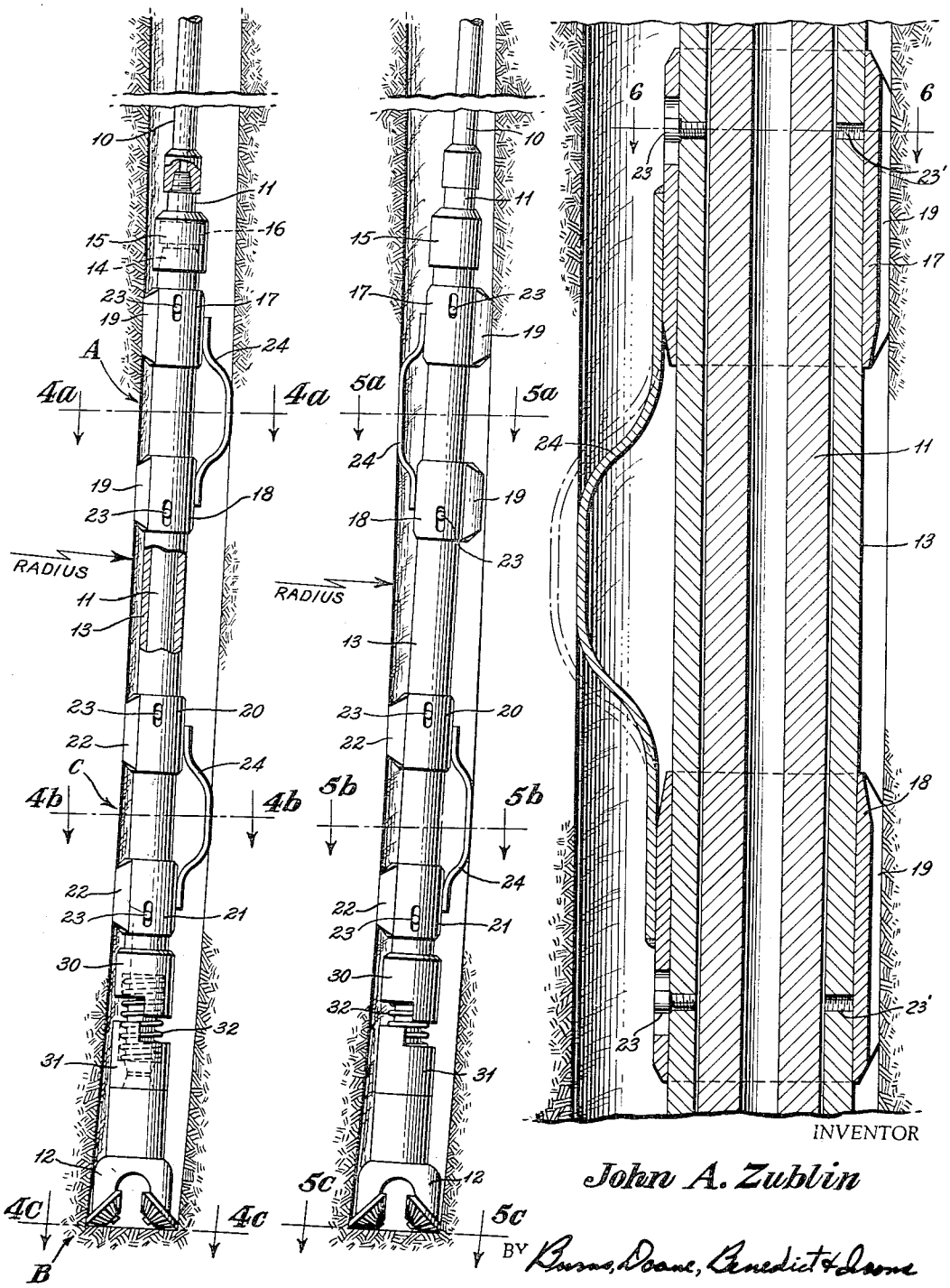
May 15, 1956 J. A. ZUBLIN 2,745,635

APPARATUS FOR DRILLING WELLS OF LARGE RADII CURVED BORES

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Fig. 1. Fig. 2. Fig. 3.



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APPARATUS FOR DRILLING WELLS OF LARGE RADII CURVED BORES

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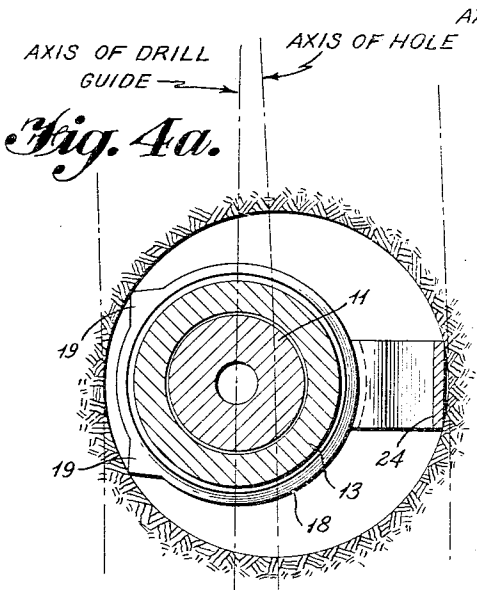


Fig. 4a.

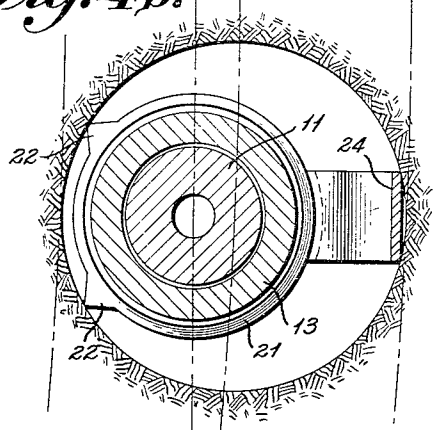


Fig. 4b.

