

Jan. 28, 1969

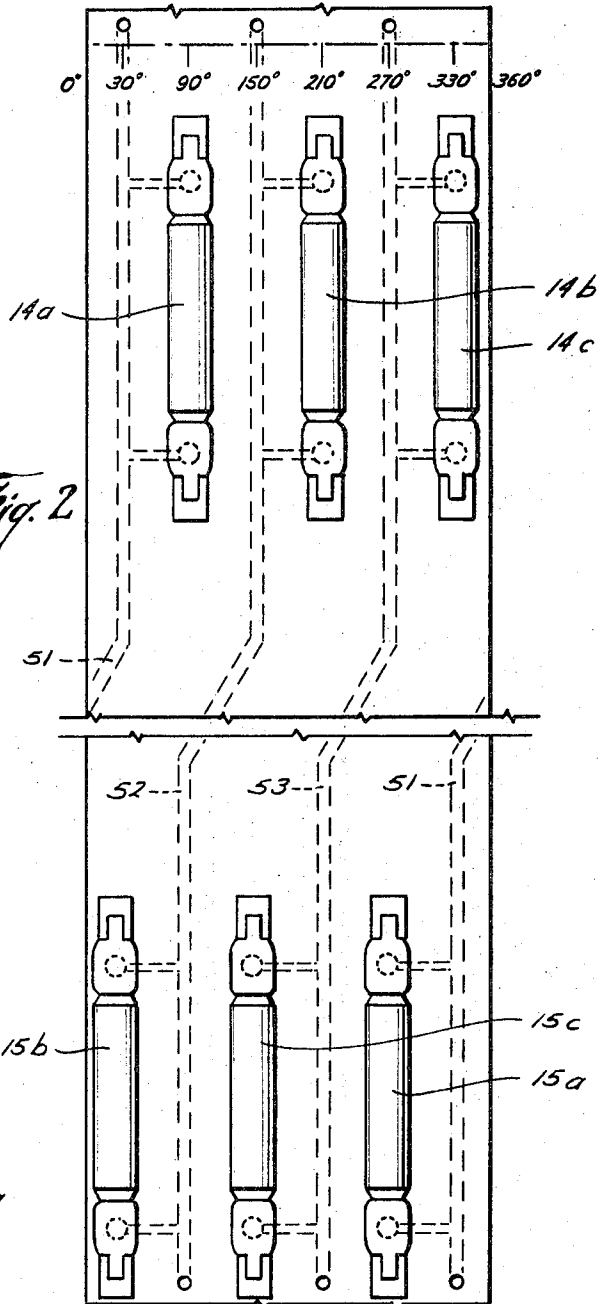
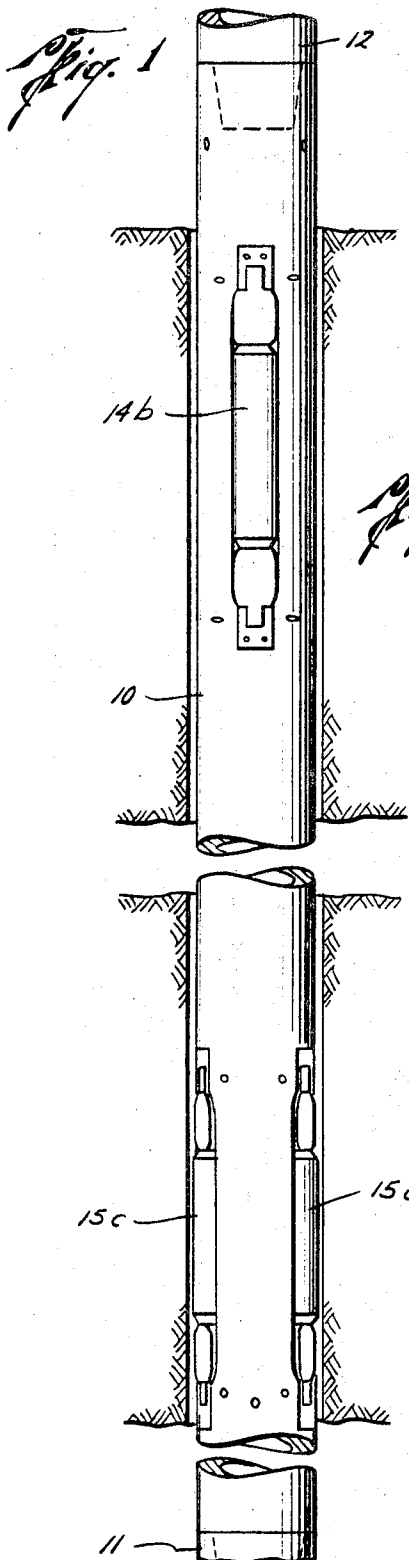
J. D. JETER ETAL

3,424,256

APPARATUS FOR CONTROLLING DIRECTIONAL DEVIATIONS OF A
WELL BORE AS IT IS BEING DRILLED

Filed Jan. 10, 1967

Sheet 1 of 5



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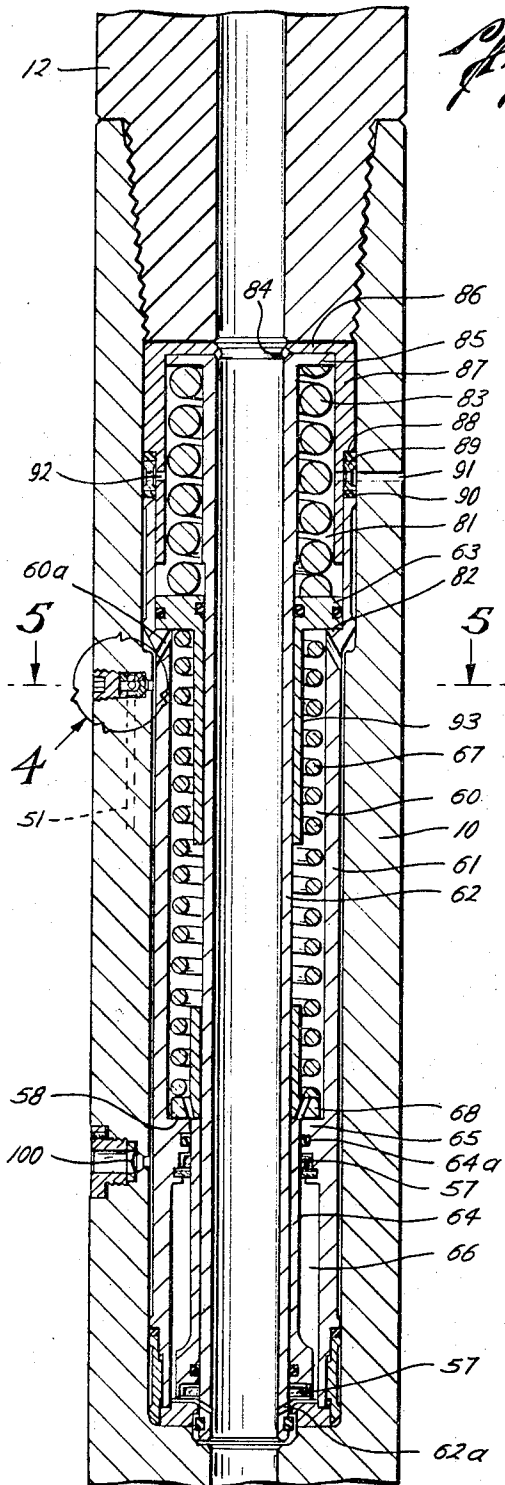


