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3,129,776

FULL BORE DEFLECTION DRILLING APPARATUS

Filed March 16, 1960

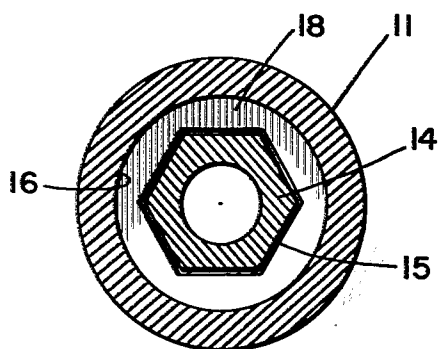


FIG. 3.

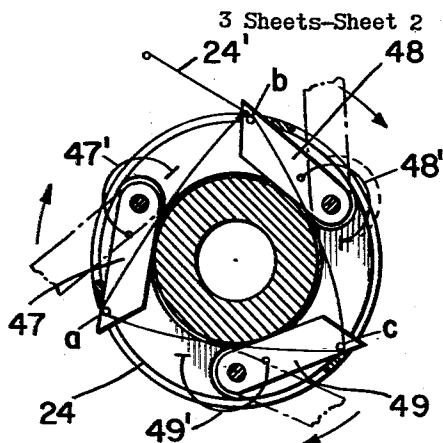


FIG. 4.

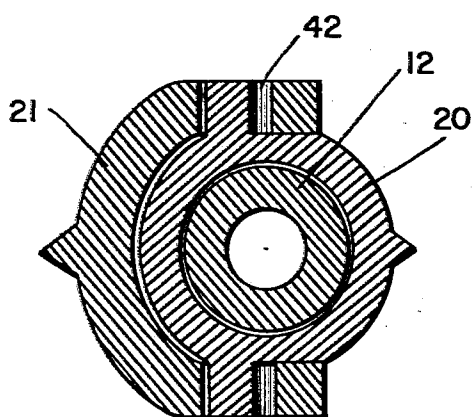


FIG. 5.

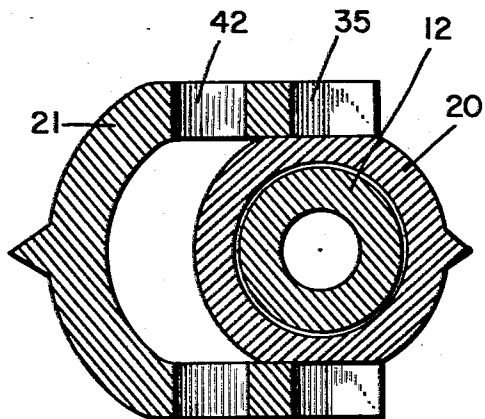


FIG. 6.

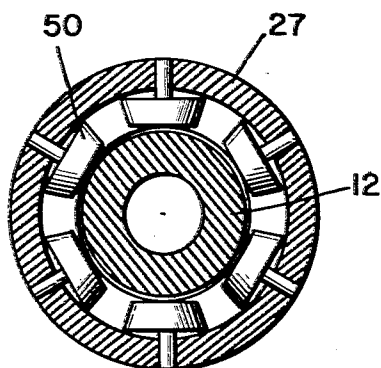


FIG. 7.

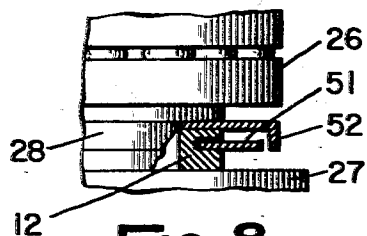


FIG. 8.