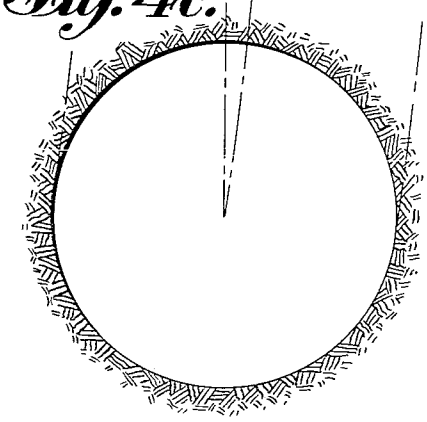


Fig. 4c.

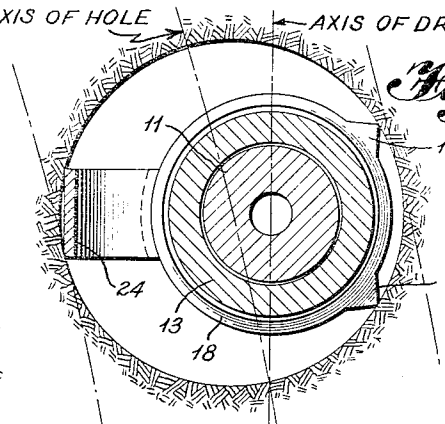


Fig. 5a.

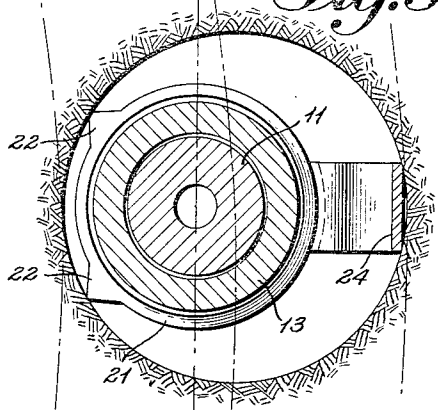


Fig. 5b.

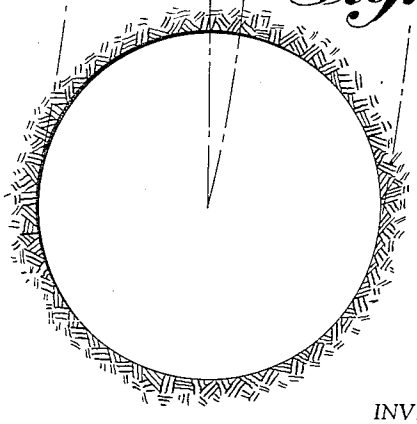


Fig. 5c.

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APPARATUS FOR DRILLING WELLS OF LARGE RADII CURVED BORES

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Fig. 7.

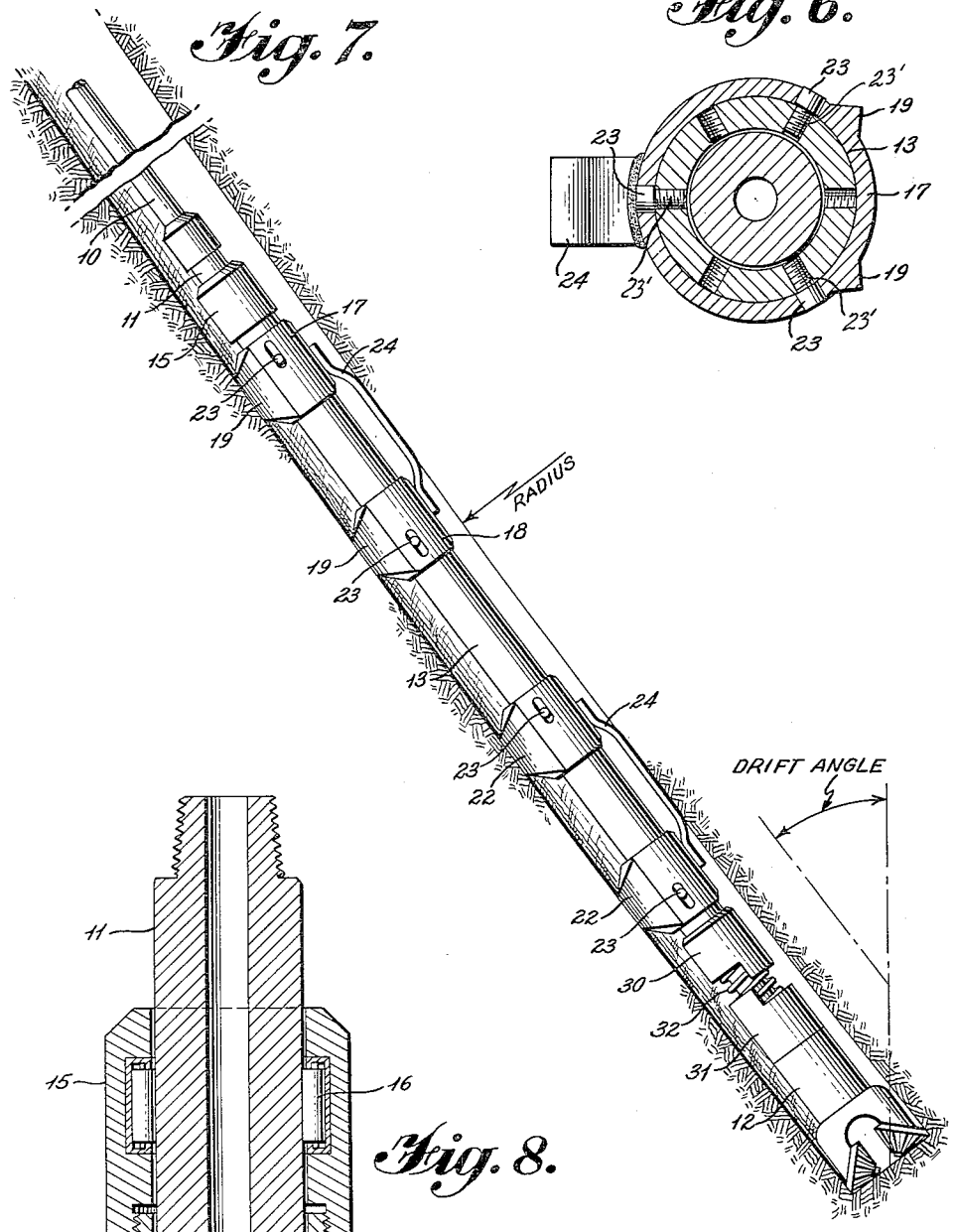


Fig. 6.

