United States Patent

[11] 3,627,356

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[45] Patented **Dec. 14, 1971**

[54] **DIRECTIONAL DRILLING APPARATUS WITH RETRIEVABLE LIMITING DEVICE**
23 Claims, 13 Drawing Figs.

[52] **U.S. Cl.** **285/118,** 175/61
[51] **Int. Cl.** **E21b 7/08,** F16l 27/04
[50] **Field of Search** 175/61, 73–76, 256; 285/118

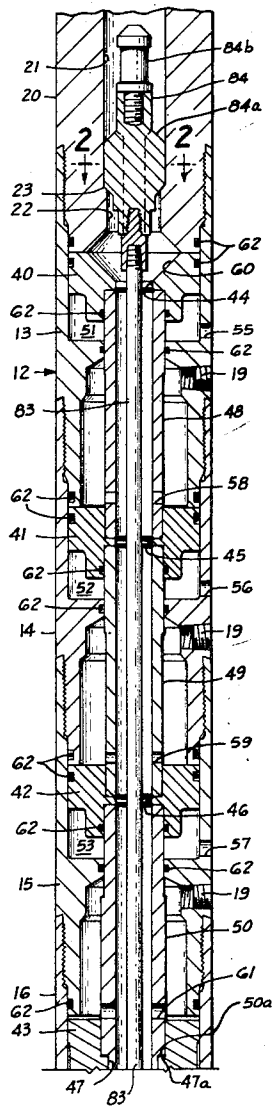
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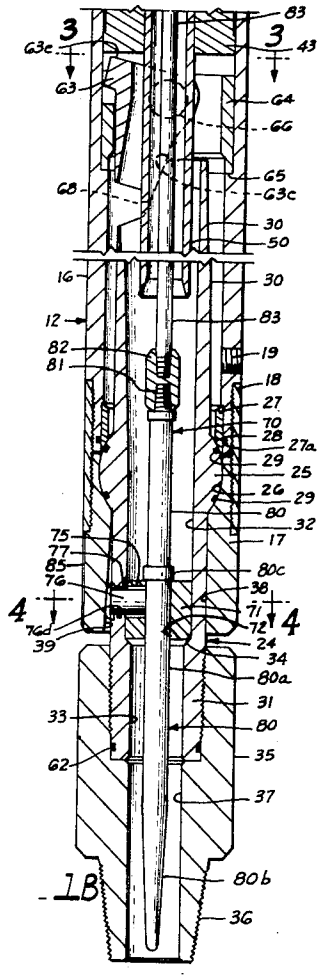
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ABSTRACT: A deflection tool is provided for use in the directional drilling of a well bore into the earth. The tool includes a lower tubular assembly pivotally mounted within an upper tubular assembly. I use, the upper assembly is coupled to the lower end of a string of drill pipe and the lower assembly is coupled to a downhole fluid motor unit which drives a rotary drill bit. Drilling fluid flowing down the drill string drives a piston and lever mechanism located in the upper tubular assembly for urging the lower tubular assembly to pivot relative thereto. when a zero or other less than maximum pivot angle is desired, a retrievable limiting probe is run into the deflection tool for setting a limiting plug which limits the extent of the pivotal movement. Different pivot angles are obtained by using limiting probes of different size.





