Sept. 20, 1960 S. C. MOORE 2,953,350

ORIENTING APPARATUS

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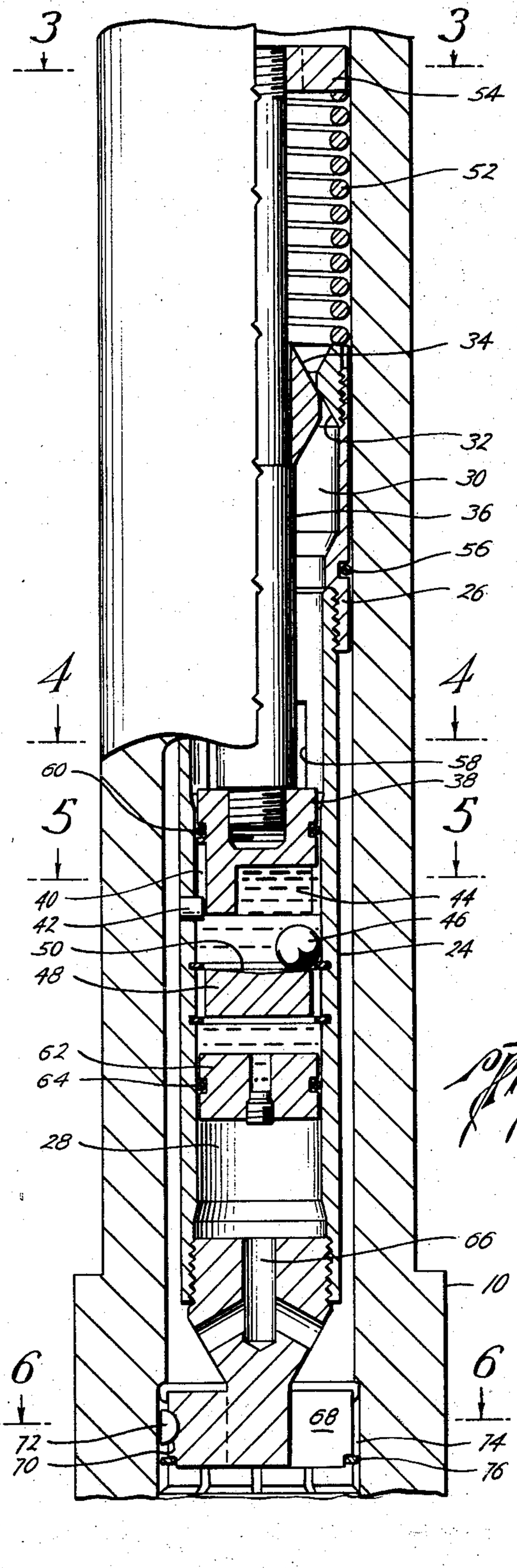

