Jan. 5, 1960 D. L. SIMS 2,919,897

DEFLECTION DRILLING TOOL

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Fig. 1

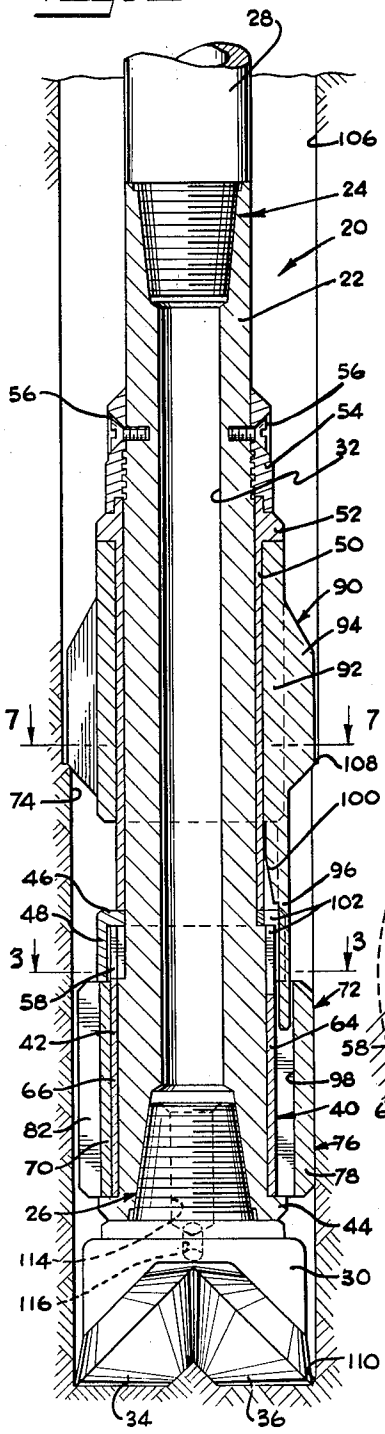


Fig. 2

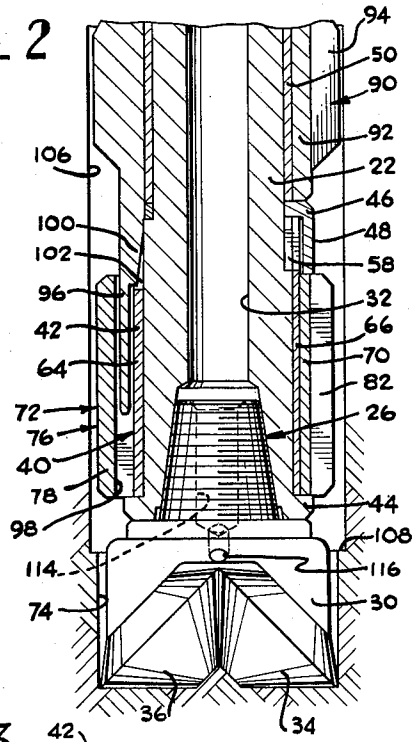
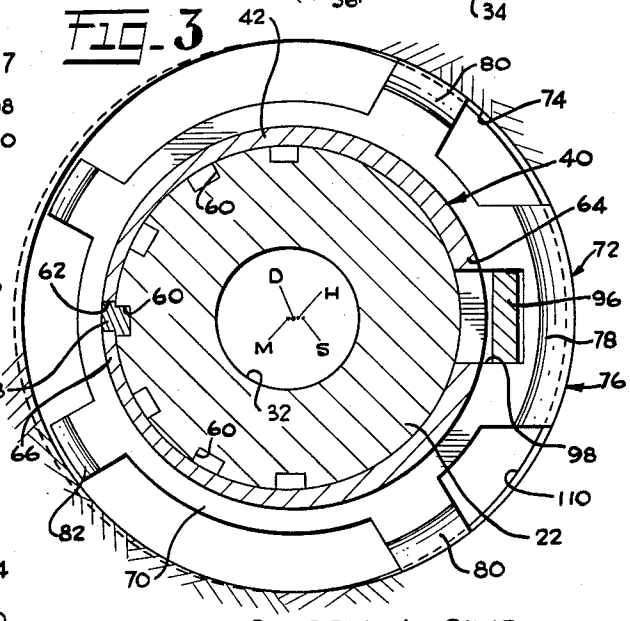