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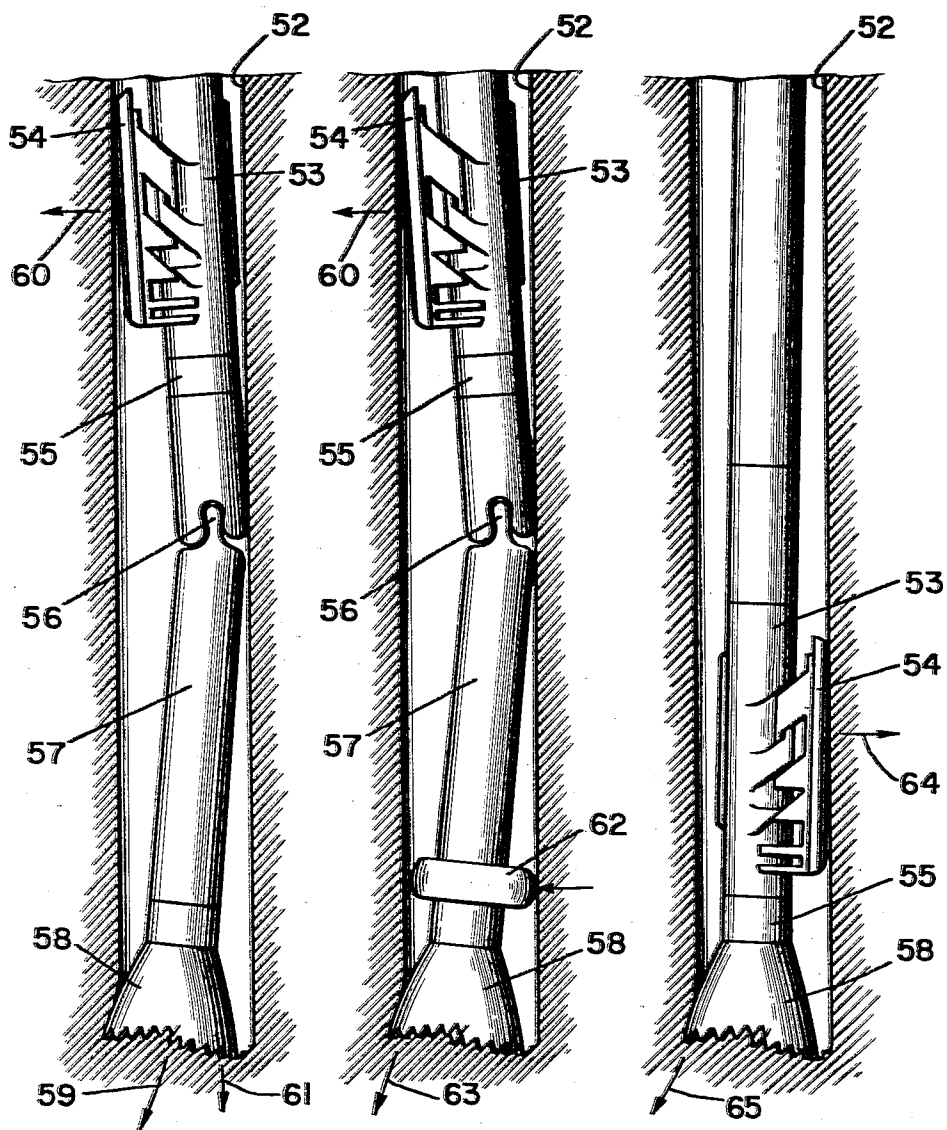


FIG. 9.

FIG. 10.

FIG. 11.

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3,129,776 FULL BORE DEFLECTION DRILLING APPARATUS

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This invention relates generally to oil well tools and more particularly to an improved apparatus for deflecting the direction of drilling in a bore hole.

It is oftentimes desirable to deflect the direction of an oil well bore hole. In some instances, the earth formations may be such that it is simpler to drill around the formations rather than through them. In other cases, oil deposits may be located under a body of water but for reasons of economy the drilling apparatus is set up on the shore. In this case, the bore hole may be deflected to curve in a direction towards the underwater deposits.

Heretofore, deflection drilling has been accomplished by means of a crescent shaped wedge or whip stock. In using the whip stock, the drill pipe string is pulled from the bore hole and the whip stock is secured about the lowermost pipe to which the drilling bit is connected. The entire structure is then lowered into the bore hole and the whip stock serves as a wedge to deflect the drill bit in the desired direction. Generally a smaller diameter drill is employed with the whip stock in order that the apparatus may be accommodated within the bore hole. Therefore, it is usually necessary to ream the smaller deflected hole with a normal bit after the deflection operation has been completed.

