

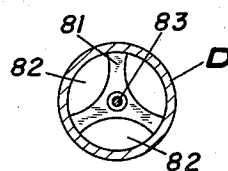
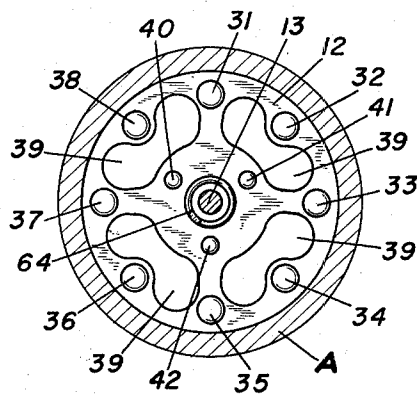
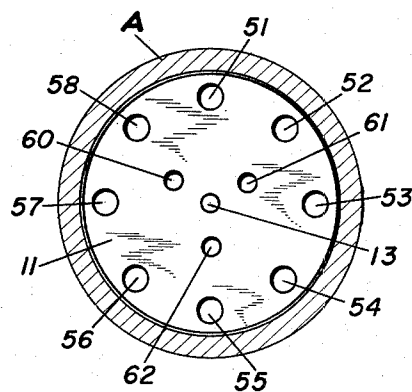
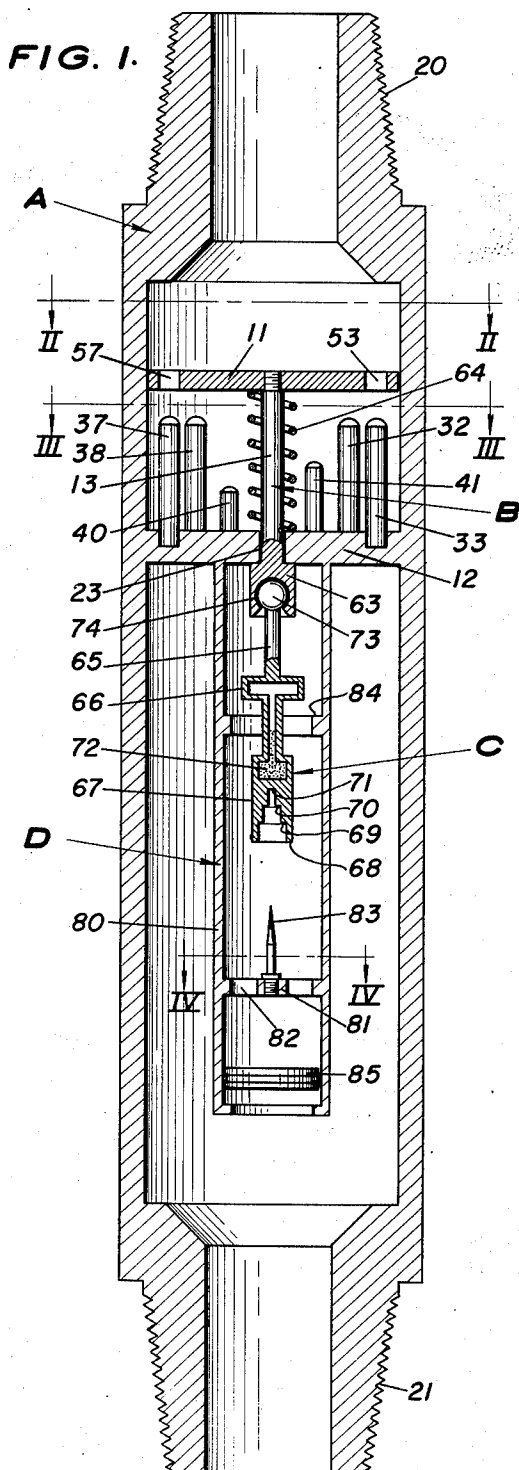
Sept. 4, 1956

