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METHOD AND APPARATUS FOR PROVIDING A WELL BORE WITH A DEFLECTED EXTENSION

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METHOD AND APPARATUS FOR PROVIDING A WELL BORE WITH A DEFLECTED EXTENSION

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This invention relates to a method and apparatus for providing a well bore with an extension deflected relative to the bore, and it is a general object of the invention to provide a method and apparatus by which a well bore can be deflected, say, for example, either straightened or inclined in a predetermined manner without resort to hazardous mechanisms or practices and in an effective and practical manner.

This application is filed as a continuation in part of my application entitled "Method and Apparatus for Providing a Well Bore With a Deflected Extension," Serial No. 186,341, filed September 23, 1950, now abandoned.

There are various occasions during the drilling of wells, for example oil wells, when a well bore reaches a point from which it is desired to establish an extension or continuation of the bore inclined or at an angle to the part initially established. Such an operation may involve straightening a bore that has become deflected from the true vertical, or it may involve leading the bore off or away from the vertical and, possibly, in a predetermined direction therefore.

The deflecting of well bores has been accomplished by various methods and by the use of various devices. It is most common that such operations be performed with the aid of large, cumbersome, expensive devices known as whipstocks or that they be carried out with drilling strings in which there are pivoted joints, while in other cases combinations of such equipment are employed. It has also been proposed to equip the drill string with an abutment for deflecting it to one side of the bore, but such structure has not proved practical.

It is well recognized, generally, that methods and equipment such as have heretofore been used for the operations above mentioned have been expensive, have required several and often expensive round trips of equipment, are not altogether dependable or reliable, and if carried out with any degree of accuracy they involve or require various time consuming and expensive surveying operations, and in most cases require successive use of various different tools that are heavy, cumbersome and expensive.

It is a general object of this invention to provide a method to be employed in the drilling of a well bore by which a bore that has been initially drilled to a given point, or in a given manner, can be extended or continued in a different direction so that there is an extended portion that is deflected from the initial bore, all without the use of or resort to dangerous complicated or highly expensive tools or equipment.

It is another object of the invention to provide a method of the general character referred to which includes certain operations serving to check or verify the action, with the result that predetermined deflection of the bore if not initially accomplished as intended can be gained with accuracy and certainty.

It is another object of the invention to provide a method of the general character referred to by which deflection of a well bore is gained by first establishing a pitched counterbored of limited size at the bottom of the well bore, then without replacement of the countercoring equipment proceeding to establish a large extension of the bore which may be the size of the bore, or substantially that.

A further object of the invention is to provide a method of the general character referred to which provides for the drilling of a counterbore at the bottom of a well bore and pitched relative thereto, the extending of that counterbore and the continuing from the extension with a second extension pitched relative to the first extension, all with drilling equipment that remains at the well serving to perform the several different operations mentioned.

Another object of the invention is to provide apparatus for carrying out the method hereinabove referred to, which apparatus involves few simple practical parts that are inexpensive of manufacture, convenient to handle or transport, and which are such that they can be operated properly and accurately without the exercise of unusual or great care. The apparatus provided by the present invention is compact, limited as to size and weight and is such that one unit supplemented by ordinary standard unit of equipment will drill or perform through a large range of hole sizes.

It is another object of the present invention to provide apparatus of the general character referred to which eliminates from the deflecting of the well bore the hazards, uncertainties, and various other disagreeable and costly features that commonly attend apparatus provided for the purpose stated.

It is a further object of this invention to provide apparatus of the general character referred to in which boring equipment is provided involving, generally, a drill string, a bit, and a shoe, which elements are related so that the shoe guides the bit by a wedging action and remains in a given rotative position in the well bore and advances in the bore as the bit operates, all without the severe working of parts such as occurs when knuckle joints, or the like, are employed, and without deflection of the cutters of the bit against a hard metal face, such as occurs when a whipstock is employed to drill out at the side of a well bore. With the structure of the present invention the bit operates smoothly and efficiently, always advancing the well bore, and it is not subject to undue wear as by working against or rubbing on a deflecting wedge or the like.

