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APPARATUS FOR DRILLING HOLES DEVIATING LATERALLY FROM A STRAIGHT BORE

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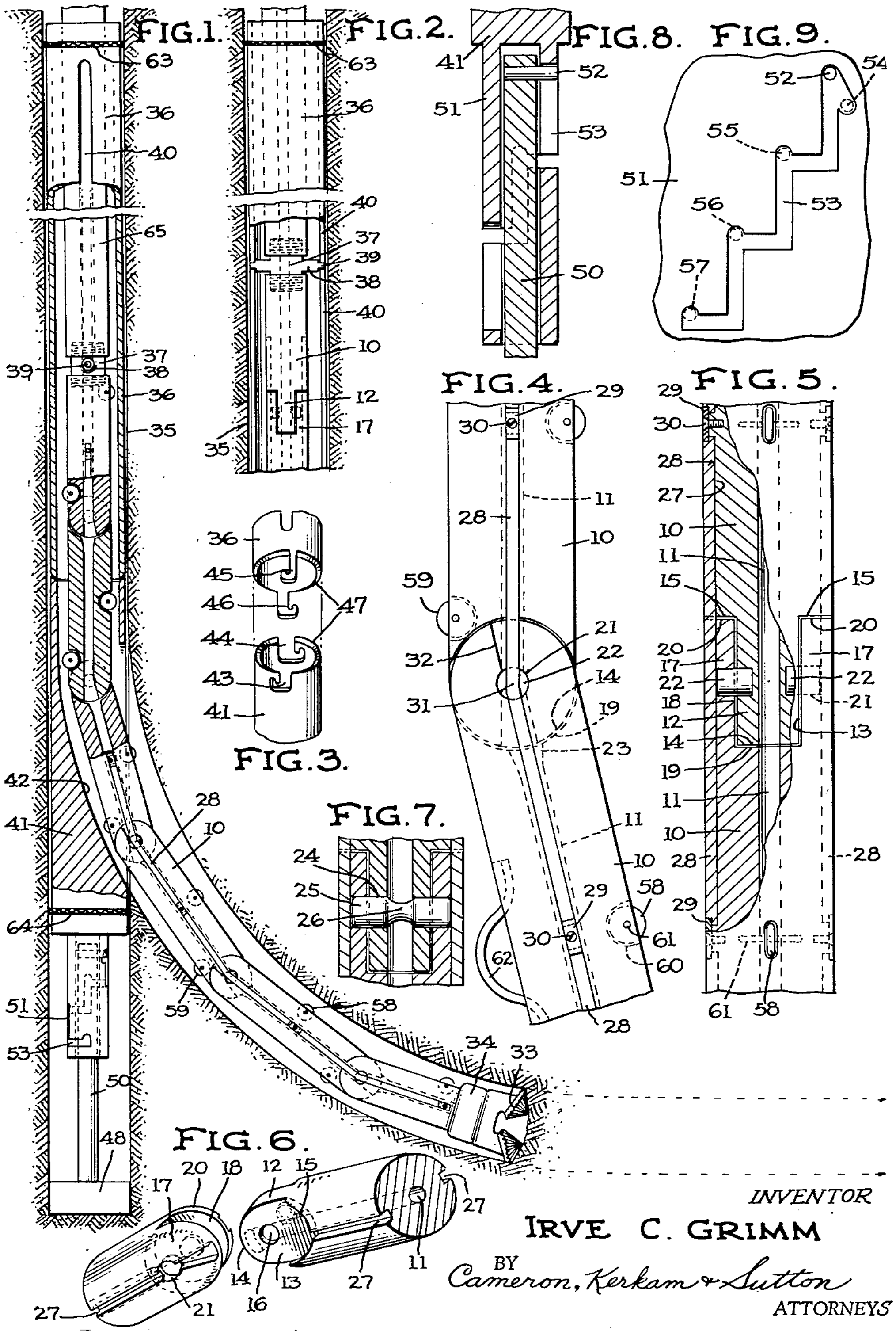

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APPARATUS FOR DRILLING HOLES DEVIATING LATERALLY FROM A STRAIGHT BORE

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This invention relates to drilling apparatus, and especially to apparatus for drilling or boring wells in the earth, such as oil and gas wells, although the apparatus may be used advantageously for drilling or boring through any desired material for any desired purpose. More particularly, the invention is concerned with controlling the direction of drilling or boring so as to enable holes to be drilled which deviate laterally from an existing straight bore.