Fig. 3



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DEFLECTION DRILLING TOOL

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FIG. 4

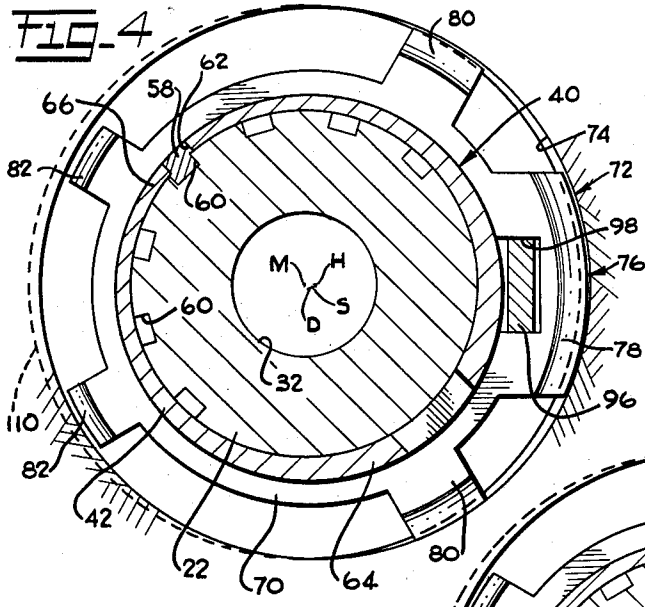


FIG. 7

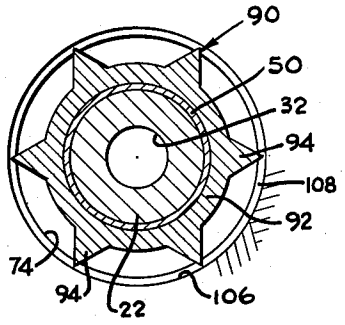


FIG. 5

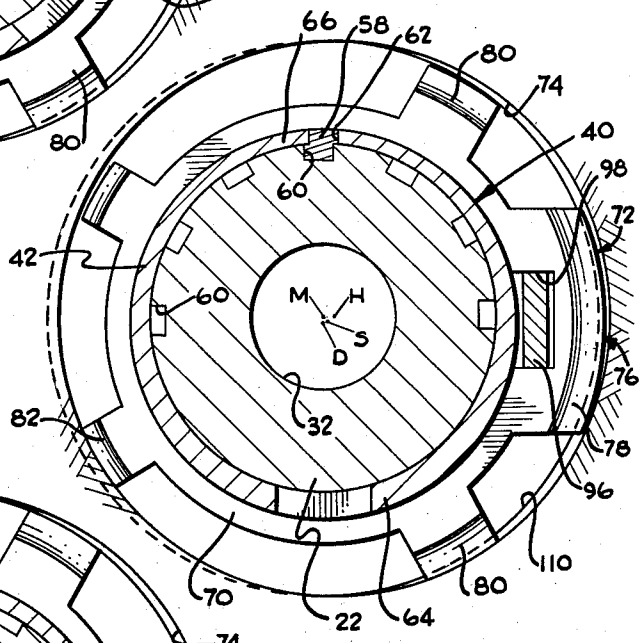
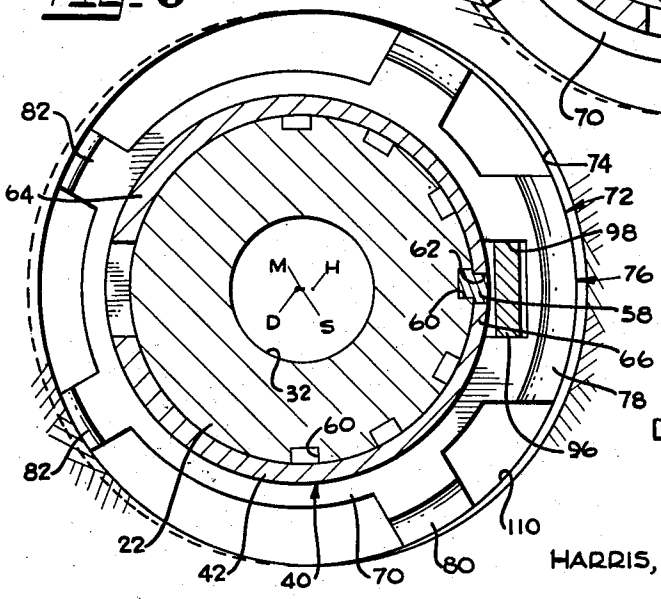


FIG. 6



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DEFLECTION DRILLING TOOL

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Fig. 8

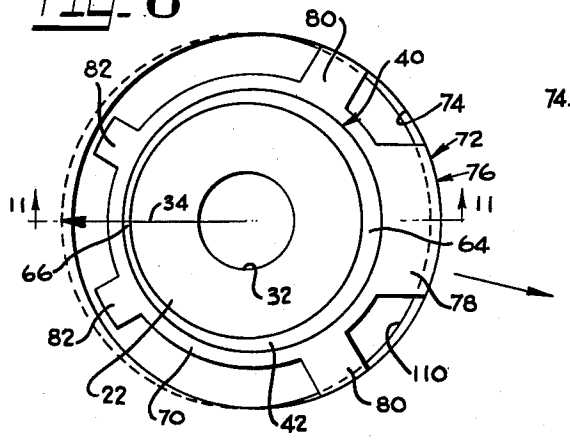
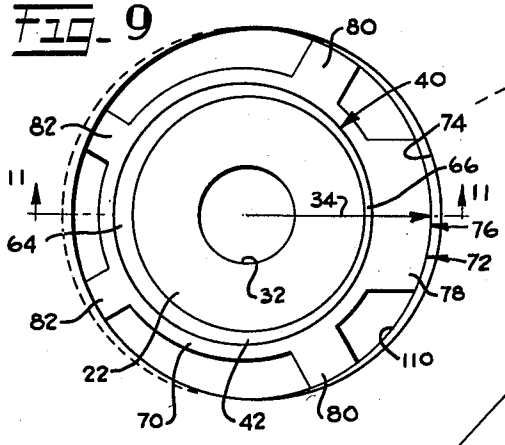