W. J. BIELSTEIN
DRILL HOLE INCLINOMETER

2,761,218

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

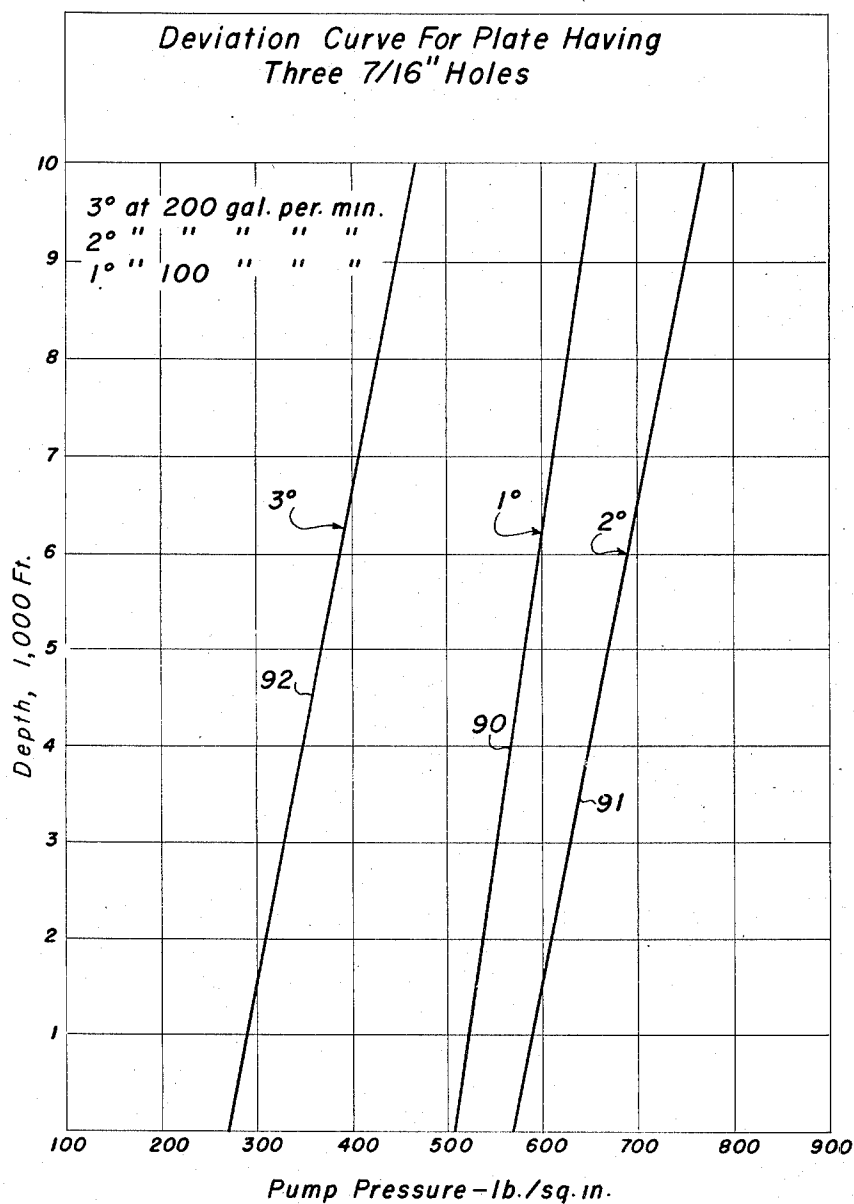


FIG. 5.

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DRILL HOLE INCLINOMETER

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4 Claims. (Cl. 33—205)

This application is directed to a device adapted to be arranged in the drill stem adjacent the drill bit used in drilling boreholes by the rotary drilling method whereby the amount of inclination of the borehole may be signalled to the operator.

The device of the present invention is adapted to be arranged in the drill stem so that normal drilling operations may be carried out without any substantial hindrance to the circulation of the drilling fluid down through the drill stem and when an indication of the borehole deviation from vertical is desired, the device is operated, such operation causing a signal to be received at the surface by changes in the outlet pressure at the mud pump. After the signal has been received, the device may be rendered idle or inoperative so that it makes no substantial interference with the usual drilling operations until another determination of the borehole inclination is desired. Thus, the inclination of the borehole may be secured at any time desired in a simple manner which requires no more handling of the drill pipe than the use in the usual manner of a rotary drilling rig for drilling a borehole.