Fig. 8.

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APPARATUS FOR DRILLING WELLS OF LARGE RADII CURVED BORES

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Fig. 10.

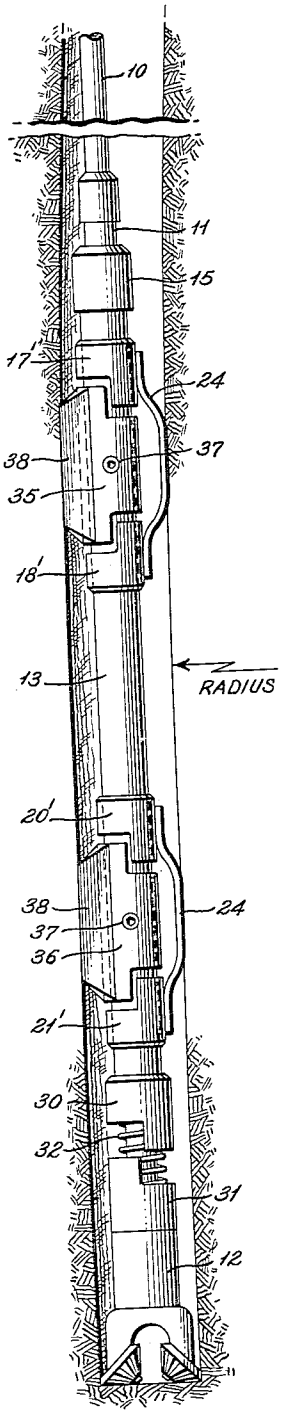


Fig. 11.

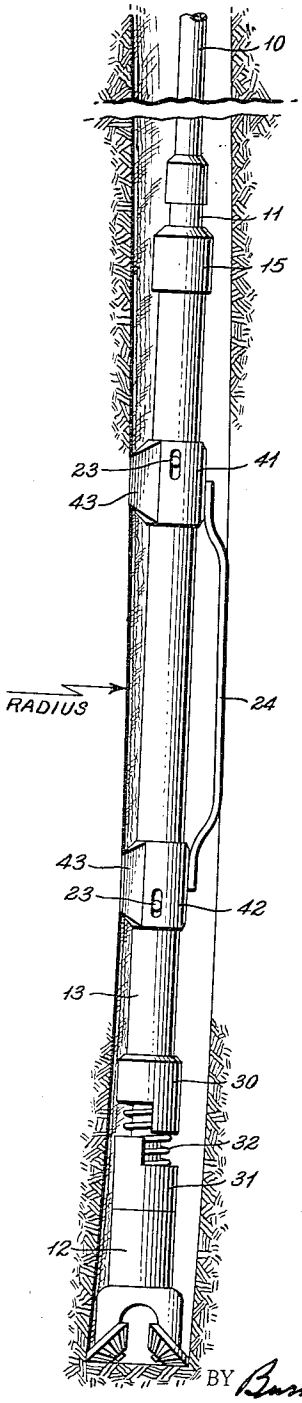
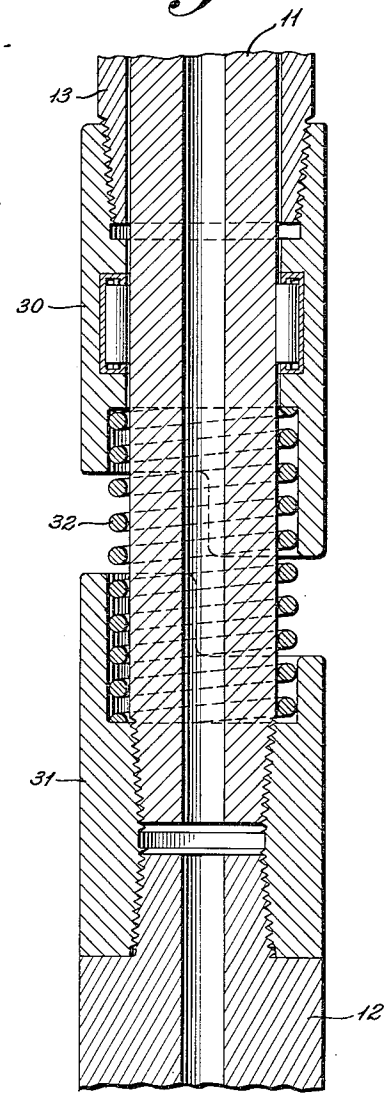


Fig. 9.



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2,745,635

APPARATUS FOR DRILLING WELLS OF LARGE RADII CURVED BORES

John A. Zublin, Los Angeles, Calif.

Application July 20, 1953, Serial No. 368,857

5 Claims. (Cl. 255—1.6)

This invention relates to a method and apparatus for drilling oil wells with oriented curved bores of large radii. More specifically the invention is directed to a method and apparatus by which oriented curved bores of large radii may be effectively drilled with but one round trip of the drilling equipment.

The need for the drilling of deflecting bores having as their purpose the recovery of oil from points in a producing formation horizontally spaced a substantial distance from the point of initiation of the vertical well bore, has become increasingly pronounced with attempts to recover oil, for example from under-water formations. Indeed there are many instances where real need for the drilling of a deflecting bore in a given azimuth is apparent.

The present invention is not concerned with the production of small radii curved deviating bores such as draining holes drilled directly from a vertical well bore laterally into the producing formation, but rather is concerned with the production of a deflecting bore as a continuation of an initially straight well bore in the original drilling of which the bore is deflected in a curved path having a radius of the order of 1,000 to 2,000 feet or larger.

In prior art practices of drilling deflecting bores, the expedient of using whipstocks has been largely resorted to. Generally speaking, the tubular drill strings employed in rotary drilling have sufficient inherent flexibility to permit of their deviation from the vertical in an amount approximating about three degrees per hundred feet of length of drilling string. Again speaking generallly, whipstocks set in a vertical well bore for the purpose of causing a deflection of the drill bit usually contemplate a deflection from the vertical of from around three degrees to five degrees.