Fig. 9



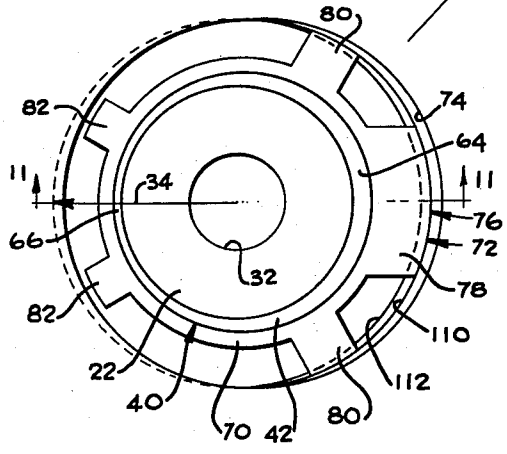


Fig. 10

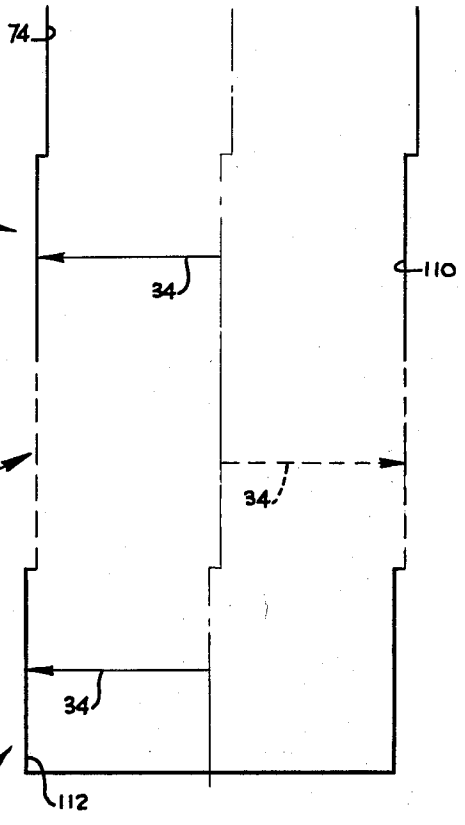


Fig. 11

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2,919,897

DEFLECTION DRILLING TOOL

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Application July 7, 1958, Serial No. 746,949

10 Claims. (Cl. 255—1.6)

The present invention relates in general to drilling tools for oil wells and the like and, more particularly, to a tool for deflecting a drill bit laterally in a predetermined direction to cause the bit to drill a hole at an angle to the original hole, this application being a continuation-in-part of my co-pending application Serial No. 474,855, filed December 13, 1954, now abandoned.

A primary object of the invention is to provide a deflection drilling tool which is merely interposed between the lower end of the drill string and the bit, all components of the tool being carried by the drill string so that it may be run into and out of the well readily.

The deflection drilling tool of the invention includes a mandrel which is rigidly coupled at its upper end to the lower end of the drill string and at its lower end to the drill bit so that rotation of the drill string is transmitted to the bit through the mandrel, the mandrel being tubular so that normal drilling mud circulation may be maintained with the tool of the invention in use.

In order to deflect the hole formed by the drill bit laterally relative to the original hole in a predetermined direction, it is an object of the invention to provide means for laterally displacing the axis or center of the mandrel relative to the axis or center of the original hole in such direction. Consequently, the drill bit is deflected laterally in the same direction.

An important object of the invention is to provide means for laterally displacing the center of the mandrel comprising an eccentric on and rotatable with the mandrel, a deflection bearing encircling the eccentric, stop means on one side of the deflection bearing engageable with one side of the peripheral wall of the hole formed by the drill bit for displacing the center of the mandrel toward the other side of the hole, and anchor means engageable with the wall of the hole formed by the drill bit for preventing rotation of the deflection bearing so as to maintain the desired orientation of the stop means.

Another object is to provide an eccentric having the form of a sleeve the angular position of which relative to the mandrel may be varied to properly orient the eccentric relative to the drill bit.

A further object is to provide an anchor means for the deflection bearing which includes an anchor bearing encircling the mandrel and spaced longitudinally from the deflection bearing, means on the anchor bearing engageable with the wall of the hole formed by the drill bit for preventing rotation of the anchor bearing, and means connecting the deflection bearing to the anchor bearing so that the anchor bearing holds the deflection bearing against rotation to maintain the desired orientation of the stop means on the deflection bearing.

Another object is to provide locking means responsive to longitudinal movement of the anchor bearing relative to the mandrel for locking the anchor bearing, the mandrel, and the deflection bearing together so that a predetermined orientation of the stop means on the deflection bearing may be achieved merely by rotating the drill string.

The foregoing objects, advantages, features and results of the present invention, together with various other objects, advantages, features and results thereof which will be evident to those skilled in the deflection drilling art in the light of this disclosure, may be attained with the exemplary embodiment of the invention described in detail hereinafter and illustrated in the accompanying drawings, in which:

Fig. 1 is a vertical sectional view of the deflection drilling tool of the invention in a well and illustrates the beginning of lateral deflection of a hole formed by a drill bit connected to the tool;

Fig. 2 is a fragmentary vertical sectional view illustrating the starting of a hole by the drill bit, Fig. 2 illustrating an earlier stage of the operation of the invention than Fig. 1;

Figs. 3, 4, 5 and 6 are transverse or horizontal sectional views all taken along the arrowed line 3—3 of Fig. 1 and respectively illustrating different operating positions of various components of the deflection drilling tool of the invention;

Fig. 7 is a transverse sectional view taken along the arrowed line 7—7 of Fig. 1;

Figs. 8, 9 and 10 are semi-diagrammatic, horizontal sectional views similar to Figs. 3, 4, 5 and 6 and respectively illustrating different events in the operation of the invention; and

Fig. 11 is a diagrammatic, composite vertical sectional view taken as indicated by the arrowed lines 11—11 of Figs. 8, 9 and 10 of the drawings.

