

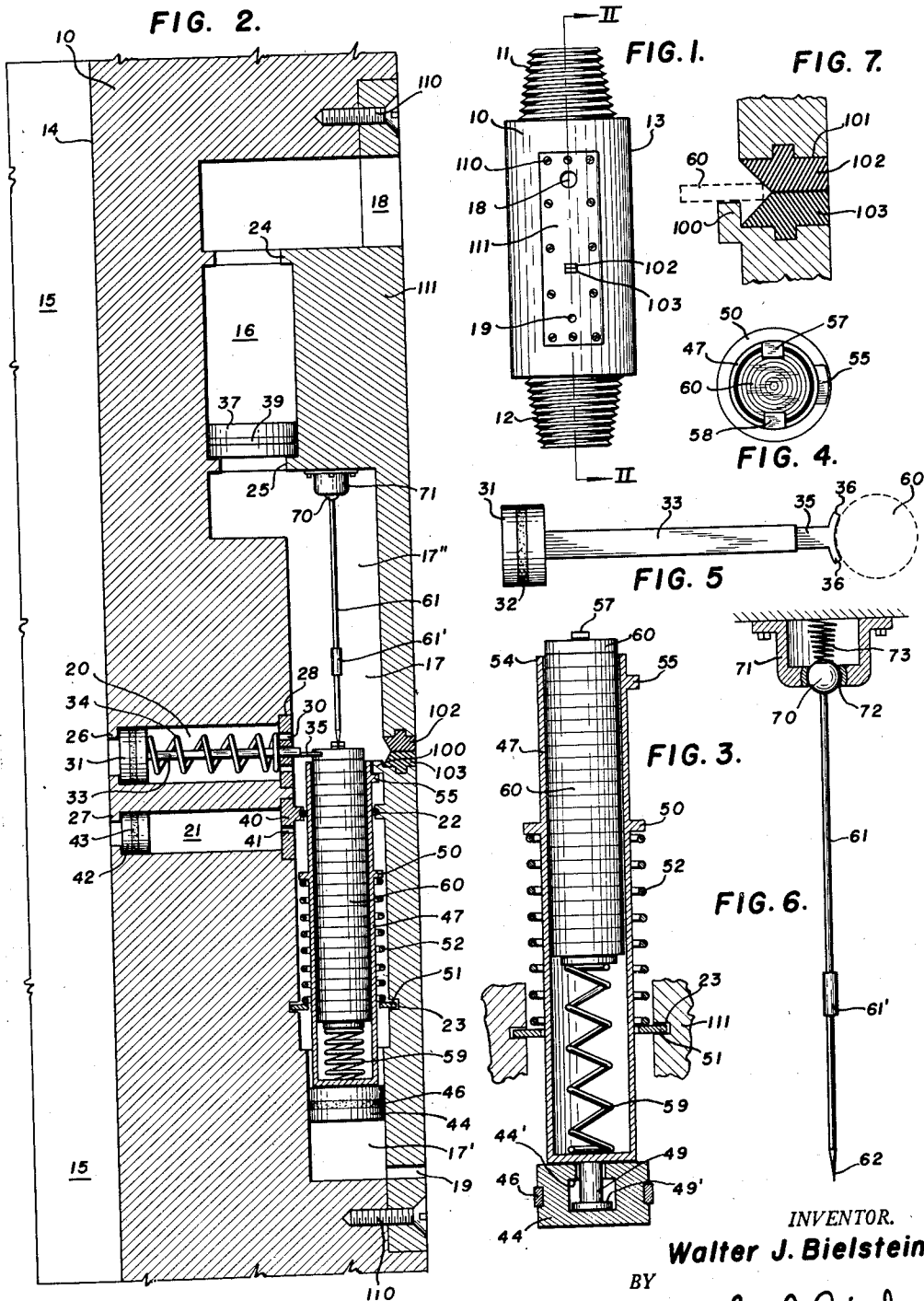
Aug. 26, 1952

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2,608,002

DEVICE FOR INDICATING INCLINATION OF BOREHOLES

Filed Dec. 28, 1950



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UNITED STATES PATENT OFFICE

2,608,002

DEVICE FOR INDICATING INCLINATION
OF BOREHOLES

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Application December 28, 1950, Serial No. 203,192

5 Claims. (Cl. 33—205.5)

1

This invention relates to the art of drilling boreholes into subsurface formations by the rotary drilling method and, more particularly, relates to the art of ascertaining and indicating deviations from vertical of a borehole drilled by said method.