Fig. 2

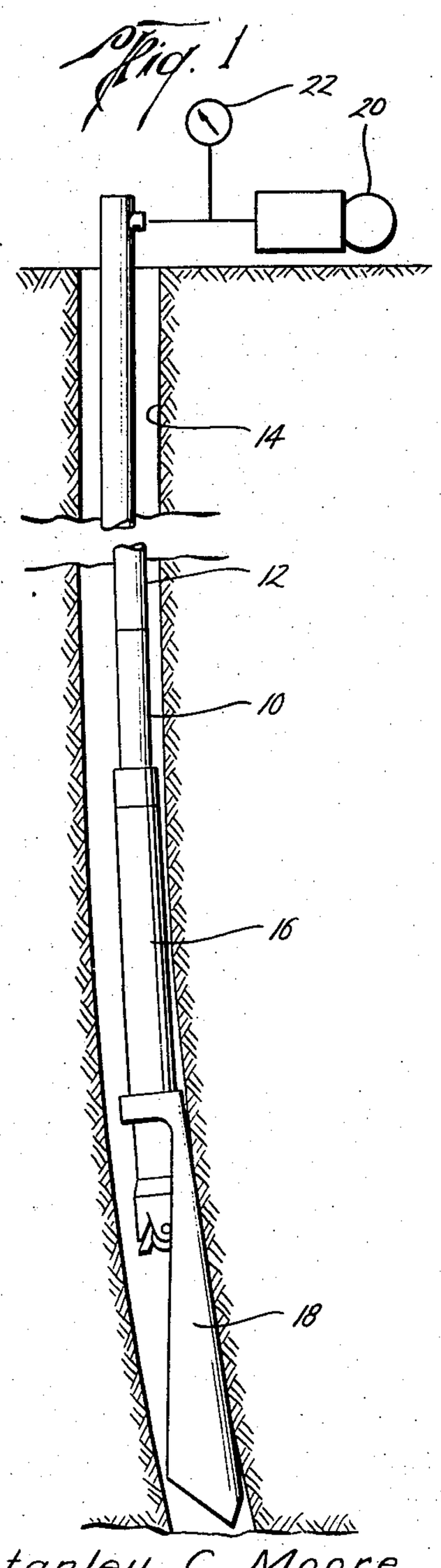

Fig. 1

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Fig. 7

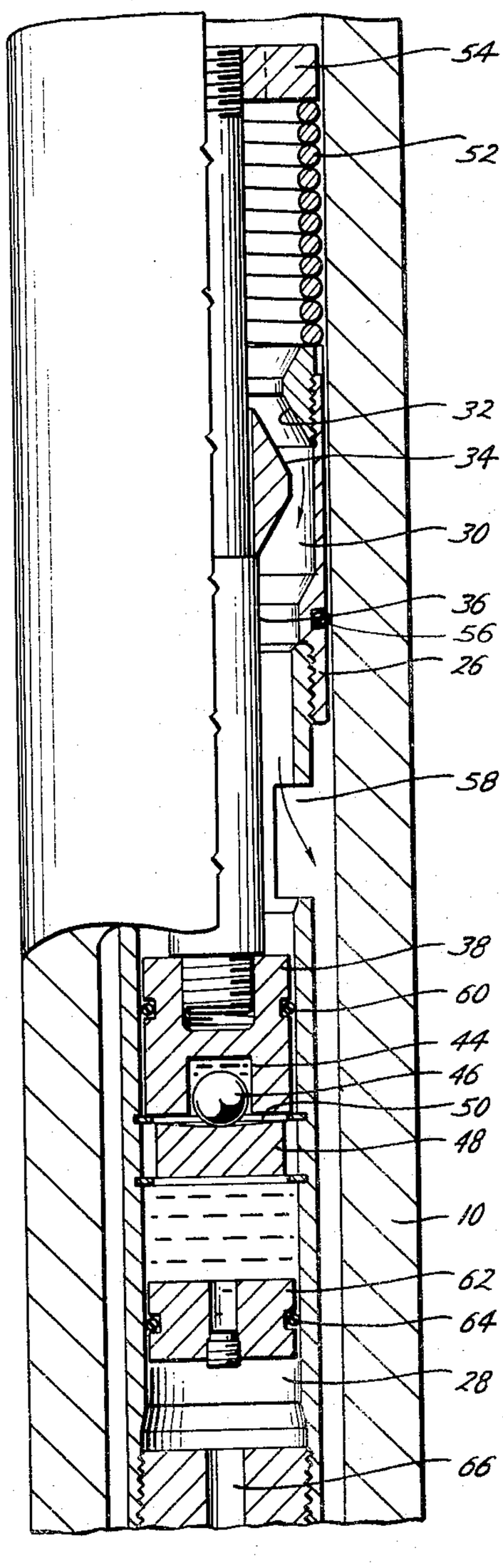

Fig. 3

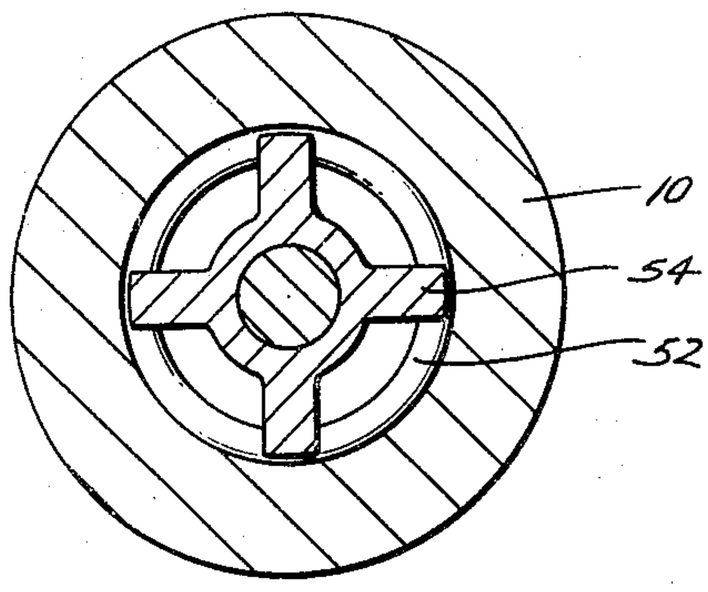

Fig. 4