Fig. 3

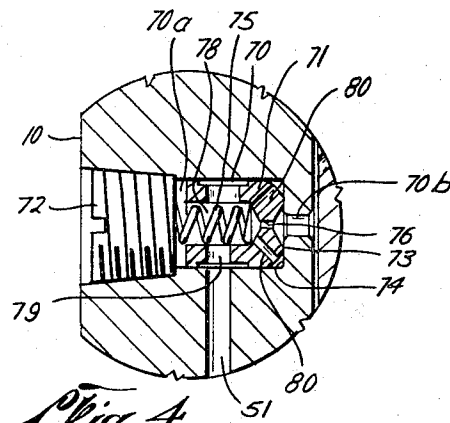


Fig. 4

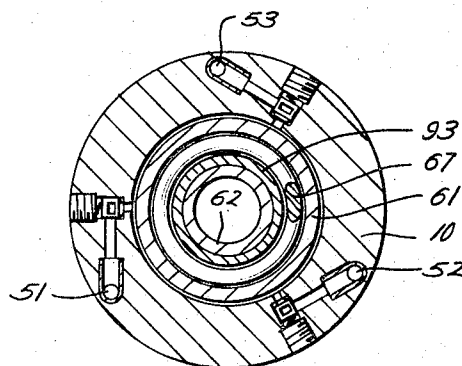


Fig. 5

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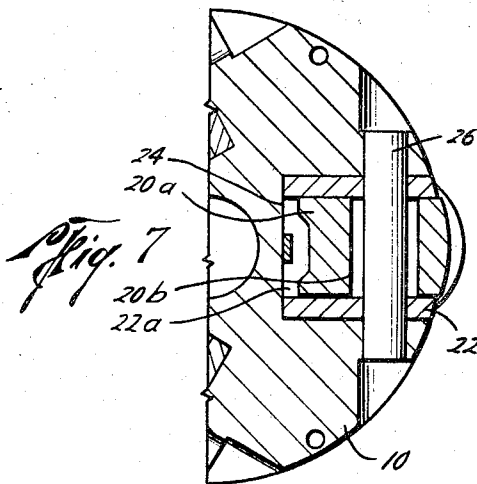
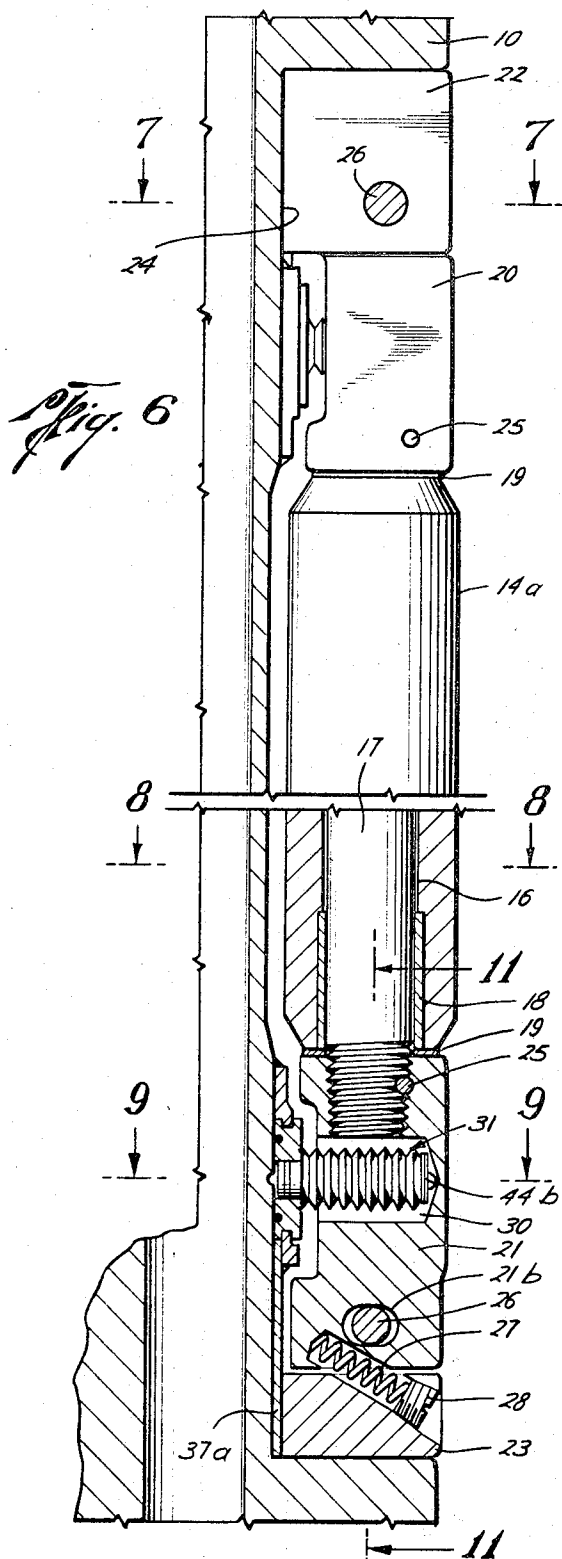
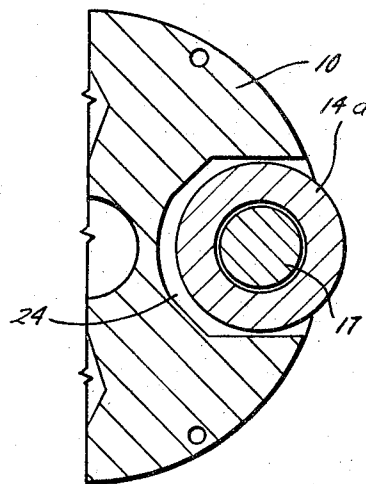


