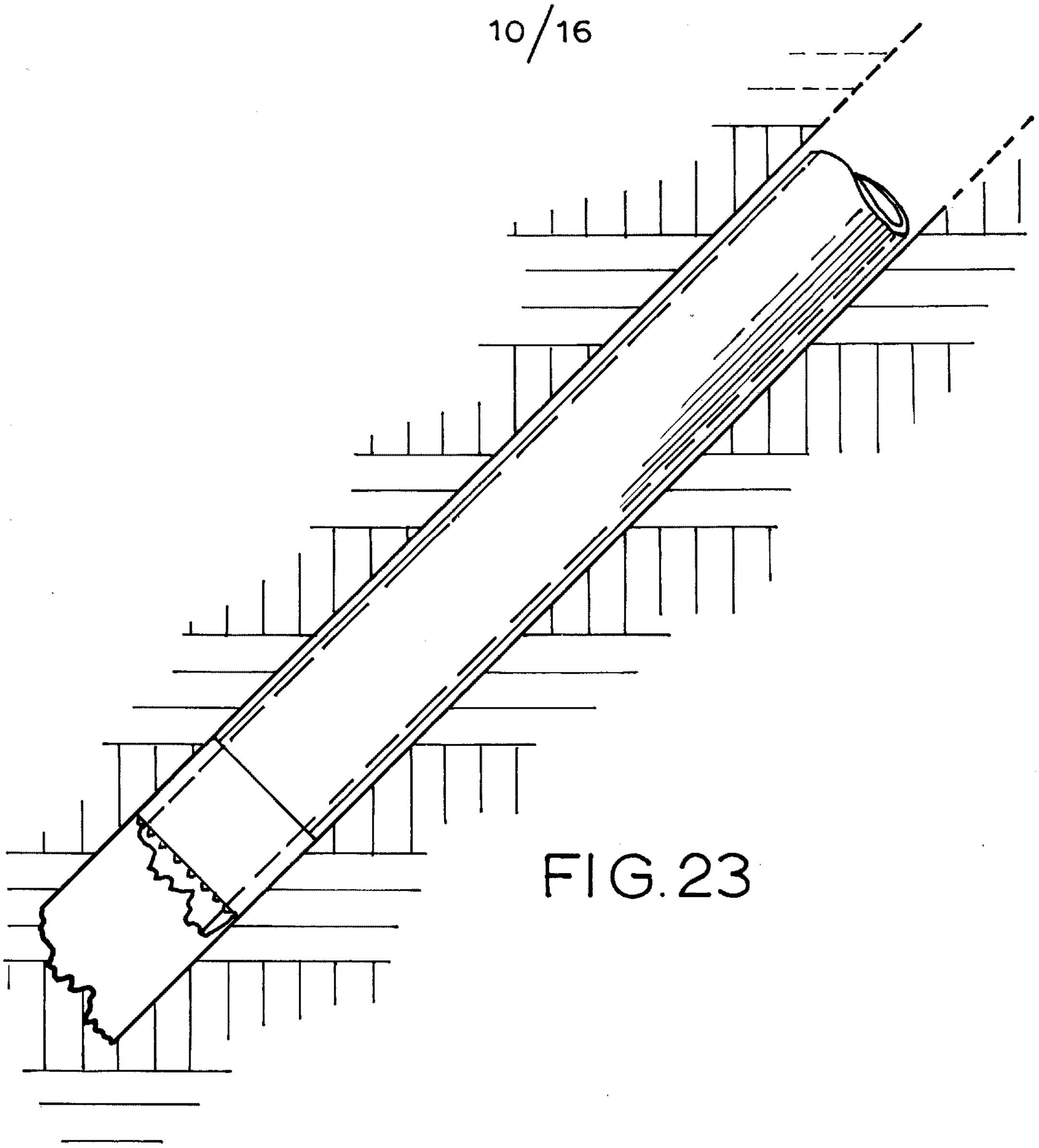

FIG. 23

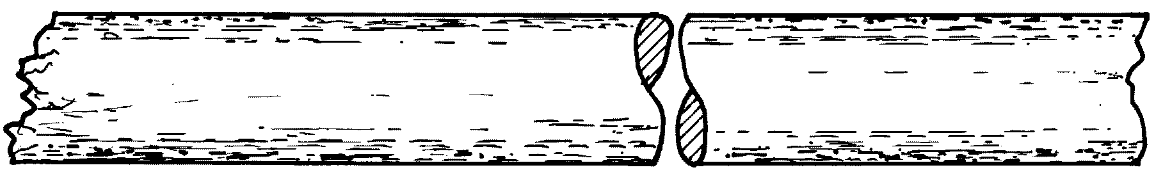

FIG. 24

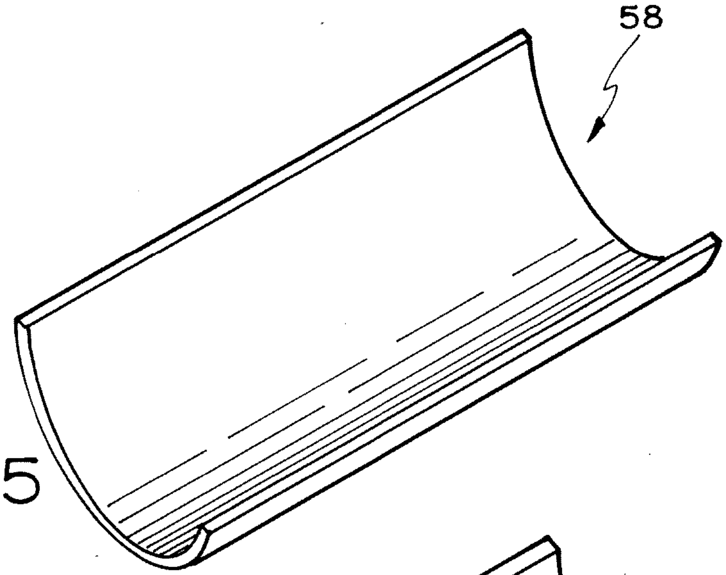

FIG. 25

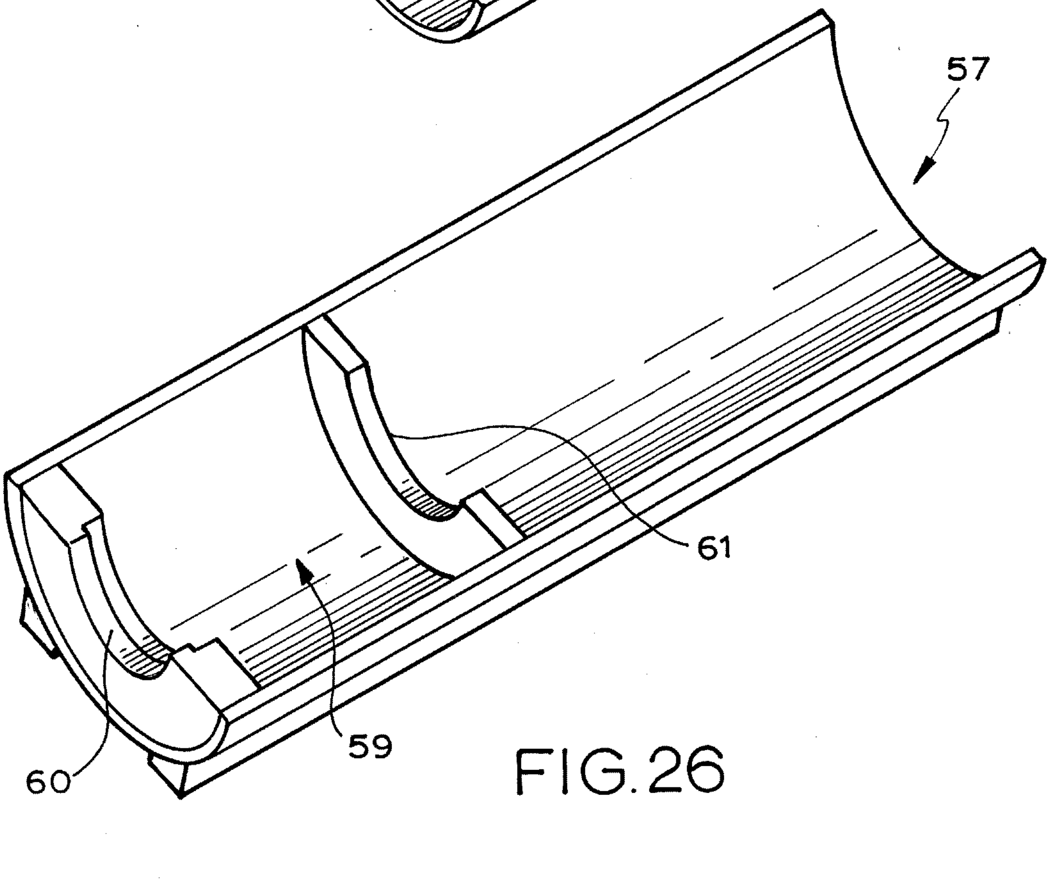

FIG. 26

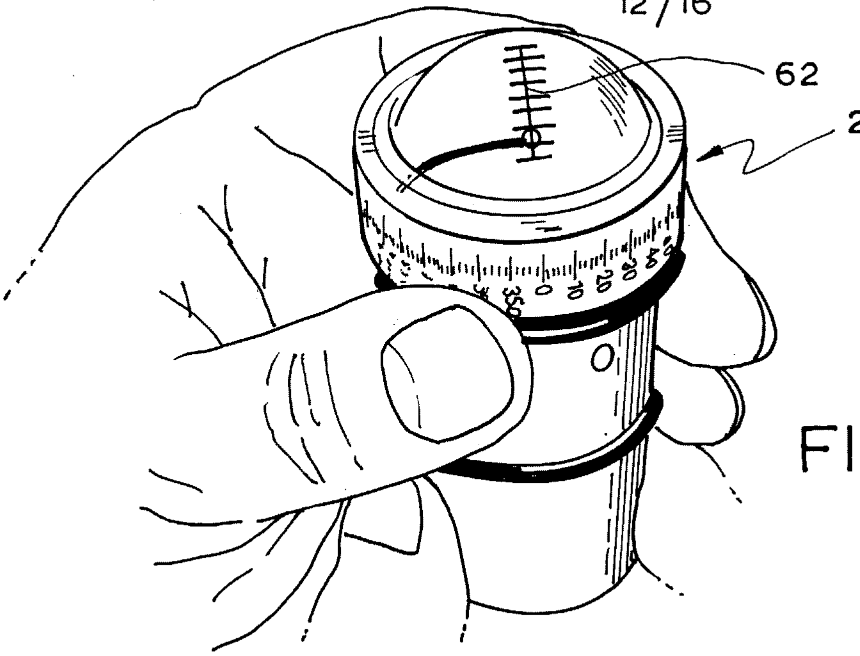

FIG.27

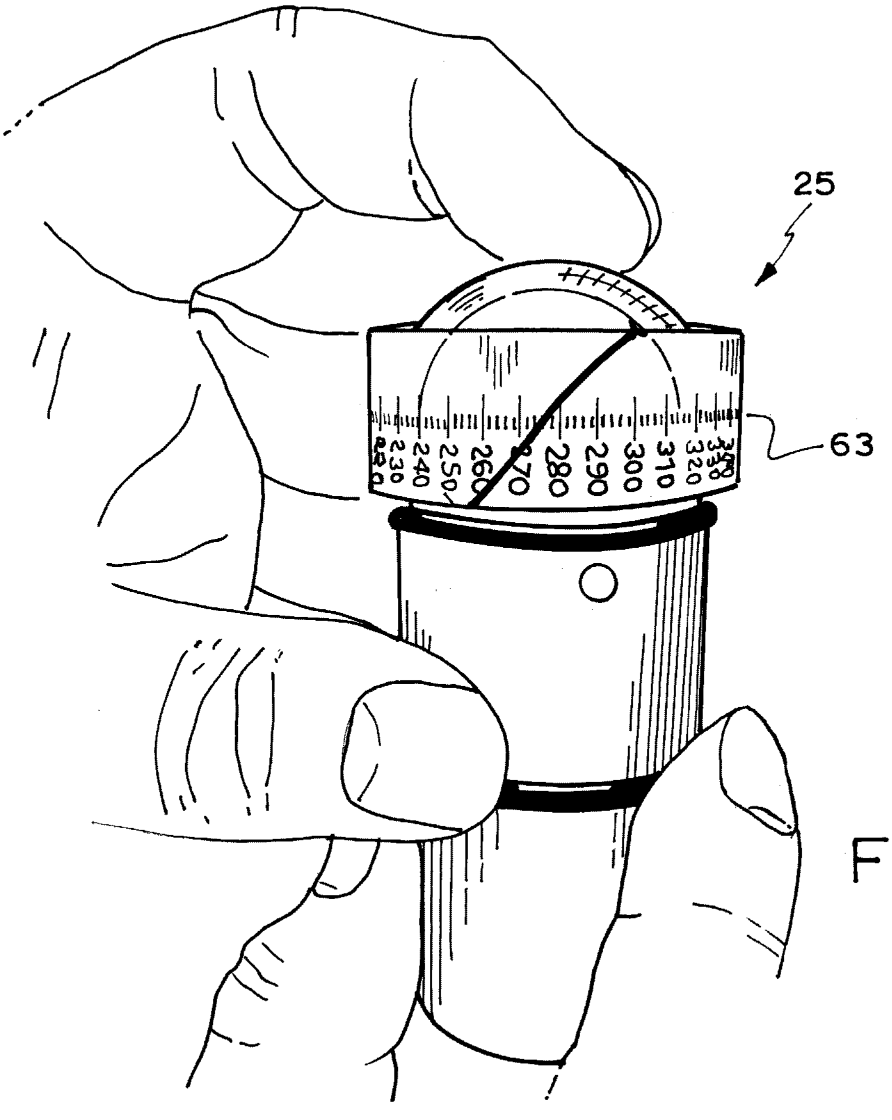

FIG.28

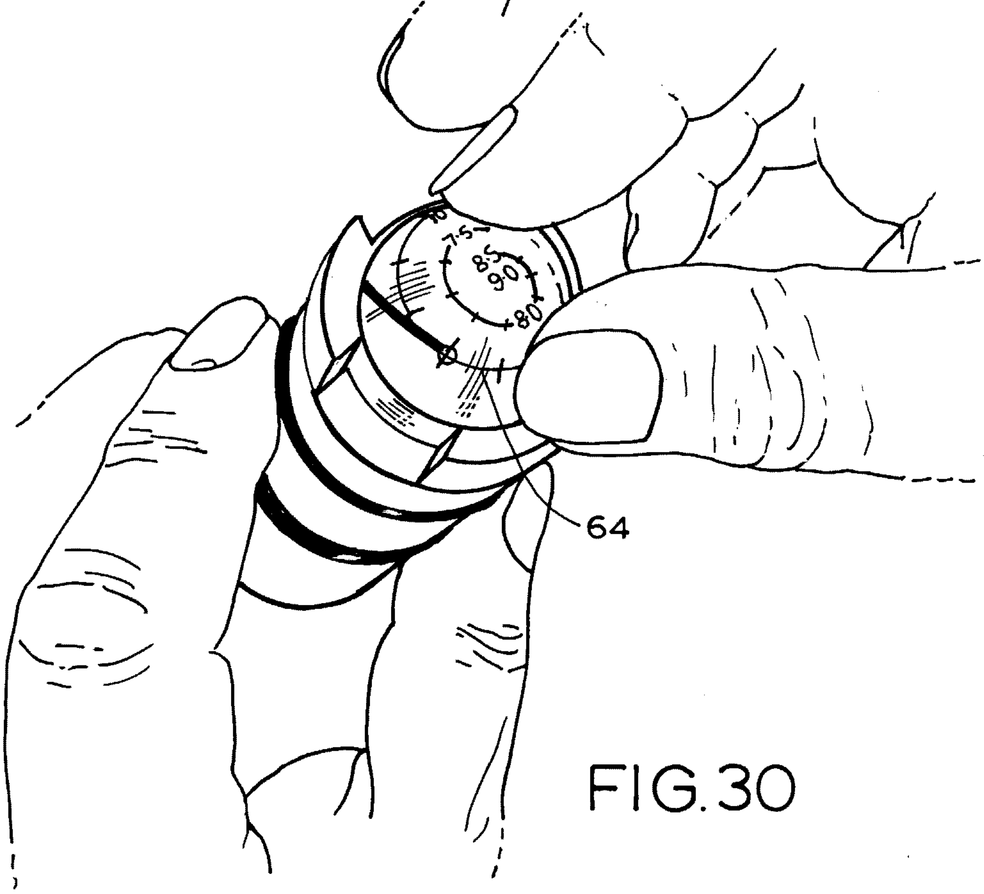

FIG.30

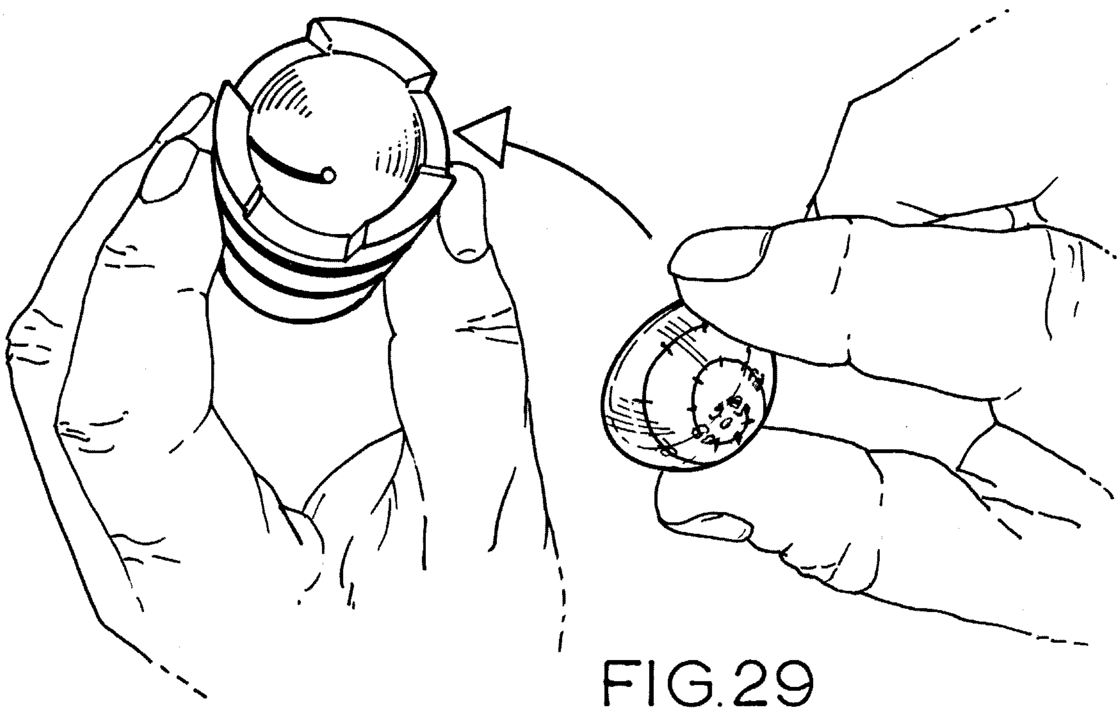

FIG.29

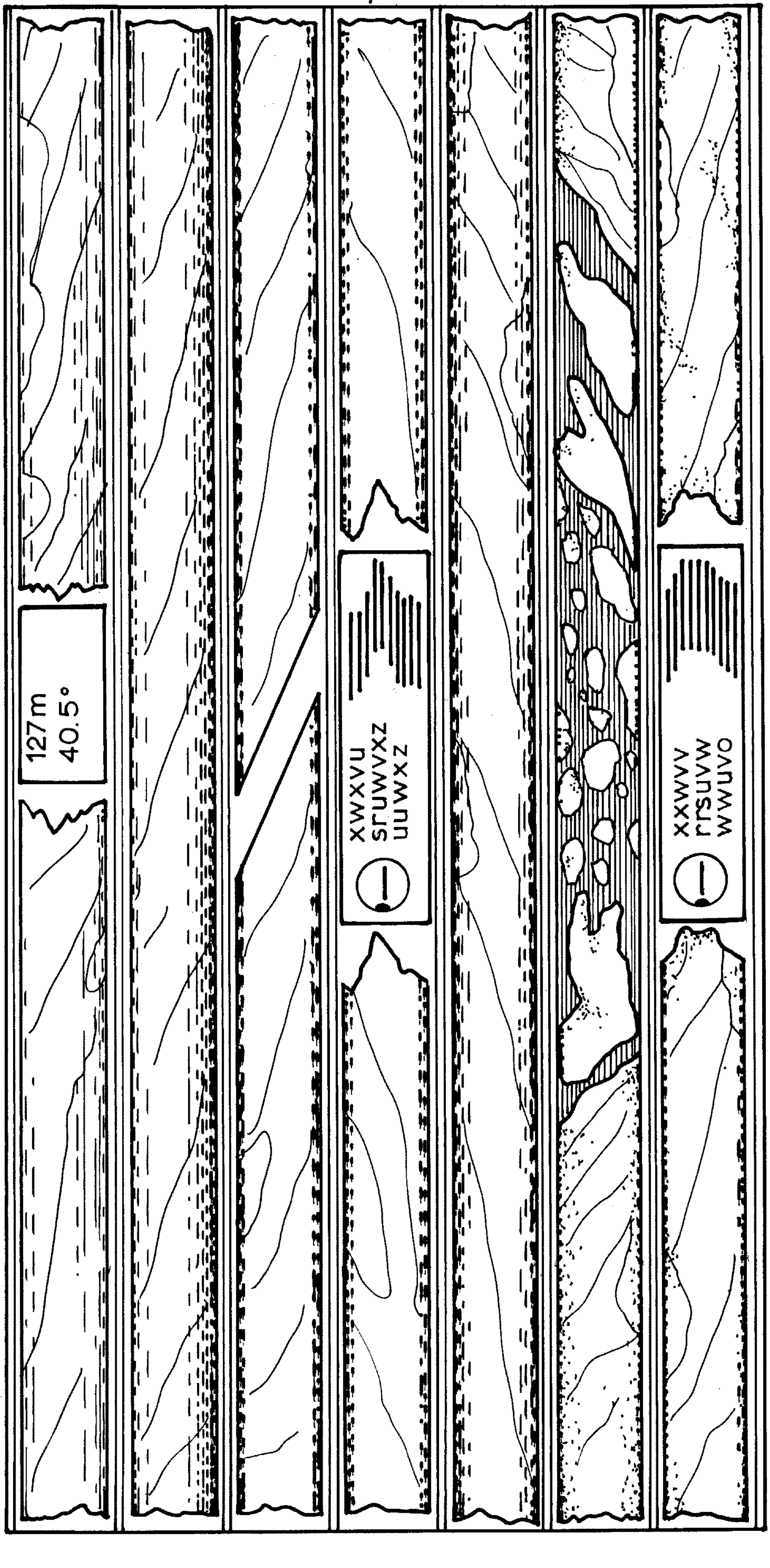

FIG. 31

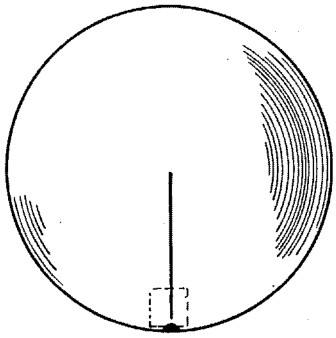

FIG. 32A

