

[54] ROTARY BIT GUIDE

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[58] Field of Search.....175/61, 73, 76, 79, 81;
166/212, 226, 141

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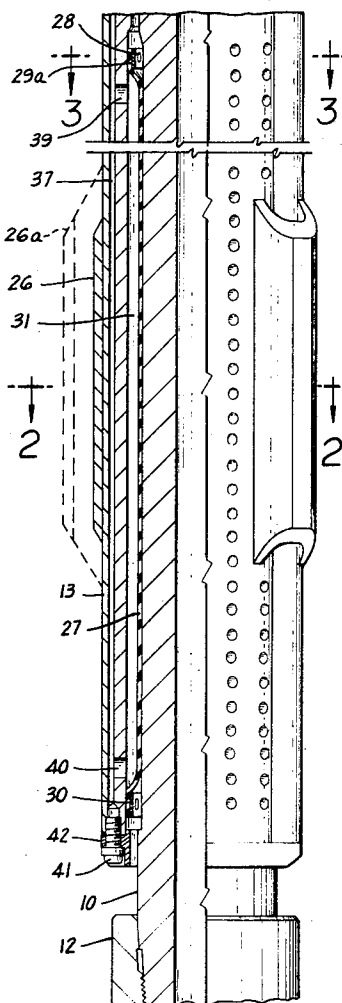
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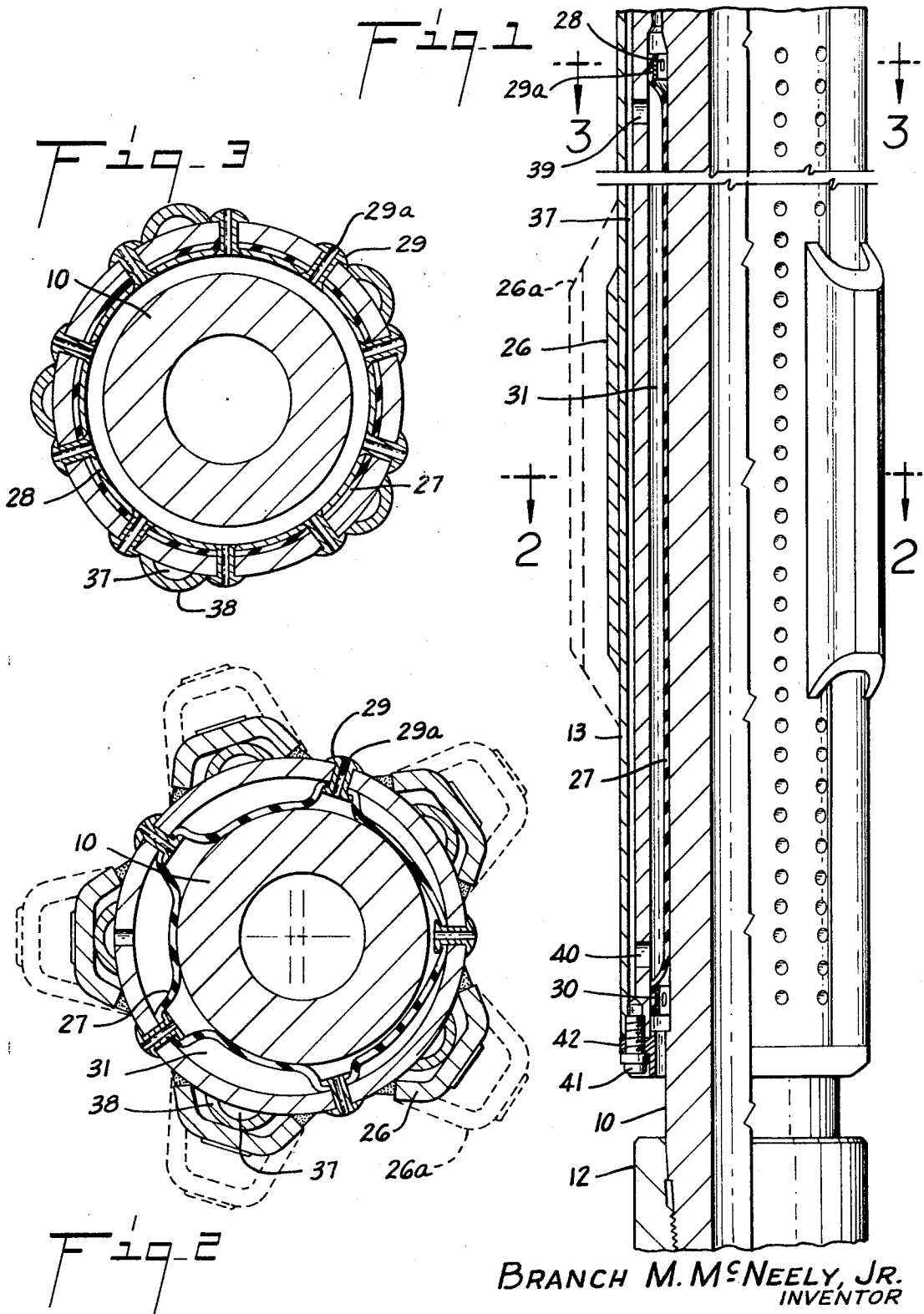
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ABSTRACT