In practice it has been found that when drilling a deflecting bore through the medium of the whipstock, the drilling string, after it passes the whipstock, tends to follow the path of least resistance and return to a straight line. The tendency of the drill string to return to its normally straight form by reason of its natural semi-resilient characteristics is encouraged by the force of gravity acting downwardly on the deviating end of the drill string. Because of this inherent tendency of the rotary drill string to follow the path of least resistance, it has been the prior art practice in the drilling of deflecting bores through the use of whipstocks to drill a limited distance beyond the point of setting of a given whipstock; to then withdraw the drill string and bit from the well bore and set another whipstock at the lower depth to which the deflecting bore had been drilled, this procedure being repeated throughout the drilling of the deflecting bore. Such practice has entailed the necessity for a complete round-trip for the drilling equipment each time a whipstock is set. Each round-trip and each setting of the whipstock entails hazards that, quite apart from the sheer loss of time involved, render the drilling of deflecting bores of large radii very costly.

In the drilling of curved bores, as well as straight bores, through different formations, it has been found that such bores will not have a uniform diameter throughout their length. A drill bit of a certain size, in the hardest sections of the variable formation, will drill a hole substantially equal to the bit diameter. In softer sections of the formation, the same bit will drill a hole somewhat larger or oversize in relation to the bit diameter. This difference in diameter along the length of the bore may vary as much as several inches. Accordingly, it becomes necessary that an apparatus to drill curved bores be adaptable to the various diameters produced by the same size bit in drilling through a formation of varying hardness.

Furthermore, in oil well drilling of curved bores, it often becomes necessary to change the radius of the curved bore either to correct the direction of the bore hole, or to change the desired termination point for such bore hole. Presently available equipment for performing these operations has been found to be ineffective in controlling the direction of drilling, and also requires the withdrawal of the apparatus with a subsequent change of the parts in order to correct the direction or change the desired terminus of the bore hole.

It is a purpose and object of the present invention to provide a method and apparatus by which a deflecting bore may be produced through conventional rotary drilling techniques as a direct continuation of an initiated straight well bore.

Furthermore, it is the purpose and object of the present invention to provide a greatly simplified method and apparatus for drilling deflecting bores of large radii through the medium of which it is possible to completely eliminate the use of whipstocks and complete the drilling of the deflecting bore or even a series of deflecting bores without removing the apparatus from the well.

More specifically, it is the purpose and object of this invention to provide a method and apparatus for initiating and continuing the drilling of a deflecting bore at substantially the same fixed radius sufficiently large to lie within the limits of inherent flexibility of the conventional rotary drill string, the curve of such deflecting bore conforming to such fixed radius irrespective of variations in diameter of the bore caused by variations in the characteristics of the formation through which the bore extends.

From an apparatus standpoint, the purpose and object of this invention is to provide a unit suspendible from the lower end of a rotary drill string susceptible of manipulation in such a manner as to effect the initiation and continued drilling of a curved deflecting bore of a large radius irrespective of bore diameter variations caused by varying formation hardness without the use of other elements or instrumentalities than those suspended from and carried by and insertable into a well bore through the medium of a conventional rotary drill string.

The expression "curved bores of large radii" as used herein is intended to identify and define degrees of curvature attainable through the inherent flexibility of a normal rotary drill string. Generally speaking, the radii of deflecting bores in the drilling of which the present invention is addressed lie within the limits of 1,000 to 3,000 feet. It will be readily recognized, however, that this range of radii is in no way limiting as to the scope of this invention. As the radius of curvature of the deflecting bore increases toward infinity, such deflecting bore approaches a more nearly straight well bore. As will be obvious from the description hereinafter, certain variations in the dimensions adopted for the structure of this invention could result in a well bore being drilled with the structure having a radius of deflection of infinity, thus producing a straight bore hole.

Additional purposes and objects of the invention will become apparent as the description proceeds, which will be given in connection with the accompanying drawings forming a part thereof and in which:

Figure 1 is a fragmentary view in side elevation with parts broken away, illustrating a drilling unit suitable for practicing the method and exemplifying the apparatus of the present invention.

Figure 2 is a side elevation of the drilling unit shown in Figure 1 illustrating the mode of operation of the unit with certain of the parts in an alternate position.

Figure 3 is a detailed sectional view illustrating a structure by which a deflecting force is applied to the drilling unit.

Figures 4*a*, 4*b* and 4*c* are cross-sectional views taken, respectively, on lines 4*a*—4*a*, 4*b*—4*b*, and 4*c*—4*c* of Figure 1, illustrating the relationship of the drilling unit axis and the well bore axis in drilling uniformly deflecting bores having large radii.

Figures 5*a*, 5*b* and 5*c* are cross-sectional views taken, respectively, on lines 5*a*—5*a*, 5*b*—5*b* and 5*c*—5*c* of Figure 2, illustrating the relationship of the drilling unit axis and well bore axis in drilling, with the drilling unit set-up shown in Figure 2, uniformly deflecting bores of large radii.

Figure 6 is a detailed cross-sectional view taken on line 6—6 of Figure 3.

Figure 7 is a fragmentary view in side elevation illustrating a drilling unit exemplifying this invention, producing a bore deflection of uniform large radius as a continuation of a well bore having a relatively large drift angle.

Figure 8 is a detailed sectional view illustrating the manner in which the drilling unit may be suspended from a conventional rotary drill string.

Figure 9 is a detailed sectional view through the clutch mechanism incorporated in the drilling unit and illustrating certain operational features thereof.

Figure 10 is a fragmentary view in side elevation illustrating a modified form of drilling unit suitable for practicing the method and exemplifying the apparatus of the present invention.

Figure 11 is a fragmentary view in side elevation illustrating another embodiment of the drilling unit which may be utilized in practicing the method and exemplifies the apparatus of the present invention.