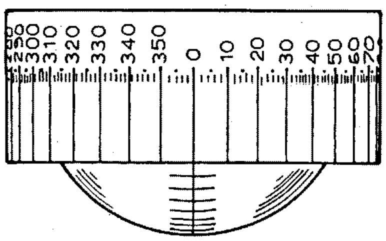

FIG. 32B

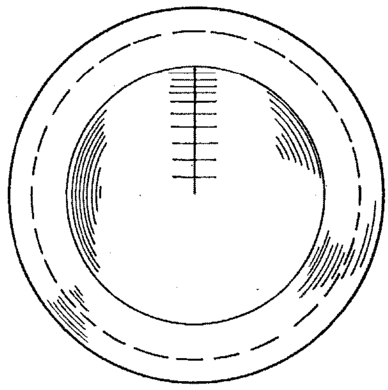

FIG. 32C

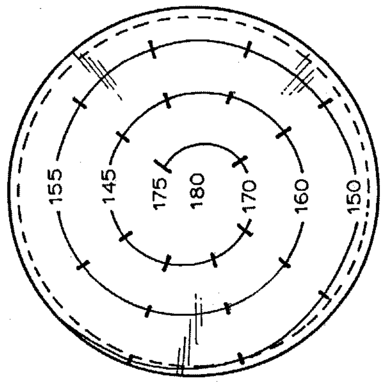

FIG. 32D

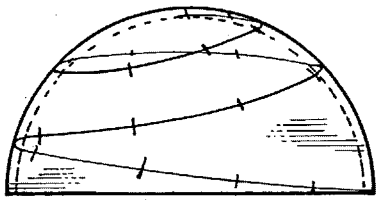

FIG. 32E

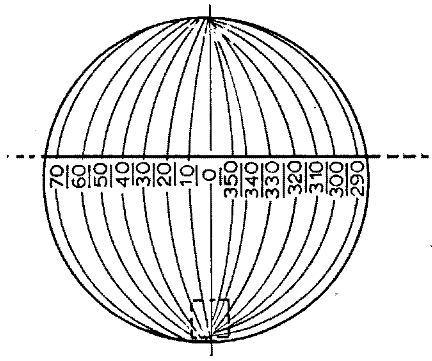

FIG. 33A

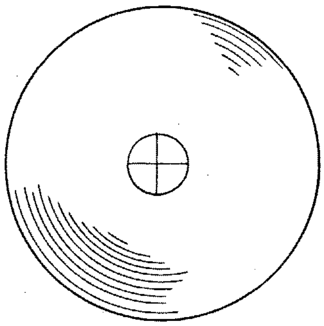

FIG. 33B

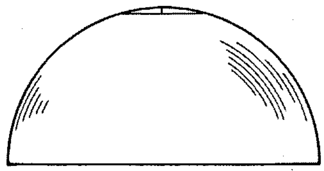

FIG. 33C

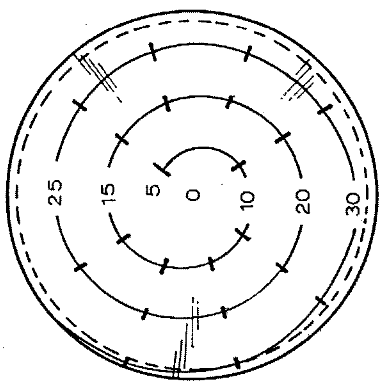

FIG. 33D

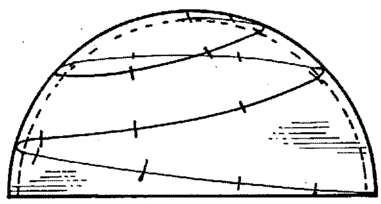

FIG. 33E

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2019/000068

