July 10, 1962 B. M. McNEELY, JR 3,043,381

MEANS FOR CONTROLLING DIRECTIONAL DEVIATIONS IN A WELL BORE

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Fig. 1

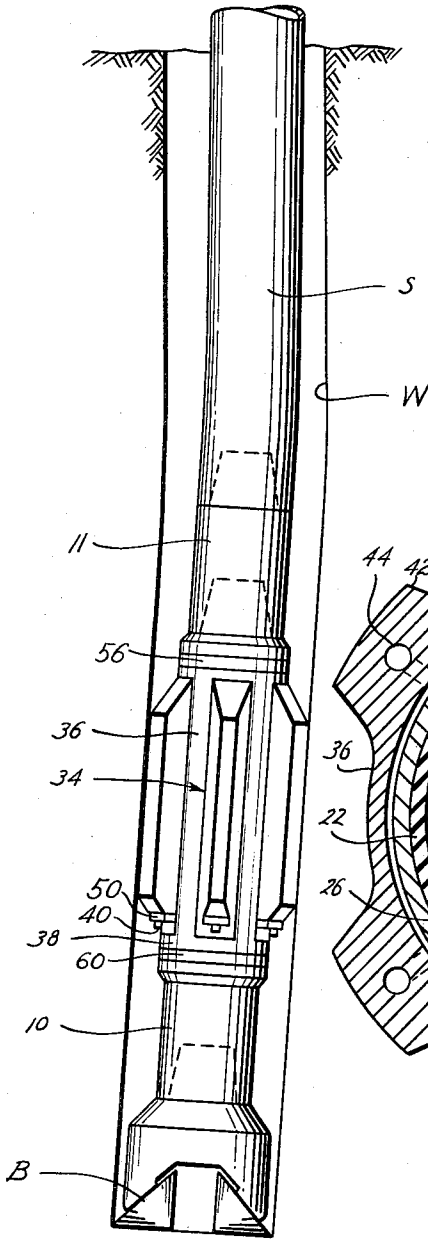
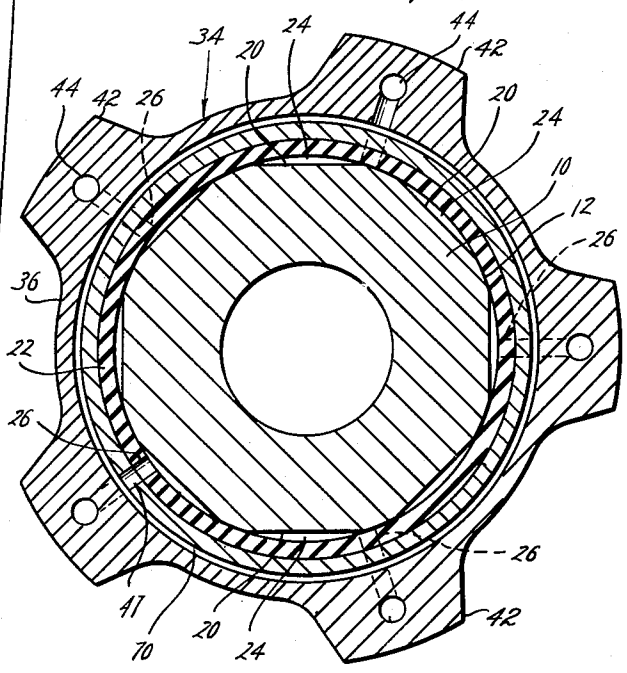