In addition to the foregoing, whip stock deflection drilling is usually accomplished in a series of steps until the desired total deviation has been achieved. Thus, after a given distance of deflected drilling has been accomplished and the deflected hole reamed, the pipe string must be pulled and the whip stock re-attached and re-oriented to commence a next step. As a result, the deflected bore resembles a series of straight bore portions connected end to end each forming an angle with the other at the step points, rather than a smooth gradually curving bore hole. The stepped structure, referred to as dog legs, can result in sticking of the drill pipe as a result of key seating from wear of the pipe string against the sides of the bent bore hole portions. Moreover the process of removing the pipe string and re-orienting at each step is extremely costly both in time and labor.

A further problem in deflection drilling arises when it is desired to reverse the direction of the deflection. This operation conventionally requires repositioning the whip stock in circumferential steps of 30° to turn the bore hole back on itself in the manner of a cork screw, since the whip stock itself will not seat properly on the opposite side of the bore hole wall.

With the foregoing in mind, it is a primary object of the present invention to provide a greatly improved apparatus for deflection drilling in which the above operations associated with the use of a whip stock may be avoided.

More particularly, it is an object to provide a deflection apparatus for effecting full bore deflection in a smooth curve to the end that remaining dog legs and key seating are wholly avoided.

Another important object is to provide a full bore deflection apparatus which may be re-oriented without withdrawing the drill string so that considerable time and labor is saved.

More general objects of the invention are to provide improved deflection apparatus of extremely rugged con-

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struction and of mechanically simple design incorporating a minimum number of movable components to the end that great reliability is realized.

Briefly, these and many other objects and advantages of this invention are attained by providing an upper pipe section adapted to be secured to the drill pipe string. A mandrel in turn is arranged to telescope within the lower end of the upper pipe section. A pad actuating sleeve surrounds the mandrel and is connected to the upper pipe section in such a manner that permitting an increased portion of the weight of the drill pipe string to bear on the upper pipe section will slide the sleeve longitudinally over the mandrel itself. A shoe or pad member is coupled to the sleeve and keyed against longitudinal movement to the lower portion of the mandrel. The coupling structure itself takes the form of inclined surfaces on the sleeve and pad member at angles between the axis of the sleeve and a normal thereto.

With the foregoing arrangement, a downward force on the upper pipe section through the drill pipe string will slide the sleeve longitudinally along the mandrel to cam the pad member in a lateral direction to bear against the side wall of the bore hole and thus deflect the direction of the lower portions of the drill pipe. Upper and lower bearings are included for enabling rotation of the mandrel to take place within the sleeve so that rotary drilling operations can continue with the pad member in expanded position.

The structure also includes further apparatus for facilitating orientation of the deflection tool within the bore hole and for enabling contraction of the pad member when desired.

A better understanding of a preferred embodiment of the invention will be had by referring to the accompanying drawings, in which:

FIGURE 1 is an overall elevation view partly in cross section and partly cut-away illustrating the improved deflection apparatus of this invention with the pad member in retracted position;

FIGURE 2 is a view similar to FIGURE 1 showing the pad member in expanded position;

FIGURE 3 is a cross section taken in the direction of the arrows 3—3 of FIGURE 1;

FIGURE 4 is another cross section taken in the direction of the arrows 4—4 of FIGURE 1;

FIGURE 5 is a cross section taken in the direction of the arrows 5—5 of FIGURE 1, showing the pad in retracted position;

FIGURE 6 is a view similar to FIGURE 5 taken in the direction of the arrows 6—6 of FIGURE 2 showing the pad in its expanded position;

FIGURE 7 is a cross section taken in the direction of the arrows 7—7 of FIGURE 2;

FIGURE 8 is an enlarged fragmentary view of a portion of the structure at the lower end of FIGURE 1;

FIGURE 9 is a schematic illustration partly in cross section of a bore hole showing one means in which the deflection apparatus of this invention may be used;

FIGURE 10 is a view similar to FIGURE 9 illustrating a modified manner in which the deflection apparatus can be used; and,

FIGURE 11 illustrates a third means in which the deflection apparatus can be used.