A. CLASSIFICATION OF SUBJECT MATTER

E21B 25/16 (2006.01) E21B 25/18 (2006.01) E21B 47/024 (2006.01) E21B 47/026 (2006.01) G01C 9/10 (2006.01) G01C 17/04 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: PATENW IPC/CPC E21B25/16, E21B25/18, E21B, G01C17/04, G01C19/10, E21B25/005 and keywords(ball, gravity, sphere, follower, lock, restrain, portable, manual, hand held, azimuth, dip, clinometer, measure, gauge) and like terms.

AusPat/IP Australia Internal databases: Applicant/Inventor name search.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C   [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 July 2019	17 July 2019

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
Email address: pct@ipaustralia.gov.au

Authorised officer

Dereje Yitagesu
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Telephone No. +61262104083

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:

   because they relate to subject matter not required to be searched by this Authority, namely:

   the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including

2. ☐ Claims Nos.:

   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos:

   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No. **PCT/AU2019/000068**

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/078232 A1 (2iC AUSTRALIA PTY LTD.) 25 August 2005 Abstract, pages 11-13 & figs 1-6	1-11 & 20-23
X	EP 1198657 B1 (SHELLJET PTY LIMITED) 25 August 2004 figs 1-5, para[0015]-[0029]	1-11 & 20-23
X	US 2009/0071716 A1 (VAN RUTH) 19 March 2009 figs 1-2, para[0028]-[0041] & abstract	12-19