Another object of the invention is to provide apparatus of the general character referred to wherein an instrument is combined or cooperates with a drilling tool and guide, to the end that readings or records can be obtained as desired, for the purpose of accurately locating the guide in the well bore so that the deflected bore is directed in the desired manner.

It is a further object of the invention to provide apparatus of the general character referred to wherein the instrument employed is so combined with the equipment provided for drilling as to make possible certain checks to assure readings or records which are accurate.

It is a general object of the invention to provide a simple, compact, practical tool characterized by a bit and a guide shoe permanently rotatively related thereto, which alone will advance a well bore with a hole of limited size and which, supplemented by a few simple standard elements of drilling equipment, will make possible extension of a large well bore with a hole of the same size.

It is a further object of the invention to provide well deflecting apparatus, that is, a bit and a combining deflecting device, which are such that as a unit they are easily and freely operable in the ordinary well bore at the bottom thereof where deflection of the bore is desired. The structure provided by the invention is such
that there is little or no danger of it becoming wedged or stuck in an ordinary well bore and it is unnecessary to upbeaters or other like equipment to insure its proper introduction into an ordinary well. In the case of most equipment employed for deflecting a well bore, for example, in the case of whiststop equipment, the equipment necessary is large and cumbersome and is ordinarily just enough smaller than the bore to permit it to be passed through, and which commonly results in complications that are completely avoided or eliminated by the present invention.

It is a further object of this invention to provide a device for deflecting a well bore characterized by a drill string and deflecting element or shoe, which parts are permanently coupled and the structure is free of temporary or dependable features of construction such as shear pins, or the like.

It is a further object of this invention to provide apparatus of the general character referred to, serving to deflect a well bore by proceeding downwardly from the bottom thereof, as distinguished from equipment that is intended to gain deflection by cutting away a side of the bore such, for instance, as is the case when a whipstock is employed.

It is another object of this invention to provide apparatus for deflecting a well bore by means of a wedging device or shoe applied to, or arranged adjacent the drilling element or bit and serving to continue or advance as the bit proceeds thereby maintaining constant and uniform wedging action at the bit to the end that constant deflection is maintained, as distinguished from the limited deflection that is incidental to the use of a whipstock where the bit is deflected by the whipstock and proceeds beyond or past it.

It is a further object of this invention to provide well deflecting apparatus of the general character referred to, whereby the desired deflection is gained by elements acting at the point where drilling occurs, that is, at the bit and without dependence upon bending or flexure of the drilling string above the bit.

It is a further object of this invention to provide well deflecting apparatus of the general character referred to, characterized by a bit and a guide element permanently coupled to the bit, which guide element is related to the bit and to the operating string so that it can be readily oriented in the well bore and will thereafter remain oriented or in a predetermined rotative position in the bore while the bit proceeds to drill and said element goes forward with the bit.

It is a further object of this invention to provide bore deflecting apparatus practical and serviceable in a typical well bore to establish or drill one or more branches or lateral extensions, such as are commonly referred to as drain holes. With the apparatus of the present invention, an extension of a well bore in the form of a drain hole can be not only started away from the well bore but will continue away from the well bore at a predetermined rate and in a predetermined direction as long as the deflecting operation is continued, and because of the wedging action gained by the apparatus, a gradually curved drain hole may be formed ideal for draining of fluid into the well bore.

The various objects and features of my invention will be fully understood from the following detailed description of a typical preferred manner of carrying out the method and of a typical preferred form of apparatus and may be fully appreciated from the following description reference is made to the accompanying drawings, in which:

Sheet 1 of the drawings illustrates, somewhat diagrammatically, the various possible steps employed in the course of a simple carrying out of the invention. Fig. 1 being a view illustrating the establishment of the bore or counter bore at the bottom of the initially formed well bore, which operation is performed by the use of the drill string and bit later used in carrying out the other steps of the method. Fig. 2 shows the drill string elevated to position the bit well above the bottom of the bore and shows the surveying instrument with a portion depending from the bit and into the open well bore. Fig. 3 is a view showing the shoe related to the bit oriented in the desired manner and seated in the seat or counterbore established as shown in Fig. 1. It illustrates the progress of the drilling operation which establishes the desired extension of the well bore and serves to illustrate the manner in which such extension may be at an angle relative to the initial bore and illustrates the manner in which the guide shoe continues to act in conjunction with the advance of the bit, and Fig. 5 is a view of the bit of the bore, being enlarged so that the extension is brought to a size corresponding to that of the initial bore, which operation may or may not be performed, as circumstances require.