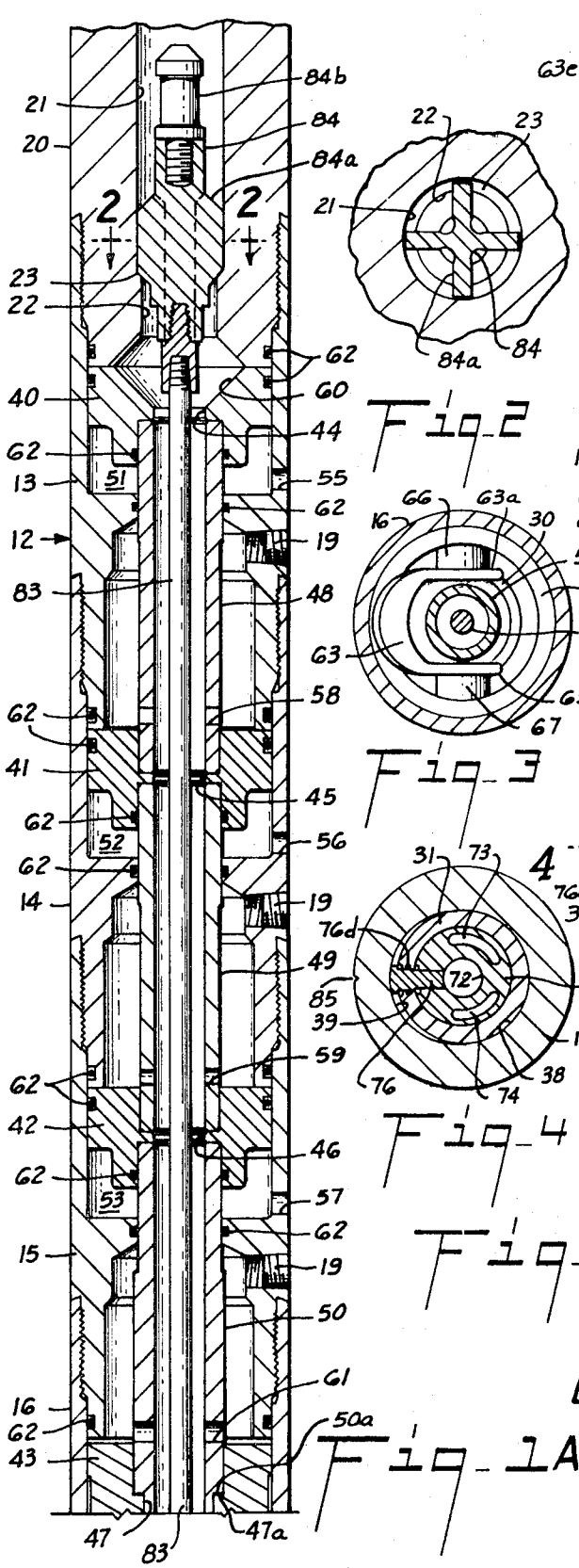


Fig. 1A

Fig. 2

Fig. 3

Fig. 4

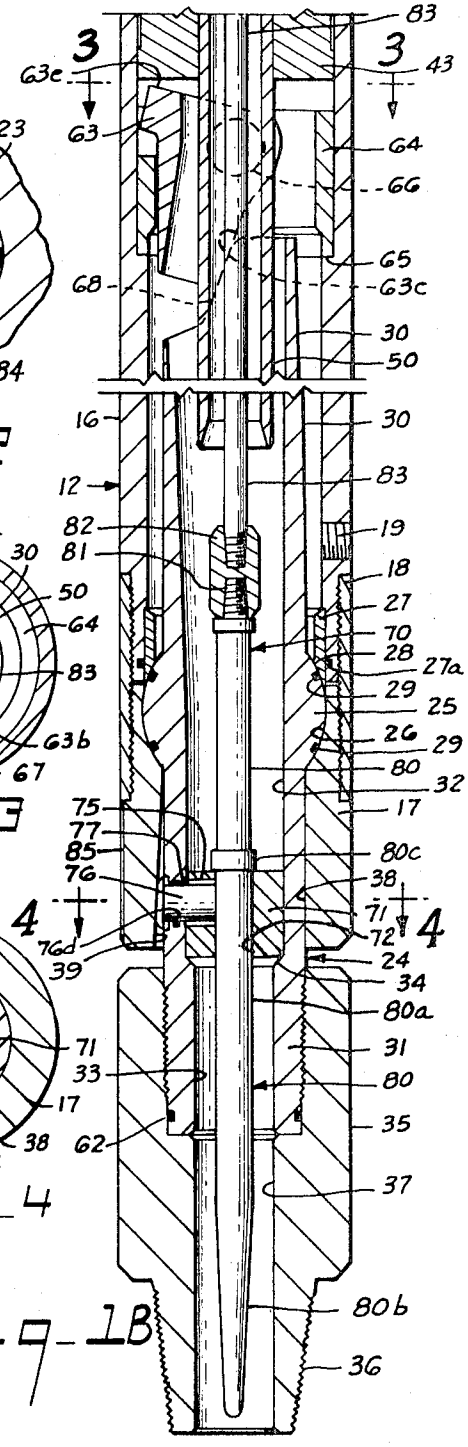


Fig. 1B

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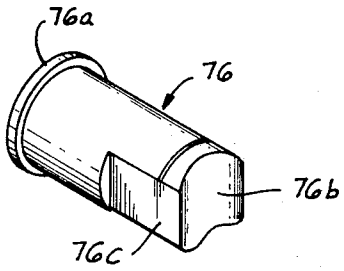


Fig. 6

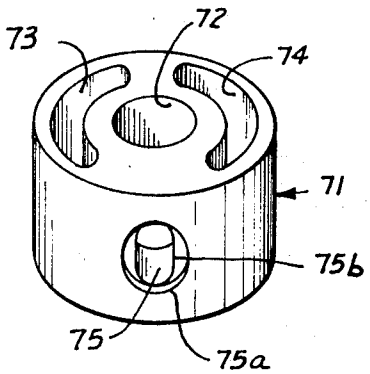


Fig. 5

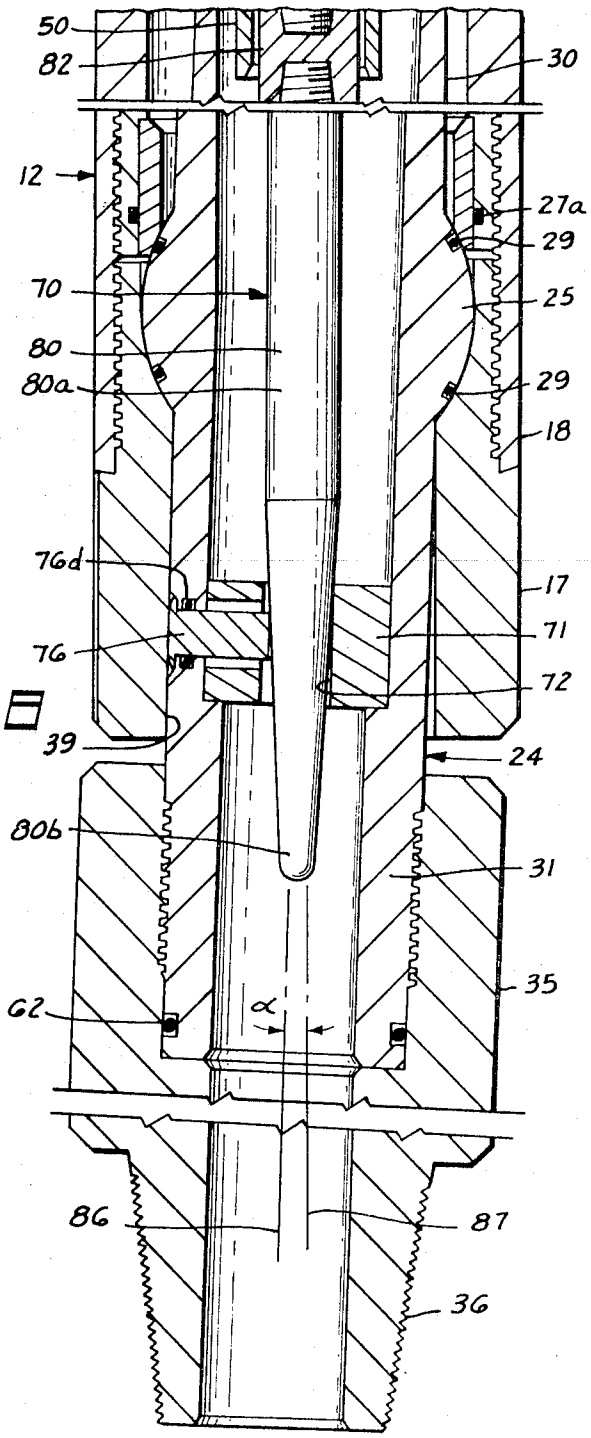


Fig. 8

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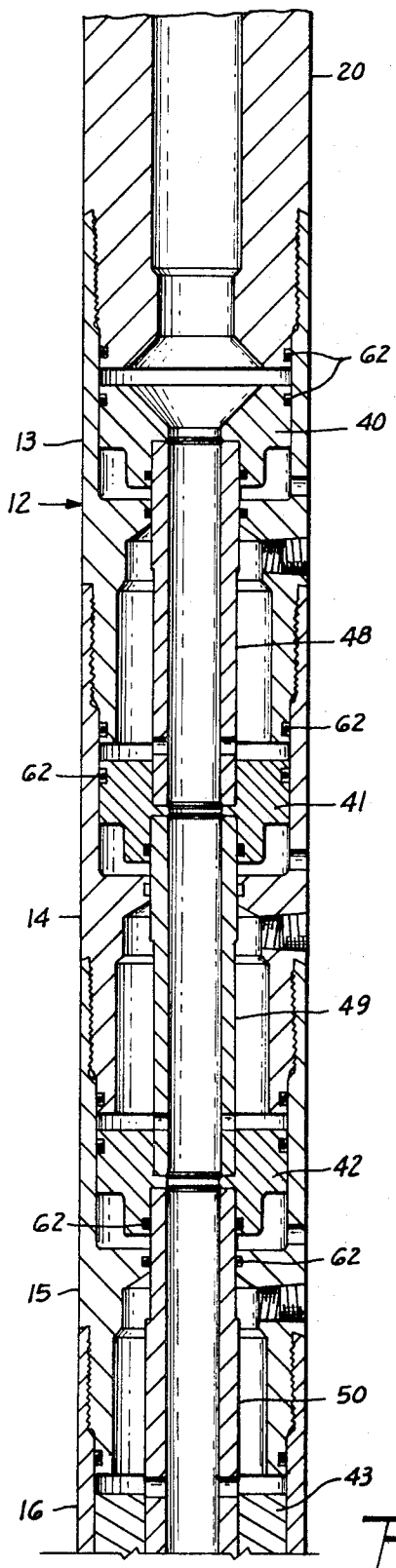