A device for controlling the directional deviation of a well bore. An outer member is concentrically spaced around a mandrel which is connectable at opposite ends to form part of a drill string, the outer member having longitudinal ribs extending from its outer surface to frictionally engage the walls of the well bore and thereby restrict rotation of the outer member in the well bore. A first set of deformable pressure chambers which preferably comprise part of a rotary pump are located between the outer member and the mandrel. A second set of deformable pressure chambers, located between the outer member and the mandrel, communicate via fluid passageways with the first set of pressure chambers. A fulcrum means is located between and in contact with said outer member and said mandrel whereby when fluid is transferred from the first set of chambers to the second set of chambers thereby causing the second set of chambers to apply a force against the mandrel in a lateral direction, the mandrel can pivot relative to the outer member.

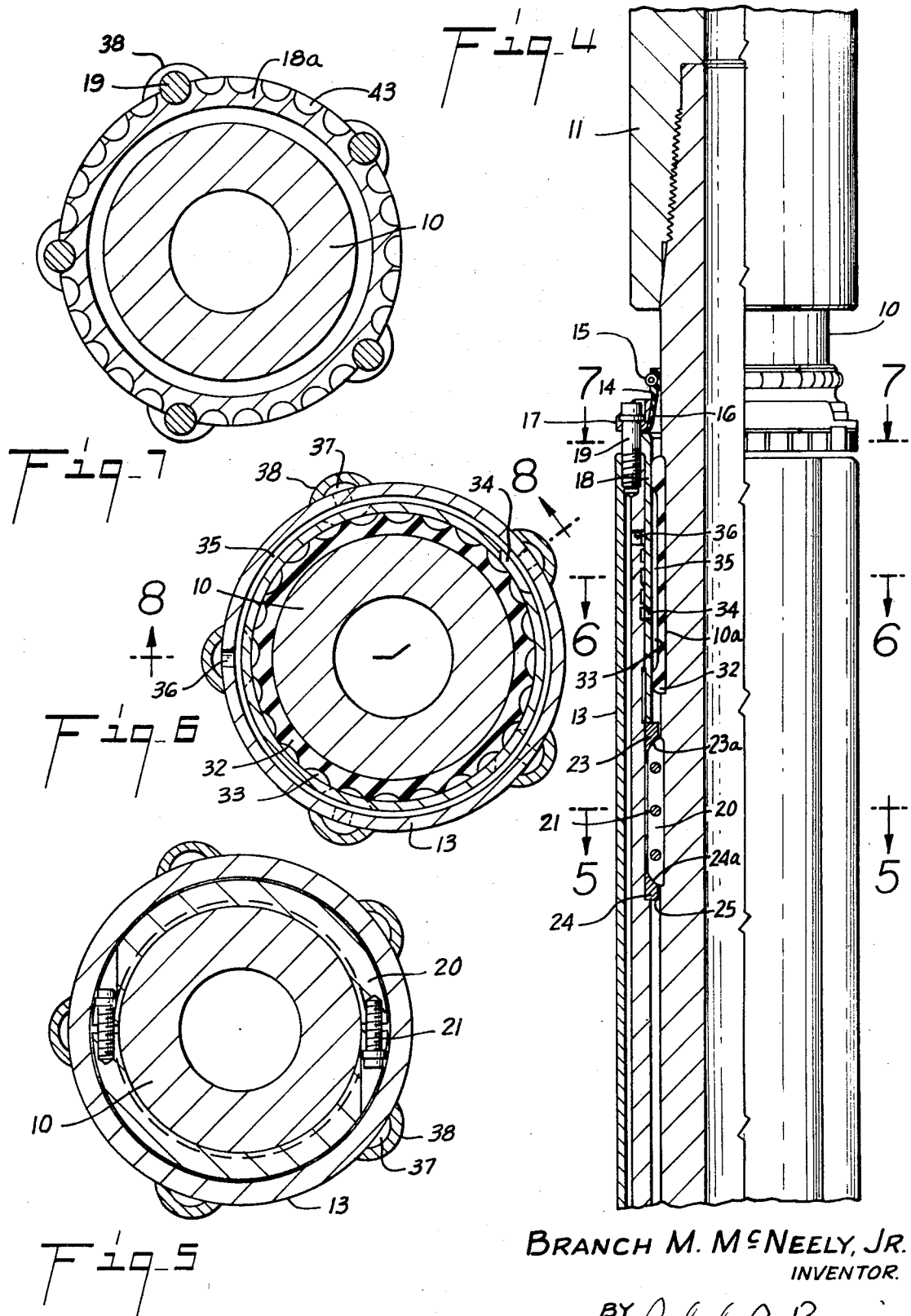
10 Claims, 9 Drawing Figures





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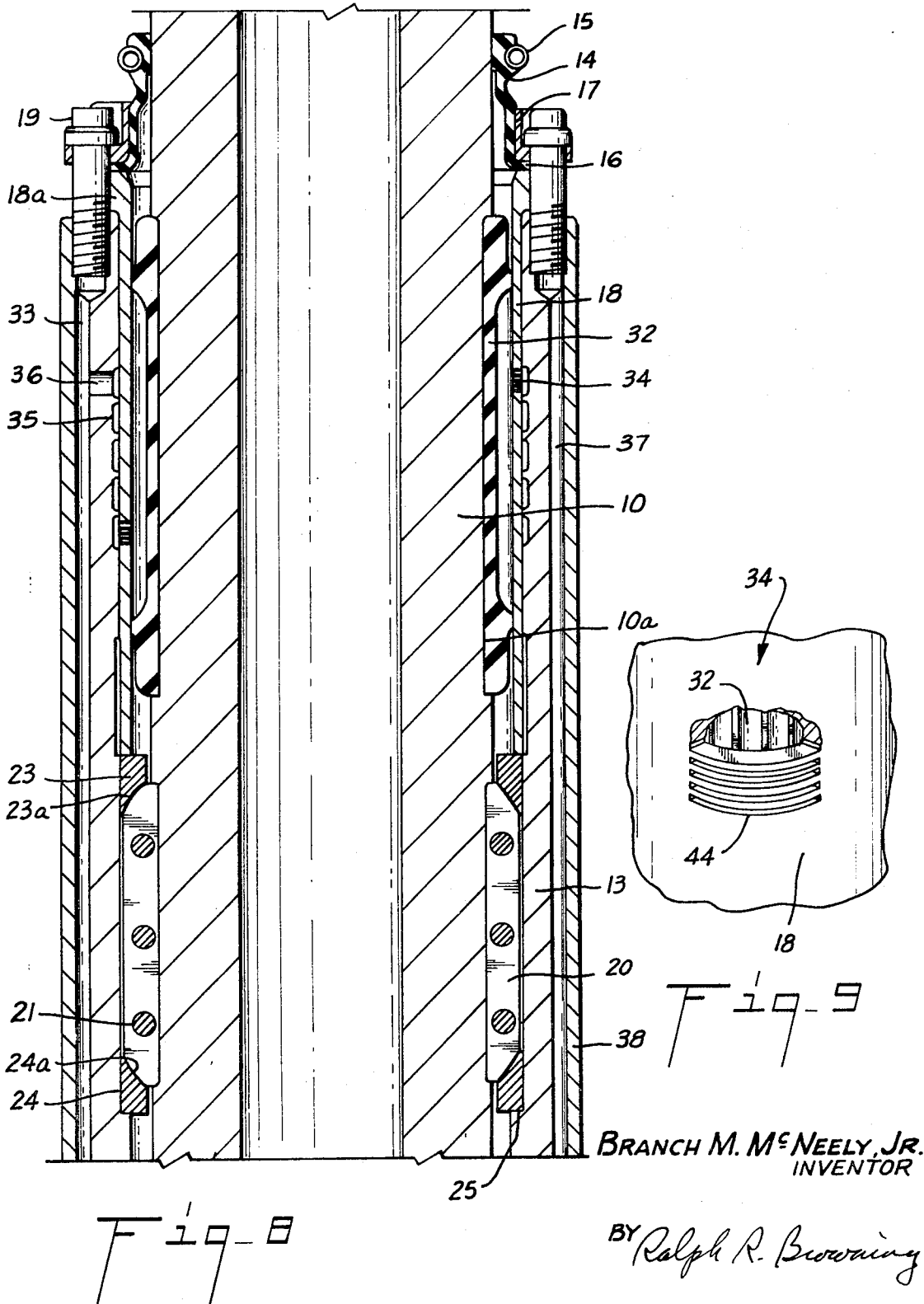
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ROTARY BIT GUIDE

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus for controlling directional deviations in a well bore and more particularly relates to an apparatus for exerting a lateral force on the drill string to control or influence the direction taken by the drill bit as it drills a well bore.