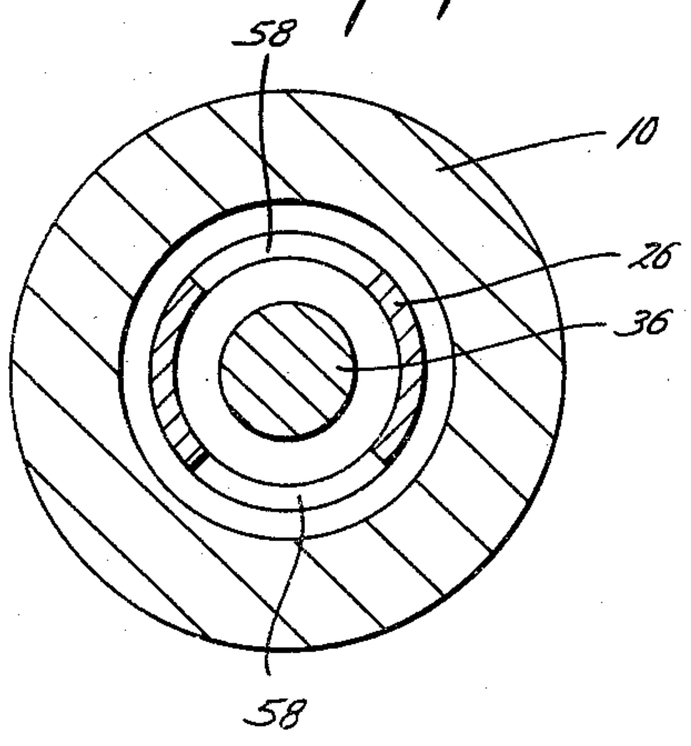

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Fig. 8

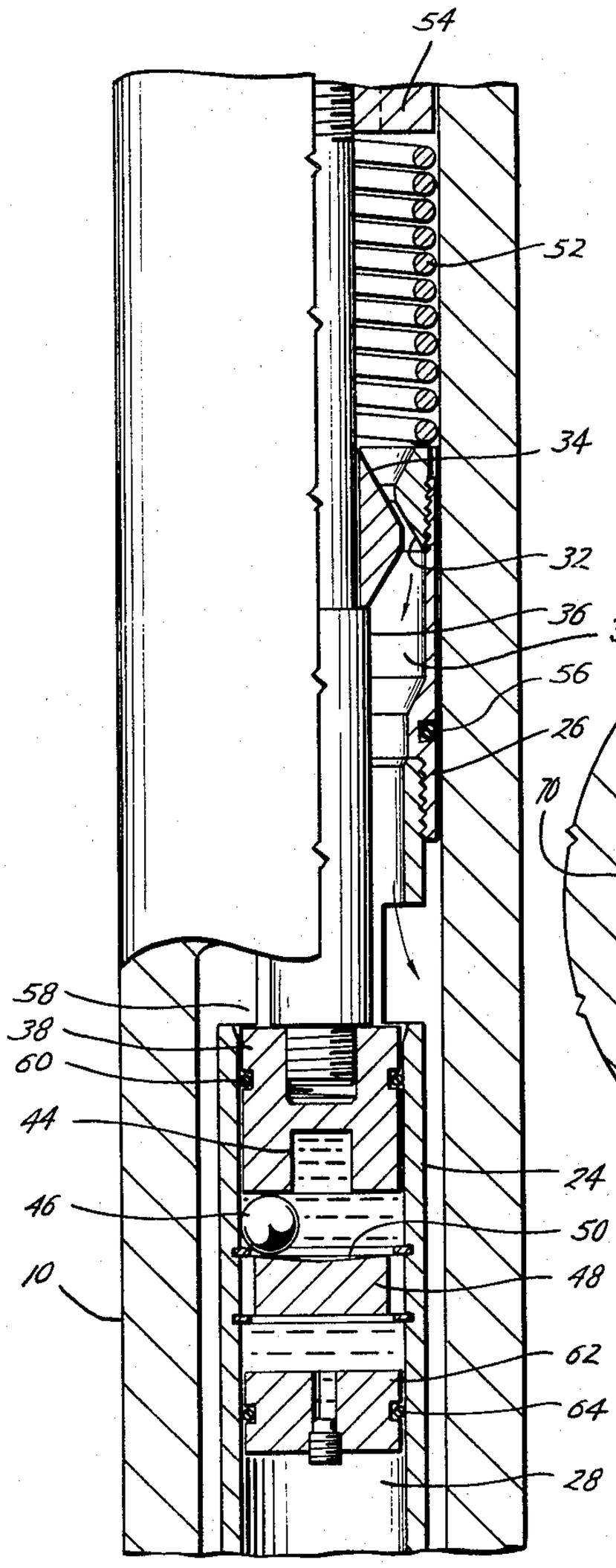


Fig. 5

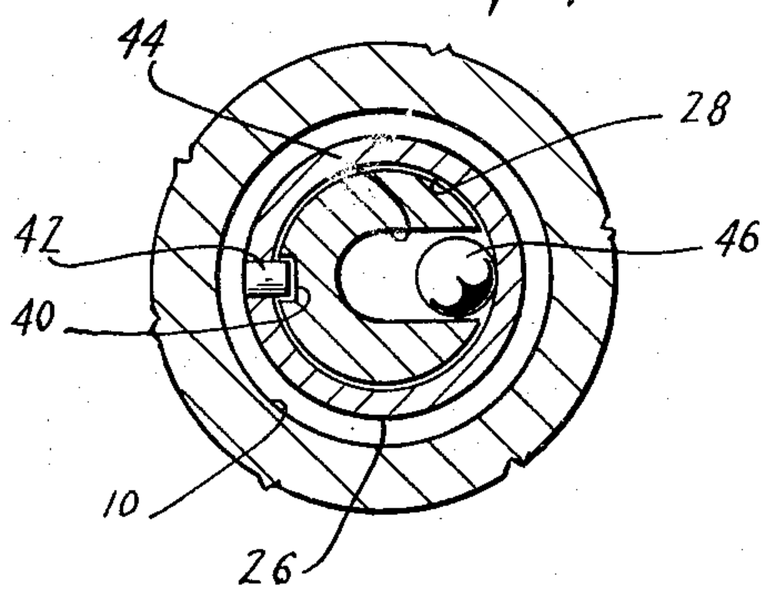
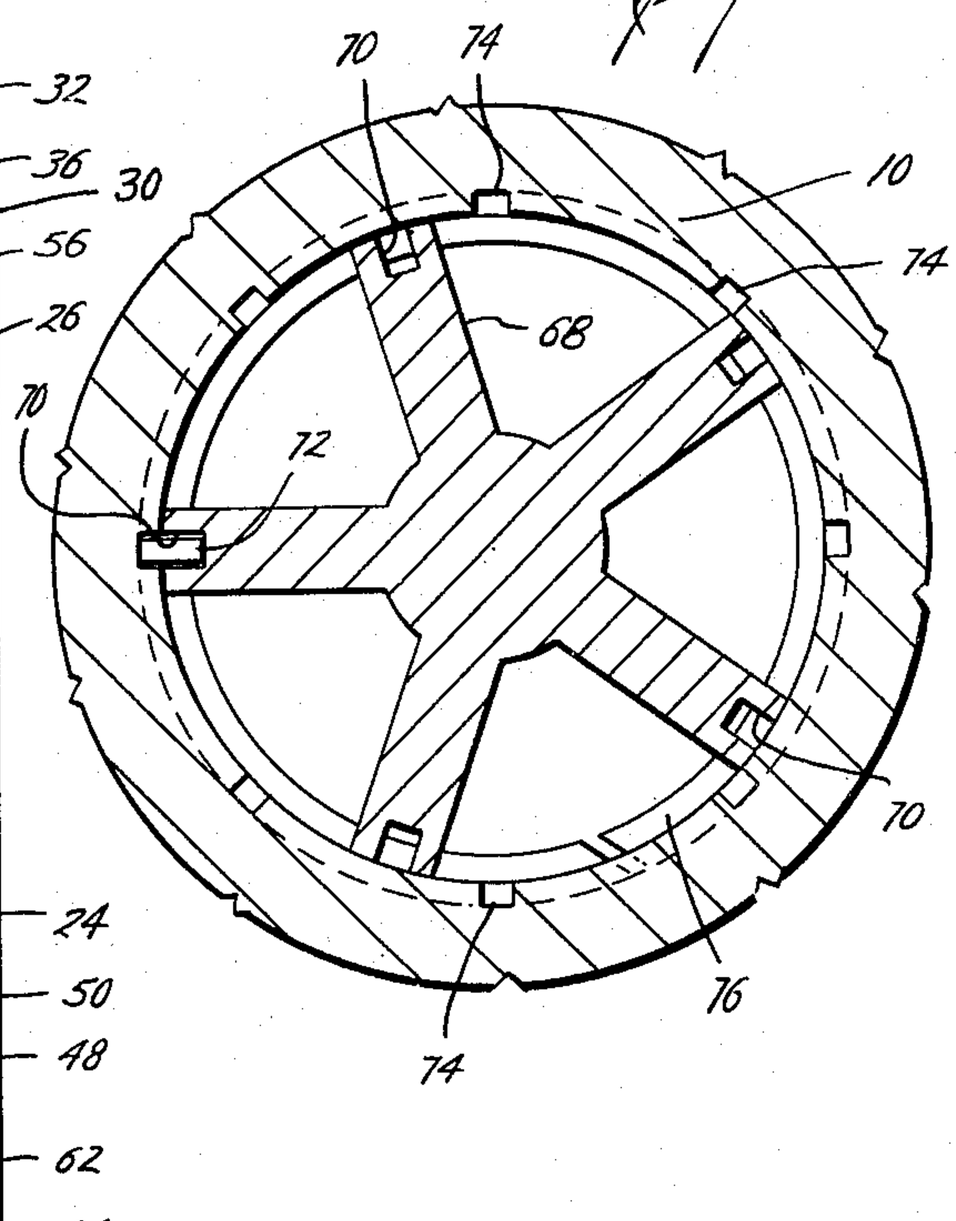