Fig. 3



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Fig. 2

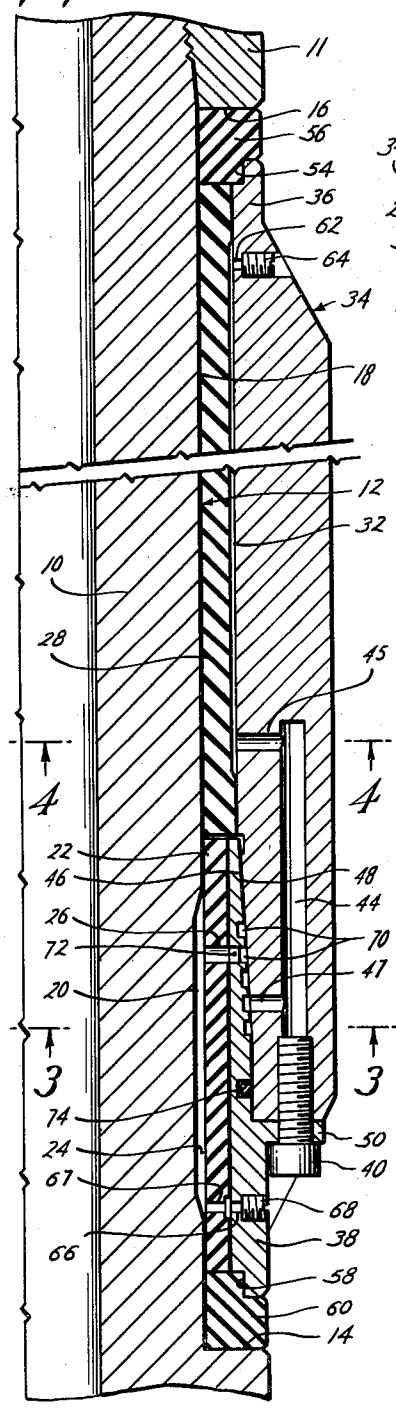


Fig. 4

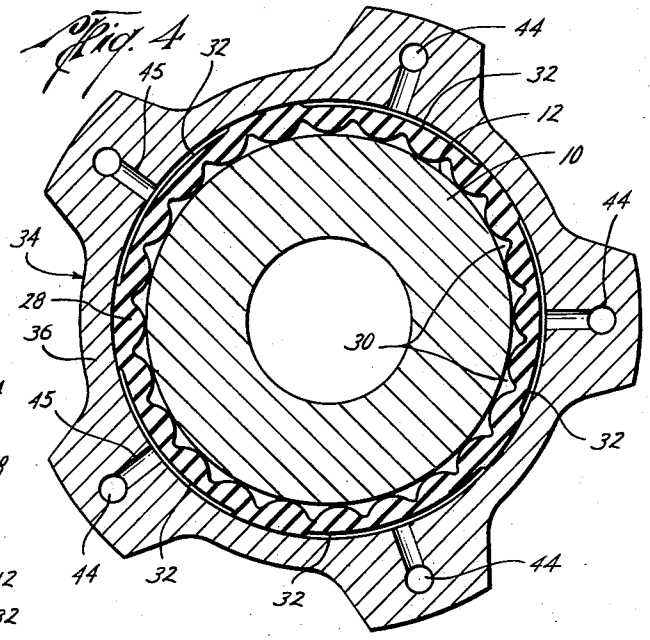
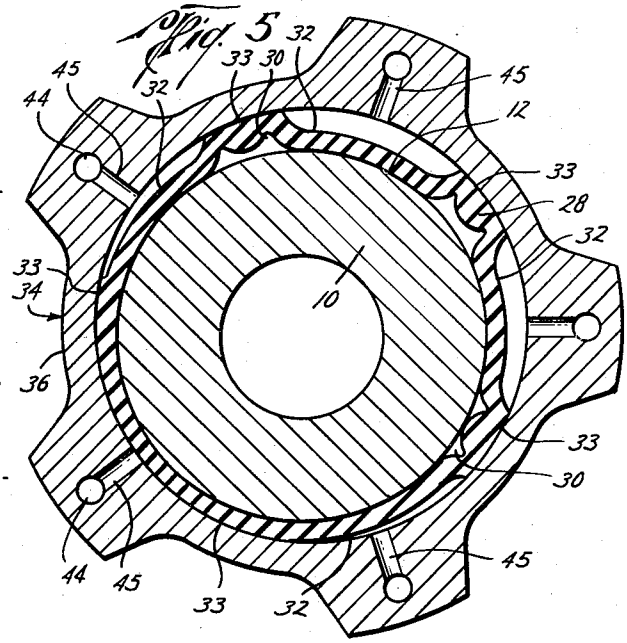


Fig. 5



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MEANS FOR CONTROLLING DIRECTIONAL DEVIATIONS IN A WELL BORE

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Fig. 7

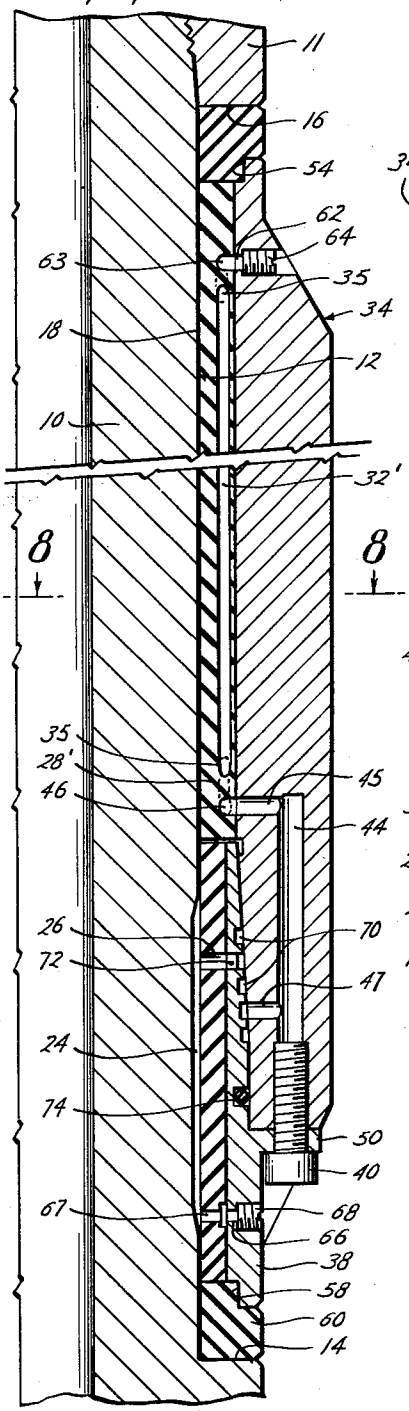


Fig. 8

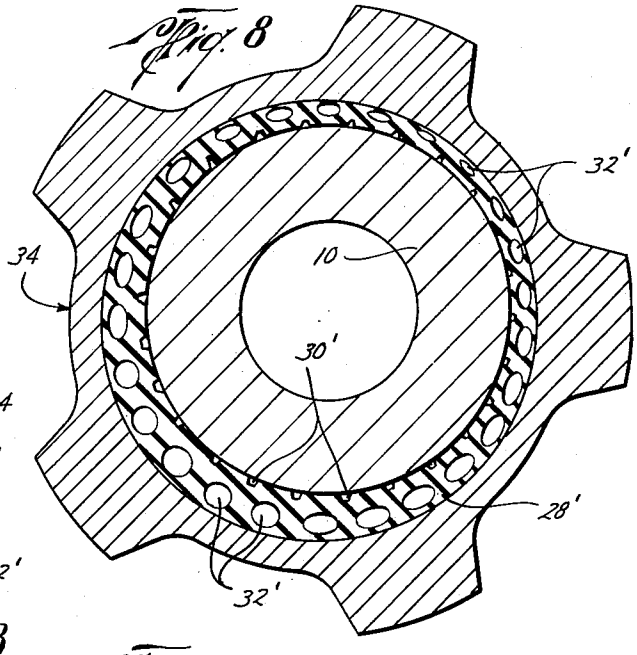
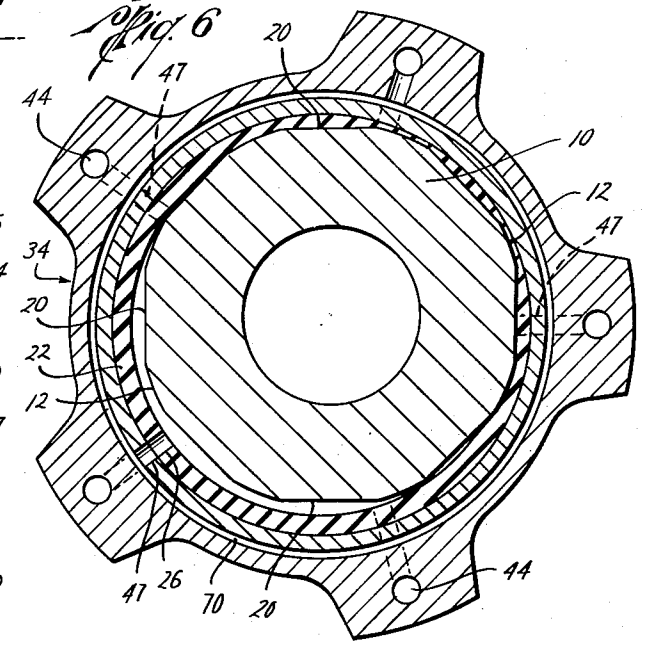