Fig. 6 is an enlarged vertical sectional view of the structure provided by the present invention, showing the lower end of a drill string having a bit mounted thereon through a sub, which sub forms a part of the mounting means which carries the guide shoe, the sleeve that supports the guide shoe being shown in a down position relative to the parts shown in Fig. 6 and showing a different positioning of the parts, and showing the sleeve that carries the guide shoe adjusted or mounted in an elevated position on the sub. Fig. 8 is an enlarged detailed transverse sectional view taken as indicated by line 8—8 on Fig. 6. Fig. 9 is an enlarged detailed transverse sectional view taken as indicated by line 9—9 on Fig. 7. Fig. 10 is a side elevation of a portion of the structure taken as indicated by line 10—10 on Fig. 6. Fig. 11 is a transverse sectional view taken as indicated by line 11—11 on Fig. 6. Fig. 12 is an enlarged detailed sectional view taken as indicated by line 12—12 on Fig. 6. Fig. 13 is an enlarged detailed sectional view of a portion of the structure shown in Figs. 6 and 7, illustrating the surveying instrument in operating position with reference to the other parts and partly in section to show certain essential parts thereof. Fig. 14 is a transverse sectional view taken as indicated by line 14—14 on Fig. 13. Fig. 15 is an enlarged vertical section taken as indicated by line 15—15 on Fig. 14. Figs. 16, 17 and 18 are views illustrating the type of readings or records obtained by use of the surveying instrument, and Fig. 19 is an elevational view showing the particular relationship of the bit and the shoe.

Figs. 20 to 24, inclusive, occurring on Sheet 5 of the drawings, illustrate an embodiment of the invention differing somewhat from the structure illustrated in Figs. 1 to 19, inclusive. Fig. 20 is similar to Fig. 1, except that the structure includes a hole opening tool. Fig. 21 is a view similar to Fig. 2 showing use of the equipment illustrated in Fig. 20. Fig. 22 is a view similar to Fig. 3 showing use of the equipment shown in Fig. 20. Fig. 23 is a view similar to Fig. 4 illustrating use of the equipment illustrated in Fig. 20, and Fig. 24 is a view illustrating use of the equipment shown in Fig. 5.

Another carrying out of the invention is illustrated in Figs. 25 to 27, inclusive, occurring on Sheet 7 of the drawings. In this case, Fig. 25 illustrates a continuation of a well bore in a particular manner, and Fig. 26 illustrates the use of equipment to ascertain the relationship of bore extension and the original bore, and Fig. 27 is a view illustrating the establishment of a second extension at an angle to the first term of the operation and a deviation from the first extension of the bore.

The present invention can be used to advantage in a wide variety of situations and for the purpose of performing various operations. Since the invention is particularly practical as applied to the deflection of a well bore, either for the purpose of extending a bore downwardly for the purpose of correcting a bore that is angularly related to the vertical or for side tracking an obstacle in a bore, it will be described in such a situation.
Further, since the invention can be carried out to advantage with more or less conventional well drilling equipment, and by following conventional rotary drilling practice, it will be described generally in this connection.

The structure or apparatus provided by the present invention involves, generally, a well drilling string S and a drill head or bit A carried or operated by means of the string S. A shoe or guide B is cooperatively related to the bit A and may be advantageously carried by a mounting means C that involves a tubular sub 10 connecting the bit A and string S, and a sleeve 11 carried by the sub and supporting the shoe. A means D releasably locks the shoe B in a predetermined position with reference to the string S and in a preferred arrangement it is a fluid pressure actuated means acting between the sub 10 and sleeve 11. An instrument E, in the general nature of a well surveying instrument, is operable through the string S and into cooperative relationship with the tool at the lower end of the string and which is formed, generally, by the bit, the shoe, the sub, and the sleeve. A stop means F operates to check movement or descent of the instrument to operating position in the event that the means D is released, in which case the shoe may be in an indeterminate rotative position with reference to the string. Further, a means G indicates, and preferably records, improper positioning of the instrument E in the tool at the time the instrument operates and thus provides the operator at the head of the well with a check on performance.