Fig. 8



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APPARATUS FOR CONTROLLING DIRECTIONAL DEVIATIONS OF A
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Fig. 9

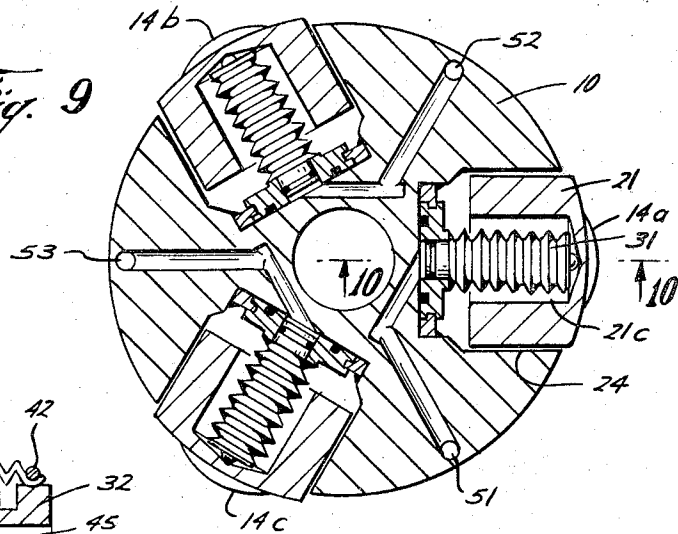


Fig. 10

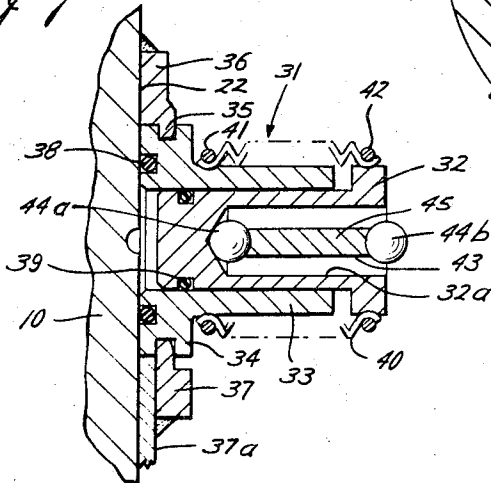


Fig. 11

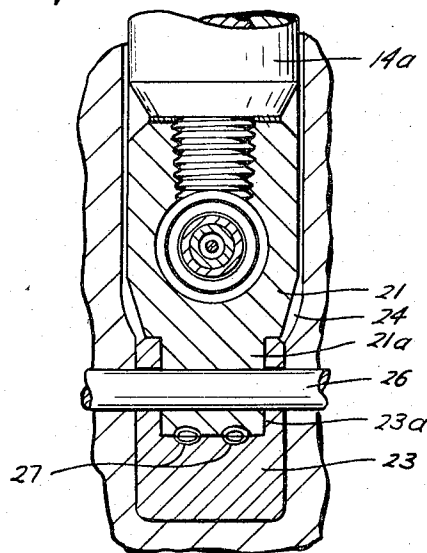
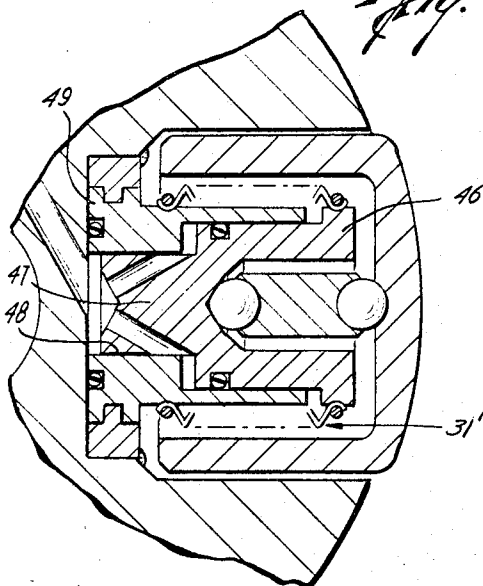


Fig. 12



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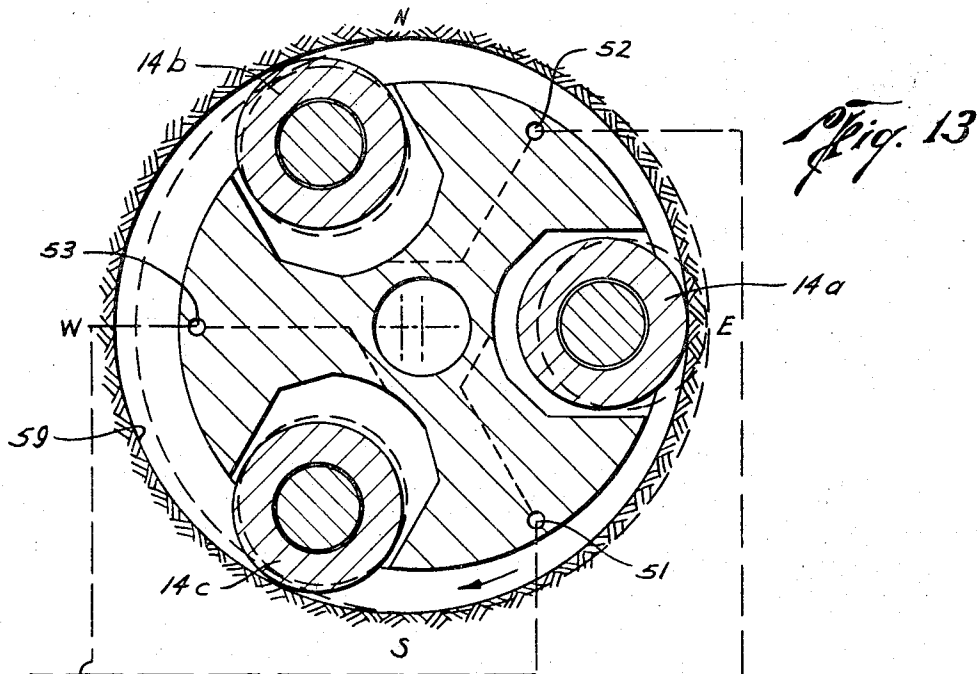