In the drilling of boreholes by the rotary drilling method, the equipment employed includes a drill bit which is mounted on the lower end of a string of pipe known as drill pipe, the drill pipe being provided at its upper end with a kelly rod or grip stem by means of which the drill pipe is rotated through the medium of a rotary table. While the drill stem is rotated in the borehole for the purpose of deepening the borehole, it is common practice to circulate a drilling fluid continuously through the drill stem and the drill bit. This drilling fluid is pumped downwardly inside the drill stem through the eyes of the bit and upwardly in the annular space between the drill stem and the borehole walls. Ordinarily the drilling mud leaving the borehole is passed over a shale shaker in order to separate from the drilling fluid the coarser material suspended therein after which the drilling fluid may be stored in a pit or tank for further use.

During the drilling of boreholes by the rotary drilling method it has been found difficult to maintain a vertical course. Because deviations from the vertical, if of any appreciable magnitude, cause many difficulties, it has been the practice to survey the borehole from time to time to determine whether or not the borehole is deviating from vertical and to determine the extent of the deviation, if any. Obviously, such a procedure is time-consuming and is otherwise unsatisfactory, particularly in that deviation cannot be determined at the time that drilling is being accomplished. By the time that deviation becomes known, the borehole may have deviated so far from the vertical as to cause serious difficulties in straightening same. It is apparent, therefore, that any practical method for determining and indicating deviation should detect and indicate any deviation at the very inception thereof so that proper steps may be taken by the drilling crew to restore the vertical alignment of the borehole.

It is an object of the present invention to provide a device which is an integral part of the drill string and which is adapted to determine and indicate the degree of inclination of the borehole from the vertical. It is a further object of the present invention to provide such a device which indicates degree of inclination while the borehole is being deepened.

2

The present invention may be described briefly as a tubular member, which may suitably be a drill collar sub, adapted to be removably secured to the drill string and made a part thereof, said tubular member having a longitudinal chamber defined by the walls thereof, a free swinging pendulum carrying marking means on the lower end thereof suspended in said chamber, record means carried in said chamber for receiving an impression thereon from said marking means and means for ejecting said record means from the longitudinal chamber and through the outer wall of said tubular member into the upwardly moving stream of drilling fluid. The record means is made of a material having such a specific gravity that it will be carried upwardly by the drilling mud and deposited on the shale shaker, or other suitable means for intercepting said record means, from which it may be recovered and examined by the drilling crew for determining the deviation of the borehole from the vertical.

The aforementioned objects and other advantages of my invention will be apparent from the following detailed description taken in connection with the accompanying drawings. In the drawing, like numerals indicate like parts throughout.

Fig. 1 is a view of a drill collar sub, which houses the apparatus of the present invention;

Fig. 2 is a fragmentary cross-sectional view of the device of my invention taken along the line II—II of Fig. 1;

Fig. 3 is a cross-sectional view showing in detail a portion of the mechanism illustrated in Fig. 1;

Fig. 4 is a top view of that portion of my device shown in Fig. 3;

Fig. 5 is a view of a portion of the device shown in Fig. 1;

Fig. 6 is a detailed view of the means employed for suspending the stylus shown in Fig. 1; and

Fig. 7 is a detailed view of a portion of the device shown in Fig. 1.