Supplemental Box

Continuation of: **Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-11 & 20-23 are directed to a kit for borehole orientation with a gravity follower.. The feature of a manual read out device separate from the borehole orientation is specific to this group of claims.

- Claims 12-19 are directed to a borehole orientation device with a gravity follower.. The feature of a compass and a face orientator in a form of sliding pins is specific to this group of claims.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is The feature relating to the borehole orientation with a gravity follower

However this feature does not make a contribution over the prior art because it is disclosed in:

D1, see novelty section below for discussion of disclosure

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori*.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2019/000068**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
WO 2005/078232 A1	25 August 2005	WO 2005078232 A1	25 Aug 2005
		AU 2005212537 A1	25 Aug 2005
EP 1198657 B1	25 August 2004	EP 1198657 A1	24 Apr 2002
		EP 1198657 B1	25 Aug 2004
		AU 4900400 A	28 Dec 2000
		AU 773593 B2	27 May 2004
		CA 2294409 A1	03 Dec 2000
		CA 2378748 A1	14 Dec 2000
		GB 2370589 A	03 Jul 2002
		US 6659196 B1	09 Dec 2003
		WO 0075480 A1	14 Dec 2000
		ZA 200110321 B	14 Mar 2003
US 2009/0071716 A1	19 March 2009	US 2009071716 A1	19 Mar 2009
		AU 2007266330 A1	06 Dec 2007
		CA 2651818 A1	06 Dec 2007
		WO 2007137351 A1	06 Dec 2007

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.