For convenience, the invention will be described hereinafter and illustrated with respect particularly to the drilling of oil wells, an application of the invention which has important utility. It is often the case that the yield obtainable through the usual straight, approximately vertical or slanting bore extending from the surface of the earth to an underground oil-producing formation can be very substantially increased by supplemental bores deviating laterally from the original bore at the level of the producing horizon and extending more or less horizontally to points in the producing formation from which increased production can be obtained. Various means have been proposed for drilling such laterally deviating holes, but as far as I am aware none has proved satisfactory.

The present invention provides novel and improved apparatus for accomplishing the above objectives, said apparatus being designed for ease and economy of manufacture, providing positive directional stability and control of the drill, and insuring successful operation together with the advantages of durability, easy recovery of equipment from the well, etc.

As in drilling equipment heretofore proposed, the present invention provides for the positioning of deflecting means in the straight bore at or slightly above the producing horizon so as to cause the drill to deviate laterally from the axis or direction of the bore, and for thereafter moving the drill in a curved path which extends from the direction of the straight bore to the more or less horizontal direction ultimately desired. To these ends, the drill pipe which carries the drill is made flexible, preferably by means of a plurality of end-to-end pivotally or universally jointed sections which are capable of assuming positions at an angle to each other so as to conform to the desired curvature of the deviating path of the drill. This deviation may extend throughout a full 90° arc (e.g., from the vertical to the horizontal) or may be less as in a case in which it might be desired to have the deviating hole slant downwardly away from a vertical bore. The flexible drill pipe itself does not rotate, but the jointed sections are hollow or tubular and together they provide a continuous unobstructed conduit for unrestricted fluid flow in case of the use of a fluid-operated drill of the turbo type, as well to provide fluid flow for the removal of cuttings. Vane type drills, impact drills, or any other desired type of drill may be employed.

An important feature of the present invention resides in the means employed to adjust and maintain the successive jointed sections at appropriate angles to each other so that the drill pipe conforms, both as to curvature and as to orientation, with the desired curved path through which the drill bit is to travel. Initial deflection of the drill bit is caused by the deflecting means mentioned above, but it will be understood that in order to cause the drill to follow the desired curved path, it is also nec-

essary to provide the proper angularity between enough sections to make up the length of the curved path from the deflecting means to the point at which the deviating curved bore is to end or from which the drill is to continue its travel in a straight path in a desired new direction.

For the above purpose, the present invention utilizes means resiliently urging the sections to the desired positions of relative angularity, in the form of bars of resilient metal or their equivalent which are prebent at intermediate points and given initial sets with their ends at a desired angle to each other. When said ends are suitably connected one to each of a pair of jointed sections of drill pipe, the sections tend to assume positions at an angle to each other which corresponds to the angle of bend of the resilient bar. The bar itself then acts to maintain the sections resiliently in the desired angular relation to one another, yieldably resisting any effort to bend the sections closer together or to straighten them out into alignment. If desired, a maximum limitation of the angularity of the sections can be provided in any suitable manner in the pivot joints or otherwise. Then the angles of bend in the bars can be made somewhat more acute than the limited angles which the sections are capable of assuming relative to one another so that the bars move the sections to their positions of maximum angularity relative to one another and hold them in these positions under tension.

It will be evident also that such prebent bars will control the direction or orientation of bend between the sections and that when a series of such bars at the successive jointed connections are arranged so that the bend angles in the bars are all in the same plane, the result is that the successive angles between the jointed sections and the overall curvature of the drill pipe are all in the same plane and twisting of the drill pipe is prevented.

For convenience in placing and replacing the bars as hereinafter described, they are preferably detachably secured to the outsides of the sections with their straight ends parallel with the axes of the sections and with their intermediate bend angles bridging the pivotal connections between sections. They can be removably secured to the sections in any desired way, as by means of suitable brackets, for example, but preferably grooves are formed in the outer sides of the sections in which the straight ends of the bars are housed, thus confining the bending action in the bars to the intermediate portions thereof between the adjacent sections. With such an arrangement, it is also advantageous to employ two bars at each joint in the flexible drill pipe and to provide each section with diametrically opposite grooves. In the case of pivotal rather than universal joints, the two opposite grooves are aligned with the ends of the pivot axis so that the bend angles in the bars lie in planes perpendicular to the pivot axis.