Fig. 13

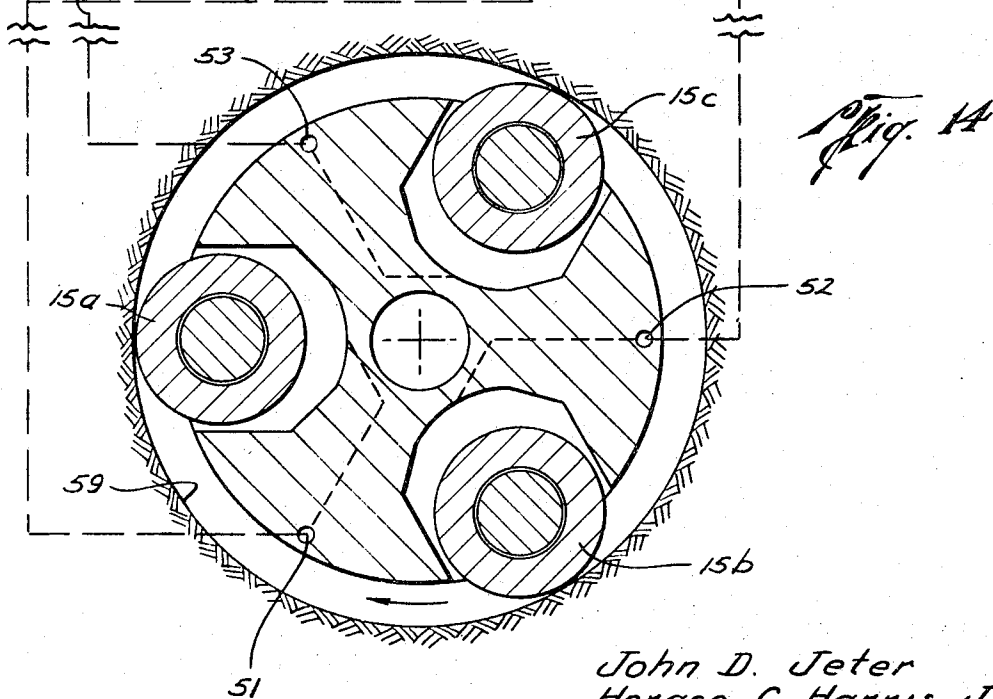


Fig. 14

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3,424,256

APPARATUS FOR CONTROLLING DIRECTIONAL DEVIATIONS OF A WELL BORE AS IT IS BEING DRILLED

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U.S. Cl. 175-76

18 Claims

Int. Cl. E21b 7/08, 3/12

ABSTRACT OF THE DISCLOSURE

An apparatus for controlling well bore directional deviations with upper and lower laterally movable borehole abutments which exert lateral force on the drill string in which they are incorporated. The force on the upper abutments is transmitted through a hydraulic system to the lower abutments. The hydraulic system has a higher pressure than the pressure of the drilling system and has a substantially constant volume between the abutments.

This invention relates generally to apparatus for controlling the direction taken by a well bore as it is being drilled and, in particular, to apparatus for exerting a lateral force on the drill string, adjacent the drill bit, to control or influence the direction taken by the drill bit as it drills a well bore.

In rotary drilling, a drill string is made up, usually, of a drill bit, drill collars located directly above the bit to provide the weight for forcing the bit against the bottom of the hole or well bore, and drill pipe that extends from the drill collars to the surface. When the well bore is inclined from the vertical, the drill string will lay against the wall of the well bore. Apparatus for employing the force exerted on the wall by the drill string to deviate the direction taken by the drill bit is described in U.S. Patent No. 3,092,188. The patent describes both a mechanical and a hydraulic system for utilizing this force.

In both systems, laterally movable upper abutment means are carried by the drill string to be forced against the wall of the well bore by the drill string, when the well bore is inclined from the vertical. Laterally moveable lower abutment means are carried by the drill string adjacent the bit and means are provided to transmit the force exerted on the upper abutment means to the lower abutment means. The lower abutment means then transmit the force to the wall of the well bore adjacent the bit thereby exerting a lateral force urging the bit to change its course through the earth.

In the hydraulic system, the force is transmitted to the lower abutment means through a closed hydraulic system charged with a given volume of hydraulic fluid. When the apparatus is lowered into a well bore filled with liquid drilling mud, the hydraulic system is subjected to the hydrostatic head of the mud, which tends to reduce the volume of the hydraulic fluid due to entrained compressibles. This reduces the distance the abutment means can be moved laterally, which reduces the effectiveness of the apparatus. Further, as the apparatus operates, some hydraulic fluid will leak from the system. This, coupled with the volume reduction due to hydrostatic pressure, greatly shortens the effective operating life of the apparatus.

It is an object of this invention to provide apparatus that employs a hydraulic fluid system to transmit to the lower abutment means the force exerted on the upper abutment means by the drill string lying against the wall of the well bore in which the hydraulic system is supplied with hydraulic fluid, while the apparatus is operating, that has a higher pressure than the pressure of the drilling fluid

in the well bore outside the pipe string to keep the system filled with hydraulic fluid even though it is subjected to high hydrostatic pressure and loses fluid due to leakage of fluid from the system.

It is another object of this invention to provide such apparatus with a hydraulic system of substantially constant volume between the abutment means, while the apparatus is operating, even though some hydraulic fluid leaks from the system and the fluid is subjected to high hydrostatic pressures.

It is another object of this invention to provide apparatus for exerting a lateral force on a drill string adjacent the drill bit that employs the pressure of the drilling fluid to maintain a substantially constant volume of hydraulic fluid between the upper and lower abutment means, while the apparatus is operating.

It is another object of this invention to provide apparatus for exerting a lateral force on a drill string adjacent the bit that employs the pressure drop between the inside and outside of the drill string at the apparatus, when drilling fluid is being pumped down the drill string and returned to the surface along the outside of the drill string, to maintain a force transmitting hydraulic connection between the upper and lower abutment means.

With a fixed volume of hydraulic fluid between the abutment means, as in the apparatus described in the above-mentioned patent, for the apparatus to function properly inward lateral movement of one abutment means moved the other abutment means outwardly. Thus, both abutment means could not be retracted completely or extended completely at the same time.

It is a further object of this invention to provide such apparatus in which both the upper and lower abutment means are retracted until drilling fluid is circulated down the drill string at a rate sufficient for drilling to begin, at which time both abutment means are moved to an extended position in engagement with the wall of the well bore.

It is another object of this invention to provide such apparatus in which the volume of hydraulic fluid between the abutment means will decrease, when the circulation of drilling fluid is stopped, allowing the abutment means to return to their retracted position.

It is yet another object of this invention to provide such apparatus in which a given pressure differential between the inside and outside of the apparatus above that produced during normal drilling operations will retract the abutment means.

These and other objects, advantages, and features of this invention will be apparent to those skilled in the art from a consideration of this specification, attached drawings, and appended claims.