Fig. 6



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ORIENTING APPARATUS

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15 Claims. (Cl. 255—1.6)

This invention relates to methods and apparatus for orienting a well member with respect to the low side of an inclined well bore in which the member is placed and further will indicate the absence of inclination of a well bore.

In both directional and conventional straight down well drilling it is frequently desired to change the direction of the well bore. In the case of straight down drilling the bore may unintentionally become deviated from the vertical and it becomes necessary to change direction to bring the bore back to vertical. In the case of directional drilling it may be desired to change from one direction of inclination to another. In both cases the procedure would usually be to position a whipstock in the well bore in such a position as to direct the drill bit in the desired direction. It is necessary to orient the whipstock relation to the well bore in order that the whipstock properly redirects the drill bit.

In the case of restoring a well bore to vertical, it is only necessary to position the whipstock so that it faces the low side of the bore and knowledge at the surface of the direction of deviation of the bore from vertical is unnecessary. Therefore, it is only needed to orient the whipstock with respect to the low side of the hole, which can be readily accomplished by means of the invention.

In the case of directional drilling, it is necessary to know the precise direction of the bore. This is preferably accomplished initially by the use of known well surveying apparatus. However, once the direction of the bore is known the present invention can be used to set a whipstock to redirect the bore by orienting it with respect to the low side of the bore for the vertical plane, including the line of direction of a well bore also includes the radial line from the low side of the hole through the bore axis.

If time and accuracy are not critical, it may be assumed that there is no twist in the drill pipe between the surface and the bottom, in which case the orientation of the apparatus of the invention relative to the uppermost strand of drill pipe may be determined by the rigid mechanical connection therebetween and the absolute direction of the inclined bore will be apparent at the surface from knowledge of the position of its low side and intent well survey by other means may be omitted, even in directional drilling.

There are other uses to which the subject invention may be put, such as orienting a side wall coring tool with respect to the low side of the well bore so as to take a sample in a particular direction or so as to take successive samples at azimuthally spaced directions. However, for clarity in description the tool will be described hereinafter primarily with reference to its use in connection with drilling.

The apparatus of the invention falls within that class of orienting devices in which the information determined by the sensing device at the well bottom (or other below the surface location) is immediately indicated at the surface through a telemetering system, making it unnecessary to stop operations and wait for the sensing device to be brought to the surface.

Various devices to indicate the orientation of well conduit within inclined well bores have been proposed. For example, there has been proposed an orientation member incorporated in a drilling string to vary the flow pressure of fluids continuously pumped through the conduit as the conduit is continuously rotated through a preselected direction relative to the well bore inclination. This is accomplished by a ball member adapted to roll about a ball race having a flat bottom disposed normal to the axis of the conduit. A flow port is disposed within the race which is covered by the ball when the member is rotated in a particular direction relative to the direction of well bore inclination. Since the fluid pumped through the flow port is usually a drilling mud traveling at high velocity and having entrained drilling cuttings or the like, it is difficult for such a ball to respond only to gravity and cover the port as desired for proper operation. The ball is subject to being swept about by the fluid turbulence and is also subject to becoming entangled with the materials suspended in the drilling fluid.

It is therefore the general object of this invention to provide an inclination indication apparatus adapted for incorporation into a segment of well conduit which will indicate the inclination, as well as the absence of inclination, of the well conduit segment independently of the type or velocity of the well fluid pumped through said conduit.

It is a further object of the invention to provide method for using said apparatus.