Referring to the drawing in which like numerals refer to like parts throughout, 10 designates a tubular member fluidly connectible to a source of drilling fluid under pressure, as by means of threaded upper end portion 11 and threaded lower end portion 12. Preferably the external and internal diameters of tubular member 10 are the same as the external and internal diameter of a conventional drill collar. Tubular member 10 defines outside cylindrical surface 13 and internal cylindrical surface 14, the internal surface 14 bounding internal central passage 15 which ex-

3

tends longitudinally through tubular member 10.

The wall of body 10 defines a vertically extending cylindrical chamber 16 and vertically extending cylindrical chamber 17, chamber 16 being in fluid communication at its lower end with the upper end of chamber 17. The upper end of cylindrical chamber 16 fluidly communicates with external surface 13 of body 10 through duct 18. The lower extremity of cylindrical chamber 17 fluidly communicates with external surface 13 of body 10 through duct 19. Chamber 20 traverses the wall of body 10 horizontally and fluidly connects chamber 17 with central passage 15. Cylindrical chamber 21 horizontally traverses the walls of body 10 and fluidly connects the lower portion of chamber 17 with central passage 15, chamber 21 being disposed below chamber 20. Annular sealing means 22 is positioned within chamber 17 between the juncture of chamber 20 with chamber 17 and the juncture of chamber 21 with chamber 17. Annular recess 23 is positioned in chamber 17 at a point in chamber 17 below the juncture of chamber 17 and chamber 20 but above port 19.

Chamber 16 defines an inwardly projecting shoulder 24 at its upper end and inwardly projecting shoulder 25 adjacent its juncture with chamber 17. Chamber 20 defines inwardly projecting shoulder 26 at the juncture of chamber 20 with central passage 15. Chamber 21 defines inwardly projecting shoulder 27 at the juncture of chamber 21 with central passage 15.

Mounted within chamber 20 and affixed to the end of said chamber which connects with chamber 17 is guide plate 28 which defines a central opening passing transversely therethrough coaxially with chamber 20 and also defines a plurality of openings 30 spaced from the central opening. Mounted slidably within chamber 20 for longitudinal movement therein is piston 31 carrying suitable sealing means 32 for providing a fluid-tight seal between piston 31 and the walls of chamber 20. Sealing means 32 may suitably be an O-ring. Piston rod 33 is mechanically affixed to piston 31 and passes slidably through the central opening defined by guide member 28. Helical spring 34 circumscribes rod 33, one end of said spring being biased against guide member 28 and the other end biased against piston 31, the said spring tending to bias piston 31 away from guide member 28. Affixed to that end of rod 33 opposite from the end affixed to piston 31 is a forked member 35 extending longitudinally from rod 33 and defining two prongs 36 lying in a horizontal plane.

Piston 37 is slidably disposed within chamber 16, the outer periphery of piston 37 carrying a sealing means 39 thereon for providing a fluid-tight seal between piston 37 and the walls of chamber 16. Sealing means 39 may suitably be an O-ring.

Mounted within chamber 21 at the juncture of said chamber with chamber 17 is orifice plate 40 which is traversed by orifice 41. Piston 42 is slidably disposed within chamber 21 for longitudinal movement within said chamber between inwardly extending shoulder 27 and orifice plate 40. Piston 42 carries on its outer periphery sealing means 43 for providing a fluid-tight seal between piston 42 and the walls of cylindrical chamber 21. Sealing means 43 may suitably be an O-ring.

Piston 44 is slidably arranged within chamber 17 adjacent the lower end thereof for longitudinal movement therein. Piston 44 carries on

4

its outer periphery sealing means 46 for providing a fluid-tight seal between piston 44 and the walls of chamber 17. Sealing means 46 may suitably be an O-ring.