When a deviating bore is to be drilled, the jointed sections with prebent bars in place are assembled end-to-end in sufficient number that their total length is that required for drilling the curved deviating path. Then for lowering this curved flexible drill pipe into the well bore, the assembled sections are preferably pulled forcibly into a straight guide tube, the result of which is to straighten out the resilient prebent bars temporarily. Preferably the deflecting means is then suspended from the end of the guide tube and the whole assembly lowered into the well bore as a unit. When the deflecting means is anchored in the bore at the desired points, its connection with the guide tube holds the latter against rotation, and a sliding connection between one of the sections and the guide tube prevents rotation of the drill pipe. The guide assembly also provides a convenient tubular package for transporting the curved spring-loaded assembly.

As the drill advances past the deflecting means, the jointed sections emerge one by one from the stationary guide tube and promptly take up the predetermined angular positions so that the length of drill pipe from the guide tube to the drill bit is always curved to the desired arc. Once the desired length of this arc has been traveled by the drill, the jointed sections and drill are pulled back into the guide tube which is then lifted out of the well bore. If further straight drilling in the new direction is desired, jointed sections of sufficient length to traverse the curved hole plus the desired amount of additional straight hole to be drilled are assembled with the prebent bars replaced by straight bars of resilient metal. These bars can bend as the sections follow along the curved bore previously drilled but can then straighten out and maintain the drill pipe straight as the drill advances beyond the end of the curved path.

The drawings show an embodiment of the invention adapted to accomplish the above stated operation and results, but it is to be understood that said drawings are for purposes of illustration only and are not to be construed as a definition of the limits of the invention, reference being had to the appended claims for this purpose.

In the drawings,

FIG. 1 is a somewhat diagrammatic view, partly in section, which illustrates the use of apparatus embodying the invention;

FIG. 2 is a partial side view of the upper part of FIG. 1;

FIG. 3 shows a preferred form of detachable connection between the guide tube and whipstock hereinafter described;

FIGS. 4 and 5 are detail views taken at right angles to one another and showing the preferred form of pivotal connection between adjacent drill pipe sections;

FIG. 6 is an exploded view showing the mating ends of adjacent sections in perspective;

FIG. 7 shows an alternative form of pivot pin; and

FIGS. 8 and 9 show details of the adjustable connection between the whipstock and the anchor hereinafter described.

Referring first to FIGS. 4, 5 and 6, the flexible drill pipe is composed of a plurality of similar substantially cylindrical sections **10** each having an axial bore or passage **11** therethrough. The preferred form of connection between sections is pivotal as differentiated from universal in character. In the form shown, one end of each section **10** terminates in a tongue-like projection **12** having flat sides **13** that are parallel to each other and to the section axis, the thickness of the tongue **12** being less than the section diameter but sufficient to accommodate the passage **11** which extends therethrough. The outer end surface **14** of the tongue **12**, and also the end surfaces **15** of the section at the base of the tongue **12** on either side thereof, are all curved to correspond with the surface of an imaginary circular cylinder having its axis perpendicular to the sides **13** of the tongue **12** and intersecting the axis of the section **10**. Formed in each of the sides **13** is a circular socket **16** having its axis coincident with the axis of curvature of the surfaces **14** and **15**.

The other end of each section **10** terminates in a pair of spaced ears **17**, the inner faces **18** of which are flat and parallel to the sides **13** of the tongue **12**, said faces **18** being spaced apart by a distance sufficient to accommodate a tongue **12** between them. The passage **11** terminates in the bottom surface **19** between the ears **17**, and this surface **19** together with the outer end surfaces **20** of the ears **17** are all curved to correspond with the surface of an imaginary circular cylinder having the same diameter as the first mentioned circular cylinder and having its axis parallel to the axis of said first circular cylinder and intersecting the axis of the section. Each ear **17** is provided with a circular hole **21** therethrough of the same diameter as the sockets **16** and with its axis coincident with the radius of curvature of the surfaces **19** and **20**.