Referring particularly to Fig. 1 of the drawings, the deflection drilling tool of the invention is designated generally by the numeral 20 and includes a mandrel 22 having at its respective ends coupling means 24 and 26 for rigidly connecting it to the lower end of a drill string 28 and to a drill bit 30, respectively, whereby rotation of the drill string is transmitted to the bit through the mandrel. In the particular construction illustrated, the lower end of the drill string 28 and the bit 30 are threaded into opposite ends of the mandrel 22 to provide the respective coupling means 24 and 26. The mandrel 22 is tubular so as to provide an axial passage 32 therethrough by means of which normal drilling mud circulation may be maintained when the tool 20 is in use.

The bit 30 may be of any desired type, the one shown for illustrative purposes being a roller bit having two rotary cutters 34 and 36, although this number may be varied. For reasons which will become apparent, the cutter 34 will sometimes be referred to hereinafter as a master cutter, the cutter 36 being a trailing one which operates in the track formed by the master cutter, as is well known in the bit art.

The mandrel 22 includes an eccentric 40 which is rotatable therewith, this eccentric, in the construction illustrated, having the form of an eccentric sleeve 42 telescoped onto the mandrel 22. Axial movement of the eccentric sleeve 42 relative to the mandrel 22 is prevented by locating the eccentric sleeve between an external annular flange 44 on the mandrel at its lower end and a cup-shaped washer 46 which encircles the mandrel, this washer having an annular skirt 48 which encloses the upper end of the eccentric sleeve. Axial movement of the cup-shaped washer 46 relative to the mandrel 22 is prevented by a sleeve 50 telescoped onto the mandrel and seated at its lower end against the washer to hold it against the upper end of the eccentric sleeve 42, thereby holding the lower end of the eccentric sleeve against the annular flange 44. The sleeve 50 is provided at its upper end with an external annular flange 52 for a purpose to be described, and the sleeve 50 is held against upward axial movement relative to the mandrel 22 by a

collar 54 seated on the upper end of the sleeve 50 and threaded onto the mandrel. The collar 54 is prevented from backing off by lock screws 56 extending therethrough and threaded into the mandrel 22. It will be noted that the sleeve 50 and the collar 54 are thus rigidly connected to the mandrel 22 and, for convenience, they may be regarded as forming an integral part of the mandrel.

The mandrel 22 is prevented from rotating relative to the eccentric sleeve 42 by a key 58, Fig. 3, disposed in one of a plurality of circumferentially spaced longitudinal grooves 60 in the mandrel and a longitudinal slot 62 in the eccentric sleeve, the key 58 being Z-shaped in cross section and the groove 60 and slot 62 in which it is disposed being correspondingly angularly offset so that the key 58 cannot move laterally out of the groove and slot.

With the foregoing interconnections between the eccentric sleeve 42 and the mandrel 22, the eccentric sleeve is, in effect, an integral part of the mandrel and may be so regarded for convenience.

The eccentric sleeve 42 is provided with points 64 and 66 which are of maximum and minimum thickness, respectively, these points of maximum and minimum thickness being referred to hereinafter as the thick and thin sides, respectively, of the eccentric sleeve for convenience. The thick side 64 of the eccentric sleeve 42 is located diametrically opposite the cutter of the drill bit 30 which is regarded as the master cutter, i.e., is located diametrically opposite the cutter 34. In other words, the master cutter 34 is located in longitudinal alignment with the thin side 66 of the eccentric sleeve 42.

Since the drill bit 30 is shown as threaded into the lower end of the mandrel 22, the angular position of the bit relative to the mandrel upon assembly depends on the structure of the threaded connection therebetween and, in order to permit positioning of the thick side 64 of the eccentric sleeve 42 diametrically opposite the cutter of the bit which is regarded as the master cutter, i.e., the cutter 34, the key 58 is inserted into the groove 60 in the mandrel 22 nearest the master cutter and into the slot 62 in the eccentric sleeve 42. In the particular construction illustrated, the grooves 60 are angularly spaced apart by 30° so that the desired diametrically-opposite positioning of the thick side 64 of the eccentric sleeve 42 and the master cutter 34 will never be off by more than 15°, which is sufficiently accurate for all practical purposes. Of course, if a finer adjustment of the angular position of the thick side 64 of the eccentric sleeve 42 relative to the master cutter 34 is desired, this may be accomplished readily, as by providing additional grooves in the mandrel 22 between the grooves 60 shown.

The eccentric 40 is encircled by and is journalled in an annular bearing 70 which is referred to hereinafter as a deflection bearing since it cooperates with the eccentric to displace the axis or center of the mandrel 22, and thus the axis or center of the drill bit 30, laterally, as will be described in more detail subsequently. The deflection bearing 70 is held against axial movement relative to the mandrel 22 by disposing it between the annular flange 44 at the lower end of the mandrel and the skirt 48 of the cup-shaped washer 46, as shown in Fig. 1, of the drawings.