The preferred embodiment of the invention will now be described in detail in connection with the attached drawings in which:

FIG. 1 is a view in elevation of the apparatus of this invention positioned in a well bore;

FIG. 2 is a schematic drawing illustrating the relative positions of the abutment means;

FIG. 3 is a vertical sectional view through the upper portion of the apparatus of FIG. 1;

FIG. 4 is a view, on an enlarged scale, of the portion encircled on FIG. 3 and indicated with the number 4;

FIG. 5 is a cross sectional view taken along line 5-5 of FIG. 3;

FIG. 6 is a view, on an enlarged scale, partially in elevation and partially in vertical section, one of the upper abutment means mounted on the body of the apparatus;

FIG. 7 is a sectional view taken along line 7-7 of FIG. 6;

FIG. 8 is a sectional view taken along line 8-8 of FIG. 6;

FIG. 9 is a sectional view taken along line 9—9 of FIG. 6;

FIG. 10 is a sectional view on an enlarged scale taken along line 10—10 of Fig. 9;

FIG. 11 is a sectional view taken along line 11—11 of FIG. 6;

FIG. 12 is a cross sectional view of the cylinder and piston arrangement employed to transmit the hydraulic pressure produced by the cylinder and piston arrangement of FIG. 10 to a lower abutment means;

FIG. 13 is a cross sectional view taken about midway between the ends of the upper abutment means with the apparatus lying against one side of the well bore; and

FIG. 14 is a view similar to FIG. 13 through the lower abutment means to illustrate the resultant force imposed on the drill string adjacent the bit.

By employing a hydraulic force transmitting connection between the upper abutment means and the lower abutment means, the force imposed on the upper abutment means can be applied laterally on the drill string adjacent the bit in any desired direction. In the embodiment shown, the apparatus of the invention is arranged as a hole straightener. In other words, the lateral force imposed on the drill string adjacent the bit will be in a direction to tend to move the bit toward the low side of the hole and toward a more vertical penetration of the earth.

The apparatus includes an elongated body 10 adapted to be made up in a drill string. In FIG. 1, the body is connected in a drill string between drill bit 11 and upper drill collar or other drill stem member 12. Mounted on the body in longitudinally spaced relationship are three upper abutment means comprising rollers 14a, 14b, and 14c and three lower abutment means comprising rollers 15a, 15b, and 15c. Rollers are preferred, however, other forms adapted to ride over irregularities in a well bore can be used.

Means are provided for mounting each abutment means on the body for independent lateral movement with respect to the longitudinal axis of the body beyond the periphery of the body for engagement with the wall of a well bore. All of the upper and lower abutment means are mounted on the body the same way so only one will be described in detail. The mounting of one of the upper abutment means, roller 14a, is shown in FIGS. 6, 9, and 11.

Roller 14a is provided with a longitudinally extending central opening 16 to receive shaft 17. The opening is enlarged adjacent each end of the roller to accommodate journals 18. Only the lower end of the roller is shown in section, so only one journal is shown, however, another is similarly positioned adjacent the upper end of the shaft. Thrust bearings 19 are located between the ends of roller 14a and roller end blocks 20 and 21. Shaft 17 is threadedly connected to the end blocks, which connection is staked by pins 25 to prevent further relatively rotation between the shaft and the blocks after the members are assembled.

The roller end blocks and roller assembly are mounted on the body by mounting blocks 22 and 23 for lateral movement relative to the longitudinal axis of body. The mounting blocks are located at opposite ends of longitudinal groove or recess 24 in body 10. The mounting blocks have slots 22a and 23a into which narrow portions 20a and 21a of the roller end blocks extend. The mounting blocks are held in recess 24 by pins 26, which extend through the blocks and an opening provided therefor in the body. The pins also extend through elongated openings 20b and 21b in portions 20a and 21a of the roller end blocks. The elongated openings in the roller end blocks allow the end block and roller assembly to move laterally between a retracted position within the periphery of the body and an extended position beyond the periphery of the body in engagement with the wall of the well bore. As shown in FIG. 11 and at the bottom of FIG. 6, two inclined holes are drilled through each

mounting block into the adjacent roller end block. A coil spring 27 is placed in each hole and compressed between the bottom of the hole and pipe plug 28 to urge the roller assembly toward its retracted position.

Hydraulically operated power means are associated with each abutment means for moving the abutment means laterally beyond the periphery of the body into engagement with the wall of a well bore. In the embodiment shown, the power means comprise two piston and cylinder assemblies. Each such assembly is attached to the bottom of a recess and extends into an opening in one of the roller end blocks, as shown in FIGS. 6 and 9. Thus, piston and cylinder assembly 31 is attached to the bottom of recess 24 and extends into opening 21c of block 21.

FIG. 10 is a vertical sectional view through piston and cylinder assembly 31. They are all of the same construction so only one will be described in detail. The assembly includes piston 32 and cylinder 33. The cylinder has outwardly extending annular flange 34 adjacent the end that engages the bottom of recess 24. The flange has an annular groove to receive protrusions 35 on hold down members 36. Three such hold down members are spaced 90° apart and welded to the bottom of the recess, as shown in FIGS. 9 and 10. The cylinder and piston assembly is mounted in the recess by sliding it into position between the three permanently attached hold down members. Removable hold down 37 is then moved into engagement with the annular groove on the cylinder flange at a position diametrically opposite from the middle permanently attached hold down member. The removable hold down has portion 37a that extends to the end of longitudinal recess or groove 24 and is held in position by mounting block 23, as shown in FIG. 6. Seal ring 38 seals the cylinder to the bottom of the recess.

Seal ring 39 is carried by the piston and is in sliding, sealing, engagement with the inner walls of the cylinder. To isolate seal ring 39 from drilling mud, bellows 40 has one end attached to the outside surface of the cylinder by snap ring 41. The other end is attached to the upper end of the piston by snap ring 42.

To prevent the torque on roller 14a from being transmitted to piston 32, force transmitting assembly 43 is provided. It consists of two ball bearings, 44a and 44b, which are connected together by spacer rod 45. Piston 32 is provided with a recess 32a into which a portion of the spacer extends. The recess has a drill point bottom, which is engaged by ball bearing 44a. Ball bearing 44b engages the drill point bottom of opening 30 in roller block 21.