Thus when the sections are assembled end-to-end as indicated in FIG. 6, pivot pins **22** can be inserted through the openings **21** and into the sockets **16** to establish and maintain the pivotal connection, the cooperating surfaces **15**, **20** and **14**, **19** all being concentric with the pivot axis. The passages **11** in the two sections are then in end-to-end communication as shown in FIGS. 4 and 5. To maintain this communication when the sections are bent relative to one another as hereinafter described, the mouth of one or both ends of the passage **11** can be flared as indicated at **23** in FIG. 4.

FIG. 7 shows an alternative form of pivot means that can be employed if desired. In this case the sockets **16** described above are converted into holes **24** which extend all the way through the walls of the tongue **12** and open into the passage **11**. Thus a single pin **25**, the ends of which correspond to the pins **22** mentioned above, can be inserted in the aligned holes **21**, **24** in the axis of curvature of the surfaces **14**, **19** and **15**, **20**. Preferably the middle section of the pin **25** which traverses the passage **11** is reduced in diameter as indicated at **26** in order to minimize the obstruction of the passage.

For drilling a deviating bore, a plurality of successive sections **10** are maintained in suitable angular relation with each other, such as indicated in FIG. 4, by means of bar-like resilient elements housed in slots or grooves extending longitudinally in the outer surfaces of the cylindrical sections **10**. As shown in FIG. 6, for example, grooves **27** are diametrically opposite each other and terminate at the surfaces **15** at one end of each cylindrical section and at the surfaces **20** at the other end of each cylindrical section. The cross sectional shape of the grooves preferably corresponds with that of the bar-like resilient elements **28** housed therein and in the form shown this cross section is approximately square. If desired, the grooves **27** may be continuous from end to end of each section, but as shown in FIGS. 4 and 5, it is usually advantageous to terminate the grooves short of meeting one another at the middle of each section. The ends of the resilient bars **28** are thus spaced from one another and are suitably retained in the grooves by means such as retainers **29** held in place by screws **30**. Each bar **28** thus has approximately half its length disposed in the groove **27** of one section and approximately half its length disposed in the groove **27** of the adjoining section, these two straight half lengths being joined at an angle to each other as shown in FIG. 4 and the apex **31** of the angle being located substantially in the pivotal axis of the pins **22** or **25**.

As already explained, for drilling a deviating curved hole, these bars are prebent at an initial predetermined angle such as illustrated in FIG. 4, but are capable of being bent until the two half lengths lie in a straight line. On the other hand, when the deviating curved hole has been completed and it is desired to drill further in a straight line, the prebent bars **28** will be replaced by normally straight bars which are capable of being bent to an angle such as shown in FIG. 4. Suitable means are preferably provided to limit the degree of angularity between the successive sections particularly. For example, the end portions of the grooves **27** can be flared from the pivot pin holes **21** outwardly to the curved surfaces **20** as shown at **32** in FIG. 4 so as to limit the angle which one section **10** can assume relative to the half length of its bar **28** that is associated with the next section **10**.

The arrangement described has the advantage that the bars **28** act as retainers for the pivot pin **22** or **25** since the apices **31** of the angles of the bars are located over the ends of the pivot pins **22** or **25**. Further the two bars on opposite sides of the joints are bendable substantially only in parallel planes perpendicular to the pivot pin axes.

It will be understood that the angle between the sections and the angle to which the bars as prebent will depend upon the length and the degree of curvature of the curved path that is to be drilled. Referring for example to FIG. 1, the proportions are such that approximately six sections 10 are required to complete a full 90° deviation from the original straight bore to the laterally directed bore, in which case the angle between each two successive sections will be approximately 18°.

The use of a flexible drill pipe or string made up of jointed sections according to FIGS. 4 and 5 is illustrated in FIG. 1. Six of the sections 10 are first assembled on the ground with their pivot pins 22 or 25 and their prebent bar springs 28 in place. The end section 10 carries a drill bit 33 of any suitable type which is driven by any suitable motor indicated generally at 34 such as a fluid pressure motor which can be supplied with motive fluid through the continuous passage formed by the successive axial passages 11 in the jointed drill string or pipe. For purposes of lowering this string of six sections into the preexisting straight bore 35, it is preferred to use a guide tube 36 having sufficient length to house all six sections. Then the six jointed sections are pulled forcibly up into the guide tube 36, the resilient bars 28 meanwhile bending into a single straight length as described above. To accomplish this housing operation, and also to prevent rotation of the drill string during subsequent drilling, the upper end section 10 is preferably screwed or otherwise connected to a guide pin 37 which extends laterally at 38 into engagement with the walls of the guide tube to center the drill string therein, and is also provided with end pins 39 which project slidably into slots 40 in the sides of the guide tube so as to prevent rotation of the guide pin and drill string therein. This guide pin is likewise connected, as by a screw-threaded joint or other suitable means, to a drill pipe 65 extending upwardly through the straight bore to the usual ground level (not shown).