Fig. 6



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MEANS FOR CONTROLLING DIRECTIONAL DEVIATIONS IN A WELL BORE

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Fig. 9

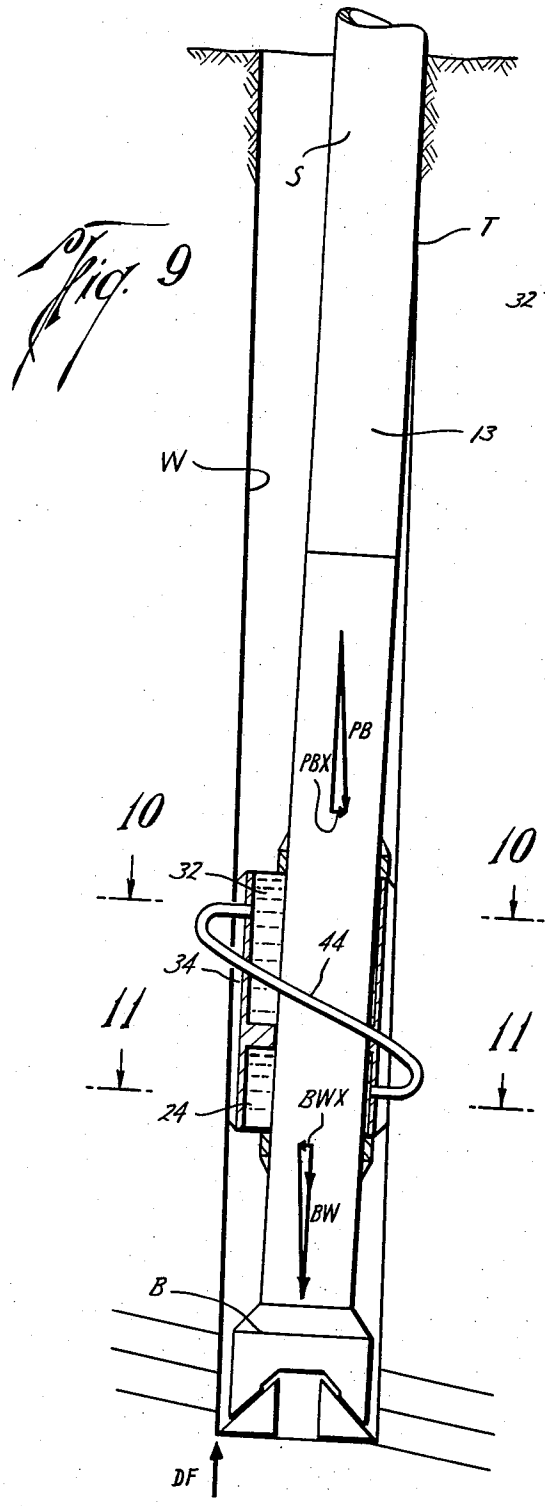


Fig. 10

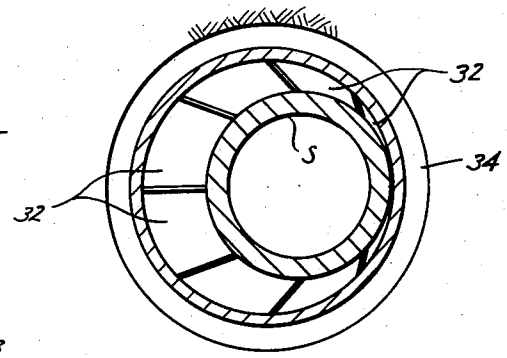
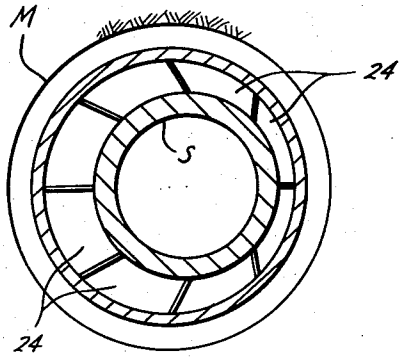


Fig. 11



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3,043,381

MEANS FOR CONTROLLING DIRECTIONAL DEVIATIONS IN A WELL BORE

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Filed May 5, 1960, Ser. No. 27,467
10 Claims. (Cl. 175—73)

The present invention relates to an apparatus for controlling directional deviations in a well bore and more particularly, relates to an apparatus for controlling vertical deviations of a well bore. The present invention is directed to an apparatus which maintains a well bore in vertical alignment and is also directed to an apparatus which may be used to control and direct the deviation of a well bore. This application is a continuation-in-part of my pending application for a Method of and Means for Controlling Directional Deviations in a Well Bore, filed June 25, 1956, Serial No. 593,632, now abandoned.

The present invention has as an important object the provision of an apparatus for directing the bit in a rotary drilling rig for either drilling a vertical or a directionally drilled well bore. The present invention might best be described generally with reference to a typical example of well deviation in rotary drilling including the forces acting on the bit to cause well bore deviation. As best seen in the diagrammatic FIGURE 9 a typical hook-up of a rotary drilling string ordinarily includes a drilling string S extending to the surface, drill collars 13 in the lower end of the drill string and a rotary bit B at the bottom. The bit generally utilized in rotary drilling has what are termed gauging surfaces on the outside flanks of the cutting teeth and will therefore drill sideways as well as vertically. Thus, if a net force or thrust is brought to bear against the bit in a direction other than the direction in which the bit is drilling, it will drill to the side.

It is generally accepted that a well bore drilled by conventional rotary methods deviates from the vertical primarily due to (1) formation characteristics (dip) and the column weight effect acting downwardly on the bit (bit weight).

That is, formations penetrated by a rotary bit are laminar in structure and are seldom in a horizontal plane, but are "dipped" and as a rock bit causes a fracture of the formation along its plane of shear the bit is caused to bear most heavily on the "up dip" side concentrating a force at this side of the bit as shown in FIGURE 9, as DF, which is termed "dip force." The result of this dip force is that the drill column is being unevenly supported and, since it is flexible to some extent, is bent and lies along the down dip side of the well bore down to a point which may be referred to as the tangency point T. The dip force acts on the drill bit and attempts to bend the bottom of the drill string about the tangency point T whereby the well hole deviates from the vertical.