The deflection bearing 70 is provided therein with an external, eccentric stop means 72 which is engageable with the wall of a hole 74 formed by the drill bit 30 and the diameter of which is slightly less than the diameter of such hole so that, as explained in more detail hereinafter, the deflection bearing 70 may shift laterally. The eccentric stop means 72 is provided on one side thereof with a main stop means 76 in the form of an external longitudinal rib 78 of substantial width, i.e., of substantial angular extent, and two external longitudinal ribs 80 of intermediate width respectively angularly spaced from the rib 78 on opposite sides thereof by equal amounts. The ribs 78 and the ribs 80, hereinafter referred to as the main rib and the stabilizing ribs, respectively, are located on the side of the eccentric stop means 72 of maximum eccentricity relative to the deflection bearing 70. This is indicated in Fig. 3, for example, wherein the center, S, of the stop means 72 is shown offset laterally from the center, D, of the deflection bearing 70 in the direction of the side of the deflection bearing on which the main rib 78 and the stabilizing ribs 80 are located. The center of the deflection bearing D and the center of the stop means S are marked throughout Figs. 4 to 8 also, and the centers of the mandrel 22 and the hole 74 formed by the drill bit 30 are identified by the reference characters M and H, respectively, throughout Figs. 3 to 8.

The main rib 78 and the stabilizing ribs 80 have relatively large surface areas, this being particularly true of the main rib, so that, when they are seated against one side of the hole 74 formed by the drill bit 30, they positively limit movement of the mandrel toward such side of the hole, as will be discussed in more detail hereinafter in considering the operating of the tool 20.

The stop means 72 also includes two external, longitudinal ribs 82 of relatively narrow widths equally angularly spaced from the point of minimum eccentricity of the stop means 72. The ribs 82 serve primarily to guide the deflection bearing 70 in the hole 74, and will be referred to hereinafter as guide ribs.

As previously indicated, the maximum eccentricity of the stop means 72 is in the direction of the side of the deflection bearing 70 on which the main stop means 76, formed by the main rib 78 and the stabilizing ribs 80, is located. This has the effect of providing the main rib 78 and the stabilizing ribs 80 with greater radial dimensions, relative to the deflection bearing 70, than the guide ribs 82, the main rib 78 having the greatest radial dimension. In other words, the main rib 78 is radially longer than the stabilizing ribs 80, and the stabilizing ribs are radially longer than the guide ribs 82.

In order to maintain a predetermined orientation of the stop means 72 in the hole 74 to deflect the hole in a predetermined direction, as will be described hereinafter, the deflection bearing 70 is prevented from rotating with the mandrel 22 by an anchor means 90 engageable with the wall of the hole 74. The anchor means 90 includes an anchor bearing 92 having thereon external longitudinal splines 94 the outer edges of which lie on a circle having a diameter greater than that of the hole 74 so that the splines score the wall of the hole during downward movement of the tool 20 to key the anchor bearing 92 to the formation. The anchor bearing 92 holds the deflection bearing 70 against rotation through the medium of a depending, longitudinal finger 96 on the anchor bearing which extends into an internal longitudinal groove 98 in the deflection bearing, this groove being formed in that portion of the deflection bearing which carries the main rib 78 for structural reasons. It will now be seen that the reason for making the key 58 Z-shaped in cross section is to prevent it from moving radially outwardly into the groove 98 as the mandrel 22 and the eccentric 40 rotate in the deflection bearing 70.

The anchor bearing 92, which encircles and acts as a journal for the sleeve 50 of the mandrel 22, is movable axially of the mandrel between an unlocked position wherein it is seated against the flange 52 on the sleeve 50, as shown in Fig. 1, and a locked position wherein it is seated against the upper side of the cup-shaped washer 46, as shown in Fig. 2 of the drawings. When the anchor bearing 92 is in its locked position, a key 100 on the inner side of the finger 96 is disposed in a keyway 102 formed in the cup-shaped washer 46 and in the eccentric sleeve 42 on the thick side 64 thereof, such keyway being formed in the thick side of the eccentric sleeve for structural reasons.

As will be apparent, when the anchor bearing 92 is

disposed in its upper, unlocked position, the key **100** is withdrawn from the keyway **102**, as shown in Fig. 1, so that the mandrel **22** and the eccentric **40** are free to rotate relative to the anchor bearing **92** and the deflection bearing **70**. However, when the anchor bearing **92** is in its lower, locked position wherein the key **100** is disposed in the keyway **102**, as shown in Fig. 2, the deflection and anchor bearings **70** and **92** are keyed to the mandrel **22** and the eccentric **40** for rotation therewith upon rotation of the drill string **28**. The normal operating position of the anchor bearing **92** corresponds to the unlocked position thereof, the anchor bearing being movable into its locked position to permit rotation of the deflection bearing **70** by means of the drill string for the purpose of establishing a predetermined orientation of the stop means **72**, as will be discussed hereinafter.

Operation

It will be assumed that, prior to putting the deflection drilling tool **20** into operation, the various components thereof have been assembled in the manner hereinbefore described. Specifically, it will be assumed that the eccentric sleeve **42** has been positioned relative to the mandrel **22** with the thick side **64** of the eccentric sleeve diametrically opposite the cutter **34** of the drill bit **30**, thereby making the cutter **34** the master cutter.

The foregoing conditions obtaining, the tool **20** is lowered, by means of the drill string **28**, into a hole **106** from the bottom of which a laterally deflected hole is to be drilled. Preferably, but not necessarily, the diameter of the hole **106** is greater than the diameter of the circle defining the edges of the splines **94** on the anchor bearing **92** to facilitate running the tool **20** to the bottom of the hole **106**.

Once the drill bit **30** reaches the bottom of the hole **106**, the drill string **28** is rotated at the surface in the usual manner to cause the bit **30** to drill the hole **74**. At this stage, it is immaterial whether the anchor bearing **92** is in its locked position, or its unlocked position, since the anchor means **90** is out of engagement with the wall of the hole **106** and friction will cause the deflection and anchor bearings **70** and **92** to rotate with the mandrel **22**.