Reference will now be had to the embodiment shown in Figure 1 as illustrating the salient features of the drilling unit of this invention. A conventional hollow rotary drill string is indicated at **10** which is adapted to extend to the surface of the well and be rotated by the conventional rotary equipment. Drilling fluid is adapted to be passed down through the hollow drill string **10** which has suspended at the lower end thereof a unitary assembly embracing an inner tubular rotary drive member **11** which carries the bit **12** at its lower end so that rotation of the rotary drill string **10** and the rotary tubular drive member **11** will effect a positive rotation of the bit **12**. Surrounding the rotary drive member **11** is an elongated sleeve **13**, the upper end of which is threadably engaged at **14** with a collar **15** carrying antifriction means **16** to facilitate free rotation of the tubular drive member **11** within the sleeve **13**. The details of this mounting between the sleeve **13** and tubular drive member **11** are more clearly illustrated in Figure 8.

Mounted adjacent the upper end of the sleeve **13** are a pair of collars **17** and **18** having parallel longitudinal ribs **19** extending radially thereof. Adjacent the lower end of the sleeve **13** there is provided a pair of collars **20** and **21** similar to the collars **17** and **18** and having parallel ribs **22** extending longitudinally along the side thereof. The collars **17**—**18** and **20**—**21** are allowed limited axial movement relative to the sleeve **13** while being prevented from rotation relative to the sleeve **13** by studs **23** mounted in selected ones of threaded apertures **23'** in the sleeve **13**. The heads of studs **23** slidably engage with longitudinal slots provided in the respective collars **17**, **18**, **20** and **21**.

Figures 3 and 6 illustrate the details of construction used in mounting the collars **17** and **18** on the sleeve **13**. Particular attention is called to the plurality of threaded apertures **23'** radially spaced around the sleeve **13** as shown on Figure 6. In the specific embodiment illustrated, threaded apertures are disposed radially around the sleeve **13** at 60° intervals. The provision of these threaded apertures **23'** to receive the studs **23** enables the orientation of the respective ribbed collars **17** and **18** relative to the sleeve **13** so that such collars may be selectively secured at any one of a plurality of positions of orientation relative to the sleeve. It will, of course, be appreciated that the collars **20** and **21** may be similarly mounted on the sleeve **13** with such mounting being capable of being altered as desired to vary the orientation of the respective collars relative to the sleeve **13**.

A heavy leaf spring **24** adapted to exert a predetermined lateral force on the drilling unit has its opposite ends suitably secured to the collars **17** and **18**, as by welding such ends to the respective collars on the side thereof opposite the ribs **19**. The lower pair of collars **20** and **21** likewise has a similar leaf spring **24** secured therebetween as by welding the ends of such spring to the collars on the side opposite the parallel ribs **22**. As shown in Figure 3, the leaf spring **24** in its free position would take the form illustrated in dotted lines, causing the collars **17** and **18** to move axially toward one another. However, upon insertion in the well bore, the spring **24** is compressed to the form shown in Figure 3 to exert a strong lateral force against the rigid sleeve **13**.

Secured to the lower end of the sleeve **13** as by suitable threaded connection, is the upper member **30** of a two-member clutch, the lower member **31** of which is secured to and carried by the rotary drive member **11**. A spring **32** normally urges the clutch members **30** and **31** axially apart toward the disengaged position. When, however, an upward pull is exerted on the drill string **10**, the frictional resistance offered by the springs **24** and the ribs of collars **17**, **18**, **20** and **21**, together with the weight of the parts will tend to retain the sleeve in place so that limited vertical movement of the drive member **11** will cause engagement of the clutch members **30** and **31**. Upon engagement of the clutch members, rotation of the drive member **11** will cause the sleeve **13** to rotate therewith to facilitate orientation of the sleeve **13** to effect deflection of the bit **12** in a desired azimuth.

During the normal drilling operation, the sleeve **13** is disengaged from the rotation of the rotary drill string **10** by reason of the spring **32** maintaining clutch members **30** and **31** in disengaged position. The sleeve **13** is normally held against rotation by engagement of the heavy leaf springs **24** and certain of the ribs **19** and/or **22** carried by the collars, with the well bore, as will be described hereinafter. The engagement of the springs **24** and ribs **19** and **22** with the well bore, while preventing undesired rotation of the sleeve **13**, will permit such sleeve and the parts carried thereby to move longitudinally with the progress of the drill bit **12** during the drilling operation. Thus only upon closing of the clutch members **30** and **31** upon lifting of the rotary drill string **10** followed by forced rotation of the sleeve **13**, will the azimuth of the bore deflection be varied. It is further pointed out that the weight of sleeve **13** and the parts carried thereby is normally of sufficient magnitude so as to overcome the frictional resistance or drag created by springs **24** and the ribs on collars **17**, **18**, **20** and **21** engaging with the well bore. Thus, in normal operation the weight of the sleeve and parts carried thereby will cause it to move along with the drill collar **11** and drill bit **12**.

On the drawings the amount of well bore deviation is exaggerated to more clearly illustrate the principles of operation of the method of this invention and the signifi-

cant features of the apparatus of this invention. It will be readily recognized that in actual drilling practice with this invention, the deflection of the bore may vary from zero, i. e. a straight bore, to a degree of deviation within the inherent resilient limit of the rotary drill string.

As will become apparent from the description hereinafter, the dimensions of the parts and their relation to one another on the complete drilling unit at three contact points or zones determines the degree and direction of deviation of the well bore in drilling with the apparauts of this invention. Referring specifically to Figure 1, these zones of contact are designated as A occurring at the upper pair of collars 17 and 18, B occurring at the drilling face of the drill bit 12, and C occurring at the lower pair of collars 20 and 21.

Considering further the structural relationship illustrated for the drilling unit of Figure 1, it will be seen that such structure is shown positioned in a curved bore which bore has been produced by use of the particular drilling unit. In the structure as illustrated the radially protruding ribs 19 and 22 carrried respectively by the upper and lower collars are vertically aligned one above the other and the ribs protrude outwardly of their respective collars for the same radial distance relative to the guide sleeve axis at the upper and lower collars, a distance less than the radius of the drill bit 12.