The construction and operation of a preferred embodiment of the present invention will now be described in conjunction with the drawing in which

Fig. 1 is an elevation partly in cross section showing details of construction of said preferred embodiment;

Fig. 2 is a view taken along line II—II of Fig. 1;

Fig. 3 is a view taken along line III—III of Fig. 1;

Fig. 4 is a view taken along line IV—IV of Fig. 1; and,

Fig. 5 is in the form of a series of curves showing the variation of pump pressure with inclination of the borehole for a specific set of conditions.

Turning now specifically to the drawing, the most important parts or assemblies of the device are: a sub or section of drill pipe A in which the structure is mounted, a valve assembly B having as its principal parts plates 11, 12 and valve stem 13, a pendulum C and a stop assembly D.

The sub or section of drill pipe A is of the type well known to the art and in the design shown is provided with threads 20 at its upper end and threads 21 at its lower end for connection into the drill string. The sub may be installed at any point in the drill string; however, in normal drilling operations, the drilling bit will be attached to the lower end of sub A on threads 21, and threads 20 will be attached to the lower end of the drill string. It will be understood that if desired the sub may be provided with some other type of connection on either or both ends instead of the pin connections shown.

The valve assembly B consists of a fixed part consisting of plate 12 with a central opening 23 for slidably receiving valve stem 13. Plate 12 is provided with passages 39 through which drilling fluid may flow. Plate 12 also has arranged thereon two sets of pegs in concentric circles. All of the pegs have rounded free ends. The pegs in the outer circle are larger and longer than the pegs in the inner circle. The outer circle consists of pegs 31, 32, 33, 34, 35, 36, 37 and 38; these pegs are all of equal

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length. The inner circle consists of pegs 40, 41 and 42. Pegs 40, 41 and 42 are of unequal length, peg 40 being the shortest, peg 41 being intermediate and peg 42 being longest, but all of the pegs being shorter than the series of pegs in the outer circle 31 to 38, inclusive.

Plate 11 is provided with two series of holes set in concentric circles. An outer series 51, 52, 53, 54, 55, 56, 57 and 58 corresponds in size and location to the diameter and locations of pegs 31 through 38, inclusive, whereby said pegs fit slidably within said holes when plate 11 is moved downwardly to engage said pegs. A second series 60, 61 and 62 corresponds in size and location with pegs 40, 41 and 42, whereby said pegs fit slidably in said holes upon further downward movement of plate 11.

If plate 11 is moved downwardly, as under the influence of pressure exerted through the drill pipe by the drilling fluid, the initial movement of plate 11 causes substantially no change in the pressure of the drilling fluid. After this initial movement, the series of holes 51 through 58 then come into contact with the series of pegs 31 through 38 which causes a substantial increase in pressure in the drilling fluid, since such action limits the flow to the openings 60, 61 and 62. Further downward movement of plate 11 causes peg 41 to enter its corresponding hole 61, leaving only holes 60 and 62 available for passage of drilling fluid. Further downward movement of plate 11 causes peg 42 to enter hole 62, leaving only hole 60 for passage of drilling fluid. Further downward movement of plate 11 to its final position causes the entrance of peg 40 into hole 60 and stops all circulation of drilling fluid, since all of the holes in plate 11 have now been sealed by the entry therein of the corresponding pegs.

Plate 11 is mounted on valve stem 13. The lower end of valve stem 13 is enlarged to form a head 63 which limits the upward movement of the valve stem, and spring 64 is arranged around the valve stem between plates 11 and 12, thereby biasing plate 11 to its uppermost position, and when the force of the spring has not been overcome by some other force, the shoulders defined by head 63 are in contact with plate 12.

Pendulum assembly C consists of a shaft 65 having in its center portion an enlarged circular shoulder 66 and a lower enlarged end 67. The lower end of the pendulum is hollow and defines a series of annular surfaces arranged in a stepwise fashion of decreasing diameter in the upward direction, said surfaces being designated 68, 69, 70 and terminating in a circular upper surface 71, the center of which coincides with the axis of the pendulum. In the pendulum shown, there is a chamber 72 for receiving a weighting material such as mercury. The pendulum assembly C is secured to the movable part of valve assembly B by means of a universal joint, said joint consisting of a ball 73 attached to shaft 65 and a socket 74 defined by the lower portion of valve stem 13.