Referring first to the upper portion of FIGURE 1, there is shown a coupling 10 secured to the top of a pipe section 11 for enabling connection of the pipe section 11 directly to the end of a drill pipe string (not shown). A central tubular mandrel 12 terminates at its upper end in an enlarged cylindrical head portion 13 and upwardly extending hexagonally cross-sectional portion 14. The portion 14 is arranged to telescope within an hexagonally cross-sectioned interior portion 15 of the pipe section 11

as shown. The enlarged head 13, on the other hand, is accommodated within an increased diameter internal portion 16 in the pipe section 11 defining lower and upper annular shoulders 17 and 18. The lower end of the top coupling 10 is threaded to receive a spacing screw 19.

With the foregoing arrangement, it will be evident that the pipe section 11 may telescope over the upper end of the mandrel 12. On the other hand, because of the hexagonal cross section of the portion 14 and interior 15 the mandrel 12 and upper pipe section 11 are locked against relative rotation with respect to each other. Therefore, when the drill pipe string is rotated during a rotary drilling operation, the mandrel 14 will also be rotated regardless of the relative telescoped positions of the two members.

The extent of telescoping travel of the members may be adjusted by adjusting the extent of threading of the spacing screw 19 within the interior of the lower end of the coupling 10. The lower surface of the spacing screw acts as a stop to limit the degree of downward movement of the pipe section 11 over the top portion of the mandrel 12. The purpose for this adjustment will become clearer as the description proceeds.

A pad actuating sleeve 20 surrounds the mandrel 12 and serves as a means for actuating a shoe or pad member 21. The upper end of the sleeve 20 is connected through an upper thrust bearing 22 and spring 23 to the lower end of the upper pipe section 11. The thrust bearing 22 permits up and down or longitudinal forces to be transmitted from the pipe section 11 to the sleeve 20 while the pipe section 11 and spring 23 are rotating. An orientation assembly 24 arranged to be actuated by a wire 24' is disposed directly below the bearing 22 and secured as by welding to the upper end of the sleeve 20. This structure will be described in greater detail in connection with FIGURE 4.

The lower end of the sleeve 20 in turn is connected through a spring 25 to a roller bearing 26. The bearing 26 co-operates with a lower thrust bearing 27 and a keying means 28 keyed to the mandrel 12 to provide a guiding structure for the pad member 21 as will also become clearer as the description proceeds. The keying structure 28 essentially limits longitudinal movement of the bearings 26 and 27 and the pad member 21 with respect to the lower end portion of the mandrel 12, yet permits relative rotation of the mandrel 12 within these bearings and within the main sleeve 20.

As shown, the lowermost end of the mandrel 12 extending from the annular bearing 28 terminates in a threaded end 29 adapted for connection to a drilling means. This drilling means may include a length of drill pipe secured to a drill bit and including a flexible joint, or may simply constitute a drilling bit directly connected to the lower end of the mandrel.

Referring to the central portion of FIGURE 1, there is shown a shear pin 30 which serves to secure temporarily the sleeve 20 to the inner mandrel 12. Also, the inside interior wall of the sleeve 20 includes biased arms 31 and 32 which are received within properly positioned indents 33 and 34 in the exterior wall of the mandrel 12. This structure serves as a clutch means for holding the sleeve and thus the pad member 21 in a desired angular relationship with respect to the mandrel 12. The shear pin 30 prevents relative longitudinal movement between the sleeve 20 and mandrel 12 so that a desired positioning of the front face of the pad 21 within a bore hole may be effected from the surface of the bore hole by raising and lowering the drill pipe and rotating it as required.