Visualizing the structure of Figure 1 positioned in a previously drilled straight bore, the heavy leaf springs 24 exert a force tending to tilt or laterally displace the sleeve 13 relative to the straight well bore axis. The drill bit desirably having a radius equal to the radius of the straight well bore would be centered therewithin. The sleeve 13, acting as a rigid straight guide, is tilted about the drill bit under the lateral displacing force of springs 24 until arrested by engagement of ribs 19 with the straight well bore. With a drilling unit such as illustrated by Figure 1, the ribs 22 will not engage the straight well bore, so that the lateral deflecting force of springs 24 will be transmitted to the bore wall by ribs 19 and the drill bit 12 engaging the well bore adjacent the opposite ends of straight drill guide sleeve 13.

In this condition, rotation of drill bit 12 to extend the length of the well bore will be attended with a lateral displacing force imparted to the drill bit by lower spring 24, the deflecting force of the upper spring being carried by ribs 19 engaging the well bore wall. Thus as drilling is continued, employing the drilling unit as shown in Figure 1, drill bit 12 will not only proceed downwardly into the formation being drilled under the drilling weight applied from the top of the well but also will progress laterally under the deflecting force of lower spring 24 so as to drill a deflected path or bore from the bottom of the original straight well bore.

After a relatively short length of bore hole has been produced employing the drilling unit of Figure 1, the drill bit will have progressed through vertical and lateral components of movement to a point where guide sleeve 13, pivoting about the well bore engaged ribs 19, will carry ribs 22 into engagement with the well bore. At this point, ribs 22 transmit the lateral deflecting force of lower spring 24 directly to the well bore wall so that a laterally deflecting force is no longer transmitted to the drill bit 12.

Accordingly the drilling unit, in producing a curved well bore, reaches what may be termed a stable state wherein continued drilling with the unit will result in a curved bore of uniform large radius being produced. The apparatus in Figure 1 is shown in such stable state with the curve of the well bore being produced by use of the drilling unit corresponding with the circular arc which includes the edge of the drill bit 12, the edges of ribs 22 and the edges of ribs 19 as three zones of contact between the bore hole and the drilling unit.

Figures 4*a*, 4*b* and 4*c* illustrate cross sections of the drilling unit taken generally at the three zones of contact and showing the apparatus of Figure 1 in its relation to a curved well bore produced through utilization of the drilling unit. These figures exemplify the relationship between the axis of such a curved bore produced by the drilling unit and the straight axis of the drill guide sleeve 13. Thus it will be seen that, with the dimensional characteristics and rleationship of the parts for the drilling unit as shown in Figure 1, a particular relation between the sleeve axis and curved bore axis will be assumed upon continued drilling with the drilling unit.

It will be appreciated, as exemplified more fully hereinbelow in connection with other figures of the drawings, that the drill guide sleeve axis to well bore axis relationship is determined, when a drilling unit is positioned in a length of curved well bore produced by use of the particular unit, by the radial distance between the sleeve axis and the outer edges of the well bore engaging ribs on the upper and lower collars, by the radius of the rotary drill bit and by the orientation of the ribs on the upper collars relative to the ribs on the lower collars. Also the longitudinal or axial spacing between the upper collars, the lower collars and the drill bit is a factor entering into the determination of the position which the drill guide sleeve axis will assume relative to the axis of the curved bore produced by use of a particular drilling unit which has predetermined dimensional characteristics and relationship of the parts. These variables determine the location of the contact zones A, B and C and relationship of the axis of the rigid guide sleeve 13 to the contact zones.

In the description given hereinabove in connection with the operation of the drilling unit illustrated in Figure 1, it has been noted that the springs 24 urge the drilling unit toward a particular relation within the well bore as the drilling progresses from say a previously drilled straight bore to the deviating bore resulting from utilization of the drilling unit. It follows that once the drilling unit has arrived at this hereinabove referred to stable state, continued drilling with the unit will effect production of a well bore length continuing in the curve as determined by the structural characteristics of the particular drilling unit. Any tendency for the path of the curved well bore to stray from the predetermined curvature determined by the characteristics of the particular drilling unit will be resisted. For example, if the drill bit 12 deviates to the right as shown in Figure 1, ribs 22 will be carried by rigid straight sleeve 13 out of engagement with the well bore and the force of spring 24 will then be transmitted to the drill bit through rigid straight sleeve 13 to urge the drill bit as it drills back toward the desired curve of the well bore to be produced. Likewise if the drill bit 12 deviates to the left, sleeve 13, pivoting about ribs 22, will lift ribs 19 out of engagement with the well bore wall and the upper spring 24 will transmit a deflecting force through sleeve 13 acting as a lever to the drill bit tending to urge it back to the predetermined desired curve for continued drilling of the well bore.

From the description given hereinabove, it will be apparent that the distance between the axis of slevee 13 and the outer edges of ribs 19 and 22 may be altered as desired to provide a drilling unit which is effective in use to produce a desired particular inclination of sleeve 13 relative to the well bore and hence a predetermined curved deviation of the well bore. Accordingly drilling units may be made up in accordance with the instant invention to be effective in use for producing different degrees of inclination and/or deviation in a different azimuth depending upon the radial distance between the sleeve axis and the outer preiphery of the drilling unit at the three zones of contact. In fact, if the ribs 19 and 22 protrude outwardly to the same extent so that the radial distance from the sleeve axis to the outer edges of such ribs are equal to one another, and also equal to the radius of the drill bit 12, the axis of the sleeve 13 in use of the drilling unit will be substantially in coincidence with the well bore axis and thus such drilling unit will

produce a straight well bore or one having a radius of infinity.

As noted hereinabove the axial spacing between the upper and lower collars and between the lower collar and the drill bit may be changed to provide a drilling unit which will have characteristics to produce, in use, bore deflections of different magnitude and/or azimuth. The effect of varying the axial spacing of the parts on the drilling unit and its effect on the curvature of the bore which will be produced by such a drilling unit will be obvious from inspection of the drawings and specifically Figures 4*a*, *b* and *c* and 5*a*, *b* and *c*, which demonstrate the relation of the well bore axis to the axis of the rigid straight guide sleeve **13**.