In the use of rotary equipment to drill a well such as an oil well, a frequent problem encountered by drillers is maintaining the well bore in a predetermined or desired path into the earth. While generally it is desired that the path be vertical with respect to the surface of the earth, it is not rare that it is desired to drill the well at a certain angle from the vertical.

In the case of attempts to drill substantially vertical well bores, the most frequently encountered problem is that the various strata penetrated by the rotary bit vary in hardness and usually are inclined at an angle to the horizontal. Since the bit will follow the path of least resistance, upon encountering these inclined strata of different hardness, the bit will be forced into a direction from the vertical with the result that the well bore becomes crooked. Numerous proposals have been put forth to counteract this problem, one of which has been to employ massive drill collars immediately above the rotary bit in the drill string to provide adequate unsuspended weight on the drill bit and therefore force it vertically downward. The use of such massive collars poses additional problems however, due to the flexibility of the drill string. For example, once the rotary bit encounters an inclined strata which tends to force it out of a vertical bore, the drill string becomes unevenly supported and since the drill string does have a certain degree of flexibility, the massive weight of the collars forces the string against the side of the well bore which leads to increased deviation from the vertical.

In U.S. Pat. No. 3,043,381, there is described an apparatus for generating a hydraulic force in the well bore and applying this hydraulic force against the lower end of the drilling string in a predetermined direction to thereby direct the bit for either drilling a vertical or an oriented well bore as may be desired. The apparatus described in the aforementioned patent, while providing a most useful means for controlling well bore deviations, has certain drawbacks. For one thing, the apparatus described therein makes contact with the wall of the well bore over a considerable length. As can be readily appreciated, the use of a large down-hole drill tool which is static in the well bore impedes the flow of drilling fluids, muds, etc. Therefore, in order to reduce the effect on circulation of drilling fluids, it is preferable that any drilling tool in down-hole applications be as small as is reasonably possible. Furthermore, the rotary bit guide described in the above-identified patent operates on the principle of transferring fluid from one set of deformable chambers to a second set of deformable chambers, the second set of deformable chambers in turn acting against the drill stem to control its direction. These deformable chambers are formed using resilient sleeves having various arrangements of cavities forming the actual chambers. To achieve proper deviation control, it was necessary that the chambers be deformed to a rather large extent. This requires increased and extended flexing of the resilient sleeves causing the sleeves to wear very rapidly.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved apparatus for controlling directional deviations in a well bore.

It is another object of the present invention to provide an improved means for applying lateral force to a rotating bit in an inclined well bore in a predetermined direction relative to the direction of the inclination.

Still another object of the present invention is to provide an improved apparatus for applying lateral force to a rotating bit in an inclined bore in a direction opposing deviating forces acting on the bit.

Yet another object of the present invention is to provide an improved apparatus for applying lateral force to a rotating bit in an inclined bore which force is of a magnitude related to the angle of the inclination.

Another object of the present invention is to provide an improved apparatus for applying lateral force to a rotating bit in an inclined bore, said force being of a magnitude which is related to the drill string rotating speed.

An important object of the present invention is to provide an improved apparatus for use in combination with a rotating drilling string and a bit attached thereto for maintaining a substantially vertical well bore.

These and other objects which will become apparent from the drawings, the description given herein and the appended claims are provided by the present invention.

Basically, the present invention provides a rotary bit guide for use in combination with a rotating drill string having a bit attached thereto. An outer member having means attached thereto to maintain said outer member in substantially stationary position in the well bore is disposed in surrounding spaced relationship to a mandrel which is adapted to form part of the drill string. Means forming first and second sets of deformable fluid pressure chambers are located between the outer member and the mandrel, the sets of chambers being axially displaced from each other, the chambers within the sets being circumferentially positioned about the mandrel. A means is provided for transferring fluid under pressure from one set of the pressure chambers to the other set of the pressure chambers and a fulcrum means, located between and in contact with the outer member and the mandrel is provided whereby when fluid is transferred from one set of chambers to the other set of chambers, the chamber receiving the fluid can act against the mandrel which in turn can pivot about the fulcrum point and thereby alter the direction being taken by the bit in the well bore. Preferably, one set of the deformable pressure chambers is attached to the rotating mandrel and acts in conjunction with the rotating mandrel as the rotating element in a rotary pump. The eccentric rotation of the mandrel within the outer member caused by the inclination of the drill string within the well bore provides the pumping force for transferring fluid under pressure from the first set of pressure chambers to the second set of pressure chambers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view, partly in cross section showing the details of construction of the fluid receiving chamber end of the apparatus.