As shown in FIG. 12, piston and cylinder assembly 31, which is used with the lower abutment means, is of the same construction as the assembly just described except that the cross sectional area of the piston and cylinder is enlarged. This increases the force acting against the wall of the well bore adjacent the bit over that with which the drill string forces the upper abutment member against the wall by the ratio of the areas of the two piston and cylinder assemblies. With such an increase in diameter, the piston is more likely to cock. Therefore, piston 46 is provided with extension 47, which is received in portion 48 of the bore of cylinder 49. Portion 48 of the cylinder bore is of reduced diameter to closely fit the outside diameter of extension 47 and guide the piston, as it moves in the cylinder bore.

Since the power means associated with the lower abutment members is of larger diameter, they will move a shorter distance for a given movement of their associated upper abutment member. The disadvantage of this is believed to be offset, however, by the increased force available for moving the bit.

Hydraulic fluid conduit means connect the hydraulically operated power means associated with each of the upper abutment means with the hydraulically operated power means associated with one of the lower abutment means to transmit a pressure increase in the power means

associated with the upper abutment means, when the upper means is forced against the wall of the well bore, to the power means associated with the lower abutment means to increase the force exerted by the lower abutment means on the wall of the well bore. As stated above, the apparatus in the drawings is designed for use as a hole straightener. Therefore, as shown in FIG. 2, the power means associated with each upper abutment means 14a-14c is connected by fluid conduit means to the power means associated with the lower abutment means that is located 180° from it. Thus, passageway 51 connects the power means associated with rollers 14a and 15a. Passageway 52 connects the power means associated with rollers 14b and 15b, and passageway 53 connects the power means associated with rollers 14c and 15c.

This is further illustrated in FIGS. 13 and 14. Shown in dotted lines in FIG. 13 is the position of a vertical well bore. Also shown in dotted lines are the positions that the upper abutment means, rollers 14a, 14b, and 14c would be in if the apparatus were operating in a vertical well bore. Well bore 59, however, is drifting to the west so the drill string is lying against its east side and roller 14a is being forced against this side. The force exerted by the drill string on roller 14a will depend upon the angle of inclination of the hole and the weight of the drill string adjacent this point of contact. Whatever the force, it will cause an increase in the pressure of the hydraulic fluid in the piston and cylinder assemblies associated with roller 14a. This increase in pressure will be transmitted through the fluid in passageway 51 to the power means associated with roller 15a and increase the force that such power means hold roller 15a against the west side of the well bore. The pressure in the power means associated with both rollers will be substantially the same, but since the effective area of the piston and cylinder assemblies of the lower abutment member is greater, a greater force is exerted against the wall of the well bore adjacent the bit than is exerted on roller 14a by the drill string. The two forces are in the opposite direction with the greater urging the bit toward the lower side of the hole and toward a vertical course through the earth.

As the drill string rotates, roller 14b will begin to be forced against the wall of the well bore by the weight of the pipe string. The force, in turn, will be transmitted by the hydraulic fluid in passageway 52 to roller 15b. The procedure is continued until the apparatus has exerted lateral forces on the drill string adjacent the drill bit long enough to cause it to again be drilling a vertical hole.

Means are provided for supplying the power means and conduit means with hydraulic fluid at a pressure above the pressure in the well bore externally of the body, while the drill bit is drilling, to hold the abutment means in engagement with the wall of a well bore and to keep the conduit means and power means filled with hydraulic fluid. In the embodiment shown, reservoir 60 of hydraulic fluid is connected to the power means through the fluid conduits connecting the power means. The reservoir, in this embodiment, is located in the upper section of body 10 as shown in FIG. 3. The reservoir comprises the annular space between outer sleeve 61 and inner sleeve 62. The bore of body 10, adjacent its upper end, is of increased diameter to receive the two sleeves without reducing the flow passage through the body. The increase in diameter of the bore forms shoulder 58 upon which rests the lower ends of the sleeves. Seals are located, as shown in FIGURE 3, to seal the sleeves to the body.

The sleeves form the outer walls of reservoir 60. Its ends are formed by movable pistons, at least in part. The upper end is formed by movable piston 63. The lower end is formed by the upper end of movable piston 64, along with inwardly extending annular flange 65 on sleeve 61. The flange is located well above the lower ends of the sleeves and carries one of the piston seals 64a to

allow the piston to move upwardly a considerable distance. Inner sleeve 62 is provided with openings 62a to admit fluid from the bore of body 10 to chamber 66 to act against piston 64. If the pressure inside body 10 and chamber 66 is greater than the pressure in reservoir 60, piston 64 will move upwardly until the pressure in the reservoir is equal to the pressure inside of body 10. Thus, the reservoir has a movable wall that will maintain the pressure in the reservoir equal to that inside the body.

Preferably, on the mud side of piston seals 64a and 64b wiper rings are located to wipe the surfaces before they pass by the seal rings to prolong their life.

Resisting the movement of piston 64 into reservoir 60 is coil spring 67 which is compressed between the pistons. Lower spring guide 68 engages the end of the piston and transmits the force of the spring to it. Since the piston has to overcome the force exerted by the spring, the pressure inside the reservoir is not quite equal to that inside the apparatus. Preferably, spring 67 has a relatively low rate, being sufficient only to force the piston back down to the position shown, when the pressures inside and outside the apparatus equalize.

The reservoir is connected to hydraulic fluid conduits 51, 52, and 53, each of which connect a pair of upper and lower abutment means, as shown in FIGS. 4 and 5. Each conduit is connected to the annular space between the outside of outer sleeve 61 and the inside of body 10 through lateral openings 70 in the side wall of body 10. Reservoir 60 is connected to the outside of outer sleeve 61 by a plurality of ports 60a. Thus, when the apparatus of this invention is being run into and out of the well bore, or at any time when the pressure inside of the body does not exceed the pressure outside sufficiently to compress spring 23, the rollers will remain in their retracted position. Before drilling is commenced, fluid is circulated down the drill pipe. Usually, there will be a sufficient pressure drop into the fluid as it passes through the drill bit to increase the pressure in the reservoir over outside pressure sufficiently to move the rollers outwardly into firm engagement with the wall of the well bore and to maintain a substantially constant volume of fluid in the hydraulic system between the power means for a given diameter well bore. Variations in well bore diameter will cause slight changes in the volume of fluid in the system. Any hydraulic fluid that leaks past the seals associated with the system will be replaced by the action of piston 64, which will keep a positive pressure in the hydraulic system substantially equal to that inside the drill string at the body. If the pressure drop through the bit is not sufficient, other flow restricting devices may be used.