Assembly D is provided for cooperation with pendulum assembly C for controlling the position of the movable part of valve assembly B. Assembly D consists of a tube 80 fixed in relation to sub A. As shown, the tube 80 is fixed in position by having its upper end secured to plate 12, which in turn is fastened to sub A. Secured to tube 80 is circular member 81 having passages 82 through which fluid may flow. Mounted in the center of chamber 81 is a pin 83. Also, mounted on tube 80 is a stop ring 84 positioned slightly below the circular shoulder 66 of pendulum assembly C. A free floating piston 85 is mounted at the lower end of tube 80. Piston 85 equalizes the pressure inside and outside of assembly D and allows for changes in volume within assembly D as valve stem 13 enters the chamber on the downward stroke. Piston 85 moves up and down to allow for these changing conditions.

The device of the present invention is adapted to re-

main in the drill stem at all times. In normal drilling operations when an indication of the hole deviation is not desired, the device may be rendered inoperative by having the drill stem rotating at the time the mud pumps are started. The rotation of the drill stem causes centrifugal force to move the lower end of pendulum assembly C radially away from the center of the pipe, and upon starting the mud pumps, the imposition of fluid pressure on plate 11 causes the plate to move downwardly until the lower surface of shoulder 66 contacts the upper surface of ring 84, whereby plate 11 is locked against further downward movement with all of the openings 51 to 58, inclusive, and 60, 61 and 62 held above their points of contact with the corresponding pegs 31 to 38, inclusive, and 40, 41 and 42, whereby the mud is free to pass through the openings in plate 11 and thence through the passages 39 in plate 12. Thus, in normal drilling operations, the flow of mud through sub A is substantially unimpeded.

If it is desired to use the device to take a reading, the rotation of the drill pipe is stopped and the mud pumps are stopped to relieve the hydraulic pressure on plate 11. Spring 13 then is able to force plate 11 to its upper position. If the mud pumps are then started, the pressure imposed on plate 11 overcomes the bias of spring 13 and forces it downwardly. In the construction shown in the drawing, if the hole is straight, the pendulum assembly C hangs straight downward and moves downwardly until pin 83 comes in contact with surface 71. At this point, all of the pegs 31 to 38, 40, 41 and 42 will have entered the corresponding openings in plate 11 and completely shut off the flow of drilling fluid. If the hole deviation is approximately one degree, the pendulum assembly C moves downwardly until the upper end of pin 83 contacts angular surface 70. At this point, opening 60 is clear, since peg 42 is too short to enter it and the mud can flow through this one passage. If the angle of deviation of the hole is two degrees, pendulum assembly C moves downwardly until angular shoulder 69 rests on the end of pin 83; in this position, openings 60 and 62 are clear, since pegs 40 and 42 are both too short to enter their corresponding openings in plate 11 for this position of the pendulum. If the angular deviation of the hole is three degrees, pendulum assembly C moves downwardly until angular shoulder 68 rests on the point of pin 83. In this position, the series of pegs 31 to 38 have entered their corresponding openings 51 through 58, but openings 60, 61 and 62 are clear, since the pegs 40, 41 and 42 are too short to enter these openings when the pendulum is in this position. If the angle of deviation of the hole is four degrees or greater, the pendulum assembly C makes such an angle with the remainder of the assembly that circular shoulder 66 comes in contact with stop ring 84 upon downward movement of the pendulum and prevents any of the series of pegs 31 to 38 and 40, 41 and 42 from entering passages in plate 11 so that the pressure indication is no different from that obtained in normal drilling operations.