Since "dip force" has caused uneven support of the bit, there is another force acting upon the bit causing deviation which is the weight of the drill string acting through the bit or drill string axis which may be referred to as the "bit weight force" BW. Since the bit axis as shown in FIGURE 9 is not aligned with the well bore axis there is a component of the bit weight force BWx acting at right angles to the bit axis to increase the angle of deviation. This component BWx is a function of the angle of incidence between the well bore axis and the lower drilling string or bit axis. Of course, if the drill string were perfectly centered in the well bore, this force would not exist. However, in a deviated well bore as shown in FIGURE 9, the well bore has deviated because of the dip force DF, and the

component of the bit weight force BWx acting at right angles to the axis of the drilling string has caused the well bore to further deviate from the vertical.

However, there is a force tending to offset the dip and bit weight forces which is the component of the drill collar weight or "plumb bob force" PB (FIGURE 9), PBx, and which acts at right angles to the axis of the drill string to return the drill bit to a vertical position. The plumb bob effect is a function of hole deviation and the weight of the drill string from the point of tangency T to the end of the drill bit. This plumb bob force acts at the center of gravity between these two points and in a vertical direction and when the hole is deviated as shown in FIGURE 9, there is a component of the plumb bob force, PBx, acting at right angles to the axis of the drill string to reduce the amount of deviation. Of course, to maintain a minimum of vertical deviation in drilling a well bore, the heaviest drill collars should be used to provide a maximum plumb bob force PBx and a minimum weight on the drill bit BWx should be used to reduce the forces tending to cause deviation. However, such a procedure would cause a low drilling rate and increase the possibility of sticking the drill string in the well bore because of the tight fit of the large drill collars.

The present invention is directed to an apparatus for generating a hydraulic force down hole and applying this hydraulic force against the lower end of the drilling string in a predetermined direction to direct the bit for either drilling a vertical or an oriented well bore as desired.

The present invention is directed to providing an outer tubular member 34 disposed about the drilling string, preferably about the drilling collars and above the bit, although it may be located elsewhere. A first set of circumferentially-spaced pressure chambers 24 is provided between the tubular member and the drill string in which hydraulic pressure is generated as the drill string lays against the low side of the deviated portion of the well bore and compresses certain of the first set of pressure chambers. A second set of circumferentially-spaced pressure chambers 32 is provided between the tubular member and the drill collars which chambers are of a larger area than those of the first set. Adjustable passages 44 are provided between the pressure chambers of each set so that as hydraulic pressure is generated in pressure chambers of the first set, this hydraulic pressure is succesively passed to successive pressure chambers of the second set in a predetermined relationship. Since the effective area of the second set of pressure chambers 32 is larger than that of the first set 24 the hydraulic force applied against the drill string by the second set overcomes the hydraulic force applied against the drill collars by the first set in generating this force. By providing a large enough effective area in the second set of pressure chambers the net hydraulic force applied against the drill collars is sufficient to overcome all forces acting on the drill bit and to direct the bit back to the vertical or to some other desired direction. It should be noted that the further that the well bore is deviated, and the further the drill string leans toward the low side of the hole, the greater is the pressure that is generated in the first set of pressure chambers. And it is noted that the maximum pressure is always generated at the low side of the well bore.

Thus, referring to the diagrammatic FIGURES 9, 10 and 11 and assuming that a well bore W has deviated from the vertical while drilling, a hydraulic pressure will be generated in the first set of circumferentially-spaced pressure chambers 24 on the low side of the deviated portion of the well bore caused by the drill string S compressing the pressure chambers 24 which are on the lower

side against the outer member 34. The pressure created in the first set of pressure chambers 24 may then be passed to the second set of pressure chambers 32 in a predetermined radial relationship as desired. For instance, if it is desired that the well bore be drilled in a true vertical axis the pressure from the first set of pressure chambers 24 is passed to the second set of pressure chambers 32 which are spaced 180° from the first set of pressure chambers through a connecting line 44 (here only a single line 44 is shown) thereby creating a force which acts to direct the bit back to a vertical position. On the other hand, if it is desired to change the direction of the deviation rather than merely decrease the deviation, the fluid pressure generated in the first set of pressure chambers 24 is passed to the second set of pressure chambers 32 at whatever radial direction was desired. It is therefore noted that in order to directional drill or to direct the deviation, the well bore must already be in a deviated position in order to have a low side to cause a generation of pressure in the first set of pressure chambers 24. And in that event the change of orientation of the direction of deviation of the well bore is then made with reference to the existing deviated position. However, when the present invention is used to insure the drilling of a vertical well bore the first and second set of pressure chambers are connected together at 180° and so long as the well bore is drilled vertically no pressure is generated in the generating set of pressure chambers and no correction force is generated or needed. However, as soon as the well bore starts to deviate from the vertical, pressure is automatically created in the generating pressure chambers 24 thereby creating a force in the second set of pressure chambers 32 which decreases the deviation and brings the axis of the bit back to a vertical position.

Therefore, the present invention is useful for any rotary drilling hookup in which the bit can cut on the side and is advantageously useful to direct the bit for either drilling a vertical or to directional drill a well bore.

A further important object of the present invention is to provide a means for directing a bit in a well bore which advantageously utilizes the low side of a portion of the well bore deviated from a vertical direction to obtain a force by which the bit is directed.

It is therefore a further object of the present invention to provide a bit director which is adapted to be inserted in a drilling string and which has first and second sets of pressure containers which are operable when the drill string deviates from the axis of the well bore to create a hydraulic force which can be utilized to regulate the magnitude and direction of deviation of the well bore during the drilling operation.

Another object of the present invention is to provide apparatus for directing a bit in a well bore by utilizing hydraulic pressure generated by a portion of the drilling string in a member surrounding the drilling string moving against a fluid container at the low side of a well bore deviated from a vertical direction and applying this hydraulic pressure against a large enough portion of the drilling string and at a desired angle to direct the bit where desired.

Still a further object of the present invention is the provision of an apparatus for correcting deviations from a true vertical in a well bore whereby when the drill string and a surrounding outer member are moved into a deviated well bore the drill string and outer member are moved toward each other at the low side of the deviated well bore thereby generating a hydraulic pressure at this point and then applying this generated hydraulic pressure between the drill string and the outer member over a sufficient area and in a direction which causes the bit to drill in a direction which decreases the angle of deviation.

Yet a further object of the present invention is the provision of a means for correction for deviations from the vertical in a well bore in which no hydraulic force is generated and applied to the drill string to change the direction of drilling of the bit until the well bore is deflected from a true vertical direction.