The string S, which is the operating string that extends into the well bore W from the upper end thereof, may be of conventional construction or formation, that is, it may be made up of stands of drill pipe including a Kelly at its upper end and a drill collar, if necessary, at its lower end. Essentially, however, and insofar as the present invention is concerned, it is an elongate tubular element having an open end from the lower end to the other sufficiently large to freely pass the instrument E, and a line L, such as a cable, which may serve as a means for handling the instrument.

The bit A, in practice, vary widely in form and construction, depending upon various factors such as the earth to be operated upon, the formation to be drilled, etc. In the particular case illustrated the bit is shown as involving a body 15 with depending legs 16 carrying rotating cutters 17. The particular bit disclosed is of a type commonly used in the drilling of wells, and its various details of construction and its mode of operation are well understood by those skilled in the art.

In Fig. 6 the cutters 17 are formed to cut a limited or minimum amount of clearance for the body of the bit, whereas in Fig. 19 the cutters are shown such as to cut a substantial amount of clearance.

The shoe B, as provided by the present invention, is an element engageable with the formation, for instance, in a countere bore 20 continuing from the bottom 21 of the well bore W, and in the case illustrated it is shown as an elongate part disposed, generally, in the direction of the longitudinal axis of the tool, and it is located at the exterior of the bit A, preferably at the upper portion thereof, where it is confined to one side of the bit and has its lower end terminating above the lower end of the bit. The particular shoe shown in the drawings is arcuate or segmental in cross sectional configuration. It has a cylindrically curved exterior guide surface 23 and a cylindrically curved interior surface 24, which parts or surfaces form a general way, but at an upper end portion of the bit A, for instance, that portion of the bit where the legs join the body and continue part way around the bit, say for instance, through about 120 degrees, as shown in Fig. 11 of the drawings. The surfaces 23 and 24 are preferably of about the same radius of curvature.

The center of curvature of the inside surface 24 of the shoe is coincidental with the central axis of the bit and surface 24 fits the exterior of the bit, the outermost parts of the legs 16 or the body 15 with working clearance or it may have sliding engagement therewith so the bit bears against the shoe.

In accordance with the preferred form of the invention the exterior guide surface 23 of the shoe, though cylindrically curved, is formed so that its center of curvature axis, though close to the center of the bit, is not coincidental with or parallel to the central axis of the tool or bit, but, rather, is inclined somewhat relative thereto. The axis of the exterior guide surface extends down and inward relative to the longitudinal axis of the bit and preferably intersects that axis of the bit at a point even with the bottom of the bit. In Fig. 6 of the drawings, the dotted line X indicates the central longitudinal axis of the tool or bit while the dotted line Y indicates the axis of curvature of the exterior guide surface 23 of the shoe.

The shoe B includes, in addition to the features above noted, one or more stopper bars 30 (see Fig. 11) which serve to check or prevent turning of the shoe in a bore or opening in which the shoe is seated, as, for instance, the turning of the shoe in a seat opening 20 or in a continuation thereof, such as is established by operation of the bit as will be hereinafter described.

In the particular case illustrated, there are two keys 30 and these are located at the vertical edges or edge portion of the shoe where they project outwardly or away from the guide surface 23 and extend from one end of the shoe to the other, parallel with the axis Y about which guide surface 23 is formed. In the preferred form of the invention the keys 30 have sharpened outer edges 31, and their lower ends are sharp and pitched to extend somewhat upward and inward toward each other (see Fig. 10). The keys are preferably surfaced or provided with hard facing 32, so that they readily peel grooves out of the formation being drilled and thus act as grips that effectively prevent turning of the shoe as the bit rotates relative to the shoe in the course of drilling, as will be hereinafter described.