The means for coupling the pad 21 to the sleeve 20 in accordance with the instant invention is best shown in both FIGURES 1 and 2 and takes the form of a series of inclined surfaces 35, 36 and 37 formed into opposite sides of the sleeve 20. These surfaces are arranged to co-operate respectively with similarly inclined surface portions 38, 39 and 40 on the pad member 21. These co-

operating inclined surfaces form an angle that lies between the axis of the sleeve 20 and mandrel 12 and a direction normal thereto which in the drawing would be in a horizontal direction. The sleeve 20 also includes an inclined surface 41 co-operating with an inclined surface 42 on the pad member 21. The inclined surface 41 of the sleeve 20 is engaged by a projecting portion 44 from the surface 42 of the pad and similarly, the surface 42 of the pad is engaged by a projecting portion 43 from the surface 41 of the sleeve. These projecting portions serve to limit the lateral extent of the pad member 21 as will become clearer when the operation of the overall device is described.

With reference now to the extreme lower end portion of the pad member 21, there are provided a pair of rearwardly extending guiding surface portions 45 and 46 which sandwich the roller bearing 26 and lower thrust bearing 27 therebetween. Since the longitudinal movement of the bearings 26 and 27 is limited by the keying means 28, the pad member itself is correspondingly limited and thus its motion is confined to a lateral or back and forth movement along a normal to the axis of the mandrel 12.

Portions of the foregoing description with respect to FIGURES 1 and 2 will be clarified by referring now to FIGURES 3, 4, 5, 6, 7, and 8. In FIGURE 3, the hexagonal cross sectional structure for the upper portion 14 of the mandrel 12 is clearly illustrated and it will be evident that relative sliding or longitudinal movement of the top pipe section 11 with respect to the upper mandrel portion can take place. Rotational movement of this upper pipe section, however, will cause rotation of the mandrel.

In FIGURE 4, the orientation assembly structure 24 is shown in greater detail as including a plurality of arm members 47, 48, and 49 biased to an extended position by hair springs 47', 48', and 49', respectively but held in the retracted position shown by the wire 24'. To this end, the wire is wrapped around small pegs *a*, *b*, *c* on the members to define a single closed loop. When the wire 24' is broken or released, these arms will all rotate in a clockwise direction to the dotted line position such as shown for the arm 47 so that the ends thereof engage the side walls of the bore hole. Referring to FIGURE 2, this structure upon actuation serves to lock the sleeve 20 against rotational movement with respect to the bore hole.

In FIGURES 5 and 6, the structure of the pad member 21 with relation to the sleeve 20 is shown wherein it will be noted that both sides of the sleeve 20 and pad member 21 include the desired co-operating inclined surfaces. FIGURE 6 shows the relative positions of certain of these surfaces when the pad member 21 is in expanded position.

FIGURE 7 illustrates the lower thrust bearing 27 in the lower portion of FIGURES 1 and 2 as seen in cross section. The upper thrust bearing 22 is of identical construction and both are of a particular design capable of withstanding extremely large thrust forces. The preferred type of thrust bearing as shown in FIGURE 7 is fully set forth and described in my co-pending application Serial No. 795,655, filed February 26, 1959, for "Thrust Bearing."

As shown in FIGURE 7, this bearing includes a plurality of wheels 50 arranged to rotate about horizontal axes all extending radially inwardly and intersecting the central axis of the mandrel 12 at a common point. The lower end of this bearing is in engagement with the lowermost guiding surface 46 for the pad 21 as shown in FIGURES 1 and 2. The upper end, on the other hand, bears against the keying structure 28 and thus is limited in any longitudinal upward movement with respect to the mandrel 12.

In the enlarged cut-away view of FIGURE 8, the keying structure 28 is shown in greater detail. As shown, this structure includes an annularly extending key 51 seated within a circumferential groove about the mandrel 12. The outer peripheral edge of the key 51 in turn

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is enclosed by a cover structure having an annular flange 52 overlapping the key. While the lower bearing 26 and thrust bearing 27 are shown longitudinally spaced slightly from the keying structure, they are ordinarily in engagement with the opposite sides thereof. In actual practice, about one-eighth of an inch leeway is provided to permit some longitudinal movement of the bearings so that the guiding surface portions 45 and 46 of the pad member 21 as shown in FIGURES 1 and 2 can be easily moved back and forth with the bearings sandwiched therebetween.