The collars mounted on the sleeve **13** may also be set thereon to change the radial direction of force applied by the spring **24** with respect to the sleeve **13**. As illustrative of this possible variation to the drilling unit, Figure 2 shows a unit similar to that of Figure 1, but with the upper collars **17** and **18** rotated 180° relative to the sleeve **13** so that the upper spring **24** acts on the upper end of the sleeve **13** in a direction opposite to the direction of force applied by the lower spring **24**. Accordingly the sleeve, urged toward a tilted position within the well bore by springs **24** in effect guides the direction of drilling done by the drill bit **12** and reaches a stable position during drilling when the ribs **19** engage one side of the well bore and the ribs **22** engage the opposite side of the well bore. From the view shown in Figure 2, it will be clear that under this stable condition the sleeve **13** will be maintained in a definite position relative to the bore as determined by the radial distance between the axis of sleeve **13** and the outer edges of upper ribs **19** and the radial distance betweene the axis of sleeve **13** and the outer edges of lower ribs **22**. Continued drilling will result in the guiding sleeve **13** determining the direction of drilling performed by the drill bit **12** so that the drilling operation will continue in a substantially uniform curved direction as determined by the tilt present in the sleeve **13** and radius of the drill bit. As in the arrangement of Figure 1, the springs **24** continuously apply a strong force to urge the respective ribs carried by the collars into engagement with the opposite sides of the well bore. Such ribs prevent rotation of the sleeve **13** but in effect act as guides so that the sleeve **13** moves along with the drill bit **12** as the drilling continues.

Figures 5*a*, 5*b* and 5*c* show the relationship of the axis of the drill guide sleeve **13** and the axis of the well bore hole, and illustrate how the relationship of the collars on the sleeve **13** and the direction of force applied by the springs **24** may be employed to cause a greater curvature to be present in the bore as drilled than that with the ribbed collar and sleeve relationship of Figure 1. This greater curvature is produced by reason of the upper and lower sets of collars engaging opposite sides of the well bore wall so that sleeve **13**, upon reaching a stable condition, will have its axis intersect the well bore axis at a greater angle as clearly shown on Figures 5*a*, 5*b* and 5*c*.

Mention has previously been made as to the possibility of positioning the collars **17—18** and **20—21** on the sleeve **13** by utilizing appropriate ones of the threaded holes for the studs **23**. It will be readily appreciated that whereas in Figure 2 the two sets of collars have been shown with the springs **24** acting in opposite directions, or in other words 180° apart, the collars may be mounted on the sleeve **13** by use of appropriate threaded holes **23'** in the sleeve engaged by studs **23** so that such springs may act in directions other than 180° apart. Obviously these variations in positioning of the upper and lower springs **24** will produce varying tilts on the sleeve **13** to effect well bore deflections of different radii. In each of the above-described set-ups, a specific setting of the springs **24** when used with a rotary drill string will produce a well bore deflection of substantially uniform radius.

Figure 7 illustrates an embodiment similar to the drilling unit of Figures 1 and 2 wherein the ribs **19** and **22** protrude outwardly of their respective collars to an extent such that the axis of the sleeve **13** is positioned for the major portion of its length on the spring side of the axis of the well bore during the drilling operation when the ribs are engaged with the wall of the well bore. The springs **24** continue to apply a strong force in urging the ribs **19** and **22** into engagement with the well bore. The extent of radial protrusion of the ribs **19** and **22** as shown in Figure 7 is particularly advantageous in drilling curved bores of large radii wherein the drilling is performed at a rather large drift angle. With ribs **19** and **22** as shown in Figure 7, the weight of the parts is carried by such ribs and as the drift angle increases, the force applied by springs **24** is assisted by the gravitational pull on the parts to force the ribs **19—22** more strongly into engagement with the well bore wall. Accordingly, in using this structure at large drift angles the force of springs **24** is not employed to carry the gravitational pull on the drilling unit as would be the situation if a structure such as shown in Figure 1 is used for large drift angle drilling.

Since the relationship of the axis of sleeve **13** and the axis of the well bore in the structure shown in Figure 7 forms a curved bore in the same manner as in the structures of Figures 1 and 2, it is considered unnecessary to repeat the description of the manner in which the curved bore of large radius is produced by this apparatus. It will be appreciated that as in the case of the structures of Figures 1 and 2 the relationship of the parts on sleeve **13** in relation to one another and to the drill bit **12** enter into the determination of the position which the axis of sleeve **13** assumes relative to the axis of the well bore when the apparatus reaches a stable state for continued drilling of a uniformly curved well bore. Suffice it to state that the sole distinction is the greater distance between the guide sleeve axis and the outer well bore engaging edges of the ribs **19** and **22** which makes this apparatus more desirable for use in drilling curved bores where the drift angle is relatively large, as 40° or greater. As will be readily recognized, when the apparatus as shown in Figure 1 is initially lowered through a straight bore, with the drill bit being of size substantially equal to the well bore diameter the upper ribs **19** will engage the well bore wall first under the urging of springs **24**. On the other hand where the ribs **19** and **22** protrude outwardly to an extent as shown in Figure 7 the lower ribs will engage the well bore wall first when the apparatus is initially lowered through a straight bore.

Figure 10 illustrates a modified form of the invention adaptable for performing the method of this invention and disclosing a structural embodiment of such invention. As in the form of the drilling unit of Figures 1 and 2, the springs **24** are attached at their opposite ends to axially spaced collars slidably mounted on the sleeve **13**. Thus the upper spring **24** is secured as by welding to the collars **17'** and **18'** and the lower spring **24** secured to the collars **20'** and **21'**.

Upper and lower collars **35** and **36**, respectively, are secured to the sleeve **13** as by set screws **37** and are provided with ribs **38** which are to engage the wall of the well bore during drilling of the deflecting bore. Upper collar **35** is secured between the opposed ends of the collars **17'** and **18'**, with the adjacent ends of said collars being provided with suitable interengaging elements so that the collars **17'** and **18'** may move axially relative to the fixed upper collar **35** but are permitted only limited rotational movement relative to such upper collar by such elements. It will likewise be seen that the lower collar **36** is provided with interengaging elements at its opposite ends to engage with cooperating elements on the opposed ends of the collars **20'** and **21'** to restrain relative rotation between such collars.