Under the foregoing conditions, the drill bit **30** drills the hole **74** in alignment with the hole **106**. Ultimately, as shown in Fig. 1 of the drawings, the lower ends of the splines **94** on the anchor bearing **92** engage a shoulder **108** at the junction of the holes **74** and **106**, which causes the anchor bearing **92** to move upwardly on the mandrel **22** into its unlocked position as the drill bit **30** progresses downwardly. After the anchor bearing **92** arrives at its unlocked position, wherein it is seated against the flange **52**, further downward drilling by the bit **30** results in engagement of the splines **94** on the anchor bearing **92** with the wall of the hole **74**, the beginning of such engagement being shown in Fig. 1. The splines **94** now prevent further rotation of the anchor bearing **92** so that, at this point, the anchor bearing, through the medium of the finger **96**, prevents the deflection bearing **70** from rotating. After drilling downwardly with the bit **30** sufficiently to insure that the splines **94** have a good "bite" in the peripheral wall of the hole **74**, the tool **20** may be directionally oriented in the hole **74**.

In order to achieve directional orientation of the tool **20**, the drill string **28** is raised at the surface, which results in upward movement of the mandrel **22** and the deflection bearing **70** relative to the anchor bearing **92**, upward movement of the anchor bearing being prevented by engagement of the splines **94** with the peripheral wall of the hole **74**. During upward movement of the mandrel **22** and the deflection bearing **70** relative to the anchor bearing **92**, the key **100** on the finger **96** enters the keyway **102** in the cup-shaped washer **46** and the eccentric sleeve **42**, alignment of the key **100** with the keyway **102** being achieved by rotating the drill string **28** slowly as it is raised. Normally, it is not necessary to intentionally rotate the drill string **28** to align the keyway **102** with the key **100** since the drill string will automatically rotate the mandrel **22** as the drill string unwinds in response to decreasing bit pressure as the drill string is raised.

Once the key **100** has entered the keyway **102**, the mandrel **22**, the deflection bearing **70** and the anchor bearing **92** are all locked together, whereby the tool **20** may be rotated, by rotating the drill string **28** at the surface, until the desired orientation of the tool is achieved. Such orientation may be checked from the surface with any suitable equipment, not shown.

In orienting the tool **20**, the main stop means **76**, or, more accurately, the main rib **78**, is located diametrically opposite the desired direction of hole deflection. Once the tool **20** has been so oriented, the drill string **28** is lowered again until the bit **30** rests on the bottom of the hole **74**. This results in reengagement of the splines **94** on the anchor bearing **92** with the wall of the hole **74**, thereby moving the anchor bearing upwardly to its unlocked position so as to withdraw the key **100** from the keyway **102**, the finger **96** maintaining the desired orientation of the deflection bearing **70**. Now, the tool **20** has been properly oriented and the tool has been unlocked so that the mandrel **22** and the eccentric **40** are free to rotate relative to the deflection and anchor bearings **70** and **92**. Upon rotation of the drill string **28** at this stage, the tool **20** will progressively displace the bit **30** in a direction away from the main rib **78** to provide the desired hole deflection.

Considering the manner in which the tool **20** produces lateral deflection of the hole being drilled by the bit **30**, the eccentricity of the stop means **72** is, as previously stated, in a direction toward the main rib **78**, i.e., toward the right, as viewed in Figs. 3 to 6. Since the diameter of the eccentric stop means **72** is slightly less than that of the hole **74** drilled by the bit **30**, this actually locates the center S of the stop means **72** very slightly to the right of the center H of the hole **74**. Consequently, the main rib **78** and the stabilizing ribs **80** are forced into firmly abutting relation with the right side of the hole **74** when the thick side **64** of the eccentric sleeve **42** is on the right side of the hole, it being impossible for the deflection bearing **70** to move to the right, but it being possible for the deflection bearing to move to the left since, under these conditions, the guide ribs **82** are out of engagement with the left side of the hole **74**.

Under the foregoing conditions, i.e., with the ribs **78** and **80** firmly abutting the right side of the hole **74** and with the thick side **64** of the eccentric sleeve **42** on the right side of the hole, the centers M and D of the mandrel **22** and the deflection bearing **70**, respectively, are displaced to the left side of the center H of the hole **74** with the center M of the mandrel to the left of the center D of the deflection bearing. If the drill string **28** is now rotated in, for example, the clockwise direction, as viewed in Figs. 3 to 6, the deflection bearing **70** wobbles in the hole **74** and, after 180° of rotation of the mandrel **22** and the eccentric **40**, the deflection bearing has moved to the left to disengage the ribs **78** and **80** from the right side of the hole **74** and to engage the ribs **82** with the left side thereof. After another 180° of rotation, the ribs **78** and **80** reengage the right side of the hole **74** and the ribs **82** disengage the left side thereof. The foregoing wobbling action of the deflection bearing **70** may readily be seen by studying Figs. 3 to 6 in sequence. During the course of one-half of a revolution of the mandrel **22** and the eccentric **40**, from the position of Fig. 3 where the thick side **64** of the eccentric sleeve **42** is on the right side of the hole **74** to the position of Fig. 6 where the thick side is on the left side of the hole, the center M of the mandrel **22**, the center D of the deflection bearing **70**, the center S of the stop means **72** and the center H

of the hole 74 shift relative to each other as shown in Figs. 3 to 6. Similar shifting occurs during the next half revolution to restore these centers to the relative positions of Fig. 3.