By way of introduction it may be said that the invention includes a tubular housing to be inserted in the drill string between a drill bit assembly therebelow and a drill pipe thereabove. A downwardly opening check-throttle valve is disposed in the housing to control fluid flow therethrough. The valve includes a seat annularly disposed around the inside of the housing and a valve body adapted to seat thereon. The valve is spring biased upwardly, i.e. towards the closed position. There is a valve stem extending down from the valve body connected to the upper end of a piston. The piston is mounted for axial motion in a cylinder coaxially disposed in the housing and is held against rotation relative thereto. The cylinder is smaller than the housing, leaving an annular space therearound for fluid flow. Within the cylinder is a support on which a ball may roll around. The downward travel of the piston and hence the degree of opening of the valve is limited by engagement of the piston with the ball. There is a radially extending recess in the face of the piston so that if the ball is in the center of the support corresponding to no inclination of the well bore or if the housing is azimuthally positioned in the well bore so that the recess in the piston is in azimuthal register with the ball in the case of an inclined bore, the piston can move down farther and the valve open more, which is indicated at the surface by a drop in fluid pressure.

By separating the function of sensing the direction of inclination, which is performed by the ball and piston, from the function of telemetering the information to the surface which is performed by the valve, it is possible to completely isolate the ball from the action of the drilling fluid by enclosing it in the cylinder. Suitable sliding sealing means is provided as will be described hereinafter in more detail.

Other objects and advantages of the invention will become more apparent by reference to the following specification and claims taken in view of the accompanying drawings in which:

Figure 1 is a partly sectional view in elevation of a well bore containing a well conduit terminating in a well

bore deflection tool with the orienting apparatus of the present invention incorporated therein;

Figure 2 is a longitudinal sectional view taken at the axis of the orienting apparatus;

Figure 3 is a cross-sectional view of the apparatus taken at 3—3 of Figure 2;

Figure 4 is a cross-sectional view of the apparatus taken at 4—4 of Figure 2;

Figure 5 is a cross-sectional view of the apparatus taken at 5—5 of Figure 2;

Figure 6 is a cross-sectional view of the apparatus taken at 6—6 of Figure 2;

Figure 7 is a fragmentary longitudinal cross-sectional view taken at the axis of the apparatus at 90° from Figure 2 at a first condition of operation;

Figure 8 is a fragmentary cross-sectional view of the apparatus as shown in Figure 7 taken at a different condition of operation.

Now referring to Figure 1, there is illustrated a body 10, housing the apparatus of the present invention, incorporated into a string of well conduit 12. Conduit 12 is inserted in a well bore 14. Attached to the lower end of conduit 12 is a drilling assembly 16. As an example, a whipstock 18 is shown affixed to drilling assembly 16. Drilling assembly 16, by means of the present invention, has been placed in position to provide deflection of the well bore, upon subsequent drilling, from the inclined position illustrated to the vertical.

At the earth's surface conduit 12 is in connection with conventional drilling equipment (not shown) which includes a fluids circulating pump 20. Practice of the present invention requires knowledge of the fluids pressure through conduit 12 which is obtained at pump 20 by means of a pressure gauge 22.

Now referring to Figure 2, member 10 is seen to house inclination orientation apparatus generally indicated at 24, which is adapted for insertion and removal through one end of housing member 10.

As shown in Figures 2 and 6, orientation apparatus 24 includes a generally cylindrical elongated body 26 which is retained within the housing 10 at a preselected angle of orientation with respect to the housing by means of an orientation web member 68 connected to the lower end of said body. Orientation web 68 is provided with a plurality of longitudinal grooves 70 about the outer periphery thereof adapted for individual engagement with a key 72 supported within a groove 74 of housing 10. Body 26 may be placed within housing 10 at any rotational angle permitted by mutual registry of any web groove 70 with any housing groove 74. As shown, such registry may be had in 9° angular increments. Body 26 is longitudinally supported within the housing 10 by a removable supporting means 76, herein exampled as a snap ring, engaging the web member 68.

Body 26 is provided with an axially aligned cylinder 28 disposed within its lower end and an axial passage 30 disposed within its upper end. Concentrically disposed in passage 30 is a valve seat 32 adapted for sealing contact with a valve plug 34 upon longitudinal movement of the plug within the passage. Valve plug 34 is attached to a piston rod 36, also positioned in axial alignment with passage 30. The lower end of piston rod 36 is in connection with a piston 38. Piston 38 is housed in reciprocating relation within cylinder 28.

As shown in Figures 2 and 5, piston 38 is adapted to reciprocate in splined relation within cylinder 28 by provision of a groove 40 in piston 38 in registry with a key 42 in the wall of cylinder 28. Also provided in the lower face of piston 38, as shown in Figures 2 and 5, is a groove 44 extending from the periphery to the center of said piston of width and depth determined by a gravity responsible inclination means 46, herein embodied as a spherical ball for example. Groove 44 terminates in the center of piston 38 in semi-circular shape about the axis of said piston of radius equal to the radius of the ball.

Ball 46 is supported by a piston stop member 48, rigidly disposed within cylinder 28 by retaining means such as snap rings. Stop member 48 presents a slightly concave face 50 to ball 46, the center of which is normal to the axis of said apparatus if the face is doubly convex, e.g. spherical, and the axis of revolution of which is coaxial with body 26 in any event, e.g., if the face 50 is singly convex as in the case of a conical surface like that shown in the drawing. As provided, ball 46 may randomly traverse face 50 in direction and, in the case of a doubly concave surface, in magnitude responsive to the inclination of the axis of body 26 from the vertical. At such times that ball 46 has assumed a position upon face 50 which is in azimuthal registry with groove 44, then piston 38 is free to extend into cylinder 28 until supported by contact with piston stop 48. At such times that ball 46 has assumed any other position on the face 50 not in azimuthal registry with groove 44, then piston 38 may extend into cylinder 28 only such distance as permitted to initiate supporting contact with the ball 46, a less distance equal to the diameter of said ball.