With all of the foregoing structure in mind, the operation of the full bore deflection apparatus will now be described.

Referring first to FIGURE 1, the sleeve 20, pad 21, and pipe section 11 are in their normal in-operative positions with respect to the central mandrel 12. In this condition, the pad member 21 is fully retracted and does not appreciably increase the overall outside diameter of the apparatus beyond that of the conventional coupling joints between pipes making up the drill pipe string.

In use, the upper end coupling 10 on the pipe section 11 is threaded to the lower end of the drill pipe string and either the drill bit itself or a special type of drill pipe terminating in the drill bit is threadedly coupled to the lower end 29 of the mandrel 12. The entire structure is then lowered into the bore hole and drilling commenced. Because the shear pin 30 and clutch means 31 and 32 lock the sleeve 20 to the mandrel 12, the entire deflection apparatus will move with the drill pipe.

When a depth in the bore hole is reached wherein it is desired to deflect the direction of the drilling, the rotation of the drill bit at normal speed is stopped and the upper end of the drill pipe string is then slowly rotated until the front portion of the pad member 21 faces the side wall of the bore hole opposite to that in which the deflected direction is to take place, for that case in which the bit is coupled directly to the lower end 29 of the mandrel 12. With the pad member properly circumferentially oriented with respect to the bore hole, additional weight is placed on the drill pipe string from the surface of the bore hole. This additional weight is communicated through the upper pipe section 11 and to the sleeve member 20 through the medium of the spring 23. This spring is of greater stiffness than the spring 25 and will compress very little even under very high compression forces. The mandrel 12 is prevented from further downward longitudinal movement by the engagement of the drill bit with the bottom of the bore hole.

The force transmitted through the upper pipe section 11 and spring 23 onto the sleeve 20 is sufficient to shear the shear pin 30 and cause the sleeve 20 to slide downwardly along the mandrel 12 to the position illustrated in FIGURE 2. This sliding movement results in the surfaces 35, 36 and 37 camming against the surfaces 38, 39 and 40 of the pad member 21 resulting in the lateral movement of the pad member 21 in a direction normal to the axis of the sleeve and mandrel to an expanded position as shown in FIGURE 2. The projecting portions 43 and 44 of the sleeve 20 and pad member 21 respectively will limit the lateral outward extent of movement of the pad member. As mentioned in connection with the structure of the bearings 26 and 27 and guiding surfaces 45 and 46, the pad member 21 is prevented from moving longitudinally with respect to the mandrel 12 so that the desired camming action of the inclined surfaces will take place.

As the pad member 21 moves outwardly or away from the sleeve 20, the small wire 24' is stretched until it is broken thereby releasing the biased arms 47, 48, and 49 of the orientation assembly 24 illustrated in FIGURE 4. The extreme points of these arms engage the bore hole side walls and will lock the sleeve 20 against rotation as the pad member 21 engages the bore hole side wall. In addition to the foregoing, downward movement of the

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sleeve member compresses the spring 25, which is of lesser stiffness than the spring 23, to the position shown in FIGURE 2. The actual downward distance that the mandrel is moved through the sleeve 20 will be determined by the positioning of the spacing screw 19 in the upper coupling 10. If the pad member 21 should engage the side wall before engagement of the upper end of the mandrel by the screw 19, such additional movement of the pipe section 11 as may take place will be accommodated by the spring 23.

With the drill deflection assembly components in the position illustrated in FIGURE 2, conventional rotary drilling may now proceed with the drilling structure subject to a side force as a consequence of engagement of the pad member 21 against the bore hole side walls. This side force will cause a veering off of the drilling direction as desired. The upper bearing 22 will permit rotation of the upper pipe section 11 and the central mandrel 12 to take place while the sleeve 20 and pad member 21 are stationary. In this connection, it will be noted that the lower end of the compression spring 23 is secured to the upper portion of the bearing 22 and simply rides on this bearing as the drilling takes place.