Tubular member 47 having a closed lower end is secured at its closed lower end to piston 44 coaxially therewith by a suitable lost motion means; for example, bolt 49 which is shown most clearly in Fig. 3. The outside diameter of tubular member 47 is less than the diameter of chamber 17 and, accordingly, may be moved longitudinally in chamber 17. The outer surface of tubular member 47 carries outwardly extending shoulder 50. Disposed in recess 23 of chamber 17 and circumscribing tubular member 47 is ring member 51, ring member 51 having an internal diameter sufficiently great to permit the passage of tubular member 47 therethrough. Helical spring 52 circumscribes tubular member 47, its upper end being biased upwardly against outwardly projecting shoulder 50 and its lower end being biased downwardly against ring member 51. Sealing means 22, as for example an O-ring, provides a fluid-tight seal between tubular member 47 and the wall of chamber 17 but permits longitudinal movement of tubular member 47 in chamber 17 therethrough. Sealing means 22 effectively divides chamber 17 into a lower portion 17' and an upper portion 17''.

Projecting above the upper open end 54 of tubular member 47 are ears, or stops 57 and 58, which project toward the longitudinal axis of the tubular member 47. Tubular member 47 also carries near its upper end 54 outwardly extending lug 55. Mounted within tubular member 47 on the closed lower end thereof is helical spring 59 which exerts an upward bias against discs 60 mounted within tubular member 47. The external diameter of discs 60 is less than the internal diameter of tubular member 47 and consequently spring 59 moves disc 60 upwardly within tubular member 47 and biases said disc against ears 57 and 58. Inwardly projecting stop 100 is arranged within chamber 17 to limit the upward movement of tubular member 47 on abutment of projecting lug 55 of tubular member 47 against stop 100.

Slot 101 passes transversely through the wall of body 10 fluidly connecting chamber 17 with external surface 13 of body 10. Slot 101 carries disposed therein rubber lips 102 and 103 which yieldably close said slot against the passage of fluid therethrough. Rubber lip 102 is mechanically affixed to the upper side of slot 101 and rubber lip 103 is likewise affixed to the lower side of slot 101. Rubber lips 102 and 103 being tightly pressed together form a fluid-tight seal. The inner surfaces of rubber lips 102 and 103 are beveled so as to form an outwardly extending V. The apex of the V being adjacent chamber 17 is located directly opposite fork 35 carried by piston rod 33.

A weighted stylus 61 is suspended from its upper end within chamber 17. The lower end of stylus 61 carries a sharp metallic point 62, point 62 extending downwardly within chamber 17 sufficiently far to engage with the uppermost disc 60 carried within tubular member 47. Stylus 61 may be weighted by any suitable means such as by filling a hollow portion at the lower end thereof with mercury or by affixing a weight 61 adjacent the lower end thereof. Stylus 61 is suspended at its upper end by any means which will permit the said stylus to return to a substantially vertical position after the forces tend-

ing to cause said stylus to deviate from a vertical position have ceased to operate thereon and may suitably be suspended from the upper end of chamber 17 by means of ball bearing 70 affixed to the upper end thereof, the said ball bearing being mounted within case 71 defining opening 72 through which the stylus extends, ball bearing 70 being biased downwardly by means of spring 73. With such an arrangement, stylus 61 is pivotally suspended from its upper end but is able to move longitudinally within chamber 17 a limited amount. The suspension of stylus 61 may be more clearly seen by referring to Fig. 6. The purpose for preferably providing for such longitudinal movement will become apparent hereinafter when the operation of my device is described.

Having hereinbefore described the various parts constituting the parts of my invention and the relationship of these parts to each other, the operation of my device will now be described:

It will be understood, of course, that the various parts of the device of my invention must be assembled at the surface and when assembled, the completed assembly must be incorporated with the drill stem and is preferably located as close to the bit as is practicable.

The device of my invention is made a part of the drill stem as by connecting threaded ends 11 and 12 of said device with the drill stem. As the drill stem is run into the borehole in normal drilling operations, the mud hydrostatic head, of course, increases. This increasing mud hydrostatic head acts on piston 37 through opening 18 and on piston 44 through opening 19 to maintain the pressure in chamber 17 the same as the pressure on the outside of the device. This equalization of pressures permits the inclination of the borehole from the vertical to be determined at any selected point in the borehole by properly altering the pressure of the drilling fluid in the drill stem in the conventional manner, as by means of the mud pumps.