As shown in Figures 2 and 3, valve plug 34 is maintained in a normally closed position relative to valve seat 32 by provisions of a spring 52 positioned in compressional support between body 26 and a web member 54 attached to piston rod 36. Piston 38 is maintained in a normally retracted position within cylinder 28 by spring 52.

The upper portion of body 26 is provided in sealed relation with the inner walls of housing member 10 by a sealing means 56, herein provided as an O ring. As shown in Figures 2 and 4, the lower portion of body 26 is provided of lesser diameter than the interior of housing 10 to allow fluid flow therebetween. Fluid communication is provided between the axial passage 30, found in the upper portion of body 26, and the annular flow area provided between the reduced lower portion of body 26 and the housing 10 by means of flow ports 58 disposed in the walls of body 26.

A portion of cylinder 28 is provided in fluid isolated relation from the remainder of orientation body 26 by a sealing means 60, herein exampled as an O ring disposed about piston 38, and a second fluid isolating means, herein exampled as a piston 62 having an O ring sealing means 64. Piston 62 is disposed within cylinder 28 between stop member 48 and a fluid exhaust passage 66 found at the lower end of the cylinder. Stop member 48 is webbed about its outer periphery to permit by-pass of fluids.

The isolated chamber thus created by piston 38 and isolating means 62 prevents any drilling fluids, or the solid material normally entrained in such drilling fluids, from entering into interfering contact with the ball 46 or face 50. As herein shown, the isolated chamber is filled with a clean light oil which serves to damp ball 46 from undue oscillation. Under certain conditions however, it is noted that the isolated chamber could be provided with equal utility as an air space. When the isolated chamber is filled with oil, the isolating means 62 performs the additional function of providing displacement for fluids displaced by the extension of piston 38 into cylinder 28.

The pressure of fluids pumped through the conduit 12 into the upper end of housing 10 is applied to valve plug 34 in opposition to the compression of spring 52. This fluid pressure overcomes the force of the spring and causes the plug 34 to retract from valve seat 32, permitting fluid flow through the passage 30. Movement of the valve plug 34 is transferred through piston rod 36 to piston 38, causing its extension into cylinder 28 to the greatest distance permitted by the ball 46.

If, as shown in Figure 7, the fluid pressure is applied at such time as the axis of the orientation body **26** is inclined in correct direction to cause the ball **46** to traverse face **50** to a position in azimuthal registry with the piston groove **44**, then piston **38** may extend into cylinder **28** into direct support with stop member **48**. If, as shown in Figure 8, orientation body **26** is inclined in any other direction, then ball member **46** will serve as an intermediate stop between piston **38** and stop member **48**.

When piston **38** has fully extended into contact with stop member **48**, valve plug **34** stands fully retracted from valve seat **32**, allowing maximum fluid flow through passage **30**. When ball **38** is positioned on face **50** to provide an intermediate support for piston **38**, then valve plug **34** is retracted less from valve seat **32** to a position permitting less fluid flow through passage **30**.

Thus, when the pump **20** is providing a fluid flow through the well conduit **12**, the pressure indicated at the gauge **22** to provide such flow will be less when valve plug **34** is fully retracted and greater when the valve plug is only partially retracted.

It is now seen, when housing member **10** is positioned within a section of well bore inclined from the vertical, that the valve plug **34** will permit maximum fluid flow through passage **30** only when the ball **46** has assumed a position on the face **50** responsive to an inclination of apparatus **24** which will permit registry of the ball with the piston face groove **44**. Bearing in mind that the orientation apparatus **24**, by means of orientation web member **68**, may be preselectively oriented with the housing **10** and therefore with the well conduit **12**, it is seen that the position of ball **46** on the face **50** may be known at the earth's surface.

In operation the well conduit containing apparatus **24** is lowered into the well bore. Fluid pressure is provided by the pump **20**. A reading is taken of the fluid pressure at the gauge **22**. Such pressure is then released and the well conduit **12** rotated a small angular increment. Pump pressure is again applied and the pressure appearing at gauge **22** noted. Such intermittent application of pump pressure and incremental rotation of well conduit **12** is continued until a substantial drop in pressure is noted at gauge **22**. Such pressure drop indicates a full opening of the fluid passage **30** provided by full extension of piston **38** into cylinder **28**. Since the relative angular relation of the body **26** to the drilling assembly **16** and whipstock **18** may be preselected, the whipstock may thus be oriented in relation to the direction of inclination of well bore **14** as desired.

It is seen, by reference to Figures 2 and 5, that the ball **46** will be in the center of face **50** when the orientation apparatus **24** is in vertical alignment. As provided, the ball **46** will be in registry with the semi-circular termination of groove **44** upon such vertical alignment and will permit full extension of the piston **38** into cylinder **28**. Thus, the apparatus may be used to determine absence of inclination as well. To make such determination well conduit **12** is turned in angular increments in conjunction with intermittent application of fluid pressure from the pump **20**. A reading is taken at gauge **22** upon each pressure application. When the orientation apparatus **24** is in the vertical, pressure gauge **22** will indicate a continued lower pressure, permitted by continued registry of the centered ball **46** in the piston groove **44**, throughout a complete revolution of conduit **12**.

It is pointed out that the drilling fluids and suspended foreign materials may pass through and about orientation apparatus **24** at any velocity without detrimental effect to the inclination indicating ability of the invention.

Though only a preferred embodiment of the invention has been disclosed herein, it is obvious that certain substitutions or modifications thereto may be made by those skilled in the art without departing from the spirit or scope of the invention as defined in the appended claims.