A still further object of the present invention is the provision of a means for directionally drilling a well bore which is deviated from the vertical by generating a hydraulic pressure between a portion of the drill string bearing against the low side of the deviated portion of the well bore and an outer tubular member surrounding this portion and applying this generated hydraulic pressure between the string and the member in a direction which causes the bit to move and drill a directional well bore in a desired direction.

Other and further objects, features and advantages will be apparent from the following description of presently preferred embodiments of the invention, given for the purpose of disclosure, and taken in conjunction with the accompanying drawings, where like character references designate like parts throughout the several views and where,

FIGURE 1 is a fragmentary elevational view, in cross-section of a portion of a well bore with a drilling string located therein and showing the present invention connected in the drill string in position to control the deviation of the well bore.

FIGURE 2 is an enlarged fragmentary elevational view, in cross-section, showing the details of construction of the present invention,

FIGURE 3 is a cross-sectional view, taken along the line 3—3 of FIGURE 2 showing the position of the parts when the apparatus of the present invention is coaxially aligned with the well bore and the well bore is vertical,

FIGURE 4 is a cross-sectional view, taken along the line 4—4 of FIGURE 2, showing the relationship of the operating parts of the upper pressure chambers when the apparatus is coaxially aligned in the well bore and the well bore is vertical,

FIGURE 5 is a view similar to that of FIGURE 4 showing the relationship of the parts and the tool is in operation to change the deviation in a deviated well bore,

FIGURE 6 is a view similar to that of FIGURE 3 showing the relationship of the parts of the lower pressure chambers while the tool is in operation in a deviated well bore,

FIGURE 7 is a view similar to that of FIGURE 2, illustrating a modified form of the invention,

FIGURE 8 is a cross-sectional view, taken along the line 8—8 of FIGURE 7 illustrating the relationship of the parts during the operation of the modified form of the invention,

FIGURE 9 is a diagrammatic view of the lower end of a string of pipe in a deviated well bore illustrating the various forces acting upon the string of pipe and illustrating the present invention in diagrammatic form acting to decrease the deviation of the well bore,

FIGURE 10 is a diagrammatic cross-sectional view taken along the line 10—10 of FIGURE 9, and

FIGURE 11 is a diagrammatic cross-sectional view taken along the cross-sectional line 11—11 of FIGURE 9.

Referring now to the drawings, and particularly to FIGURE 1, the apparatus of the present invention is illustrated herein in connection with its use in the drilling of well bores, such as for oil and gas wells, the invention being incorporated in a tubular drilling string S of conventional design having a conventional drill bit B. The invention is shown in FIGURE 1 positioned in the bore of a well W to regulate and control the direction of the bore during the drilling.

The apparatus of the present invention comprises a tubular body or mandrel 10, which may take the form of a section of drill pipe which is adapted to be threadedly connected at its upper end to the lower end of an upper section of the drilling string and its lower end to the bit B. While not shown in detail in FIGURE 1, the lower

portion of the drilling string S adjacent to the drill bit B generally includes a plurality of drill collars to add weight and stiffness to the lower end of the drill string.

Referring now to FIGURE 2, the body **10**, in the present illustration has an upper end portion **12** of reduced external diameter to form an external, annular, upwardly facing shoulder **14** on the body. The lower end of the upper section **11** of the string S forms a downwardly facing, external, annular shoulder **16** surrounding the body **10**.

The reduced portion of the body has an upper cylindrical external portion **18** below which a number of elongated, external, flattened portions **20** (FIGURES 2 and 3) are provided which are spaced apart peripherally about the exterior of the body in order to provide a hydraulic driving force as will be more fully described hereinafter.

A lower resilient sleeve **22** surrounds the body **10** and overlies the flattened areas **20** thereof and extends upwardly and downwardly beyond the flattened areas **20** to form fluid containers to provide lower enclosed pressure chambers **24** between the interior of the sleeve and each of the flattened areas **20** of the body. The sleeve **22** is formed of a resilient material, such as rubber, or the like, and has a number of openings **26** equally spaced around and through the periphery of the sleeve **22** and are thereby in fluid communication with the interior of the sleeve and thus the individual lower pressure chambers **24**. The openings **26** lead to the exterior of the sleeve and to individual upper pressure receiving chambers which will be more fully discussed hereinafter to transfer fluid pressure from the lower pressure chambers **24** to the upper pressure chambers when the body **10** is eccentrically pressed against the sleeve **22** thereby increasing the fluid pressure in certain of the lower chambers **24**.

Referring now to FIGURES 2 and 4, an upper resilient sleeve **28** is positioned above the lower sleeve **22** and surrounds the cylindrical portion **18** of the body and said sleeve is formed with internal longitudinal grooves or corrugations **30** and is provided with external recesses or pressure chambers **32** which are individually formed around the periphery of the upper sleeve **18**. The upper pressure chambers **32** are provided with a greater area than the lower pressure chambers **24** and as will be more fully discussed hereinafter, when certain of the upper pressure chambers or recesses **32** receive fluid pressure from certain of the lower pressure chambers **24**, the upper sleeve **18** is pressed against the body **10** exerting a thrust against the body **10** and the bit B to direct the bit in the desired direction (FIGURE 5).

A tubular outer member **34** surrounds the body **10** and the upper and lower sleeves **18** and **22**. The outer member **34** is made up of upper and lower elements **36** and **38**, respectively, which are secured together, as by means of bolts **40**. The outer member is rotatable about the body **10** and is provided with longitudinally extending external lugs **42** spaced apart about its periphery for frictional engagement with the well bore W to hold the outer member **34** against rotation in the bore.

Each lug **42** has a passageway **44** therein which opens at one end through a branch passageway **45** (FIGURE 4) into one of the upper pressure chambers **32** of the upper sleeve **28** and at its lower end through a side passageway **47** (FIGURE 3) into the exterior of the upper element **36** at a location opposite the lower sleeve **22**. The external surface of the upper sleeve **28**, which may be formed of rubber and the like, is bonded to the interior of the upper element **36** in any suitable manner as by vulcanizing or the like, at the locations **33** (FIGURE 5) between and completely surrounding the recesses or chambers **32**, to maintain these chambers separate from each other thus forming a series of circumferentially-spaced pressure chambers **32**.

The upper element **36** also has an internal tapering surface portion **46** (FIGURE 2) positioned for seating engagement with a similarly tapered external surface portion **48** of the lower element **38**, as best seen in FIGURE 2. The lower element **38** is fitted within the lower end portion of the upper element **36** and has extended external lugs **50** upon which the lower end of the element seats, which lugs are perforated to receive the bolts **40**, which are threadedly secured to the upper element.