Fig. 7A

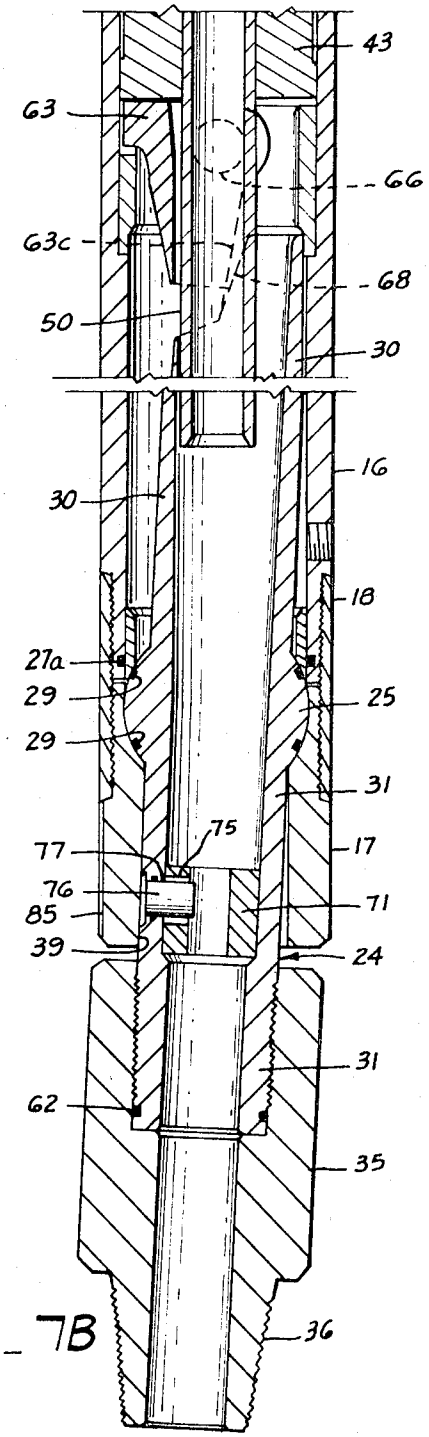
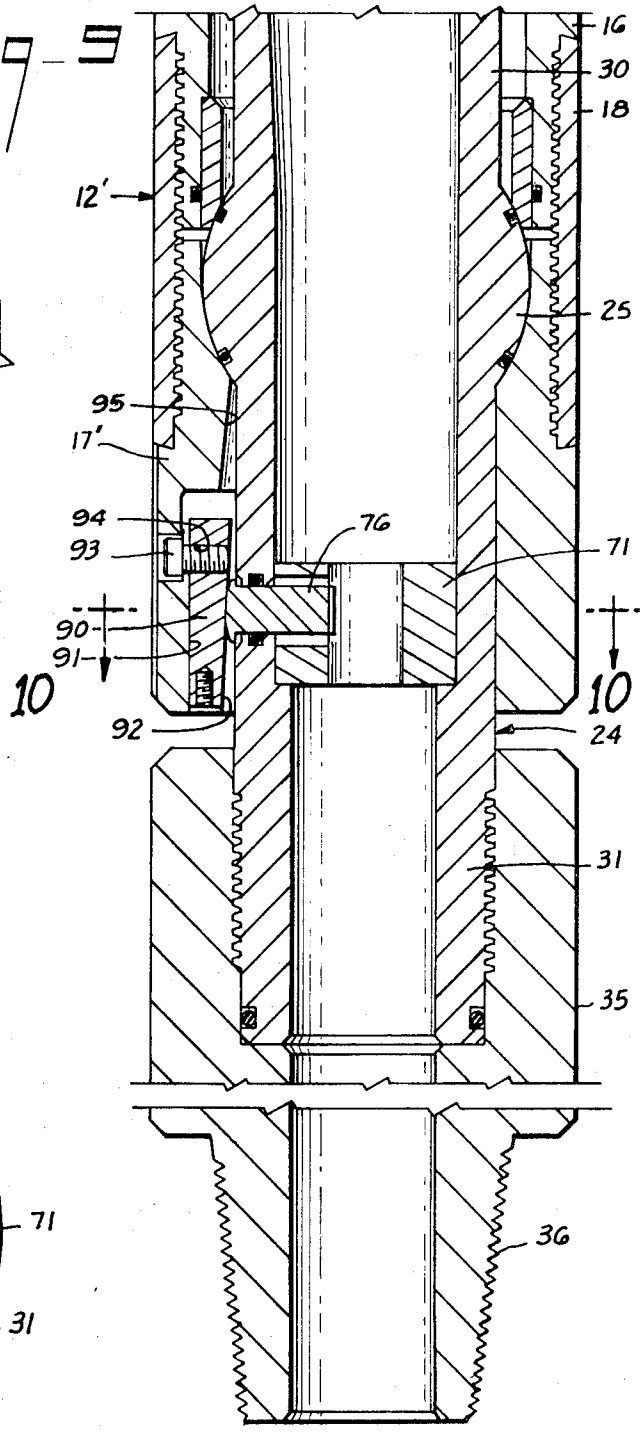


Fig. 7B

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Fig. 9



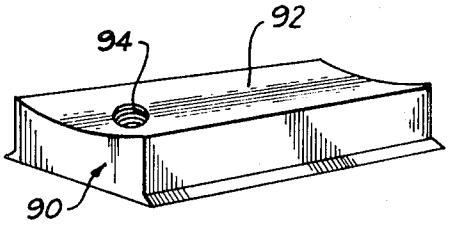


Fig. 11

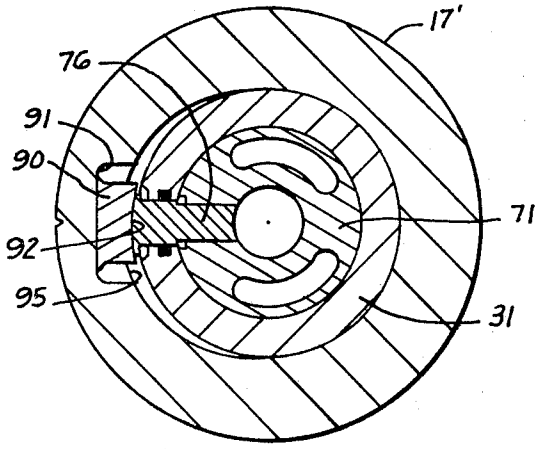


Fig. 10

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DIRECTIONAL DRILLING APPARATUS WITH RETRIEVABLE LIMITING DEVICE

BACKGROUND OF THE INVENTION

This invention relates to directional drilling methods and apparatus for use in drilling well bores into the earth and is particularly useful in connection with drilling apparatus wherein the drill bit is driven by a downhole fluid motor.

In the drilling of oil and gas wells, the use of downhole fluid motors for rotating the drill bit is becoming more widespread. In a goodly number of such cases, it becomes desirable at some intermediate point in the drilling process to change the direction in which the well bore is being drilled. It has been heretofore proposed to accomplish such change by pulling the drill string from the well bore, inserting a bent tool or bent sub into the drill string intermediate the drill bit motor and the lower end of the drill pipe to impart a predetermined amount of inclination to the motor-drill bit assembly, such inclination being anywhere from ½° to 3°. The drill string, motor, drill bit and permanently bent sub are thereafter run back into the well bore. Drilling is then recommenced and the angular bend in the bent sub serves to urge the drill bit in the desired new direction.

The use of a permanently bent sub has various disadvantages. Since the downhole motor unit and drill bit extend a substantial distance below the bent sub, the lateral displacement caused by the presence of the angular bend in the bent sub substantially reduces the clearance between the lower portion of the drill string and the wall of the well bore. Among other things, this means that greater care must be exercised when running in or withdrawing the drill string from the well bore. Such running in or withdrawal must be done at a slower rate of speed. Even with the exercise of care, the chances of damaging the mud cake on the wall of the well bore or of damaging the drill bit are increased. There is a much greater tendency for the drill bit to gouge and scrape the wall of the well bore. There is a much greater chance of the drill bit striking a hard shoulder or ledge protruding into the well bore. In addition, the screwing and unscrewing of the pipe joints may be more difficult because of the binding effect caused by the presence of the bent sub. For similar reasons, the orienting of the drill bit and motor unit in the desired compass direction may be rendered more difficult. Furthermore, the necessity of having to pull the drill string in order to add or remove the bent sub requires a substantial expenditure of rig time.