It will be apparent from Figs. 3 to 6 that, during one revolution of the mandrel 22 and the eccentric 40, the center M of the mandrel is always to the left of the center H of the hole 74 and that the center M of the mandrel is always to the left of the center S of the stop means 72, except when the thick side 64 of the eccentric sleeve 42 is on the left side of the hole, as shown in Fig. 6, under which conditions the centers M and S at least substantially coincide. In other words, the interaction of the stop means 72 and the eccentric 40 is such that the center M of the mandrel 22 can never shift to the right of the center S of the stop means 72 and, consequently, can never shift to the right of the center H of the hole 74. Since the center M of the mandrel 22 is always forced to the left in the foregoing manner, and since the center of the bit 30 coincides with the center of the mandrel, it follows that the center of the bit is also forced to the left by the interaction of the stop means 72 on the deflection bearing 70 and the eccentric 40. Consequently, the bit 30 drills a hole 110, Figs. 1, 3 to 6 and 8 to 11, which is offset to the left of the hole 74. The amount that the hole 110 is offset to the left of the hole 74 depends on the eccentricity of the eccentric sleeve 42, being equal to the difference between the thicknesses of the thick and thin sides 64 and 66 thereof. This eccentricity is small, being, for example, one-sixteenth inch.

A more general and perhaps simpler way of visualizing the manner in which the interaction between the stop means 72 and the eccentric 40 results in deflection of the hole 110 to the left of the hole 74 as the mandrel 22 and the eccentric 40 rotate [with the main stop means 76, comprising the ribs 78 and 80, disposed at the right side of the hole 74], is to consider the main stop means as cooperating with the right side of the hole 74 to form a barrier or wall which positively prohibits movement of the deflection bearing 70 to the right from the position shown in Fig. 3, it being possible for the deflection bearing to move only in a region to the left of the right side of the hole 74. Consequently, every time the thick side 64 of the eccentric sleeve 42 is on the right side of the hole 74, the master cutter 34, being diametrically opposite the thick side of the eccentric sleeve, is caused to undercut the left side of the hole 74, thereby forming the hole 110 which is offset to the left. When the thick side 64 of the eccentric sleeve 42 is on the left side of the hole 74, the deflection bearing 70 moves to the left to prevent the master cutter 34 from undercutting the right side of the hole 74. Thus, the main stop means 76, comprising the main and stablizing ribs 78 and 80, cooperates with the right side of the hole 74 to form a physical barrier which causes the thick side 64 of the eccentric sleeve 42 to force the master cutter 34 always to the left. It will be understood that any cutters on the bit 30 other than the master cutter 34, such as the cutter 36, merely track behind the master cutter so that it is necessary only to consider the master cutter.

After the offset hole 110 is started, the bit 30 continues to drill straight downwardly until such time as the stop means 72 enters the upper end of the offset hole 110, whereupon another shift to the left, as viewed in Figs. 3 to 6, occurs, the bit now being forced to drill a hole, not shown in Figs. 3 to 6, offset to the left of the hole 110. Thus, as the bit 30 progresses downwardly, there is a step-by-step deflection to the left by increments equal to the eccentricity of the eccentric 40.

Figs. 8 to 11 of the drawings show semidiagrammatically the step-by-step offsetting of the successive holes formed by the bit 30 to the left for the case where the main stop means 76 is located on the right side of the original hole 74 formed by the bit. Fig. 8 shows how, when the thick side 64 of the eccentric sleeve 42 is on the right side of the hole and the main and stabilizing ribs 78 and 80 are in engagement with the right side of the hole, the master cutter 34 is forced to the left to form the leftward-offset hole 110, such leftward offset of the hole 110 being shown diagrammatically in vertical section in the upper portion of Fig. 11. Fig. 9 shows that, when the thick side 64 of the eccentric sleeve 42 is on the left side of the hole 74, with the stop means 72 still within the hole 74, the deflection bearing 70 shifts to the left to cause the master cutter 34, which is now on the right side, to continue forming the leftward-offset hole 110. This condition is shown in the intermediate portion of Fig. 11, as indicated by the dotted arrow leading from Fig. 9 to Fig. 11. Referring to Fig. 10, the bit 30 has now progressed downwardly far enough to lower the deflection bearing 70 and its stop means 72 into the hole 110. Under these conditions, with the thick side 64 of the eccentric sleeve 42 on the right side of the hole 110, the main and stabilizing ribs 78 and 80 engage the right side of this hole to force the master cutter 34 even further to the left so as to form a further-leftward-offset hole 112. This leftward offset of the hole 112 relative to the hole 110 is shown in the lower portion of Fig. 11, as designated by the arrow leading from Fig. 10. Continued downward progress of the bit 30, of course, results in continued progressive offsetting to the left, the use of the tool 20 being terminated when the desired total offset has been achieved.

As previously indicated, the ribs 82 of the stop means 72 are primarily merely guide ribs and, in considering the operation of the tool 20, they may be regarded as omitted if desired since the magnitude of the shifting of the deflection bearing 70 to the left each time the thick side 64 of the eccentric sleeve 42 rotates from the right side to the left side is determined by the eccentricity of such sleeve, and not by the guide ribs 82. The important thing to keep in mind is that the main and stabilizing ribs 78 and 80 cooperate with the right side of the hole in which they are disposed to cause the thick side 64 of the eccentric sleeve 42 to force the opposite cutter of the bit 30, i.e., the master cutter 34, to undercut the left side of such hole. Thus, the hole deflection always progresses to the left for the particular tool orientation illustrated.