When one of the upper rollers is forced against the wall of the well bore by the drill string, the pressure of the hydraulic fluid in the connecting conduit means may increase substantially. If this fluid pressure is transmitted to the reservoir, as well as to the power means associated with the lower abutment means, most of it would be absorbed in the reservoir by simply moving piston 64 and the desired force adjacent the bit would not be obtained. Therefore, means are provided for restricting the return flow of hydraulic fluid from the power means and conduit means to the hydraulic fluid supply means. In the embodiment shown, such means comprises the valve shown in FIGURE 4. Preferably, a check valve is not used. This would prevent the flow of fluid back to the reservoir completely and this would prevent the return of the abutment means to their retracted position, when the pressure differential is removed from across the apparatus. Therefore, a modified check valve is used.

As shown in FIG. 4, fluid conduit 51 is connected to reservoir 60 through opening 70, which extends through the wall of body 10. The mid portion of opening 70 is of increased diameter to form chamber 70a. The outer end of the chamber is closed by pipe plug 72. Check valve body 71 is located in chamber 70a. It has an annular ridge 73 on one end to engage shoulder 74 between

chamber 70a and port section 70b of opening 70. Coil spring 75 extends partially into recess 78 in the body and is compressed between the body and the pipe plug to hold the annular ridge in engagement with the shoulder. The ridge and the shoulder do not necessarily form a fluid tight seal, but one that would greatly restrict the flow of fluid therebetween. The valve body has a small central opening 76 in alignment with port 70b. Fluid can flow from the reservoir through port 70b and opening 76 into passageway 51 at all times. Opening 76, however, is small enough that when a pressure surge hits the hydraulic fluid in fluid conduit 51, most of the pressure will be transmitted to the power means associated with the lower abutment means and provide the force desired, before the pressure can be depleted through opening 76. Thus, the valve restricts the flow of hydraulic fluid from the power means to the reservoir, but doesn't stop it altogether.

When hydraulic fluid is being transferred from the reservoir to the fluid conduits, the flow of hydraulic fluid will compress spring 78 moving the annular ridge 73 away from shoulder 74. Hydraulic fluid can then flow freely through the plurality of ports 80 located on the other side of the ridge from port 76 and into passageway 51 through lateral openings 79.

There may be occasions when it is desirable to retract the abutment means, even though a pressure differential exists between the inside and outside of the apparatus. In other words, it may be desirable to continue circulating but to have the abutment means retracted. Means are provided to accomplish this by increasing the volume of the reservoir with an increase in pressure differential across the body of the apparatus of a given amount. This increase in volume of the reservoir will allow the pressure in the reservoir to decrease sufficiently to retract the abutment members, even though a pressure differential does exist between the inside and outside of the body 10.

In the embodiment shown, piston 63 forming the upper wall of reservoir 60 is held against upwardly facing shoulder 82 of outer sleeve 61 by coil spring 83.

Above piston 63, annular pressure chamber 81 is provided that is open to the pressure outside of the body. The inside of the chamber is formed by the upper portion of inner sleeve 62. The upper end of the inner sleeve is provided with outwardly extending flange 85, that abuts flange 86 on a short stub sleeve 87. This stub sleeve extends to a point adjacent the upper end of outer sleeve 61 where it is reduced in diameter to extend into the outer sleeve a short distance and to provide shoulder 88. Between the upper end of sleeve 61 and shoulder 88 is perforated ring 89. On each side of the ring are pressure seals 90. Opening 91 extends laterally through the wall of the body to connect the outside of the body to the space between the seals. Opening 92 extends through sleeve 87 at the ring to connect the space between the seals to the chamber and admit outside pressure to the top side of piston 63.

Piston 63 is then urged away from shoulder 82 by the pressure differential between the reservoir and the outside of the body plus the force of spring 67 as it is compressed by piston 64. Coil spring 83 is designed to hold piston 63 against movement by these forces as long as the pressure differential across the piston doesn't exceed that produced by normal drilling operations. The spring is designed to be compressed, however, when the pressure differential reaches a given amount, preferably, an amount well above the exceeded operating differential. When this pressure differential exists, piston 63 will move away from shoulder 82. This piston has an area larger than piston 64 so the volume of the reservoir will increase as it moves even though piston 64 moves with it, which it will do, of course. In fact, piston 64 will move further than piston 63 in the beginning. For as the volume of the reservoir increases, piston 64 will move toward piston 63. It will

do this until annular spring guide 68 engages the lower end of spring guide 93, which is integrally attached to piston 63. Up until this occurs, the pressure in the reservoir is equal to the pressure inside body 10 and the rollers are extended. Now further movement of the pistons reduces the pressure in the reservoir allowing the rollers to retract. The pressure differential required to obtain this further movement is greater than is required to move the piston into engagement, however, due to the reduction in area over which the pressure inside the body is acting. Therefore, the pressure differential required is that which can act over the smaller area of piston 64 and move piston 63 against the pressure outside and the force of spring 83.

Such an increase in pressure differential may result from a decrease in the annular flow area between the drill string and the well bore below the upper end of the apparatus. This is most likely to occur when the drill string is stuck or about to be come stuck in the well bore close to the bottom. At this time, of course, it is very desirable to retract the rollers, without having to stop the circulation of drilling fluid. Other means can be used to increase the pressure differential, such as increasing the volume of fluid pumped, its viscosity, and increasing the restriction to flow of the fluid in the drill string below the reservoir.

If for some reason the pressure in the reservoir becomes excessive, pressure rupturable disc 100 is mounted in the side wall of the body. One side of the disc is exposed to the pressure in the reservoir and the other side to the pressure externally of the body. This disc can be designed to rupture at any desired differential pressure. When it does, of course, the hydraulic fluid will be lost from the reservoir and the abutment means will be retracted by the springs associated therewith.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. Apparatus for exerting a lateral force on a drill string adjacent the drill bit to control directional deviation of a well bore, comprising, an elongated body adapted to be made up in a drill string adjacent a drill bit, upper abutment means and lower abutment means, means mounting the abutment means on the body in longitudinally spaced relationship for independent lateral movement with respect to the longitudinal axis of the body beyond the periphery of the body for engagement with the wall of a well bore, hydraulically operated power means associated with each abutment means for moving the abutment means laterally beyond the periphery of the body into engagement with the wall of a well bore, hydraulic fluid conduit means connecting the hydraulically operated power means for transmitting the pressure increase in the power means associated with the upper abutment means, when the upper abutment means is forced against the wall of a well bore, to the power means associated with the lower abutment means to increase the force exerted by the lower abutment means on the wall of a well bore, means connected to the power means for supplying the power means with hydraulic fluid at a pressure above the pressure in the well bore externally of the body, while the drill bit is drilling, to hold the abutment means in engagement with the wall of a well bore and to keep the conduit

means and the power means filled with hydraulic fluid, and means for restricting the return of hydraulic fluid from the power means and conduit means to the hydraulic fluid supplying means.