It will be understood that the guide tube is lowered into the bore by means of adding lengths of drill pipe above it. During such lowering of the guide tube, the guide pin 37 will be located at the top of the guide tube with its pins 39 in the ends of the slots 40 at the top of FIG. 1. In this position all six sections 10 below the guide pin 37 will be pulled up into and housed within the guide tube.

Once the guide tube has been lowered to the desired point and drilling of the deviating hole is to begin, power is supplied to the motor 34, and as the drill bit 33 moves out of the guide tube 36, it is deflected laterally in the desired direction by means of a suitable whipstock and anchor assembly. These are preferably arranged to be lowered into the straight bore 35 by suspension at the lower end of the guide tube. To this end a whipstock 41 having an inclined deflecting surface 42 is suspended from the guide tube by detachable means such as shown in FIG. 3. The cylindrical wall of the upper end of the whipstock is provided with bayonet-type notches 43, 44 and the lower end of the guide tube is provided with cooperating hooks 45, 46 adapted to engage in notches 43, 44 respectively. As shown, this engagement is effected simply by lowering the guide tube so that the hooks 45, 46 enter the open ended slots 43, 44, after which a slight clockwise rotation of the guide tube or counterclockwise rotation of the whipstock causes the hooks to engage in the bayonet slots to suspend the whipstock from the guide tube. Preferably one of the hooks, i.e., hook 46, is larger than the other hook 45 so as to insure that the whipstock is always attached to the guide tube in the same relative position. In order to effect a tight joint between the guide tube and whipstock during drilling, cooperating bevels 47 can be formed on the meeting end surfaces thereof.

It will be understood from the above description that when it is desired to lift the guide tube from the bore 35, it can be detached from the whipstock 41 by lowering it slightly to take the strain off the hooks 46 and then by giving it a slight counterclockwise rotation relative to the whipstock so that the hooks 45, 46 are in position to be lifted straight up out of the slots 43, 44, leaving the whipstock in the bore 35 at the desired position. Thus when it is desired to remove the drill string from the bore 35, it can be pulled back up into the guide tube 36, after which the guide tube can be detached from the whipstock and lifted out of the bore. This is necessary, of course, when it is desired to replace the prebent bars 28 by straight bars as hereinafter described.

To position and maintain the whipstock at the desired point in the bore 35, any suitable anchoring means can be employed as indicated diagrammatically in FIG. 1 at 48. The stem 50 which extends upwardly from the anchoring device 48 can then be connected to the whipstock 41 in any desired manner. In many instances, however, it is desirable to provide for relative rotation between the whipstock 41 and the anchor so that a series of deviating lateral bores can be made in different directions from the preexisting straight bore 35. FIGS. 8 and 9 show the details of a preferred form of connection between the anchor and whipstock for accomplishing this relative rotation. With reference to FIG. 8, the lower end of the whipstock is provided with a tubular extension 51 within which the stem 50 of the anchor telescopes. At the upper end of the anchor stem, a pin 52 therein projects outwardly and engages in a slot 53 in the wall of the tubular extension 51, whereby the anchor and whipstock may rotate relative to each other.