FIG. 2 is a cross-sectional view taken along the line 2—2 of FIG. 1 showing a detail of the fluid receiving chambers.

FIG. 3 is a cross-sectional view taken along the line 3—3 of FIG. 1 showing the details of forming one end of the receiving chambers.

FIG. 4 is an elevational view, partly in cross section showing the details of construction of the pressure generating chamber end of the apparatus.

FIG. 5 is a cross-sectional view taken along the line 5—5 of FIG. 4 showing the details of construction of the fulcrum assembly of the present invention.

FIG. 6 is a cross-sectional view taken along the line 6—6 of FIG. 4 showing details of construction of the generating chambers.

FIG. 7 is a cross-sectional view taken along the line 7—7 of FIG. 4 showing a detail of the assembly for interconnecting selected receiving chambers to various ports adjacent the generating chambers.

FIG. 8 is an enlarged cross-sectional view taken along the line 8—8 of FIG. 6.

FIG. 9 is an enlarged perspective view of the slotted ports connecting the generating chamber and the fluid passageways leading to the receiving chambers.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In rotary drilling operations, when the well bore is inclined from the vertical, the drill string will lie against the wall of the well bore on what may be referred to as the "low side" of the well bore. The improved apparatus described herein employs a portion of the force exerted on this low side of the well bore by the drill string to deviate the direction taken by the drill bit either back to the vertical or in a deviated direction depending on the assembly of the apparatus, as will be seen below.

As used herein, "upper and lower" refer to the relative position in the well bore of the device, it being understood, the apparatus can be reversed if desired. Turning first to FIGS. 1 and 4, the improved apparatus of the present invention is seen to comprise a tubular body or mandrel 10 which in usual practice is adapted to be connected at its upper end to the lower end of a plurality of drill collars to add weight and stiffness to the lower end of the drill string and at its lower end to the bit portion 12 of the drill string. Surrounding mandrel 10 and in spaced relation thereto is an outer generally tubular member 13. As best seen in FIGS. 1, 4 and 7, outer member 13 is movably attached to mandrel 10 whereby mandrel 10 can move laterally relative to outer member 13 which is relatively stationary in the well bore. Referring to FIGS. 4 and 7, a flexible flanged rubber sleeve 14 surrounds mandrel 10 and is held in engagement thereto by a garter spring 15 which fits into an annular groove 15a on the outer surface of sleeve 14. While being held snugly against mandrel 10, sleeve 14 still allows mandrel 10 to rotate therein. The other end of sleeve 14 has a radially outwardly extending flange 16 which is sandwiched between a collar 17 and a rigid flanged sleeve 18 (described more fully below). Flange 16 is compressed against the flange of sleeve 18 by a series of bolts 19 which screw into threaded openings in outer member 13 and which force collar 17 against flange 16.

As best seen in FIGS. 4 and 5, mandrel 10 has secured thereto the bearing portion 20 of a swivel bearing assembly which acts as a fulcrum for mandrel 10. Bearing 20 comprises a generally annular member, having spherical end bearing surfaces. While bearing 20 can be of a single piece construction and secured to mandrel 10 by a sweat fit or other such means, it is usually more convenient to construct bearing 20 from substantially semicylindrical pieces which are placed around mandrel 10 and brought into tight frictional engagement with mandrel 10 by means of a plurality of bolts 21. As can be seen, mandrel 10 has an annular groove 22 on its outer surface into which the base of bearing 20 fits. Since bolts 21 act, when tightened, to compress the semicylindrical pieces into tighter engagement, bearing 20 is tightly held against mandrel 10 and will consequently rotate therewith. Other methods of securing bearing 20 to mandrel 10 can of course, be employed. The seat for bearing 20 is provided by seat members 23 and 24 respectively which preferably are made of brass. Seat member 23 abuts the inner surface of outer member 13 on one surface and the end of rigid sleeve 18 on an adjoining surface. Seat member 24 abuts the inside surface of outer member 13 on adjoining surfaces, outer member 13 being provided with a shoulder 25 against which one side of seat member 24 rests. Seat members 23 and 24 have arcuate surfaces 23a and 24a in which ride the spherical end surfaces of bearing 20 as mandrel 10 rotates. As will be recognized, since members 23 and 24 are spaced from mandrel 10, and since the outer face of bearing 20 is spaced from the inside surface of outer member 13, mandrel 10 can pivot relative to outer member 13, i.e., bearing 20 and seat members 23 and 24 act in combination as a fulcrum.