With continued drilling, the pad 21 will move longitudinally down the side of the bore hole. The friction between the front face of the pad and the bore hole will tend to move the pad upwardly relative to the remaining structure. The lower guiding surface portion 46 bearing against the bottom of the lower thrust bearing 27 accommodates the major portion of this force which is dissipated in the thrust bearing 27. The small leeway of perhaps one-eighth of an inch between the keying structure 28 and the bearings 26 and 27 will permit small movements of the pad to take place as a consequence of small variations in the force resulting from the friction of the pad 21 on the bore hole sidewalls.

To re-orient the deflecting apparatus when another drill pipe section is added, the downward pressure of the drill string on the top pipe section 11 is decreased to permit the lower compression spring 25 to move the sleeve 20 upwardly over the mandrel 12. The spring 25 thus acts as a retraction spring and the retraction of the pad 21 itself is achieved by the co-operating inclined surfaces 41 on the sleeve 20 and 42 on the pad member 21.

With the pad member 21 returned to the position illustrated in FIGURE 1, the clutch means 31 and 32 on the interior wall of the sleeve 20 will engage within the indents 33 and 34 when the mandrel is rotated to a position in which the indents are opposite the clutch means. The orientation arms will hold the sleeve stationary when the mandrel is rotated counter-clockwise to register the arms within the detents. The pad member and sleeve will thus be rotationally locked to the mandrel and held in such position until the pad is properly oriented. The orientation assembly arms will not interfere with rotation of the mandrel and sleeve in a clockwise direction as viewed in FIGURE 2 so that re-orientation can be effected from the surface without having to withdraw the pipe string.

After the deflection drilling operation has been completed, the entire string of pipe may be removed and the deflection apparatus disconnected from the drill pipe string. The apparatus can then be reconditioned by providing a new shear pin and re-wiring the orientation assembly for its subsequent use in a different deflection operation.

Referring now to FIGURES 9, 10 and 11 there are illustrated respectively three different ways in which the deflection apparatus may be employed. Referring first to FIGURE 9 for example, there is schematically illustrated a bore hole 52 including a string of drill pipe to which the deflection apparatus 53 of the present invention is secured. As shown, the pad member 54 is expanded against the left hand portion of the wall of the bore hole 52. The lower end coupling 55 of the deflection apparatus is connected to a drilling means in the form of a pipe structure including a flexible joint 56 and lower pipe sec-

tion 57. The extreme lowermost end of the section 57 connects to the drill bit 58.

With the above arrangement, and assuming it is desired to cause the bore hole 52 to veer off to the left as indicated by the arrow 59, the pad 54 will exert a force against the side wall as indicated by the arrow 60. This action in turn will swing the lower end of the drill pipe string towards the right but because of the flexible joint 56, the direction of the drill pipe 57 and bit 58 will result in progression of the bore hole in a leftward direction. Under these conditions however, the major portion of the force on the bit will be at the right hand end as indicated by the arrow 61.

To correct the foregoing situation, the structure of FIGURE 9 may be modified as shown in FIGURE 10 by including a fulcrum member 62 surrounding the lowermost portion of the pipe 57 just above the drill bit 58. This fulcrum will bear against the right hand side of the bore hole 52 and thus transfer the force on the drill bit from its right hand side to its left hand side as indicated by the arrow 63.

In both of the embodiments of FIGURES 9 and 10, the length of pipe section 57 affects the degree of deflection. Thus by making this section longer, there will be less deflection and by making it shorter there will be greater deflection.

In the third mode of operation shown in FIGURE 11, the bit 58 may be secured directly to the lower end coupling 55 of the mandrel in the deflection apparatus 53 and the apparatus itself oriented so that the pad will bear against the right hand portion of the bore hole 52 as indicated by the arrow 64. With this arrangement, the bit 58 will be directly forced in a direction to cause the bore hole to veer off to the left as indicated by the arrow 65.