FIG. 9 shows the preferred shape of this slots 53 in developed form, assuming the tubular extension 51 to be opened down its front center line in FIG. 1 and spread apart to lie flat in the form shown in FIG. 9. As shown, the pin 52 is in the uppermost end of the slot in which position the anchor assembly supports the whipstock in its lowermost position with the parts 50 and 51 fully telescoped. When it is desired to lift the whipstock and anchor from the bore 35, on the other hand, a slight counterclockwise rotation of the guide tube and whipstock, together with lifting thereof, causes relative displacement of pin 52 and slot 53 until the pin is in the dotted line position 54 in FIG. 9 in which the whipstock extension 51 picks up and lifts the anchor assembly. On the other hand, once a deviating bore such as indicated in FIG. 1 has been completed, and assuming that it is desired to make another such deviating bore in a horizontal direction 90° removed from the first deviating bore, then by lifting the guide tube so as to cause the whipstock 41 and its slot 53 to move up relative to the pin 52 (FIG. 9) and then rotating the guide tube and whipstock clockwise, the pin 52 assumes the position 55 in FIG. 9 in which the deflecting surface 42 has been turned through an angle of 90° relative to the position shown in FIG. 1. Similarly the pin 52 can be caused to assume positions 56 and 57 with further rotation of the deflecting surface.

Any suitable antifriction means can be employed for facilitating the movement of the jointed sections into and out of the guide tube 36, etc. As shown by way of example, each section has an antifriction roller 58 adjacent the midpoint of its length on one side, and a similar antifriction roller 59 adjacent one end on its diametrically opposite side, the arrangement as shown in FIG. 1 providing rolling antifriction contact between the sections and the walls of the guide tube, the deflecting surface 42, and also the walls of the deviating bore itself. These antifriction rollers may be mounted in any suitable manner, as by providing recesses 60 at suitable points in the outer surface of the sections 10 in which the rollers rotate, the roller pins 61 being mounted in any suitable manner.

Once the deviating curved path has been completed to the horizontal (i.e., slightly beyond the position of the drill bit shown in FIG. 1), and assuming that it is now desired to continue drilling in a straight line in the horizontal direction, then the drill string and guide tube are removed from the bore as described above and the required number of jointed sections are assembled with the prebent bars 28 replaced by straight bars. In lowering the reassembled drill string back into the bore 35, it is not necessary to employ the guide tube 36 because the normal condition of the drill string is straight, but it is usually advisable to employ a compensating torque during subsequent drilling. As the drill bit reaches the deflecting surface 42 and follows around the pre-drilled curved path, however, the pivotal connections between the sections permit them to be bent back to the angular relative positions shown in FIG. 1 by bending the straight bars 28 so as to follow around the curved path. Thereafter, as the drill continues horizontally, the bars reassume their straight condition and maintain the drill string as a straight assembly for such further drilling.

When thus returning the straight drill string to position for further drilling of the deviating bore, it may be desirable to provide means for centering the drill string in the bore. To this end centering devices such as the arc-shaped springs 62 shown in FIG. 4 can be secured in any suitable manner to those sides of the sections 10 which are on the bottom as the sections pass around the curved path and on into the extended straight horizontal bore. Such devices can be secured in any suitable manner and, of course, can be made detachable so that they can be removed.

It will be understood that cuttings together with fluid from the motor 34 pass back up in the annular space surrounding the flexible drill pipe between it and the walls of the bore or the walls of the guide tube. To prevent fouling of the anchor, and other parts, flexible fiber or rubber seals can be provided at suitable points, such as at 63 around the top end of the guide tube and at 64 around the lower end of the whipstock.

It will be understood that the invention is not restricted to the details shown in the drawings and particularly described above and that various changes can be made in the form, details of construction and arrangement of the parts without departing from its spirit. Reference should therefore be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. Well drilling apparatus adapted to drill a hole deviating laterally from a substantially straight bore which comprises a drill pipe and a drill bit and driving motor therefor at its end, means adapted to be positioned in said bore for directing the drill laterally in the direction of the desired deviation, said drill pipe including a plurality of end-to-end sections, means pivotally connecting each pair of adjacent sections for angular adjustment relative to one another, and a plurality of resilient means each associated with one of said pairs of sections, each resilient means having end portions extending parallel to and being secured to the sections of its associated pair and an intermediate resiliently bendable portion, said end portions in the unstressed condition of said intermediate portions maintaining the pairs of end-to-end sections in substantially axial alignment, said intermediate portions being resiliently bendable to the angles to which their associated pairs of sections are adjusted as they are directed laterally from said straight bore and being stressed thereby to urge their associated pairs of sections resiliently back to substantially axial alignment.

2. Well drilling apparatus as defined in claim 1, said resilient means comprising a resilient bar-like member normally maintaining said two sections of a pair in said aligned relative positions and bendable for adjusting said two sections to said angular relative positions.