The operation of a device constructed in accordance with the present application with specific dimensions will now be discussed in conjunction with the curves of Fig. 5. In this example, it will be assumed that the inclinometer of the present invention is located in the drill stem at a known depth in the well. In Fig. 5 the ordinate represents the depth of the inclinometer in the borehole in thousands of feet and the abscissa represents pump pressure required to maintain the stated flow of drilling mud when the inclinometer is tilted or deviated from the vertical axis the indicated amount. It may be further assumed that plate 11 has holes 51 through 58, each $\frac{3}{16}$ inch in diameter, and holes 60, 61 and 62, each $\frac{1}{16}$ inch in diameter. With the borehole one degree off, only one $\frac{1}{16}$ inch hole, hole 60, remains open, and, with a drilling mud circulating rate of 100 gallons per minute, the pressure will correspond to that shown

by curve 90 on Fig. 5. If the borehole is two degrees off, two $\frac{1}{16}$ inch holes, holes 60 and 61, remain open, and, at a drilling mud circulating rate of 200 gallons per minute, the pressure will correspond to that shown in curve 91 of Fig. 5. If the hole is three degrees off, all three $\frac{1}{16}$ inch holes, holes 60, 61 and 62 of plate 11, remain open and, with a drilling mud circulating rate of 200 gallons per minute, gives the pressure shown by curve 92 of Fig. 5. As explained heretofore, if the borehole is four degrees off, the shoulder 66 of pendulum contacts stop ring 84 and holds the plate 11 so that it is out of contact with all of the pegs mounted on plate 12, and the openings 51 through 58 and 60, 61 and 62 remain in full open position. With the depth of the inclinometer in the well bore known and by recording or measuring the pump pressure required to maintain the specific flow of mud, the degree of tilt of the inclinometer which indicates the well deviation may be ascertained from the curves.

While I have disclosed a specific embodiment of the present invention and given examples with specific dimensions, it will be understood that this is by way of illustration only and not by way of limitation.

I claim:

1. A borehole inclinometer comprising, in combination, a section of pipe adapted to be arranged in and form a part of the drill stem, a valve assembly consisting of a fixed part and a movable part mounted in said section of pipe, said movable part being arranged to assume a first position in which the valve assembly has a predetermined flow area and longitudinally movable under the influence of fluid pressure in said section of pipe from the first position to a second position while maintaining said flow area substantially constant and longitudinally movable from said second to a third position where the valve has a lesser flow area, a pendulum mounted by a universal joint on said movable part and having a first stop and a second stop surface, first and second stop members mechanically connected to said section of drill pipe with said first stop member longitudinally spaced from the first stop surface of the pendulum when the movable part of the valve assembly is in its first position a distance approximately equal to the longitudinal distance between the first and second positions of the movable part of the valve assembly and said second stop member longitudinally spaced from the second stop of the pendulum a longitudinal distance substantially equal to the longitudinal distance between the first and third positions of the movable part of the valve assembly with the first stop spaced angularly away from the vertical axis of the pendulum a greater distance than the second stop whereby the first stop is adapted to hold said movable part of the valve assembly in its second position when the pendulum is under the influence of rotative forces at the time fluid pressure is imposed upon said movable part and whereby the movable part of the valve assembly is held in the third position when the axis of the drill pipe deviates a predetermined amount and the pendulum is not under the influence of rotative forces at the time fluid pressure is imposed upon said movable part.

2. A borehole inclinometer comprising, in combination, a section of pipe adapted to be arranged in and form a part of the drill stem, a valve assembly consisting of a fixed part and a movable part mounted in said section of pipe, said movable part being arranged to assume a first position in which the valve assembly has a predetermined flow area and longitudinally movable under the influence of fluid pressure in said section of pipe from the first position to a second position while maintaining said flow area substantially constant and longitudinally movable from said second to a third position where the valve has a lesser flow area, a pendulum mounted by a universal joint on said movable part and having a circular shoulder above its lower end and defining a first stop surface and its lower end defining a second stop surface,