As mentioned above, member 13 remains substantially stationary in the well bore as mandrel 10 rotates. To this end, outer member 13 is equipped with a series of circumferentially spaced and generally longitudinally extending ribs 26 which serve to hold outer member 13 in frictional engagement with the walls of the well bore. As seen best in FIGS. 1 and 2, ribs 26 can be of any size depending on the size of the well bore,

ribs 26a shown in phantom lines extending outwardly from outer member 13 further than ribs 26 to accommodate a larger diameter well bore.

As shown in FIGS. 1, 2 and 3, a lower flexible sleeve 27 surrounds mandrel 10 and is sealingly engaged at opposite ends to the inside surface of outer member 13. At its upper end, i.e., higher in the well bore, flexible sleeve 27 is sandwiched between the inside surface of outer member 13 and sealing rings 28. A series of circumferentially disposed brads extend through outer member 13, the upper end of sleeve 27 and seal ring 28 holding them in tight sandwiched engagement. In like fashion, flexible sleeve 27 is sealed at its lower end, i.e., lower in the well bore, by being sandwiched between lower seal ring 30 and the inside surface of outer member 13. As in the case of the upper end of flexible sleeve 27, a series of circumferentially disposed brads 29 hold outer member 13, the lower end of flexible sleeve 27 and lower seal ring 30 into tight sandwiched engagement. Flexible sleeve 27 is also sealingly engaged with the inside surface of outer member 13 at circumferentially disposed, longitudinally extending positions by brads 29. It should be noted that brads 29 have a cylindrical bore extending therethrough allowing open communication between the well bore and the space between the resilient sleeve 27 and mandrel 10. This, of course, allows drilling fluids, muds and other such down-hole additives to move freely in and out of the well tool providing lubrication and assisting in heat transfer at the bearing surfaces. Therefore, although it is possible that sleeve 27 be secured to the inside surface of outer member 13 by vulcanizing or other such techniques, brads are preferred. At any rate, as is clearly seen, the sealing of flexible sleeve 27 at its upper and lower end and at circumferentially disposed longitudinally extending positions provides a series of circumferentially disposed, separate pressure chambers 31 bounded by the inside surface of member 13 and the outside surface of flexible sleeve 27. Since sleeve 27 is of a flexible nature being made of rubber, plastic or other such material, chambers 31 are of a flexible or deformable nature. For purposes of description, chambers 31 will hereinafter be referred to as receiving or servo chambers.

Attention is now directed to FIGS. 4, 6 and 8. An upper resilient sleeve 32 surrounds and frictionally engages mandrel 10, sleeve 32 being partially recessed in an annular groove 10a in the outer surface of mandrel 10. The outer surface of upper resilient sleeve 32 has a series of peripherally disposed, generally longitudinally extending recesses, the recesses having a cross-sectional shape such that upper resilient sleeve 32 has a generally scalloped appearance when viewed in transverse section. As noted particularly in FIG. 4, the recesses or chambers 33 do not extend the full length of upper resilient sleeve 32, but are bounded on their ends by portions of sleeve 32.

As best seen in FIGS. 4 and 6, rigid sleeve 18 is disposed in an annular space between outer member 13 and upper resilient sleeve 32. Sleeve 18 has a series of circumferentially disposed and axially displaced slotted ports 34 which extend through sleeve 18 and which communicate with chambers 33. From FIG. 9, it can be seen that ports 34 comprise a series of slotted openings 44 cut transversely through sleeve 18. The use of slotted openings rather than a single large port prevents resilient sleeve 32 from extruding into port 34 when sleeve 32 is compressed against the side of sleeve 18 by the eccentric rotation of mandrel 10. On its inner surface abutting sleeve 18, outer member 13 has a series of annular grooves 35 axially displaced from one another, each groove being displaced so as to communicate with a like axially disposed slotted port 34 in sleeve 18. Leading from each of annular grooves 35 is a passageway 36 in outer member 13 which communicates with a passageway 37 which extends substantially the entire length of outer member 13 and which are formed by hollow, elongated semicylindrical lugs 38 attached to outer member 13 by welding or some suitable means, it being understood that lugs 38 could be cast integrally with outer member 13, or that passageways 37 could be made internally of the walls of

member 13, the lugs being dispensed with. Passageways 37 communicate at their lower end with chambers 31 through upper and lower passageways 39 and 40 respectively. Thus it is seen that fluid communication exists between recesses or chambers 33, hereinafter referred to as generating or motor chambers, and receiving or servo chambers 31.

The system described above including generating or motor chambers 33, ports 34, grooves 35, passageways 36, passageways 37, 39 and 40, and chambers 31 can be filled with fluid by removing bolt 41 which allows entrance into passageway 37. The system is made closed and fluid tight by means of brass sealing member 42 through which bolt 41 extends, bolt 41 being threadedly engaged in outer member 13.