With the drilling fluid in chamber 15 under pump pressure, pistons 31 and 42 are forced into their full forward position, that is, outwardly from chamber 15. When piston 31 is in its full forward position, spring 34 is in compression. It should be noted that orifice 41 in orifice plate 40 is of such size as to retard the movement of piston 42 to its full forward position inasmuch as the fluid present in the space between orifice plate 40 and piston 42 must be forced through orifice 41 into the lower portion 17' of chamber 17. While piston 42 is moving to its full forward position, piston 44 is moving toward its full down position and reaches the full down position when piston 42 reaches its full forward position. Inasmuch as spring 52 is confined between outwardly projecting shoulder 50 carried by cartridge 47 and annular ring 51, spring 52 is in compression as piston 44 moves to its full down position. Of course, discs 60 are always biased upwardly against inwardly projecting ears 57 and 58 by means of spring 59. So long as pressure is maintained, piston 44 and consequently cartridge 47 remain in the down position. With cartridge 47 in the down position weighted stylus 61 is free to move about in chamber 17. Consequently, as the drill stem is being rotated, as it ordinarily will be during normal drilling operation, stylus 61 is whirled about against the walls of chamber 17.

When it is desired to secure an indication of the deviation from vertical of the borehole, rota-

tion of the drill stem is discontinued and the pressure on drilling mud within chamber 15 is reduced as, for example, by stopping the mud pumps. With the mud pressure so reduced, coil spring 34 returns piston 31 to its full back position, that is, spring 34 forces piston 31 toward central passage 15 until piston 31 abuts against stop 26. Of course, as piston 31 returns to its full back position, disc ejector 35 also moves in cooperation therewith and is thereby placed in position of ejection of a disc 60 when drilling fluid pressure is again increased in chamber 15. At the same time that piston 31 begins to move to its full back position, coil spring 52 causes disc cartridge 47 to move upwardly within chamber 15. The upward movement of cartridge 47 is retarded by virtue of the fact that fluid within the lower portion 17' of chamber 17 must pass through orifice 41 into chamber 21, the orifice being of such a size as to provide the desired amount of retardation. Upward movement of cartridge 47 and, accordingly, piston 44 forces hydraulic fluid through orifice 41 into chamber 21 until piston 42 is forced into its full back position, that is, until piston 42 is forced toward passage 15 until it abuts against stop 27. By the time piston 42 has reached its full back position, the lug 55 of disc cartridge 47 abuts against inwardly projecting shoulder 100, the interval of time between the reduction of pressure within chamber 15 and the time that the lug 55 of cartridge 47 abuts against inwardly projecting shoulder 100 being sufficiently great to permit stylus 61 to come to rest. Accordingly, as lug 55 abuts against inwardly projecting shoulder 100, the uppermost of the discs 60 in cartridge 47 comes in contact with marker 62 carried by stylus 61. When marker 62 is of the mechanical type shown in Fig. 1, an indentation is made by the marker in the topmost disc 60.

When drilling fluid pressure is again increased within chamber 15, as by means of resumption of operation of the mud pumps, piston 31 is again moved toward its full forward position, thus causing the forks 36 of disc engaging member 35 to engage with the previously marked topmost disc 60 and to force the engaged disc laterally with respect to cartridge 47 and between rubber lips 102 and 103 and outwardly into the mud stream. This disc is, of course, carried upwardly by the upflowing mud stream to the surface of the earth and may be recovered therefrom as by means of passing the mud through a shale shaker or other screening device.

While piston 31 is being moved to its full forward position by the increased mud pressure, piston 42 is also being moved to its full forward position. Accordingly, fluid is forced by piston 42 from chamber 21 through orifice 41 into the lower portion 17' of chamber 17 forcing piston 44 downwardly. After piston 44 has moved down sufficiently far to cause surface 49' of bolt 49 to abut against shoulder 44' of piston 44, disc cartridge 47 also moves downwardly in cooperation with piston 44. The lost motion between disc cartridge 47 and piston 44 is provided so as to allow sufficient time for the uppermost disc 60 to be ejected from the cartridge by forked member 35 before the cartridge is started downwardly within chamber 17. Of course, after disc cartridge 47 has reached its lowermost position of travel, the cycle is completed and the device is ready to make the next recording in the manner hereinbefore described.