Another somewhat different method of changing the direction of a fluid motor driven drill bit is described in U.S. Pat. No. 3,068,946, granted to Messrs. Frisby and Cook on Dec. 18, 1962. Frisby and Cook employ a so-called "knuckle joint" which, at the appropriate moment in the drilling operation, is connected into the drill string between the drill pipe and the fluid motor unit. Their knuckle joint is flexed or bent by applying weight to the drill bit. Their knuckle joint, however, suffers from various disadvantages. For one thing it requires the withdrawal of the drill string from the well bore in order to insert or remove the knuckle joint at the appropriate points in the drilling process. More importantly, perhaps, their device does not provide any positive control over the flexing or bending of the knuckle joint. Weight can be applied to the drill bit, but there is no positive assurance that the knuckle joint has flexed in the desired manner. Depending on its orientation, it may have been limited in a straight or unflexed position. Also, since their knuckle joint is free to pivot at any time, there is increased danger of hanging up the drill string when running it into the well bore with the knuckle joint in the string.

Since the present invention may be characterized as a modified form of knuckle joint, it is pertinent to note that various forms of knuckle joints have been heretofore proposed for use in various types of subsurface well bore operations other than the actual drilling of the well bore. Representative of these is the knuckle joint described in U.S. Pat. No. 2,680,483, granted to F. L. LeBus on June 8, 1954. The LeBus knuckle joint is intended for use as a fishing tool for recovering drill pipe from the well bore. As a probably consequence of this different use, it includes features which render it unsuitable for use in a drill string having a downhole fluid motor for driving the drill bit. For one thing, the LeBus device requires the running into the tool of a plug for plugging the fluid flow passage through the tool in order to operate a piston mechanism which causes the tool to bend or knuckle. Such plugging of the flow passage would not allow sufficient flow of drilling fluid to enable proper operation of a downhole fluid motor located below the knuckle joint. In addition, the LeBus tool has no means for keeping the joint in a straight position for purposes of drilling a straight section of the well bore. Thus, assuming the restriction plug were not present, the use of the LeBus device would require the pulling of the drill string from the well bore in order to insert and remove the knuckle joint before and after the drilling of a curved section of the well bore. Furthermore, since the LeBus knuckle joint is free to pivot when it is being run into the well bore, there would be an increased likelihood of hanging up the drill strong when running it into the well bore.

SUMMARY OF THE INVENTION

It is an object of the invention, therefore, to provide new and improved apparatus of directional drilling which is easier, faster and more accurate than those heretofore proposed.

It is another object of the invention to provide new and improved apparatus of directional drilling which minimizes the chances of damaging either the mud cake on the wall of the well bore or the drill bit.

It is a further object of the invention to provide a new and improved deflection tool for use with fluid motor driven drill bits and which can be connected in the drill string the entire time the well bore is being drilled.

It is an additional object of the invention to provide a new and improved deflection tool for use with fluid motor driven drill bits and which can be limited in a positive manner at different desired angles (including a straight angle) at different stages in the drilling operation without having to pull the drill string from the well bore.

In accordance with the invention, a deflection tool adapted to be connected in a drill string for use in the directional drilling of a well bore comprises first tubular means and second tubular means pivotally coupled thereto. The tool also includes fluid-responsive means carried within the tubular means and responsive to drilling fluid pressure in the tubular means for urging one of the tubular means to pivot relative to the other. The tool further includes locking means including a retrievable limiting device adapted for passage through the drill string and into the tubular means for limiting the extent of such pivotal movement.

For a better understanding of the present invention, together with other and further objects and features thereof, reference is had to the following description taken in connection with the accompanying drawings, the scope of the invention being pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Referring to the drawings:

FIGS. 1A and 1B are partial cross-sectional elevational views of different portions of a deflection tool constructed in accordance with the present invention;

FIGS. 2, 3, and 4 are cross-sectional views taken along the correspondingly numbered section lines of FIGS. 1A and 1B;

FIG. 5 is a perspective view of a guide bushing used in the FIG. 1B portion of the tool;

FIG. 6 is a perspective view of a limiting plug used in the FIG. 1B portion of the tool;

FIGS. 7A and 7B show the tool of FIGS. 1A and 1B after it has been operated to put it in a bent position;

FIG. 8 is an enlarged view of the lower portion of the tool showing the probe in nonseated position and the connector bushing restricting fluid flow;

FIG. 9 shows in a cross-sectional manner a modified form of construction for the lower portion of the tool of FIGS. 1A and 1B;

FIG. 10 is a cross-sectional view taken along section line 10—10 of FIG. 9; and

FIG. 11 is a perspective view of a removable pivot stop block employed in the modified embodiment of FIG. 9.

DESCRIPTION OF THE FIRST EMBODIMENT

Referring to FIGS. 1A and 1B of the drawings, there is shown a first embodiment of a deflection tool adapted to be connected in a drill string for use in the directional drilling of a well bore into the earth. These figures show the tool in its straight or undeflected position. FIG. 1A shows the upper portion of the tool, while FIG. 1B shows the lower portion of the tool.

As shown in FIGS. 1A and 1B, the deflection tool includes an upper tubular assembly 12 which is of an elongated cylindrical construction. This tubular assembly 12 includes a series of cylinders 13, 14 and 15 which are threaded together in an overlapping end-to-end manner. The tubular assembly 12 further includes a hollow cylindrical body member 16 which is threaded onto the lower end of the lower cylinder 15. The upper tubular assembly 12 further includes a cylindrical pivot joint seating member 17 which is connected to the lower end of the body member 16 by means of an internally threaded connecting sleeve 18. Suitable tool cleanout plugs 19 are threaded into cooperating passageways at spaced points along the length of the tubular assembly 12. A top sub 20 is threaded onto the upper end of the tubular assembly 12. The upper end (not shown) of the top sub 20 is provided with a threaded pin for connecting the top sub 20 to the lower end of a nonmagnetic survey collar which forms part of the drill pipe string. Top sub 20 includes an interior longitudinal passage 21 having a reduced diameter lower portion 22 and a shoulder 23 formed at the boundary between the portions of different diameter.

The deflection tool further includes a lower tubular assembly 24 pivotally coupled to the upper tubular assembly 12. As indicated in FIG. 1B, this lower tubular assembly 24 is pivotally mounted within the lower portion of the upper tubular assembly 12. To this end, the lower assembly 24 is provided with an enlarged spherical ball joint portion 25 which is seated in a spherical socket 26 formed in the upper end of the pivot-joint-seating member 17 of the upper tubular assembly 12. A retaining ring 27 holds the spherical ball 25 in place in the socket 26. The lower end 28 of the retaining ring 27 is provided with a spherical curvature which matches that of the spherical ball portion 25. A pair of O-ring seals 29 are located in lateral grooves which encircle the ball portion 25, while a further O-ring seal 27*a* is located in a circular groove in the lower part of body member 16 adjacent the retaining ring 27. These seals 27*a* and 29 prevent leakage of the drilling fluid around the ball and socket joint. The ball joint portion 25 can be suspended on its pivot axis in the manner described in the above-mentioned U.S. Pat. No. 2,680,483 to LeBus.

The lower tubular assembly 24 further includes an upper tubular portion 30 located above the pivot axis (an axis passing through the center of the ball portion 25 at right angles to the plane of the paper in FIG. 1B) and extending upwardly within the upper tubular assembly 12. Though the length of tubular portion 30 may vary within limits, it preferably should be of suitable length to provide sufficient mechanical advantage for insuring that the lower tubular assembly 24 is pivoted in the desired manner.