As explained above, mandrel 10 which is adapted for rotation with the drilling string is rotating within the well bore whereas outer member 13 is stationary, being frictionally held by ribs 26 or 26a depending on the diameter of the well bore. Since upper sleeve 32 is frictionally held in the annular groove 10a on the outer surface of mandrel 10, sleeve 32 also rotates with mandrel 10. This rotation of mandrel 10 having sleeve 32 affixed thereto results in a rotary pump mechanism. Having in mind that the entire internal fluid system is filled with fluid, and assuming that mandrel 10 is coaxially aligned with outer member 13 (a condition existing when the drilling string is centered in a vertical well bore) such that it is undergoing no eccentric rotation within outer member 13, no fluid will be transferred from generating or motor chambers 33 to receiving or servo chambers 31. However, should mandrel 10 deviate from this condition, such that it is rotating eccentrically within outer member 13, a pumping action will begin whereby fluid from chambers connected to the low pressure side of the pump will be displaced to chambers connected to the high pressure side of the pump. The high pressure side of the pump is, of course, constituted by the side of outer surface 13 to which mandrel 10 most closely approaches in its eccentric rotation therein. As will be seen from viewing FIG. 6, should mandrel 10 be eccentrically displaced within outer member 13, some of chambers 33 lying between sleeve 18 and mandrel 10 will be compressed forcing fluid therein to be dissipated while the remaining chambers on the low pressure side will be taking in fluid, the amount, of course, being dependent upon the displacement of mandrel 10 from sleeve 18.

Referring now to FIGS. 4 and 7, it can be seen that sleeve 18 has a flanged portion 18a at one end which has a series of peripherally disposed substantially semicircular cutouts 43. Cutouts 43 serve the purpose of allowing sleeve 18 to be radially adjusted such that receiving chambers 31 and ports 34 in sleeve 18 can be radially positioned in any of a number of different relationships. Thus, for example, by proper orientation of sleeve 18, it is possible that ports 34 be connected to pressure chambers 31 such that the pressure ports 34 and chambers 31 are in fluid communication in exact radial alignment. When assembled in this fashion, i.e., ports 34 being radially aligned with receiving chambers 31, the apparatus will then act to decrease any deviation from the vertical in the well bore and, thus, ensure that the well bore is drilled vertically. For example, assuming that a vertical bore is being drilled and then the drill string begins to deviate from this path, mandrel 10 will begin to rotate eccentrically rather than concentrically within outer sleeve 13. This, of course, will produce a high pressure and a low pressure side in the rotary pump means. Since the receiving chambers 31 and the ports 34 in fluid communication with the rotary pumping means are now in phase, fluid being expelled from the high pressure side of the pump will act to direct the mandrel 10, via receiving chambers 31 back to the vertical. On the other hand, if each of the ports 34 is connected so as to be in fluid communication with a receiving chamber 31 which is 180° out of phase with it, then once the deviation has started, it will be increased. Of course, if the ports 34 and pressure chambers 31 are connected so as to be at angles intermediate between 0° and 180°, the drill string will then drill a bore which is at an angle to the already existing deviated well bore depending on the pressure being exerted by

chambers 31 against mandrel 10. It should be specifically noted that in order to directionally drill or deviate the well bore, the well bore must already be in a deviated position in order to force the mandrel into eccentric rotation within outer member 13, i.e., to have a low pressure and high pressure side of the pump means. On the other hand, if the rotary bit device herein is intended to maintain the well bore in substantially vertical position, then provided the drill string does not deviate from this position, no pressure is generated in chambers 33 with the result that no pressure acts via chambers 31 against mandrel 10. Therefore, the well bore continues in a substantially vertical path. FIG. 2 depicts a condition wherein certain of the receiving chambers 31 contain more fluid than other of the chambers, i.e., the drill string has deviated from the vertical and mandrel 10 is rotating eccentrically. The apparatus herein, if so set that the pressure ports 34 and chambers 31 are in fluid communication directly aligned will operate automatically to adjust mandrel 10 back to a substantially concentric arrangement relative to outer member 13 such that chambers 31 will again be of substantially equal volume. In any event, in order to directionally drill the well bore or to maintain the well bore in a vertical condition, it is only necessary to vary the position of sleeve 18 relative to outer member 13. As can be seen in FIG. 7, cutouts 43 and the flange of sleeve 18 give the flange of sleeve 18 a scalloped appearance when viewed in transverse cross section. When bolts 19 are removed, sleeve 18 can be rotated until the desired cutout 43 is in alignment with the bolt hole at which point bolts 19 can be inserted being partially encircled by cutouts 43 of flange 18a. As explained above, the radial positioning of sleeve 18 relative to the outer member 13 results in differing radial relationships of receiving chambers 31 to ports 34.