That being claimed is:

1. In inclination orientation apparatus the combination of a generally cylindrical body being adapted for placement in axial alignment within a well conduit, a chamber defined within said body in fluid isolation from the interior of said conduit, a first stationary inclination element disposed within said chamber having a dished face positioned with its lowest point (as determined when the axis of said body is vertical) disposed at the axis of said body, a second gravity actuated inclination member in contact with said face being free to assume a position on said face indicative of the direction of inclination of the axis of said body from a vertical position, a longitudinally displaceable control member positioned in splined relation within said chamber, said control member having a groove in its lower surface for receiving said second inclination member when said control member assumes a position with said groove lying in the vertical plane through the axis of said body, said control member being adapted for greater displacement to a first position when registered with said second inclination member and for lesser displacement to a second position when not registered with said second inclination member, a normally closed valve means disposed with said body in linked relation to said control means being adapted to be opened by fluid flow through said conduit to positions responsive to the displacement of said control member to create flow pressure variation within said conduit responsive to said positions.

2. An inclination orientation apparatus comprising, a generally cylindrical body being adapted for placement in axial alignment within a well conduit in pre-selected rotational relation to said body, a chamber adapted to contain a damping fluid defined by said body in fluid isolation from the interior of said conduit, a first stationary inclination element disposed within said chamber having a generally concave face positioned coaxial to the axis of said body, a gravity actuated ball member in contact with said face being free to assume a position on said face indicative of the direction of inclination of the axis of said body from a vertical position, a displaceable control member positioned within said chamber being adapted to maintain constant rotational relation with the axis of said body during said displacement, said control member having a radial recess on its face adjacent said ball member for receiving said ball member when said ball member assumes a position on said face along a particular radius extending from the axis of said body, said control member being adapted for displacement to a first position when registered with said second inclination member and for displacement to a second position when not registered with said second inclination member, a normally closed valve means disposed within said body in linked relation to said control member being opened by fluid flow through said conduit to create pressure variation within said conduit responsive to the displacement of said control member.

3. In inclination orientation apparatus the combination of a generally cylindrical body being adapted for placement in axial alignment within a well conduit, a chamber adapted to contain a damping fluid defined within said body in fluid isolation from the interior of said conduit, a first stationary inclination element disposed within said chamber having a generally concave face positioned coaxial to the axis of said body, a gravity actuated ball member in contact with said face being free to assume a position on said face indicative of the direction of inclination of the axis of said body from a vertical position, a longitudinally displaceable piston positioned in splined relation within said chamber, said piston having in its face that is adjacent said ball member a radial recess for receiving said ball member when said second inclination member assumes a position on

said face along a particular radius extending from the axis of said body, said piston being adapted for displacement to a first position when registered with said ball member and for displacement to a second position when not registered with said ball member, a valve means disposed with said body in linked relation to said piston being opened by fluid flow through said conduit to positions responsive to the displacement of said piston to create flow pressure variations within said conduit responsive to said positions.

4. An inclination orientation apparatus comprising, a generally cylindrical body being adapted for placement within a well conduit in preselected relation to said conduit, a chamber defined within said body, a first stationary inclination element disposed within said chamber having a dished face positioned with its lowest point as determined when the axis of said body is vertical disposed at said axis, a second gravity actuated inclination member in contact with said face being free to assume a position on said face indicative of said inclination of the axis of said body from a vertical position, a longitudinally displaceable control member positioned in splined relation within said chamber, means to isolate said chamber from any fluids in the interior of said conduit, said control member having a recess in its lower surface for receiving said second inclination member only when said second inclination member is particularly positioned on said face, said control member being adapted for displacement to a first position when registered with said second inclination member and for displacement to a second position when not registered with said second inclination member, a valve disposed with said body in linked relation to said control means being opened by fluid flow pressures through said conduit to flow positions responsive to the displacement of said control member.

5. In a method of orienting a segment of well conduit relative to the inclination of a well bore the steps of incorporating an inclination orientation means into the well conduit in preselected rotational relation to said conduit, said orientation means being adapted to provide a first restriction to fluid flow through said conduit upon said conduit being inclined in a single direction and to provide a second different restriction to fluid flow upon said conduit being inclined in any other direction, inserting said conduit into a well bore, applying a fluid flow through said conduit, measuring a pressure required to produce said flow, halting said fluid flow, rotating said conduit an angular increment within said well bore, again applying said fluid flow through said conduit, again measuring a pressure caused by said fluid flow, repeating said rotation of said conduit and intermittent application of said fluid flow until a different pressure is measured, said different pressure being indicative of said orientation means being inclined in said direction.

6. In a method of detecting the inclination of a segment of well conduit within a well bore the steps of incorporating an inclination means being adapted to provide a first restriction to fluid flow through said conduit when said conduit is vertical and is inclined in a direction preselected in relation to said conduit and to provide a second restriction to fluid flow upon said conduit being inclined in any other direction relative to said conduit, into a well conduit, inserting said conduit into a well bore, applying a fluid flow through said conduit, measuring a pressure required to produce said flow, halting said fluid flow, rotating said conduit an angular increment within said well bore, again applying said fluid flow through said conduit, again measuring a pressure caused by said fluid flow, repeating the steps of rotating said conduit interposed by the steps of applying said fluid flow and determining said pressures through at least one revolution of said conduit, a change in the pressures thus determined at any rotational increment of said conduit being indicative of inclination of said conduit and no change in the pressures thus determined at every rotational increment being indicative of no inclination of said conduit.