The lower tubular assembly 24 further includes a lower tubular portion 31 located below the pivot axis and extending downwardly and out of the lower end of the upper tubular assembly 12. The ball portion 25, the upper portion 30 and the lower portion 31 are formed from a single piece of metal. A common longitudinal passageway 32 extends from one end to the other of the lower tubular assembly 24 provided by these portions. Passageway 32 includes a reduced diameter lower portion 33, which construction provides a shoulder 34 near the lower end of such passage 32. Threadedly connected to the bottom end of the lower portion 31 of the lower assembly 24 is a bottom sub 35. Such bottom sub 35 includes at the lower end thereof a threaded pin 36 which is adapted to be connected to a downhole fluid motor unit which drives a rotary drill bit. Bottom sub 35 includes a longitudinal center bore or passage 37 for passing the drilling fluid to the fluid motor unit located therebelow for purposes of energizing such unit.

As can be seen from FIG. 1B and the cross-sectional view of FIG. 4, the interior of the lower portion of the upper tubular assembly 12 is shaped to allow pivoting of the lower assembly 24 in only one direction and to limit the maximum extent of such pivotal movement. As there seen, the pivot-joint-seating member 17 is provided with a lower center bore 38 which is cylindrical on the right-hand side thereof and which has formed in the left-hand side thereof a tapered recess 39 having a cylindrical curvature for enabling the lower portion 31 of the lower assembly 24 to move toward the left as viewed in FIG. 1B. As such, the tapered recess 39 recedes from the longitudinal center axis of the pivot joint seating member 17 as it progresses in a downwardly direction. As will be better appreciated hereinafter, the wall of the tapered recess 39 sets the maximum limit for the extent of pivotal movement of the lower tubular assembly 24. The deflection tool further includes fluid-responsive means carried within the upper tubular assembly 12 and responsive to drilling fluid pressure in such upper assembly 12 for producing a lateral thrust on the upper portion 30 of the lower tubular assembly 24 for causing such assembly 24 to pivot about the pivot axis. Such fluid-responsive means includes a series of three longitudinally spaced pistons 40–42 slidably mounted for longitudinal movement within the upper part of the upper assembly 12. Pistons 40–42 are of toroidal shape and, as such, include longitudinal center bores 44–46, respectively, which extend longitudinally therethrough. Pistons 40–42 are interconnected by tubular stem members 48 and 49, the extremities of which are fitted into enlarged portions of the center bores 44–46 of the pistons 40–42. A piston-shaped ram 43 is mounted on a lower stem member 50 which is fitted into the lower enlarged portion of the center bore 46 of the lower piston 42. Ram 43 includes a longitudinal center bore 47 having a shoulder 47*a* which is engaged by a mating shoulder 50*a* on stem member 50 whereby stem member 50 can drive ram 43 in a downwardly direction. As indicated in FIG. 1B, the lower stem member 50 extends through the ram 43 and a goodly distance into the upper portion 30 of the lower assembly 24.

The interior of the upper portion of the upper assembly 12 and, more particularly, the interior of the cylinders 13–15 are constructed to provide individual piston chambers 51–53 for the different pistons 40–42, respectively. Chambers 51–53 are provided with fluid outlets 55–57, respectively, at the lower extremities thereof for enabling the lower ends of these chambers to communicate with the lower pressure well bore fluid exterior to the upper assembly 12. The upper ends of the piston chambers 52 and 53 are adapted to receive the higher pressure drilling fluid within the drill string by way of inlets 58 and 59 which extend through the sidewalls of the stem members 48 and 49, respectively. The upper end of the upper piston 40 is exposed directly to the drilling fluid leaving the lower passage 22 in the top sub 20. A concave recess 60 is provided in the top of the upper piston 40 for providing an exposed piston surface even when the piston 40 is at the upper end of its range of movement. An inlet 61 is provided in lower stem member 50 just above ram 43 for equalizing the pressure on the top and bottom sides thereof.

O-ring seals 62 provide fluid seals between the various pistons 40–42 and their corresponding cylinder walls, between the various stem members 48–50 and the center bores in the corresponding pistons and at the various other indicated points where it is desired to maintain a fluidtight barrier. In addition to interconnecting the various pistons 40–42 so that

they work in unison with one another and are mechanically coupled to the ram 43, the stem members 48–50 also provide a longitudinal flow passage for conveying the drilling fluid through the upper tubular assembly 12 and into the lower tubular assembly 24. This flow passage provided by the stem members 48–50 is of reduced internal diameter relative to the remainder of the longitudinal flow passages within the tubular assemblies 12 and 24.

In addition to the piston mechanism just described, the fluid responsive means further includes means for converting downward movement of the pistons into a lateral thrust on the upper portion 30 of the lower tubular assembly 24. This movement or force converting means includes a control lever 63 pivotally mounted within a tubular cage 64 which is located within the upper tubular assembly 12 adjacent the upper end of the upper portion 30 of the lower tubular assembly 24. The cage 64 rests on a shoulder 65 inside of the main body member 16. As indicated in the cross-sectional view of FIG. 3, the control lever 63 is of a U-shaped construction having side members 63*a* and 63*b* which straddle the centrally located stem member 50. Pivot pins 66 and 67 pivotally connect these side members 63*a* and 63*b* to the cage 64. As indicated in FIG. 1B, the downwardly extending legs of the side members 63*a* and 63*b* include contact faces 63*c* and 63*d* which engage oblique or slanted contact faces 68 formed by cutting away a corner portion of the upper end of the tubular portion 30. Only the rearward contact face 63*c* of control lever 63 is visible in FIG. 1B, the nearer face 63*d* being in front of the cross section plane. The control lever 63 further includes an upper contact surface 63*e* which is adapted to be engaged by the underside of the ram 43 during its downward movement. When ram 43 bears against this contact surface 63*e*, it causes a pivoting of the control lever 63 which, in turn, causes the contact faces 63*c* and 63*d* to push the upper end of the tubular portion 30 of the pivotal assembly 24 toward the right. In this manner, control lever 63 converts downward movement of the pistons 40–42 and ram 43 into a lateral thrust on the upper portion 30 of the pivotal assembly 24.

The deflection tool further includes limiting means including a retrievable limiting device 70 adapted for passage through the drill string and into the tubular assemblies 12 and 24 for limiting the extent of the pivotal movement of the lower tubular assembly 24 relative to the upper assembly 12. In addition to the limiting device 70, this limiting means or limiting mechanism also includes a guide bushing 71 located within the center bore or passageway 32 of the lower portion of the pivotal assembly 24 and resting on the shoulder 34 formed therein. A perspective view of this guide bushing 71 is shown in FIG. 5. As there indicated, the guide bushing 71 includes a longitudinal center passage 72 for receiving the lower end of the retrievable locking device 70 and a pair of C-shaped longitudinal side passages 73 and 74 for passing drilling fluid past the guide bushing 71. Guide bushing 71 further includes a lateral passage 75 running from the longitudinal center passage 72 to an opening 75*a* at one side of such guide bushing 71.

As indicated in FIG. 1B, the limiting mechanism further includes laterally movable positioning means movably carried by the lower portion 31 of the pivotal lower tubular assembly 24 and extending into the center bore 32 of such lower portion 31 for engagement by the retrievable limiting device 70. This laterally movable positioning means is comprised of a positioning plug or limiting plug 76 which is slidably mounted in a lateral passage 77 through the sidewall of the lower portion 31 and the lateral passage 75 in the guide bushing 71. A perspective view of the limiting plug 76 is shown in FIG. 6. Such limiting plug 76 includes an enlarged head 76*a* at one end thereof for engaging the tapered recess 39 formed in the wall of the upper tubular assembly 12. The opposite end of plug 76, which end is adapted to extend into the guide bushing center bore 72, is provided with a cylindrical curvature corresponding to the curvature of the retrievable limiting device 70. Opposite sides of plug 76 are cut to provide a pair of flat faces 76*c* which cooperate with corresponding flat sidewalls 76*b* in the inner portion of the guide bushing lateral passage 75 for maintaining the proper alignment for the cylindrically curved end surface 76*b* of the plug 76. As indicated in FIG. 1B, the length of the positioning or limiting plug 76 is greater than the combined length of the lateral passages 75 and 77 in the guide bushing 71 and the sidewall of the lower tubular portion 31. An O-ring seal 76*d* provides a fluid seal between the limiting plug 76 and the wall of passage 77.