An important feature of the invention is that the drilling mud flowing downwardly through the drill string 28 and the passage 32, and into an axial passage 114 in the drill bit 30, is discharged outwardly and downwardly, through an outwardly and downwardly inclined passage 116 in the bit, in the form of a jet which impinges on the side and bottom of the hole being drilled by the bit at a point ahead of the master cutter 34. In the particular construction shown, the passage 116 is so oriented as to cause the jet formed thereby to lead the master cutter 34 by 90°, although this angle is preferably 30°, or less, the jet being as close as possible to the master cutter. This jet facilitates the action of the master cutter 34 by hydraulic removal of the formation. If the latter is quite soft, it is possible to make hole with the jet alone and, if the jet is close enough to the master cutter, it will operate with the same eccentricity as the master cutter and the hole will be deflected in the same way.

Although an exemplary embodiment of the present invention has been disclosed herein for purposes of illustration, it will be understood that various changes, modifications and substitutions may be incorporated in such embodiment without departing from the spirit of the invention as defined by the claims which follow.

I claim:

1. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said

drill bit; an eccentric on and rotatable with said mandrel; a bearing encircling said eccentric; stop means on one side of said bearing engageable with one side of the peripheral wall of a hole formed by said drill bit; and anchor means engageable with said wall of said hole for preventing rotation of said bearing to maintain a predetermined orientation of said stop means in said hole.

2. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel, said eccentric comprising a sleeve telescoped over said mandrel and means for rigidly connecting said sleeve to said mandrel; a bearing encircling said eccentric; stop means on one side of said bearing engageable with one side of the peripheral wall of a hole formed by said drill bit; and anchor means engageable with said wall of said hole for preventing rotation of said bearing to maintain a predetermined orientation of said stop means in said hole.

3. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel, said eccentric comprising a sleeve telescoped over said mandrel and means for rigidly connecting said sleeve to said mandrel in any one of a plurality of angularly spaced positions relative to said mandrel; a bearing encircling said eccentric; stop means on one side of said bearing engageable with one side of the peripheral wall of a hole formed by said drill bit; and anchor means engageable with said wall of said hole for preventing rotation of said bearing to maintain a predetermined orientation of said stop means in said hole.

4. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel; a bearing encircling said eccentric; stop means on one side of said bearing engageable with one side of the peripheral wall of a hole formed by said drill bit, said stop means including at least one longitudinal rib of substantial angular extent on said one side of said bearing; and anchor means engageable with said wall of said hole for preventing rotation of said bearing to maintain a predetermined orientation of said stop means in said hole.

5. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel; a bearing encircling said eccentric; eccentric stop means on said bearing engageable with the peripheral wall of a hole formed by said drill bit; and anchor means engageable with said wall of said hole for preventing rotation of said bearing to maintain a predetermined orientation of said stop means in said hole.

6. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel; a deflection bearing encircling said eccentric; stop means on one side of said deflection bearing engageable with one side of the peripheral wall of a hole formed by said drill bit; an anchor bearing encircling said mandrel and spaced longitudinally from said deflection bearing; means on said anchor bearing engageable with the wall of said hole for preventing rotation of said anchor bearing; and means connecting said deflection bearing to said anchor bearing so as to maintain a predetermined orientation of said stop means in said hole.

7. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel; a deflection bearing encircling said eccentric; stop means on one side of said deflection bearing engageable with one side of the peripheral wall of a hole formed by said drill bit; an anchor bearing encircling said mandrel and spaced longitudinally from said deflection bearing; means on said anchor bearing engageable with the wall of said hole for preventing rotation of said anchor bearing; means connecting said deflection bearing to said anchor bearing so as to maintain a predetermined orientation of said stop means in said hole; and means for locking said mandrel, said deflection bearing and said anchor bearing together so as to transmit rotation of said mandrel to said deflection bearing and said anchor bearing to vary the orientation of said stop means in said hole.

8. A deflection drilling tool according to claim 7 wherein said anchor bearing is movable axially of said mandrel, said locking means including locking elements on said mandrel and said anchor bearing which are interengageable in response to longitudinal movement of said anchor bearing relative to said mandrel.

9. In a deflection drilling tool, the combination of: a tubular mandrel; means at one end of said mandrel for rigidly coupling same to a drill string so as to transmit rotation of said drill string to said mandrel; means at the other end of said mandrel for rigidly coupling a drill bit thereto so as to transmit rotation of said mandrel to said drill bit; an eccentric on and rotatable with said mandrel; a bearing encircling said eccentric; stop means on one side of said bearing engageable with one side of the peripheral wall of a hole formed by said drill bit; anchor means engageable with said wall of said hole for preventing rotation of said bearing to maintain a predetermined orientation of said stop means in said hole; and means for locking said mandrel and said bearing together to transmit rotation of said mandrel to said bearing, in opposition to the action of said anchor means, to vary the orientation of said stop means in the hole.

10. A deflection drilling tool as defined in claim 1 including a drill bit rigidly coupled to said other end of said mandrel, said drill bit having cutting means opposite the point of maximum eccentricity of said eccentric, and said bit having therein a passage communicating with the interior of said mandrel and directed outwardly and downwardly toward a point on the path of said cutting means which leads said cutting means upon rotation of said mandrel to rotate said drill bit.

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