7. An inclination orientation apparatus conprising, a generally cylindrical body being adapted for placement within a well conduit in preselected relation to said conduit, a first stationary inclination element disposed within said body having a face positioned transverse to the axis of said body, a second gravity actuated inclination member in contact with said face being free to assume a position on said face indicative of said inclination of the axis of said body from a vertical position, a longitudinally displaceable control member positioned in splined relation within said body, said control member having a recess in its lower surface adapted for registry with and reception of said second inclination member only when said second inclination member assumes one of a particular group of positions on said face, said control member being adapted for displacement to a first position when registered with said second inclination member and for displacement to a second position when not registered with said second inclination member, and a valve disposed within said body in linked relation to said control member being opened by fluid flow pressures through said conduit to flow positions responsive to the displacement of said control member.

8. Well apparatus comprising a first member having a dished surface, a ball on said surface, a second member, means mounting said second member for reciprocation relative to said dished member along an axis, the low point of said dished surface being on said axis when said axis is vertical, said second member having a radial recess on the side thereof facing said first member adapted to receive said ball when in register therewith, valve means, and means connecting said valve means to said second member to control the possible degree of movement of said valve means in accordance with the possible extent of axial movement of said second member toward said dished surface as determined by the position of said ball on said surface relative to said radial recess.

9. In combination with the apparatus of claim 8, a tubular member adapted for connection in a pipe string and housing said apparatus with said axis of said apparatus extending in the same direction as the axis of said tubular member, means sealing between said valve means and said tubular member to cause all fluid passing through said tubular member to pass through said valve means, and locating means holding said first member in preselected azimuthal relation to said tubular member.

10. The combination of claim 9 in which said locating means includes a spider connected to said first member to have a constant azimuthal relation thereto having a plurality of equally azimuthally spaced webs, each web having a slot in its outer peripheral end, said tubular member having a plurality of equally azimuthally spaced grooves on its inner periphery, the number of grooves being different from the number of slots with no common divisor for said numbers, and key means to hold a selected one of said slots in alignment with a selected one of said grooves.

11. In combination with the apparatus of claim 8, means forming a chamber having a first portion with an internal cylindrical surface, said second member having a cylindrical piston portion received in said cylindrical surface portion of said chamber for axial movement therein, means sealing between said piston portion and cylindrical surface portion of said chamber, said first member being also disposed in said chamber, said ball being disposed in said chamber between said first and second members, said means forming a chamber having a second cylindrical surface portion, a second cylindrical piston axially slidably disposed in said second cylindrical surface portion of said chamber, means sealing between said second piston and said second cylindrical surface portion, said second piston being on the opposite side of said first and second members from said first piston,

said chamber being filled with a liquid, said chamber forming means being open at both ends beyond said pistons to expose the exterior ends of said pistons to the pressure outside said chamber forming means.

12. In combination with the apparatus of claim 11, tubular means, said valve means including a valve and seat, said tubular means connecting said seat with said chamber forming means, said second member being connected to the valve of said valve means, a valve stem connected to said valve, and compression spring means bearing on said valve seat and engaging said valve stem urging said valve to closed position.

13. An orientation determination apparatus comprising a tubular housing adapted to be incorporated into a string of well conduit above a drilling assembly, a generally cylindrical elongated body disposed in said housing, said body being provided with an axial passage in its upper portion and an axially aligned cylinder in its lower portion communicating at its upper end with said axial passage, the lower portion of said body having a smaller external diameter than the inside diameter of said housing leaving an annular fluid passage therebetween, the lower portion of said body having ports therethrough placing said annular fluid passage in communication with the interior of said cylinder, means between the lower portion of said body and said housing holding said body against axial motion relative to said housing and in preselected azimuthal angle of orientation relative to the axis of said housing, the last said means having passage means therethrough placing said annular passage in communication with the portion of said housing therebelow, means sealing between the outside of the upper portion of said body and the inside of said housing, a valve seat disposed concentrically in said passage about the inner periphery thereof, a piston disposed in said cylinder for reciprocation therein below said ports, a piston rod connected to the upper part of said piston and extending concentrically upwardly through said passage and above said seat, a valve plug attached to said piston rod and adapted to engage the lower side of said valve seat, a web member attached to said piston rod above said seat, a helical spring disposed around said piston rod between the upper side of said valve seat and said web member and bearing at its ends against said seat and web member and urging said valve plug against said seat, means holding said piston in splined relationship within said cylinder comprising a key in the wall of the cylinder, said piston having a groove parallel to the cylinder axis slidably receiving said key, said piston having a groove in its lower face extending radially from the center of the piston to the periphery thereof, a stop member secured within said cylinder below said piston, the upper face of said stop member being concave, a ball disposed on said upper face of the stop member, said ball having a diameter less than the width of said groove, said ball limiting the downward movement of said piston toward said stop member when out of registry with said groove and thus limiting the possible movement of said valve plug away from its seat when said ball is out of registry with said groove to a lesser movement than is possible when said ball is in registry with said groove.

14. The combination of claim 13 with means sealing between said piston and cylinder, a second piston disposed in said cylinder for reciprocation therein below said stop member, means sealing between said second piston and said cylinder, said stop member having passage means therethrough placing the space in said cylinder between the stop member and second piston in communication with the space in said cylinder between said stop member and the first said piston, said spaces being filled with liquid, said cylinder having passage means therethrough placing the space in the cylinder below said second piston in communication with said annular passage between said body and said housing.

15. The combination of claim 13 in which said means holding said body in said housing comprises a web member connected to said body, said web member having a plurality of azimuthally spaced radial arms each having a groove at its outer end, a key received within a selected one of said grooves, said housing having a plurality of azimuthally spaced slots in its inner face, the spacing of said slots being different from that of said grooves, said key also extending into a selected one of said slots, and a snap ring engaging said web member and said housing.

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