2. The apparatus of claim 1 in which the means for supplying hydraulic fluid under pressure to the power means includes, a reservoir of hydraulic fluid carried by the body and having one movable wall exposed to the pressure inside the body to keep the pressure of the hydraulic fluid in the reservoir substantially equal to the pressure in the body, and means connecting the power means and conduit means to the reservoir.

3. The apparatus of claim 2 further provided with means for resiliently urging the abutment means laterally toward the longitudinal axis of the body.

4. The apparatus of claim 3 further provided with resilient means to resist the pressure imposed on the moveable wall of the reservoir by the pressure in the body to urge the wall in a direction to increase the volume of the reservoir and allow the resilient means associated with the abutment means to move them laterally toward the longitudinal axis of the body.

5. The apparatus of claim 2 in which the hydraulically operated power means associated with each abutment means comprises a hydraulic cylinder, a piston mounted for reciprocation in the cylinder, and means attaching one of the piston and cylinder to the associated abutment means and one to the body.

6. The apparatus of claim 5 in which the abutment means includes an elongated roller for engaging the wall of a well bore and means for mounting the roller for rotation around its longitudinal axis with said axis parallel to the longitudinal axis of the body and for movement laterally of the body.

7. The apparatus of claim 6 in which both the upper and lower abutment means includes an equal number of said rollers equally spaced around the exterior of the body with the rollers of the lower abutment means positioned so each roller is located on the body diametrically opposite one of the rollers of the upper abutment means and in which the fluid conduit means connect the power means of each pair of diametrically opposed rollers to each other and to the reservoir to allow pressure changes in the hydraulic fluid to be quickly transmitted between the power means, and in which said flow restricting means separately restricts the flow of fluid from the conduit means connecting each pair to the reservoir so the transmission to any other connected pair or to the reservoir of an increase in pressure in the conduit means of one diametrically opposed pair of power means will be delayed.

8. The apparatus of claim 2 further provided with means for increasing the volume of the reservoir when the pressure inside the body exceeds the pressure outside by a predetermined amount to reduce the pressure in the reservoir to allow the abutment means to be moved laterally toward the axis of the body.

9. The apparatus of claim 8 in which the reservoir volume increasing means includes a second movable wall on the opposite side of the reservoir from the first movable wall and having a larger area than the first wall, means resiliently holding the second movable wall from movement away from the first wall, and means for moving the second wall with the first wall after the first wall has moved a predetermined distance toward the second.

10. Apparatus for exerting a lateral force on a drill string adjacent the drill bit to control directional deviation of a well bore, comprising, an elongated body adapted to be made up in a drill string adjacent a drill bit, a plurality of upper abutment means spaced circumferentially about the side exterior surface of the body and a plurality of lower abutment means spaced circumferentially about the side exterior surface of the body in longitudinally spaced relationship from the upper abutment means, means mounting the abutment means on the body for independent

ent lateral movement with respect to the axis of the body between an extended position beyond the periphery of the body for engagement with the wall of a well bore and a retracted position nearer to the longitudinal axis of the body, hydraulically operated power means associated with each abutment means for moving the abutment means laterally to said extended position beyond the periphery of the body into engagement with the wall of a well bore when supplied with hydraulic fluid of higher pressure than the pressure in the well bore outside the body, hydraulic fluid conduit means connecting the power means associated with each upper abutment means to the power means associated with one of the lower abutment means for transmitting pressure changes between said power means, a reservoir of hydraulic fluid carried by the body, said reservoir having one movable wall exposed to the pressure inside the body to transmit the pressure inside the body to the hydraulic fluid in the reservoir to urge the abutment means toward their extended positions outwardly against the wall of the well bore when the pressure inside the body exceeds the pressure outside the body, means separately connecting each connected pair of power means with the reservoir, and means for restricting the flow of hydraulic fluid from each connected pair of power means back to the reservoir whereby in use a lateral force exerted by the drill string on one of the upper abutment means will cause a corresponding increase in the hydraulic pressure in its associated power means which is transmitted through the connecting conduit means to the power means associated with one of the lower abutment means to cause the lower abutment means to exert a lateral force on the wall of the well bore adjacent the drill bit that is proportional to the lateral force being exerted on the upper abutment means.

11. The apparatus of claim 10 further provided with resilient means urging the abutment means to their retracted position.

12. The apparatus of claim 11 further provided with resilient means urging the movable wall of the reservoir in a direction to increase the volume of the reservoir to permit the resilient means associated with each abutment means to move the abutment means to their retracted positions.

13. Apparatus for exerting a lateral force on a drill string to control directional deviation of a well bore comprising an elongated body adapted to be made up in a drill string adjacent a drill bit, a plurality of abutment means spaced circumferentially around the body, means mounting the abutment means on the body in circumferentially spaced relationship for independent lateral movement with respect to the longitudinal axis of the body beyond the periphery of the body for engagement with the wall of a well bore, hydraulically operated power means associated with each abutment means for moving the abutment means laterally beyond the periphery of the body into engagement with the wall of a well bore, means connected to the power means for supplying the power means with hydraulic fluid at a pressure above the pressure in the well bore externally of the body, while the drill bit is drilling to hold the abutment means in engagement with the wall of a well bore, conduit means for connecting the power means to the hydraulic fluid supplying means and means for restricting the return of hydraulic fluid from the power means to the hydraulic fluid supplying means.

14. The apparatus of claim 13 in which the means for supplying hydraulic fluid under pressure to the power means includes, a reservoir of hydraulic fluid carried by the body and having one movable wall exposed to the pressure inside the body to keep the pressure of the hydraulic fluid in the reservoir substantially equal to the pressure in the body, and means connecting the power means and conduit means to the reservoir.

15. The apparatus of claim 14 further provided with

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means for resiliently urging the abutment means laterally toward the longitudinal axis of the body.

16. The apparatus of claim 15 further provided with resilient means to resist the pressure imposed on the movable wall of the reservoir by the pressure in the body to urge the wall in a direction to increase the volume of the reservoir and allow the resilient means associated with the abutment means to move them laterally toward the longitudinal axis of the body.

17. The apparatus of claim 14 in which the hydraulically operated power means associated with each abutment means comprises a hydraulic cylinder, a piston mounted for reciprocation in the cylinder, and means attaching one of the piston and cylinder to the associated abutment means and one to the body.

18. The apparatus of claim 17 in which the abutment means includes an elongated roller for engaging the wall

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of a well bore and means for mounting the roller for rotation around its longitudinal axis with said axis parallel to the longitudinal axis of the body and for movement laterally of the body.

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