It will be seen that the number of readings

which may be taken is limited only by the number of discs 60 which can be carried in cartridge 47. Inasmuch as these discs can be made relatively thin and since cartridge 47 may be of any desired length, it will be apparent that a very large number of discs may be carried in the device of my invention. Preferably, I prefer to employ a disc of approximately $\frac{1}{8}$ inch thickness when the disc is made of plastic. These discs, however, may be made of any material which will be sufficiently soft to receive an impression when contacted by marker 62 and yet sufficiently rugged to withstand the conditions to which it will be subjected while in the mud stream.

When all of discs 60 have been used, it is of course, necessary to remove cartridge 47, refill it with discs 60, and reinsert cartridge 47 in the device of my invention. Removal and replacement of cartridge 47 is accomplished by unscrewing bolts 110 and removing outer wall member 111. With outer wall member 111 so removed, cartridge 47 together with piston 44, spring 52 and ring 51 may be lifted from its normal position. Discs 60 are inserted into the upper end of cartridge 47 until the said cartridge has again been refilled. Of course, as discs are inserted in cartridge 47, spring 59 is again compressed. The refilled cartridge 47 may then be returned to its operative position within the device of my invention and secured thereon by affixing member 111 to body 10 by means of bolts 110.

What I wish to claim is:

1. A device for indicating the deviation from vertical of a drill stem employed in penetrating subsurface formations by the rotary drilling method while drilling fluid is maintained in said drill stem comprising, in combination, a tubular member defining a central longitudinal passage extending therethrough, said tubular member being adapted to be fluidly connected with and made a part of said drill stem, the walls of said member defining a chamber having a normally closed opening connecting said chamber and an outer surface of said tubular member, a pivotally suspended marker disposed in said chamber and arranged to assume a vertical position when acted upon by gravity only, ejectable record means disposed in said chamber and arranged to be marked by said marker when said marker is acted upon by gravity only, and means for ejecting said record means from said chamber through said normally closed opening after said record means has been marked by said marker.

2. A device for indicating the deviation from vertical of a drill stem employed in penetrating subsurface formations by the rotary drilling method while drilling fluid is maintained in said drill stem comprising, in combination, a tubular member having a central longitudinal passage extending therethrough and adapted to be fluidly connected with and made a part of said drill stem, said tubular member having an outer and an inner surface forming a wall portion with said inner surface defining said central longitudinal passage, said wall portion defining a longitudinal chamber and a normally closed opening connecting said longitudinal chamber and the outer surface of said tubular member, a stylus carrying a marking means pivotally suspended in said longitudinal chamber and arranged to assume a vertical position when acted upon by gravity only, a disc cartridge carrying at least one disc disposed in said longitudinal chamber and arranged to move said disc into

operative relation with the marking means of said stylus to mark said disc in response to a decrease in fluid pressure in said central longitudinal passage, and means arranged to eject said disc from said cartridge and said longitudinal chamber through said normally closed opening in response to an increase in fluid pressure in said central longitudinal passage.

3. A device for indicating the deviation from vertical of a drill stem employed in penetrating subsurface formations by the rotary drilling method while drilling fluid is maintained in said drill stem comprising, in combination, a tubular member defining a central longitudinal passage extending therethrough and adapted to be fluidly connected with and made a part of said drill stem, the wall of said tubular member defining a longitudinal chamber and a port fluidly connecting said longitudinal chamber with the outer surface of said tubular member, a deformable sealing means normally closing said port and arranged to seal said port against the passage of fluid therethrough, a stylus pivotally suspended in said longitudinal chamber and arranged to assume a vertical position when acted upon by gravity only, marking means carried by said stylus, a disc cartridge carrying at least one disc disposed in said longitudinal chamber, biasing means cooperating with said cartridge to move said disc into operative relation with said marking means to mark said disc in response to the decrease in fluid pressure in the borehole, and means arranged to eject said disc from said cartridge and from said longitudinal chamber through the deformable sealing means arranged in said port in response to an increase in fluid pressure in the borehole.