As seen in FIG. 1B, the retrievable limiting device 70 includes an elongated cylindrical probe member 80 having a cylindrical body portion 80*a* and a tapered lower end portion 80*b*. A collar 80*c* is formed at an intermediate point on the probe member 80 for purposes of engaging the top of the guide bushing 71 and thus limiting the downward movement of the probe member 80 through the guide bushing center passage 72. The upper end of the probe member 80 is provided with a threaded connector 81 which is threaded into the lower end of an enlarged connecting bushing 82 which, as will be seen, functions as a "tattletale" plug. Threaded into the upper end of the connecting bushing 82 in a connecting rod 83 which extends upwardly through the interior of the tubular stem members 48–50 and is connected to the lower end of a retrievable fishing sub 84 located in the center passage of the deflection tool top sub 20 (FIG. 1A). As indicated in the cross-sectional view of FIG. 2, the fishing sub 84 includes laterally extending blades 84*a* which are seated on the shoulder 23 intermediate the top sub passages 21 and 22. Thus, fishing sub 84 does not block the flow of drilling fluid. Fishing sub 84 further includes an upper fishing neck 84*b* which is adapted to be engaged by a wire line overshot or retrieving device (not shown) which may be lowered through the drill string by means of a wire line for purposes of withdrawing the limiting device 70 from the deflection tool and returning it to the surface of the earth. If the drilling medium or drilling fluid is a liquid-drilling mud, then the limiting device 70 can be placed in the deflection tool by dropping it through the drill string in a free-falling go-devil manner. If, on the other hand, the drilling fluid is air, the limiting device 70 is lowered into place by means of the releasable wire line overshot device.

The diameter of the connecting bushing 82 is sized to substantially restrict the flow of drilling fluid through the tubular stem members 48–50 when such bushing 82 is within the stem members 48–50. As such, the diameter of the bushing 82 is slightly less than the inside diameter of the tubular stem members 48–50, the difference being such as to provide a clearance on the order of, for example, one-sixteenth of an inch between the bushing 82 and the inner wall of the stem members 48–50. Connecting bushing 82 thus serves as a tattletale device since the decrease in mud pump pressure when the connecting bushing 82 emerges from the bottom end of the lower stem member 50 serves to signal the operator at the surface of the earth that the probe member 80 has properly entered the guide bushing 71. For this reason, the bushing 82 is located above the locking portion 80*a* of the probe member 80 a distance such that it remains in the reduced diameter passage provided by the stem members 48–50 until the probe member 80 has moved a substantial distance through the guide bushing center passage 72.

It is noted that the maximum cross-sectional area of the retrievable limiting device 70 is substantially less than the cross-sectional area of the interior of the lower tubular assembly 24. Thus, once the connecting bushing 82 leaves the lower stem member 50, a substantial flow of drilling fluid is provided through the tubular assemblies 12 and 24. The deflection tool is constructed so that such fluid flow is amply sufficient for purposes of driving a downhole fluid motor unit when such motor unit is connected to the bottom sub 35.

A scribe line 85 in the form of a narrow longitudinal groove is cut into the exterior of the upper tubular assembly 12 at the lower end thereof on the side thereof to which the lower assembly 24 is adapted to pivot. Such scribe line 85 enables an

accurate determination of the orientation of the line of deflection of the deflection tool with respect to an orienting device in a nonmagnetic directional survey collar which is connected in the drill string immediately above the deflection tool. Such a directional survey collar is of known construction and cooperates with a known type of wire line directional survey instrument which may be lowered into such collar for determining the azimuth or compass direction in which the orienting device is facing.

OPERATION OF THE FIRST EMBODIMENT

Considering now the operating of the above-described deflection tool, such tool is connected into a drill string immediately above a downhole fluid motor unit which drives a rotary drill bit. As a result of the novel manner of construction of the deflection tool, it can remain in the drill string at all times during the drilling operation, even when drilling a straight portion of the hole. This will be assumed to be the case, namely, that the deflection tool is connected into the drill string at the very beginning of the drilling of the principal part of the well bore.

Since it is usually desired that the upper portion of the well bore be a straight hole (either vertical or on a slant), the deflection tool is initially limited in its straight position. This is the position shown in FIGS. 1A and 1B. The limiting is accomplished by placing the retrievable limiting device **70** in the deflection tool with the probe member **80** extending through the passage **72** in the guide bushing **71** and the probe collar **80***c* resting on the top surface of such guide bushing **71**. In order to obtain the desired straight angle for the lower pivotal assembly **24**, the diameter of the limiting portion **80***a* of the probe member **80** is just slightly less than the inside diameter of the central passage **72** in the guide bushing **71**, a slight clearance being provided to prevent the probe member **80** from becoming stuck in the passage **72**. The presence of this probe member **80** causes a maximum extension of the limiting plug **76**. Thus, the limiting plug **76** is forced against the wall of the tapered recess **39** which, in turn, forces the lower pivotal assembly **24** against the opposite wall of the passage **38** through the lower end of the pivot-joint-seating member **17**. This locks the deflection tool at a straight angle or in a straight position in a positive manner. With the deflection tool in such straight position, the drill string is used to drill a straight portion of the well bore. The deflection tool is constructed to allow sufficient flow of drilling fluid at this time for properly operating the downhole fluid motor unit.

Assume now that at some later stage in the drilling operation it is desired to change the direction in which the well bore is being drilled. This is accomplished by placing the deflection tool in a bent or deflected position. Assuming for the moment that a maximum angle of deflection is desired, this is accomplished by removing the retrievable limiting device **70** from the deflection tool and then operating the drilling fluid or mud pump at the surface of the earth to increase the fluid pressure in the drill string. This produces the bent condition illustrated in FIGS. 7A and 7B.

The removal of the limiting device **70** is accomplished by lowering a wire line overshot device through the drill string and allowing it to grab the fishing neck **84***b* on the fishing sub **84** located at the top of the retrievable limiting device **70**. The limiting device **70** is then withdrawn from the drill strong and retrieved at the surface of the earth. Referring to FIGS. 7A and 7B, it is seen that with the probe member **80** removed, the limiting plug **76** is free to slide back into the lateral passages **75** and **77** in the guide bushing **71** and the wall of the tubular portion **31**, respectively. Thus, the lower tubular assembly **24** is now free to pivot.

Such pivotal movement is produced in a positive manner by means of the piston and control lever mechanism located in the upper portion of the upper tubular assembly **12**. The pressure of the drilling fluid in the interior of the drill string is increased, by increasing pump pressure at the earth's surface to urge the pistons **40–42** to move in a downwardly direction. This causes the ram **43** to bear against the arm portion of the control lever **63** and thus to cause such control lever **63** to pivot in a counterclockwise direction about the pivot pins **66** and **67**. This causes the contact faces **63***c* and **63***d* (latter not visible) to bear against the inclined contact faces **68** of the upper portion **30** of the pivotal tubular assembly **24**. This produces a substantial lateral thrust on the upper portion **30**, which portion functions like a lever arm to cause a pivoting of the entire lower tubular assembly **24**. This forces the lower portion **31** of the tubular assembly **24** against the tapered recess **39** in a positive manner, the limiting plug **76** being pushed into its retracted position in the lateral passages **75** and **77**.