The upper end of the upper element **36** has a counterbore **54** therein within which a seal forming member **56** is seated which is clampingly engaged between the end face **16** of the section **11** and the upper end of the element **36** to form a seal therebetween. The lower element **38** is also provided with a similar end counterbore **58** within which a similar seal forming member **60** is seated to form a seal between the lower element and the shoulder **14**. A filling opening **62** is formed in the upper element **36**, which is closed by suitable plug **64** and through which liquid may be introduced into the chambers **32**, passageways **44** and chambers **24** to fill the same, and a similar opening **66** is closed by a plug **68** which is provided in the lower element **38**, and which communicates with an opening **67** and a sleeve **22** leading into one of the chambers **24**.

The lower element **38** has a number of longitudinally-spaced, external, annular grooves **70**, and leading from each of these grooves the lower element has an opening **72** which is in communication with one of the openings **26**. Thus, a fluid communication is provided between the lower pressure chambers **24** and the upper pressure chambers **32**. At the same time, the rotational position of the upper element **36** may be adjusted relative to the lower element **38** in order to connect the lower fluid pressure chambers **24** with the desired upper pressure chambers **32**. Suitable packing, such as the O-ring **74**, located in an external groove provided therefor in the lower element **38** forms a fluid tight seal between the upper and lower elements between the external grooves **70**.

The apparatus of the present invention as described above is assembled by placing the member **60** on the body in engagement with the shoulder **14**, and the upper sleeve being placed in the member **36** and the lower sleeve **22** being in position in the member **38**. The upper and lower member elements of the tubular outer member **34** are then assembled with the sleeves so positioned therein, and the member **56** is positioned on the upper end of the upper element **36** and the upper end of the body is screwed into the lower end of the drill string section **11**. In assembling the two in this manner the lower element **38** may be positioned to establish communication between any selected one of the lower pressure chambers **24** and any one of the upper pressure chambers **32**, it being apparent that when the two are thus adjusted the remaining chambers **24** will also be in communication with corresponding ones of the upper pressure chambers **32**. It should be specifically noted that if each of the upper pressure chambers **32** are connected in communication with one of the lower pressure chambers **24** that is 180° from each of the upper pressure chambers **32** then the apparatus as connected will act to decrease any deviation in the well bore and thus insure that the well bore will be vertical (FIGURE 9). On the other hand, if each of the chambers **32** is connected in fluid communication with a lower pressure chamber **24** that is directly beneath or aligned with the chamber **32**, then the apparatus of the present invention will act to increase the deviation of the well bore (FIGURES 5 and 6). And of course if the upper chambers are connected to various lower chambers at other angles, the apparatus of the present invention will act to drill an oriented or directionally drilled well bore at an angle to the existing deviated well bore in the direction in which the pressure from pressure chambers **32** are exerted. The entire eystem, including the chambers **24**, chambers **32**

and the communicating passageways 44, is filled with a suitable liquid.

In operation, the apparatus of the present invention, constructed as described above, is connected into a drilling string in the manner illustrated in FIGURE 1, the outer diameter of the bit director or outer tubular member 34 being of a size closely corresponding to that of the interior of the well bore. Assuming that the well bore W deviates from the vertical and the direction and amount of deviation is known, the upper and lower elements 36 and 38 of the stabilizer member may be adjusted relative to each other to establish communication between the lower pressure chambers 24 and the upper pressure chambers 32 in a manner to cause liquid to be displaced from the lower pressure chambers 24 into the upper pressure chambers 32 in a desired sequence to cause the mandrel 10 in the bit B to be moved in the desired direction. Since the hole is assumed to be deviated from the vertical the string S will lie against the low side of the well bore at the tangency point T thus causing the mandrel 10, as best seen in FIGURE 6 to be eccentric in the well bore and pushing against the sleeve 22 and compressing and increasing the pressure in pressure chambers 24. Then as each of the lower pressure chambers 24 comes into communication with each of the passageways 26 during the rotation of the mandrel 10 relative to the stabilizer 34, the fluid in the pressure chambers 24 on the low side of the well bore will be compressed and flow out the passageways 26 on the low side so that the generated pressure will be supplied from these low pressure chambers 24 to the upper pressure chambers 32 as shown in FIGURE 5, and thus a large force is exerted against the mandrel 10 to direct the mandrel 10 and the bit B in the direction desired as the pressure chambers 32 have a much greater effective area than the lower pressure chambers 24.

Because of the flat surfaces 20 on the mandrel 10 (FIGURE 6) a pump is provided in which the flat surfaces rotate with the mandrel 10 and act as an impeller with the sleeve 34 acting as a stator. Thus as the chambers 24 rotate against the sleeve 26 at the low side, they entrap fluid and force it out the passageways 26 whereby more pressure is generated which is passed through the preselected exhaust port or passageway 26 which is directed to the communicating upper chamber 32 by which a directional force is applied against the mandrel 10 and the bit B. Thus, the drilling string S is rotated, hydraulic force is generated in successive lower chamber 24 at the lower side of the well bore and this hydraulic force is communicated to the preselected communicating upper pressure chamber 32 which effects a directional lateral force between the upper end of the mandrel 10 and the sleeve 34. It is noted that the upper pressure chambers 32 have more area than the lower pressure chambers 24 so that the net force applied against the drilling string S tends to move the drilling string S and the bit B in a desired direction. The effective area of the upper pressure chambers is sufficient so that the hydraulic force is applied over a sufficient area to overcome all forces tending to move the drilling string S and bit B in other than the desired direction.

In utilizing the apparatus of the present invention for drilling a straight hole, that is a well bore in a true vertical direction, the passageways, between parts 36 and 38 are set relative to one another so that the lower pressure chambers 24 and the upper communicating pressure chambers 32 are in fluid communication at 180° from each other (FIGURE 9, 10 and 11). Thus, when the well bore deviates from the true vertical direction, the sleeve 34 will engage the low side of the well bore and the lower part of the mandrel would be urged toward that low side thereby generating hydraulic pressure or force which is applied to the corresponding upper pressure chamber 32 at 180° which forces the drilling string S and the bit B to move in a direction 180° away from the deviation of the well bore and thus back to the vertical. Once the well bore has reached the vertical, no force is generated at any lower chamber 24 of a magnitude greater than the other chambers so that the mandrel 10 is maintained in a generally coaxial position with respect to the sleeve 34 until and if the well bore again tends to deviate. Thus, the apparatus of the present invention will automatically act to drill a straight hole and generate the necessary forces to compensate for any tendency of the well string S to deviate in the well bore.