4. A device for indicating the deviation from vertical of a drill stem employed in penetrating subsurface formations by the rotary drilling method while drilling fluid is maintained in said drill stem comprising, in combination, a tubular member defining a central longitudinal passage extending therethrough adapted to be fluidly connected with and made a part of said drill stem, the wall portion of said tubular member having an inner surface defining said central longitudinal passage and having an outer cylindrical surface, said wall portion defining a longitudinal chamber between said surfaces and an opening fluidly connecting said longitudinal chamber with said outer surface, a deformable sealing means normally closing said port and arranged to seal said port against the passage of fluids therethrough, a stylus pivotally suspended in said longitudinal chamber and arranged to assume a vertical position when acted upon by gravity only, a marking point carried on the free end of said stylus, a disc cartridge carrying at least one disc disposed in said longitudinal chamber, biasing means cooperating with said cartridge to move said disc into operative relation with said marking means to mark said disc in response to a decrease in fluid pressure in the borehole, and a disc engaging member adapted to engage said disc and to eject said disc from said cartridge and said longitudinal chamber through said deformable sealing means in response to an increase in fluid pressure in the borehole.

5. A device for indicating the deviation from vertical of a drill stem employed in penetrating subsurface formations by the rotary drilling method while drilling fluid is maintained in said drill stem comprising, in combination, a tubular

member the wall of which has an inner surface defining a central longitudinal passage extending through said member and a cylindrical outer wall surface, said wall defining a longitudinal chamber between said surfaces with a side port fluidly connecting said longitudinal chamber with the outer wall surface, said wall defining a first piston chamber fluidly connecting said longitudinal chamber with said central longitudinal passage and a second piston chamber fluidly connecting said longitudinal chamber with said central passage, said tubular member being adapted to be fluidly connected with and made a part of said drill stem; a pair of deformable, separable lips disposed in said port and arranged to seal said port against the passage of fluid therethrough, a stylus pivotally suspended in said longitudinal chamber and arranged to assume a vertical position when acted upon by gravity only; a marking point carried on the free end of said stylus vertically beneath the point of suspension of said stylus; a disc cartridge carrying at least one disc disposed in said longitudinal chamber for longitudinal movement in said chamber; a sealing ring circumscribing said cartridge, said sealing ring being positioned within said longitudinal chamber between the juncture of said first piston chamber with said longitudinal chamber and a juncture of said second piston chamber with said longitudinal chamber; a first piston mechanically connected with said disc cartridge for longitudinal movement within said longitudinal chamber in fluid-tight relation with the walls thereof; a second piston slidably disposed within said first piston chamber for longitudinal movement therein in fluid-tight relation with the walls thereof; a third piston slidably

disposed within said second piston chamber for longitudinal movement therein in fluid-tight relation with the walls thereof; a fourth piston slidably disposed within said longitudinal chamber above said stylus for longitudinal movement therein in fluid-tight relation with the walls thereof; a plate pierced by an orifice disposed in said second piston chamber adjacent said longitudinal chamber for regulating the rate of flow of fluid between said second piston chamber and the portion of the longitudinal chamber between said sealing ring and said first piston; a spring arranged to bias said cartridge upwardly in said longitudinal chamber to move said disc into engagement with the marking point of said stylus to mark said disc in response to a decrease in fluid pressure in the borehole; and a disc engaging member mechanically affixed to said second piston for movement therewith into said longitudinal chamber for engagement with said disc after said disc has been marked by said marking point to eject said disc from said cartridge and said longitudinal chamber through the deformable, separable lips in said side port in response to an increase in fluid pressure in the borehole.

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