3. Well drilling apparatus as defined in claim 2, said two sections each having socket-like means adapted to receive the end portions of said member.

4. Well drilling apparatus as defined in claim 2, each of said two adjacent sections having a groove in its outer surface parallel to its axis, said bar-like member having its opposite end portions lying in said grooves of said two adjacent sections and connected by said resiliently bendable intermediate portion.

5. Well drilling apparatus as defined in claim 2, said sections being pivotally connected to one another and having a continuous bore therethrough forming a fluid pressure conduit through which said drill bit may be driven.

6. Well drilling apparatus as defined in claim 1, each of said sections being substantially cylindrical in shape with an axial passage therethrough, one end of each section having a projecting tongue with flat sides parallel to each other and to the axis of the section and of less thickness than the diameter of the section, the end surface of said tongue and the end surfaces of the cylindrical section on either side of said tongue being curved to correspond with the surface of a circular cylinder having its axis intersecting the axis of the section and perpendicular to said sides, the other end of each section having a pair of projecting ears the facing inner sides of which are flat and parallel to each other and to the sides of said tongue, the end surfaces of said ears and the bottom surface of the cylindrical section between said ears being curved to correspond with the surface of a circular cylinder having the same diameter as said first circular cylinder and with its axis parallel to the axis of said first circular cylinder and intersecting the axis of said section.

7. Well drilling apparatus as defined in claim 6, said axial passage terminating in the curved end surface of said tongue and in the curved bottom surface between said ears, at least one end of said passage being flared to provide a mouth of larger area than the cross section of said passage.

8. Well drilling apparatus as defined in claim 6, said sections being assembled with the tongue at one end of one section between the ears at one end of the next section and rotatable therebetween with the respective curved surfaces in engagement with each other, and pivot means interconnecting the assembled tongue and ears in the common axis of said curved surfaces.

9. Well drilling apparatus as defined in claim 8, said pivot means comprising pins each extending through one of said ears into a socket formed on one side of said tongue.

10. Well drilling apparatus as defined in claim 9, each cylindrical section having parallel diametrically opposite grooves in its outer surfaces extending longitudinally to both ends of said outer surfaces and intersecting the pivot pin holes in said ears, said resilient means comprising bar-like resilient elements housed in said grooves and retaining said pivot pins in place, said bar-like elements being prebent to a predetermined angle at intermediate points approximately in line with the pivot axis of said pins.

11. Well drilling apparatus as defined in claim 10, said grooves flaring to greater width at their ends between said pivot pins and the curved end surfaces of said ears, whereby each eared section can pivot to said predetermined angle relative to the associated tongued section and its straight length of said bar-like element extending from said intermediate point.

12. Well drilling apparatus adapted to drill a hole deviating laterally from a substantially straight bore which comprises a drill pipe and a drill bit and driving motor therefor at its ends, means adapted to be positioned in said bore for directing the drill laterally in the direction of the desired deviation, said drill pipe including a plurality of end-to-end sections and each two adjacent sections being connected for pivotal movement about parallel axes perpendicular to the length of the drill pipe, said sections being substantially cylindrical and each having parallel diametrically opposite grooves in its outer surface extending longitudinally to both ends of said outer

surface in intersecting alignment with said pivot axes, and resilient means interconnecting and normally maintaining each two adjacent sections in predetermined positions of alignment relative to each other, said resilient means comprising bar-like resilient elements housed in said grooves, the intermediate portions of said elements between the ends of said grooves and in line with said pivot axes being resiliently bendable as each pair of sections change their relative positions of alignment as they are directed laterally from said straight bore, said sections when pivoted from said predetermined relative positions rendering said elements stressed to urge said sections resiliently back to said predetermined relative positions.

13. Well drilling apparatus as defined in claim 12, said bar-like resilient elements being substantially straight in their unstressed condition and maintaining the adjacent sections in predetermined relative positions of substantially axial alignment.

14. Well drilling apparatus as defined in claim 12, said bar-like resilient elements being pre-bent to maintain adjacent sections at predetermined angles relative to each other when unstressed, and a guide tube containing a plurality of pairs of adjacent sections in axial alignment with said bar-like elements in stressed condition, said guide tube and contained sections adapted to be lowered as a unit in said straight bore to a point therein adjacent said directing means.

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