In using the apparatus of the present invention for directional drilling, assuming there is an existing deviation of the well bore which is known, the passages between the parts 36 and 38 are set so that the desired angular relationship is provided between the lower pressure chambers 24 and the upper pressure chambers 32 in fluid communication therewith so that the lateral thrust which is to be exerted on the mandrel 10 by the upper pressure chambers 32 is properly oriented with relation to the existing deviation or low point in the well bore. Thus, as the low side of the well bore is engaged by the sleeve 34, the hydraulic force or pressure is generated in each successive lower chambers 24 as the drill string is rotated as previously described, which hydraulic force and pressure is applied in the selected upper pressure chamber 32 at a preset angle to the communicating lower chambers 24 thereby providing an effective force against the mandrel 10 in a desired direction and hence causing the bit B to directionally drill the well bore in a desired direction.

It should be noted that while the pressure chambers 24 and 32 have been designated as lower and upper chambers, respectively, that is by way of illustration only and the pressure generating chambers 24 can be located above or below the pressure receiving chambers 32 depending upon the use of the apparatus and of the magnitude of force that is desired to be produced. It is also noted that some of the chambers 32 are on the low side of the deviated portion of the well bore between the well bore W and the string of pipe and are compressed and thus also generate a hydraulic force. The hydraulic force created in chambers 32 is also applied to certain chambers 24 to move the drill string and bit in the same direction as the force that is transferred to certain chambers 32 from the chambers 24 that are on the low side thereby aiding in moving the bit in the desired direction. However, the force that is thus created in chambers 32 are transferred to chambers 24 is not as great as the force that is transferred from chambers 24 to chambers 32 because the effective area of the chambers 32 is greater than the effective area of chambers 24 and the transfer of pressure from chambers 32 to chambers 24 is a step down or reduction in mechanical advantage while the transfer from chambers 24 to 32 is a step up in mechanical advantage.

A somewhat modified form of the invention is illustrated in FIGURES 7 and 8, wherein the upper resilient sleeve 28' is provided with internal elongated pressure chambers 32', several of which may be connected in communication, as by being joined at their opposite ends, as indicated at 35 (FIGURE 7) to form internal pockets or pressure chambers at peripherally spaced intervals about the sleeve, each of which chambers or pockets is connected at one end in communication with one of the branch passageways 45, as indicated at 46, and at its other end in communication with a filling opening 62, as seen at 63. The upper sleeve may also be provided with internal longitudinal grooves 30' which serve the same purpose as the grooves 30 of the previously described form of the invention. By this construction the pockets or chambers of the upper sleeve 28' and the various passageways and the chambers 24 of the lower sleeve may be completely filled with liquid through the filling opening 62, which are then closed by the plugs 64.

Construction of this form of the invention is otherwise similar to that previously described and the operation of

the same takes place in a smiliar manner. In the operation of this modified form of the invention the liquid displaced from the chambers 24 within the lower sleeve 22 is delivered to the passageways 32' of the upper sleeve 28', in a desired sequence, depending upon the positions to which the upper and lower elements 36 and 38 have been rotated relative to each other, to cause the bit director member 34 to be canted relative to the axis of the mandrel 10, whereby the position of the mandrel 10 relative to the well bore would be adjusted to cause the force to be applied to the drilling bit B in a direction to change the direction of the well bore as desired.

It is obvious that many modifications could be made to the present invention and the invention has been disclosed herein in connection with certain specific embodiments of the same, but it will be understood that these are intended by way of illustration only and that various changes can be made in the construction and arrangement of the parts. For instance, the lower sleeve 26 may be modified similar to the modification of the upper sleeve 28' as illustrated in FIGURE 8 by providing internal elongated passages in that sleeve. Also, the flat face surfaces 20 on the mandrel 10 may be omitted and the mandrel in the lower sleeve 24 may then be merely circular in which case the pressure generated by the rotation of this mandrel would be caused merely by the mandrel 10 being eccentrically forced against the lower sleeve and compressing the fluid in the lower pressure chambers. In fact, either the lower or upper pressure chambers may be formed between the mandrel and a sleeve (FIGURE 6) between a sleeve and the outer member (FIGURE 5) or by internal elongated chambers (FIGURE 8).

It is believed that the operation of the invention is apparent from the foregoing description of presently preferred apparatus of the invention and is applicable for changing the direction of a bit B by utilizing the low side of a well bore when it deviates from the vertical. The method comprises broadly generating a hydraulic force or pressure downhole in a well bore having a portion deviating from the vertical on the low side of the well bore, and applying the generated pressure to the drill string thereby applying a force against the drill string and bit and moving the bit in the direction in which the force is applied. The method further comprehends generating a hydraulic force or pressure downhole in a well bore deviating from the vertical by confining hydraulic liquid within a generally tubular shaped outer member and a mandrel within the outer member when the mandrel is forced towards the low side of the well bore and thus the outer member and applying the generated hydraulic force between the mandrel and the outer member over a sufficient area to provide an effective force to direct the bit B in a desired direction. Thus, by simply varying the angle at which the hydraulic force generated is applied to another portion of the mandrel, the mandrel and bit B are moved in a preselected direction automatically to provide an automatic directing of the bit in the well bore W.

The apparatus of the invention is particularly advantageous in maintaining a well bore in a true vertical direction. In this aspect of the operation of the invention, the pressure generated between the mandrel and the outer member is directed between the mandrel and the outer member at another portion to force the mandrel and bit in a direction returning the drill string back to the vertical thereby causing an automatic redirecting of the well bore when it has deviated from the true vertical. Once the well bore is back at the true vertical, the mandrel will remain in a generally coaxial position with respect to the outer member and no hydraulic force or pressure greater than that generally surrounding the mandrel is generated. If the hole or well bore 10 deviates again from the vertical, the bit B is redirected as previously described.

The apparatus of the invention is also useful in directional drilling, that is drilling a bore hole in a predetermined direction. Under these circumstances, and assuming that the well bore has deviated from the vertical and the direction of deviation is known, the then effective hydraulic pressure generated between the mandrel and the outer member is applied to the mandrel and bit B thereby directing the bit in the desired direction.

Advantageously, both forms of the apparatus of the invention may be utilized in the methods of the invention.