With this modified structure it will be readily appreciated that the springs 24 will urge the axis of the sleeve 13 laterally within the well bore so that the ribs 38 carried by the collars 35 and 36 will engage the wall of the well bore. Due to the interengaging elements coupling the slidably mounted collars to the ends of the fixed collars 35 and 36, the springs 24 will be maintained in a position on the opposite side of the axis of sleeve 13 from the ribs 38 while being permitted limited longitudinal movement upon compression of the springs 24.

As in the previous structures illustrated, a line joining the edges of the ribs 38 and the edge of the drill bit 12 defines the well bore curve which will be continuously formed by utilizing the drilling unit in the well drilling operation. Thus as in the previously described structures, ribbed collars having ribs protruding to a greater or lesser extent may be used in place of the collars 35 and 36, to make up a drilling unit wherein the curvature of the bore hole produced by such drilling unit will be different. By employing different ribbed collars the drilling unit may be varied from a drilling unit capable of producing a straight bore to a drilling unit for producing a bore having a curve within the inherent resiliency of the rotary drill string.

Figure 11 discloses an alternative structure adaptable for performing the method of this invention and disclosing a structural embodiment of such invention. In this structure a single leaf spring 24 is utilized in place of the pair of springs of the previously described structures. This single spring provides the necessary force to urge the axis of sleeve 13 laterally relative to the well bore and is secured at its opposite ends to a pair of collars 41 and 42 which are mounted on the sleeve 13, guided by studs 23. The collars 41 and 42 are provided with ribs 43 which as in the previous embodiments serve to support the guiding sleeve 13 in determining the curvature of the bore created by utilizing the unit on the end of a rotary drill string.

In summary, it may be stated that the effective pressure applied to the bit and the direction of drilling performed by the spring or springs 24 in urging the sleeve 13 laterally location of the zones of contact A, B and C along the sleeve 13, the particular radial distance between the guide sleeve axis and the periphery of the drilling unit at each of such zones, and the direction of the pressure applied by the spring or springs 24 in urging the sleeve 13 laterally within the well bore.

While the invention is primarily intended to effect drilling of a deflecting bore as a continuation of an initiated straight bore, it is possible to take off from a well bore that has been previously drilled with a deflecting bore in a predetermined azimuth. Indeed, it is even possible to drill a second deflecting bore after a first bore in a given azimuth has been drilled. A slight upward pull on the drill string 10 will effect engagement of the clutch members 30 and 31 so that the unit may be oriented by partial rotation of the drill string to set up a new azimuth for the deflection of the continued boring of the oil well.

Having thus described my invention, what I claim is:

1. Apparatus for controlling the direction and extent of deviation of a well bore by the rotary drilling method comprising an elongated relatively inflexible tubular section, an elongated drill collar rotatably mounted in said tubular section, a drill bit carried at the lower end of and rotatable with said drill collar, means at the upper end of said drill collar for connecting same to the lower end of a rotary drill string for rotation therewith, a first well bore engageable fulcrum forming means mounted adjacent the upper end of said tubular section and extending outwardly from one side thereof, a first well bore engaging deflecting means carried by said tubular section adjacent the point of mounting of said first fulcrum forming means to extend outwardly from the side generally opposite said first fulcrum forming means, a second well bore engageable fulcrum forming means mounted on said tubular section at a point spaced below said first fulcrum forming means and extending outwardly from one side thereof, a second well bore engaging deflecting means carried by said tubular section adjacent the point of mounting of said second fulcrum forming means to extend outwardly from the side generally opposite said second fulcrum forming means, said well bore engaging deflecting means acting to urge the respective fulcrum forming means toward engagement with the wall of the well bore.

2. Apparatus for controlling the direction and extent of deviation of a well bore by the rotary drilling method as recited in claim 1 wherein each of said well bore engaging deflecting means includes a resilient spring carried by the tubular section and engageable with the wall of the well bore to impart a lateral deflecting force to the tubular section for urging the respective fulcrum forming means toward engagement with the opposite side of the well bore.

3. Apparatus for controlling the direction and extent of deviation of a well bore by the rotary drilling method as recited in claim 1 wherein each of said well bore engageable fulcrum forming means includes collars mounted on the tubular section and having ribs extending outwardly from one side thereof and each of said well bore engaging deflecting means includes an outwardly bowed leaf spring connected at its opposite ends to such collars and engageable with the well bore wall to impart a lateral deflecting force to the tubular section for urging the respective ribs toward engagement with the opposite side of the well bore.

4. Apparatus for controlling the direction and extent of deviation of a well bore by the rotary drilling method comprising an elongated relatively inflexible tubular section, an elongated drill collar rotatably mounted in said tubular section and capable of limited longitudinal movement relative to said tubular section, interengaging clutch elements carried by said tubular section and said drill collar respectively, means normally holding said clutch elements in disengaged position while permitting engagement of said clutch elements upon limited longitudinal movement of said drill collar within said tubular section, a drill bit carried at the lower end of and rotatable with said drill collar, means at the upper end of said drill collar for connecting same to the lower end of a rotary drill string for rotation therewith and whereby said drill collar may be moved longitudinally relative to said tubular section by lifting of the drill string for engagement of said clutch elements, a first well bore engageable fulcrum forming means mounted adjacent the upper end of said tubular section and extending outwardly from one side thereof, a first well bore engaging deflecting means carried by said tubular section adjacent the point of mounting of said first fulcrum forming means to extend outwardly from the side generally opposite said first fulcrum forming means, a second well bore engageable fulcrum forming means mounted on said tubular section at a point spaced below said first fulcrum forming means and extending outwardly from one side thereof, a second well bore engaging deflecting means carried by said tubular section adjacent the point of mounting of said second fulcrum forming means to extend outwardly from the side generally opposite said second fulcrum forming means, said well bore engaging deflecting means acting to urge the respective fulcrum forming means toward engagement with the wall of the well bore.

5. Apparatus for controlling the direction and extent of deviation of a well bore by the rotary drilling method as recited in claim 1 wherein each of said well bore engageable fulcrum forming means includes a collar rigidly mounted on said tubular section and having ribs extending outwardly from one side thereof, additional collars slidably engaged with said tubular section and disposed at the ends of said rigidly mounted collar, an outwardly bowed

leaf spring connected at its opposite ends to said last mentioned collars, and means for restraining rotational movement of said last mentioned collars relative to said tubular section.

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