Receiving chambers 31 will generally have a much greater area than generating chambers 33. In effect, the area of the receiving chambers 31 should be sufficient such that the hydraulic force being generated in chambers 33 is applied over a sufficiently large area to overcome all of the forces tending to move the drilling string in other than the desired direction. It has been found desirable that the ratio of the area of the generating chambers, i.e., chambers 33, to the receiving chambers, i.e., chambers 31, be from about 1:5 to about 1:15 although obviously smaller and larger ratios can be utilized.

It should be specifically noted that the presence of the fulcrum means comprised of bearing 20 and the seat formed by seat members 23 and 24 allows a controlled rate of eccentricity of the rotating mandrel 10 with reference to the outer member 13. This controlled rate of eccentricity is advantageous in that the wear on the resilient sleeves is substantially reduced over prior art devices employing resilient sleeves to form deformable chambers. Also, the use of the fulcrum means within the device allows the apparatus to be built with only a single point of engagement with the well bore. As explained, this is important inasmuch as the insertion into the well bore of tools which occupy too much of the annular opening between drill string and well bore interfere with the movement of drilling muds and other down-hole fluids thereby creating areas of static conditions. Static conditions in a well bore can, of course, lead to serious difficulties in the drilling operation.

While the two sets of chambers discussed, i.e., the receiving chambers 31 and the generating chambers 33 have been generally described in terms of being connected to the upper and lower ends respectively of the drill string, it is to be understood that this is by way of illustration only and that the chambers can be reversed depending on the use of the apparatus and of the magnitude of the force and exactly where it is desired to be exerted.

As will be clear from the above description, by preestablishing the radial relationship of the ports 34 to the receiving chambers 31, the resulting force on the drill string may be set in direct opposition to the direction of inclination of the well bore or in other directions as may be desirable in controlling the direction of the inclination. This arrangement offers the

added advantage that it regulates to some extent the rate of pressure build up by varying drill string rotation, i.e., mandrel 10, since pressure build up is a function of both mandrel eccentricity and rotating velocity.

I claim:

1. An apparatus for controlling the directional deviation of a well bore comprising a mandrel adapted to be made a part of a drill string having a bit attached thereto for rotation therewith in said bore, an outer member in surrounding spaced relation to said mandrel, means to maintain said outer member substantially stationary against rotation in said bore, means forming first and second sets of deformable pressure chambers located between said outer member and said mandrel, said first and second sets of chambers being axially displaced from each other, fulcrum means located between and in contact with said outer member and said mandrel whereby said mandrel can pivot relative to said outer member, and means for transferring fluid from said first set of pressure chambers to said second set of pressure chambers, said second set of chambers being circumferentially positioned about said mandrel to apply a force to move said mandrel and accordingly said string in a predetermined lateral direction when fluid is transferred under pressure from said first set of chambers to said second set of chambers.

2. The apparatus of claim 1 wherein said means to maintain said outer member stationary in said well bore comprises a plurality of circumferentially disposed longitudinally extending ribs attached to the outer surface of said outer member.

3. The apparatus of claim 1 wherein said means forming said first set of deformable pressure chambers comprises a resilient sleeve surrounding said mandrel, said resilient sleeve

having a plurality of circumferentially disposed longitudinally extending recesses on the outer surface thereof, said longitudinal recesses being generally parallel to said mandrel.

4. The apparatus of claim 1 wherein said means forming said second set of said deformable pressure chambers comprises a resilient sleeve sealingly engaged with said outer member along circumferentially spaced and longitudinally extending positions thereby forming a plurality of longitudinal chambers between said outer member and said resilient sleeve.

5. The apparatus of claim 1 wherein said fulcrum means comprises a swivel bearing assembly.

6. The apparatus of claim 5 wherein said swivel bearing assembly comprises a rigid annular sleeve secured to said mandrel and a seating means mounted on said outer member.

7. The apparatus of claim 1 wherein said means for transferring fluid from said first set of pressure chambers to said second set of pressure chambers includes a plurality of longitudinally extending passageways in said outer member.

8. The apparatus of claim 1 wherein said means for transferring said fluid includes a rotary pump means of which said first set of chambers form a part.

9. The apparatus of claim 8 wherein said first set of pressure chambers comprise the rotating element in said rotary pump means.

10. The apparatus of claim 9 wherein said means for transferring said fluid includes means for transferring said fluid into a preselected chamber in said second set of deformable pressure chambers.

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