The present invention, therefore is well adapted to carry out the objects and attain the ends and advantages mentioned as well as others inherent therein. While presently preferred embodiments of the invention are given for the purpose of disclosure, numerous changes in the details of construction, arrangement of parts and steps of the process may be made which will readily suggest themselves to those skilled in the art and which are encompassed within the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. An apparatus for controlling directional deviations of a well bore in combination with a rotatable drilling string and a bit attached to the string for rotation therewith in the bore comprising, an outer member in surrounding spaced relation to the string and shaped for frictional engagement with the wall of the bore, means forming first and second sets of peripherally-spaced resilient pressure chambers between and contacting said member and said string, said first and second sets being spaced axially from each other, said second set of pressure chambers having a larger effective area than those of said first set, and means for conducting fluid under pressure from the first set of pressure chambers to the second set of pressure chambers, said chambers in the second set receiving pressure from chambers in the first set being circumferentially positioned about said string to apply a force to move the string in a predetermined direction.

2. The invention of claim 1 wherein the means forming said first set of pressure chambers includes a plurality of flat surfaces on the exterior of said drilling string.

3. Apparatus for controlling directional deviations in a well bore in combination with a rotatable drilling string and a bit attached to the string for rotation therewith in the bore comprising, outer member means for surrounding the string and shaped for frictional engagement with the wall of the bore to hold the member against rotation in the bore, first and second sets of circumferentially-spaced fluid containers disposed between and contacting said sleeve and said outer member means, said first and second sets being spaced axially from each other, said first and second sets of fluid containers being resilient, said second set of pressure containers having a larger effective area than those of the first set, and fluid passageways connecting one each of the second set of pressure containers with the first set of pressure containers for conducting fluid under pressure between the first set of pressure containers and the second set of pressure containers, said second set of pressure containers being circumferentially positioned about said string to apply a force to move the string in a predetermined direction.

4. Apparatus for controlling directional deviations in a well bore in combination with a rotatable drilling string and a bit attached to the string for rotation therewith in the bore comprising, an outer generally tubular member rotatable about the drilling string, first and second sets of circumferentially-spaced fluid pressure containers disposed between and contacting said tubular member and said drilling string, said first and second sets of chambers being axially spaced from one another, said first and second sets of chambers being flexible, and fluid passageways connecting one each of said second pressure chambers with one each of the first set of pres-

sure chambers, said second set of fluid pressure containers having a larger area acting against the drilling string than those of the first set, said second set being circumferentially positioned relative to the first set to apply a force to move the drilling string in a predetermined direction.

5. An apparatus for controlling directional deviation in a well bore in combination with a rotatable drilling string in a bit attached to the string for rotation therewith in the bore comprising, an outer generally tubular member in surrounding spaced relation to the string and shaped for frictional engagement with the walls of the well bore to hold the member against rotation in the well bore, first and second sets of circumferentially-spaced fluid pressure containers disposed between said outer tubular member and said drilling string, said first and second sets being resilient and contacting said outer tubular member and said string, said first and second sets being spaced from one another, and fluid passageways connecting one each of the second set of fluid containers with the first set of fluid containers for conducting fluid from one set to the other set of fluid containers, said second set of fluid containers having a larger area in contact with the string and outer member than those of the first set, said second set of fluid containers being circumferentially displaced relative to the first set of fluid containers to apply a force to move the drilling string in a predetermined direction.

6. An apparatus for controlling directional deviations in a well bore in combination with a rotatable drilling string and a bit attached to the string for rotation therewith in the bore comprising, an outer tubular member in surrounding spaced relation to the string and shaped for frictional engagement with the wall of the bore to hold the member against rotation in the bore, sleeve means formed of resilient material disposed between said string and outer member, said sleeve means contacting the interior of said outer member as spaced points to form a first set of circumferentially-spaced pressure chambers, said sleeve means being sealingly engageable with said string at points axially-spaced from said first pressure chambers forming a second set of peripherally-spaced pressure chambers between said sleeve and said string, and means for conducting fluid under pressure from one each of the second set of pressure chambers to one each of the first set of pressure chambers, said second set of chambers being circumferentially positioned about the drilling string to apply a force to move the drilling string in a predetermined direction.

7. Directional drilling equipment for use in a well bore in combination with a rotatable drill string and a bit attached to the string for rotation therewith and the bore comprising, an outer tubular member in surrounding spaced relationship to the string and shaped for frictional engagement with the wall of the bore to hold the member against rotation in the bore, longitudinally-spaced sleeves formed of resilient material in said member, means forming peripherally-spaced pressure chambers between one of said sleeves and said string, the other of said sleeves having internal peripherally spaced fluid receiving chambers formed therein, and means for conducting fluid under pressure to each of said fluid receiving chambers from one each of said peripherally spaced pressure chambers, said fluid receiving chambers being circumferentially displaced from said pressure chambers to move the drilling string in a predetermined direction.

8. The invention of claim 7 wherein the means forming peripherally-spaced pressure chambers between one of the sleeves and such string includes a plurality of flat surfaces on the outer periphery of said string.

9. Directional drilling equipment for use in a well bore in combination with a rotatable drilling string and a bit attached to the string for rotation therewith in the bore comprising, an outer tubular member in surrounding spaced relation to the string and shaped for frictional movement with the well of the bore to hold the member against rotation in the bore, upper and lower sleeves formed of resilient material in said member, means forming peripherally-spaced pressure chambers between said lower sleeve and string, said upper sleeve having internal peripherally-spaced fluid receiving chambers formed therein, and means for conducting fluid under pressure from each of said pressure chambers to one of said receiving chambers, said receiving chambers being circumferentially positioned with reference to the pressure chambers to apply a force to move the drilling string in a predetermined direction.

10. A bit directing device for use in a rotatable drill string including a bit attached thereto for rotation in the well bore comprising, an outer generally tubular member rotatably disposed about the drilling string and adjacent the bit, first and second resilient sleeve members disposed between the outer member and said drill string, said first sleeve member sealingly engaging the interior of said outer member at a plurality of spaced points about its inner periphery thereby providing a first set of circumferentially-disposed pressure chambers, said second sleeve being sealingly engageable with said string at a plurality of points about the outer periphery of said string thereby forming a second set of circumferentially-disposed pressure chambers, said first and second sets being axially-spaced, said second set having a larger effective area than that of said first set, and passageway means connecting one each of said second set of pressure chambers with one of said first set of pressure chambers, said second set of pressure chambers being circumferentially displaced from the first set of pressure chambers to apply a force to move the drill string in a predetermined direction.

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