Before the deflection tool is actually bent, it is necessary to rotate or orient the drill string so that the bent portion will point in the proper compass direction after it is deflected. This is accomplished by lowering a wire line directional survey instrument into the survey collar located above the deflection tool for measuring the compass direction in which the orienting device in the survey collar is facing. The survey instrument is then returned to the surface and its record examined. From this, together with the known angular relationship between the orienting device in the survey collar and the scribe line **85** on the exterior of the deflection tool upper assembly **12**, the present compass direction in which the scribe line **85** is facing is determined. The drill string is then rotated by the drilling rig rotary table the proper amount to obtain the desired orientation for the direction in which the lower end of the pivotal assembly **24** will pivot, such direction being denoted by the scribe line **85**. Following such orientation, the rotary table is limited and the drilling fluid pressure is increased to its normal operating or drilling level. This causes the deflection tool to bend or deflect in the manner previously considered. Drilling of the well bore is then resumed, the bend angle in the deflection tool causing the drill bit to follow a new course.

As long as the deflection tool remains bent, the drill bit will continue to follow a curved path. Usually, after a curved portion of a certain length has been drilled, it is desired to resume the drilling of the well bore on a straight path. With the present deflection tool, this can be accomplished without the need of pulling the drill string from the well bore. In order to return the deflection tool to a straight position, all that is required is to run the retrievably limiting device **70** back into the deflection tool. If the drilling medium is drilling mud, this is accomplished by dropping the limiting device **70** in a go-devil fashion. If the drilling medium is air, the limiting device **70** is lowered into the deflection tool by means of a releasable wire line overshot device.

As the probe member **80** of the limiting device **70** enters the guide bushing **71**, it forces the limiting plug **76** toward the left which, in turn, forces the pivotal assembly **24** toward the right. FIG. **8** shows the situation as the tapered end of the probe member **80** begins its entry into the guide bushing **71**. Note that the connecting bushing **82** is still in a "tattletale" position in the lower stem member **50**. Consequently, if the drilling fluid or mud pump is operated with the bushing **82** in this position, the larger than normal fluid pressure indication at the surface of the earth would indicate that the probe member **80** is not properly seated in the guide bushing **71**. In such a case, the mud pump is turned off to discontinue the hydraulic pump pressure. The drill string is then slowly rotated through an angle of 180°. This enables the weight of the downhole fluid motor and drill bit to swing the pivotal lower tubular assembly **24** into a straight position at some point during such rotation. Such straightening enables the probe member to descend into the guide bushing **71** in the desired manner. Such occurrence is confirmed by the occurrence of normal drilling fluid pressure when the drilling fluid pump is again activated.

Complete entry of the probe member **80** into the guide bushing **71** moves the longitudinal center axis of the lower tubular assembly **24** from a maximum deflected position, represented by reference line **86**, to the straight position

represented by reference line 87, both reference lines being shown in FIG. 8. The maximum angle of deflection α may be on the order of, for example 3°.

It is a further feature of the present invention that the deflection tool can be limited at any desired deflection angle intermediate the zero and maximum angles. A desired intermediate deflection angle is obtained by using a probe member 80 having a limiting portion 80a of the appropriate diameter. In other words, when the diameter of the limiting portion 80a is reduced, the limiting plug 76 assumes a partially extending position, thus limiting the pivotal movement of assembly 24 resulting from the urging of the piston and lever mechanisms to a valueless than maximum but greater than zero.

By way of example, a straight portion of the well bore may first be drilled using a limiting device 70 having a maximum diameter probe member 80. This produces a straight portion of the well bore. The limiting device 70 may then be retrieved from the well bore and the maximum diameter probe member replaced by a probe member of lesser diameter. The limiting device 70 is then run back into the deflection tool and a second portion of the well bore is drilled with the deflection tool bent at an intermediate deflection angle. If, at a later stage, it should be desired to further change the curvature of the course followed by the drill bit, the limiting device 70 can again be retrieved from the drill string and the second probe member replaced by a further probe member having a third size for its diameter. If, of course, the maximum deflection angle is desired, then drilling is carried on with the retrievable limiting device 70 completely removed from the deflection tool.

DESCRIPTION OF THE SECOND EMBODIMENT

Referring now to FIGS. 9–11, there is shown a modified form of construction for the lower portion of the deflection tool of FIGS. 1A and 1B. Corresponding parts are identified by the same reference numerals as used in FIGS. 1A and 1B. Since a lower portion of the upper tubular assembly is of a modified construction, such upper tubular assembly is identified in FIG. 9 by the reference numeral 12'.

The embodiment of FIG. 9 differs from the embodiment of FIGS. 1A and 1B in that a removable pivot stop block 90 is used in place of the tapered recess 39 of the earlier embodiment for purposes of limiting the pivotal movement. This pivot stop block 90 is mounted in a rectangular recess 91 which is cut into the interior wall of pivot joint seating member 17' on one side thereof. An inner contact face 92 of the stop block 90 takes the place of the contact face of the tapered recess 39 of the FIG. 1B construction. Stop block 90 is held in place by means of a cap screw 93 which extends through a lateral passage in the wall of the pivot-joint-seating member 17' and is threaded into a threaded passage 94 in the stop block 90. As perhaps best seen in the cross-sectional view of FIG. 10, a tapered semicylindrical recess 95 is also provided in this second embodiment. The extreme left-hand portion of the inner wall of this recess 95 is to the left of the contact surface 92 of the stop block 90. Hence, the stop block 90 and not the recess 95 now determines the maximum limit of deflection for the deflection tool.

A perspective view of the stop block 90 is shown in FIG. 11. By using stop blocks of different thickness, different maximum limits can be established for the deflection angle. This provides a greater degree of flexibility in the use of the deflection tool.

While there have been described what are at present considered to be preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, intended to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A deflection tool adapted to be connected in a drill string for use in the directional drilling of a well bore comprising:
first tubular means;
second tubular means pivotally coupled to the first tubular means;
fluid-responsive means carried within the tubular means and responsive to drilling fluid pressure in the tubular means for urging one of the tubular means to pivot relative to the other;
and limiting means including a retrievable limiting device adapted for passage through the drill string and into the tubular means for limiting the extent of such pivotal movement while the limiting device is in the tubular means.

2. A deflection tool in accordance with claim 1 wherein the second tubular means is pivotally mounted within the first tubular means and extends out one end thereof.

3. A deflection tool in accordance with claim 1 wherein the fluid-responsive means includes a piston slidably located in one of the tubular means.

4. A deflection tool in accordance with claim 1 wherein the fluid-responsive means includes a plurality of longitudinally spaced pistons located within one of the tubular means and interconnected by tubular stem means for enabling the pistons to work in unison with one another.

5. A deflection tool in accordance with claim 1 wherein:
the second tubular means includes an extended portion which extends into the first tubular means;
the fluid-responsive means includes a longitudinally slidable piston located in the first tubular means;
and the fluid-responsive means includes control lever means pivotally mounted within the first tubular means adjacent the end of such extended portion for converting the longitudinal movement of the piston into a lateral thrust on the end of such extended portion.

6. A deflection tool in accordance with claim 1 wherein the retrievable limiting device includes a body portion the thickness of which controls the extent of the pivotal movement.

7. A deflection tool in accordance with claim 1 wherein the limiting means includes positioning means movably carried by one of the tubular means and engageable by the retrievable limiting device for establishing the angular relationship between the two tubular means.