It will be understood of course that in all different uses of the deflection tool, conventional rotary drilling can take place simultaneously with the deflection action, mud circulation being effected directly through the central mandrel 12 of the apparatus.

From the foregoing description, it will be evident that the present invention has provided a greatly improved deflection apparatus for use in deflection drilling. Not only is the inconvenience of pulling pipe as required for a whip stock avoided, but in addition a full bore deflection is achieved thereby rendering unnecessary any subsequent reaming of the bore hole.

Modifications that fall clearly within the scope and spirit of this invention will occur to those skilled in the art. The full bore deflection drilling apparatus is therefore not to be thought of as limited to the particular embodiment set forth merely for illustrative purposes.

What is claimed is:

1. A full bore deflection drilling apparatus for insertion in a string of drill pipe, comprising, in combination: an upper pipe section for connection to said drill pipe; a mandrel having one end adapted to be telescoped within the lower end of said upper pipe section; means for connecting the other end of said mandrel to a drilling means, said first mentioned means preventing downward longitudinal movement of said mandrel relative to said drilling means; a pad actuating sleeve surrounding said mandrel and mounted for longitudinal movement relative to said mandrel; connecting means connecting the upper end of said pad actuating sleeve to the lower end of said upper pipe section; a pad member coupled to said sleeve for lateral movement in a direction normal to the axis of said pad actuating sleeve and mandrel; guide means between said mandrel and pad member, said guide means limiting relative longitudinal movement therebetween; and a retracting spring positioned to exert a force on said pad actuating sleeve relative to said mandrel, said pad actuat-

ing sleeve and pad member including inclined cooperating surfaces in engagement with each other and forming an angle between said axis and the normal thereto, whereby downward force of said drill pipe string on said pipe section telescopes said pipe section over the upper end of said mandrel and longitudinally slides said pad actuating sleeve along said mandrel to cam said pad member laterally away from said pad actuating sleeve to an expanded position, said retracting spring retracting said pad member upon cessation of said downward force.

2. The subject matter of claim 1, including upper and lower bearings disposed adjacent to the upper and lower ends of said pad actuating sleeve for enabling rotation of said mandrel within said pad actuating sleeve whereby drilling may progress when said pad member is in its expanded position.

3. The subject matter of claim 2, in which said retracting spring is disposed between the lower end of said pad actuating sleeve and said lower bearing to urge said pad actuating sleeve upwardly upon cessation of said force on said upper pipe section, said pad actuating sleeve and pad member including inclined engaging surfaces positioned to effect a retraction of said pad member by camming action therebetween when said pad actuating sleeve moves upwardly.

4. The subject matter of claim 3, in which said lower bearing is a roller bearing and said guide means includes a thrust bearing disposed below said roller bearing; and annular keying means keyed to the lower end of said mandrel between said roller bearing and said thrust bearing, the lower end portion of said pad member including rearwardly extending upper and lower guiding surfaces sandwiching said roller and thrust bearings therebetween whereby both said pad actuating sleeve and pad member are effectively keyed against longitudinal movement to said mandrel.

5. The subject matter of claim 1, in which said full bore deflection drilling apparatus is adapted to be lowered in a bore hole having sidewalls; an orientation assembly secured to said pad actuating sleeve and including actuating means connected to said pad member responsive to expanding movement of said pad member to cause said orientation assembly to engage said side walls of said bore hole to hold said pad actuating sleeve against rotation.

6. The subject matter of claim 1, including clutch means in the form of arms pivoted to the inner wall of said pad actuating sleeve and biased against the exterior wall of said mandrel, said mandrel including indents receiving said clutch means so that both said pad actuating sleeve and pad member can be rotated with said drill pipe before expansion of said pad member is effected.

7. The subject matter of claim 3, in which said connecting means comprises a spring having a greater stiffness than said retracting spring.

8. The subject matter of claim 1, in which said upper pipe section includes an adjustable spacing screw means adapted to engage said one end of said mandrel when telescoped within said pipe section to limit the extent of relative movement between said mandrel and pipe section to a given value.

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