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a stop ring mechanically connected to said section of pipe longitudinally spaced from the circular shoulder of the pendulum when the movable part of the valve assembly is in its first position a distance approximately equal to the longitudinal distance between the first and second positions of the movable part of the valve assembly and with its upper surface angularly spaced away from the vertical axis of the pendulum and adapted to engage with the circular shoulder of said pendulum to hold said movable part of the valve assembly in its second position when the pendulum is under the influence of rotative forces at the time fluid pressure is imposed upon said movable part and a stop pin member mechanically connected to said section of pipe with its upper surface longitudinally spaced from the lower end of the pendulum when the movable part of the valve assembly is in its first position a distance equal to the longitudinal distance between the first and third positions of the movable part for engaging with the second stop surface at the lower end of the pendulum whereby the movable part of the valve assembly is moved to and held in the third position under the influence of fluid pressure in said section of pipe when the axis of the section of pipe deviates a predetermined amount and the pendulum is not under the influence of rotative forces at the time fluid pressure is imposed upon said movable valve part.

3. A borehole inclinometer comprising, in combination, a section of pipe adapted to be arranged in and form a part of the drill stem, a valve assembly consisting of a fixed part and a movable part mounted in said section of pipe, said valve assembly being arranged to assume a first position and longitudinally movable from the first position under the influence of fluid pressure in said section of pipe to a second position and to a number of other positions, the valve assembly having a substantially constant flow area when the movable part is in the first and second positions and having a progressively smaller flow area as the movable part moves in sequence to other positions, a pendulum mounted by a universal joint on said movable part and having a plurality of longitudinally and angularly spaced stop surfaces equal in number to the positions the movable valve part assumes after it moves from its first position with the first stop surface extending angularly the greatest distance from the normal axis of the pendulum and the remaining surfaces being angularly spaced from each other in a step-wise fashion, a first stop member mechanically connected to said section of pipe longitudinally spaced from the first stop surface of the pendulum a distance approximately equal to the longitudinal distance between the first and second positions of the movable part of the valve assembly and adapted to engage with the first stop surface of the pendulum when the pendulum is under the influence of rotative forces at the time fluid pressure is imposed upon said movable part whereby the movable part is held in its second position and a second stop member mechanically connected to said section of pipe and longitudinally spaced from

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the remaining stop surfaces of the pendulum when the movable part of the valve assembly is in its first position distances approximately equal, respectively, to the distances the movable part of the valve assembly moves from its first to its positions other than the second position for separately engaging the remaining stop surfaces when the pendulum is not under the influence of rotative forces at the time pressure is imposed upon said movable part, said stop member engaging a predetermined stop surface when the axis of the drill pipe is at a predetermined angle of inclination.

4. A borehole inclinometer comprising, in combination, a section of pipe adapted to be arranged in and form a part of the drill stem, a valve assembly consisting of a fixed part and a movable part adapted to move longitudinally under the influence of fluid pressure in said section of pipe from a first position to second, third, fourth, fifth and sixth positions, said fixed and movable valve parts cooperating so that there is a substantially constant flow area through the valve when the movable part is in its first and second positions and a flow area is of progressively smaller size when the movable part is in the third, fourth, fifth and sixth positions, a pendulum mounted by a universal joint on the movable part of said valve assembly and having a circular shoulder at substantially its mid-point and its lower end having one circular and three annular concentric stop surfaces arranged in a staircase fashion, a mounting tube secured to the fixed portion of the valve assembly, a stop ring mounted on said mounting tube with its upwardly facing surface longitudinally spaced from the lower surface of the circular shoulder when the movable part of the valve assembly is in its first position a distance approximately equal to the longitudinal distance between the first and second positions of the movable valve part so that the circular shoulder of the pendulum is forced into contact therewith and holds the movable valve part in the second position when said pendulum is under the influence of rotative forces at the time fluid pressure is imposed upon said movable valve element, a stop pin carried by said mounting tube longitudinally spaced away from said first, second, third and fourth stop surfaces of the pendulum longitudinal distances approximately equal respectively to the longitudinal distances between the first and third, first and fourth, first and fifth and first and sixth positions of the movable part of the valve assembly and adapted to contact said first, second, third and fourth stop surfaces, respectively, of the pendulum when the axis of the section of pipe deviates at an angle of less than 1°, 2° and 3°, respectively, when the pendulum is not under the influence of rotative forces at the time fluid pressure is imposed upon said movable valve part.

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