8. A deflection tool in accordance with claim 1 wherein the limiting means includes positioning means movable carried by the second tubular means and having a first portion for engaging the first tubular means on one side thereof and a second portion which extends into the center bore of the second tubular means for engagement by the retrievable limiting device for establishing the angular relationship between the two tubular means.

9. A deflection tool in accordance with claim 1 wherein:
the limiting means includes laterally movable positioning means carried by one of the tubular means;
and the retrievable limiting device includes a body portion for engaging the positioning means and moving it to a desired position.

10. A deflection tool in accordance with claim 1 wherein:
the first tubular means is located above the second tubular means;
the first tubular means includes interior longitudinal passage means of reduced diameter;
the second tubular means includes receiving means for receiving the retrievable limiting device;
and the retrievable limiting device is of an elongated construction adapted for passage through the reduced diameter passage means and includes a limiting portion adapted to be seated in the receiving means and an enlarged portion located relative to such limiting portion a distance such that it remains in the reduced diameter passage means until the limiting portion has entered the receiving means, such enlarged portion being sized to substantially reduce the flow of drilling fluid through the tool as long as it is within the reduced diameter passage means.

11. A deflection tool adapted to be connected in a drill string for use in the directional drilling of a well bore comprising:

upper tubular means;

lower tubular means pivotally mounted within the upper tubular means and having an upper portion located above the pivot axis and extending upwardly within the upper tubular means and a lower portion located below the pivot axis and extending downwardly and out of the lower end of the upper tubular means;

fluid-responsive means carried within the upper tubular means and responsive to drilling fluid pressure in the upper tubular means for producing a lateral thrust on the upper portion of the lower tubular means for causing the lower tubular means to pivot about the pivot axis;

laterally movable positioning means movably carried by the lower tubular means and extending into the center bore of the lower tubular means;

and a retrievable limiting device adapted for passage through the drill string and into the lower tubular means for engaging the laterally movable positioning means and thereby controlling the angular relationship between the two tubular means.

12. A deflection tool in accordance with claim 11 wherein the upper tubular means is adapted to be connected to the lower end of a string of drill pipe and the lower tubular means is adapted to be connected to a downhole fluid motor unit for driving a rotary drill bit.

13. A deflection tool in accordance with claim 11 wherein the interior of the lower portion of the upper tubular means is shaped to allow pivoting of the lower tubular means in only one direction and to limit the maximum extent of such pivoting movement.

14. A deflection tool in accordance with claim 11 wherein the fluid responsive means includes:

longitudinally movable piston means slidably located within the upper tubular means;

and means for converting downward movement of the piston means into a lateral thrust on the upper portion of the lower tubular means.

15. A deflection tool in accordance with claim 14 wherein the movement converting means comprises a control lever pivotally mounted within the upper tubular means adjacent the upper end of the upper portion of the lower tubular means and having an upper portion adapted to be engaged by the underside of the piston means during its downward movement.

16. A deflection tool in accordance with claim 15 wherein the length of the upper portion of the lower tubular means is of suitable length to provide a mechanical advantage for pivoting the lower tubular means.

17. A deflection tool in accordance with claim 11 wherein the fluid-responsive means includes:

a plurality of toroidal pistons located for longitudinal movement within an upper portion of the upper tubular means;

tubular stem means cooperating with the center bores of the pistons for interconnecting the pistons in a spaced apart coaxial manner and of providing a central flow passage through the upper portion of the upper tubular means;

the interior of the upper portion of the upper tubular means being constructed to provide individual piston chambers for the different pistons;

and means for converting downward force produced by the pistons into a lateral thrust on the upper portion of the lower tubular means.

18. A deflection tool in accordance with claim 11 wherein the laterally movable positioning means is carried within the upper tubular means by the lower portion of the lower tubular means.

19. A deflection tool in accordance with claim 11 wherein the laterally movable positioning means comprises a positioning plug slidably mounted in a lateral passageway extending through the wall of the lower tubular member.

20. A deflection tool in accordance with claim 11 wherein the cross-sectional area of the retrievable limiting device is substantially less than the cross-sectional area of the interior of the lower tubular means for enabling a substantial flow of drilling fluid through the tubular means when the retrievable limiting device is in place in the lower tubular means.

21. A deflection tool in accordance with claim 11 wherein:

the retrievable limiting device includes an elongated cylindrical probe member forming at least the lower part thereof;

the tool includes a guide bushing located within the center bore of the lower tubular means and having a longitudinal center passage for receiving the probe member, longitudinal side passages for passing drilling fluid and a lateral passage running from the center passage to an opening at one side of such guide bushing;

the lower tubular means includes a lateral passage extending through the wall thereof and in alignment with the lateral passage in the guide bushing;

and the laterally movable positioning means comprises a positioning plug slidably mounted in the lateral passages in the guide bushing and the lower tubular means, the length of such positioning plug being greater than the combined length of such lateral passages.

22. A deflection tool in accordance with claim 21 wherein the guide bushing and the cooperating lateral passage in the lower tubular means are located in a portion of the lower portion of the lower tubular means which is within the upper tubular means.

23. A deflection tool in accordance with claim 11 wherein:

the upper tubular means includes an interior longitudinal passage means of reduced diameter located at an upper location therein;

the lower tubular means includes receiving means for receiving the retrievable limiting device;

and the retrievable limiting device is of an elongated construction adapted for passage through the reduced diameter passage means and includes a lower limiting portion adapted to be seated in the receiving means and an enlarged portion located above such limiting portion a distance such that it remains in the reduced diameter passage means until the limiting portion has entered the receiving means, such enlarged portion being sized to substantially restrict the flow of drilling fluid through the tool as long as it is within the reduced diameter passage means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,627,356 Dated December 14, 1971

Inventor(s) EDWIN A. ANDERSON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the Abstract, line 10, change "when" to --When--.
Column 2, line 2, change "probably" to --probable--.
Column 2, line 46, change "fluid-responsive" to --fluid responsive--.
Column 3, line 47, and column 4, line 15, change "pivot-joint-seating" to --pivot joint seating--.
Column 4, line 27, a new paragraph should begin with "The deflection tool".
Column 4, lines 28 and 32, change "fluid-responsive" to --fluid responsive--.
Column 4, line 61, change "sidewalls" to --side walls--.
Column 4, line 74, change "fluidtight" to --fluid tight--.
Column 5, line 29, change "cross" to --cross- --.
Column 5, line 66, change "sidewall" to --side wall--.
Column 6, line 1, change "sidewalls" to --side walls--.
Column 6, line 1, after "sidewalls" change "76b" to --75b--.
Column 6, line 7, change "sidewall" to --side wall--.
Column 6, lines 32 and 34, change "wire line" to --wireline--.
Column 6, line 37, change "liquid-drilling" to --liquid drilling--.
Column 6, line 41, change "wire line" to --wireline--.
Column 7, line 6, change "wire line" to --wireline--.
Column 7, line 42, change "pivot-joint-seating" to --pivot joint seating--.
Column 8, lines 18 and 51, change "wire line" to --wireline--.
Column 9, line 10, change "extending" to --extended--.
Column 9, line 13, change "valueless" to --value less--.
Column 9, line 52, change "pivot-joint-seating" to --pivot joint seating--.
Column 10, lines 4, 17, 20, 28, and 30, change "fluid-responsive" to --fluid responsive--.
Column 10, line 45, change "movable" to --movably--.
Column 11, lines 11 and 53, change "fluid-responsive" to --fluid responsive--.

Signed and sealed this 2nd day of May 1972.

(SEAL)
Attest:

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