The mounting means C formed essentially by the sub 10 and sleeve 11 serves to support the shoe B in the desired manner with reference to the bit A, as shown throughout the drawings. The sub 10 is an elongate tubular element which may be considered as a continuation or extension of the string S, or as an upwardly projecting part of the bit. The sub is rigidly connected or coupled to the lower end of the string S, as by a suitable threaded connection, and the bit A is mounted on or carried by the lower end of the sub through a suitable threaded connection. In the case illustrated in the drawings the sub has a socket opening 35 entering it from its upper end and a pin 36 on the lower end of the string is engaged in this socket. A socket opening 37 enters the sub from its lower end and a pin 38 on the upper end of the bit body 15 is carried in the socket 37.

The sub 10, being tubular, has a forming or passage through it from one end to the other, and in accordance with the present invention the upper end portion 40 of this opening or passage is considerably smaller in diameter than the lower end portion 41 which is of substantial size and which is in the nature of a cylinder opening. The upper portion 40 of the sub opening is preferably round in cross section and of such size as to pass the instrument E with suitable working clearance. The lower cylindrical opening 41 of the sub extends upwardly into the sub from the socket 37 and carries various other parts of the structure, as will be hereinafter described.

The exterior of the sub is round in cross section, being preferably turned, and is of substantially uniform diameter except at the lower end portion of the sub where there is an enlargement or stop 43 presenting an upwardly facing stop shoulder 44. The extreme upper end portion 45 of the exterior of the sub is somewhat smaller.
than the portion 46 adjoining the stop 43, and there is a threaded portion 47 between the portions 45 and 46.

The sleeve 11 of the mounting means C is carried on the portion 46 of the sub 10 where it is held or confined by the stop 43 and a stop 48 threaded onto the part 47, so that it does not shift vertically or lengthwise of the string 5. The sleeve 11 is held on the sub so that it is freely rotatable thereon and it is preferably confined by the stops so that it does not shift axially of the sub. Sleeve 11 is fitted upon the sub so that no appreciable movement radially (or transversely) of the longitudinal axis of the tool may occur. Thus, the external or guiding surface of shoe B is definitely located in a fixed axial and radial relationship to the axis of rotation of the bit or, in more practical terms, the shoe may move relative to the bit only in rotation. The sleeve may, if it so desired, be mounted so it is adjustable or variable axially of the sub in order to vary the position of the shoe lengthwise or vertically of the bit. By varying the vertical position of the shoe relative to the bit, the deflecting or bit guiding action of the shoe is varied. In the preferred setting or relamping of parts the lower end of the shoe is positioned somewhat above the lower end of the bit. In the particular case illustrated, one or more inserts 50 may be provided between the stops 43 and 48 and it will be apparent that by varying the size and arrangement of such stops the position of the sleeve can be varied, as desired. In Fig. 6 of the drawings, I show a single insert 50 arranged between the upper end of the sleeve and the stop 43, with the result that the sleeve is in its lowestmost position. In Fig. 7 I show the other extreme positioning of the sleeve brought about by locating the insert 50 between the lower end of the sleeve and the stop 43.

In the preferred construction, wear-taking rings or bearings 52 are provided on or as a part of the upper end of a sleeve 11 and on collar 45, as this portion of the sleeve rubs or wears against either the stop 48 or insert 50 as the tool is operated to bore.

In the preferred form of the invention the shoe B hereinabove described is mounted directly on or is joined to the sleeve 11 as an integral part or combination thereof, this preferred construction being shown throughout the drawings. In the particular case illustrated, the sleeve 11 has a skirt portion 11B which depends from the part carried on the portion 46 of the sub and surrounds the stop 43 as clearly illustrated in Figs. 6 and 7 of the drawings.

The lock means D serves primarily as a releasable lock between the shoe B and the string S fixing these parts against relative rotation and with the shoe in a predetermined rotative position relative to the string, or to the sub 10 which is, in effect, a part of the string. In the form of the invention illustrated the lock means D is provided or is located between the sub 10 and sleeve 11 and it includes a lock dog or bolt 61 operated by a core 67 operable in the sub 10. The bolt is operable into and out of an opening 62 provided in the sleeve 11. The core 67 is a part of an actuating means for the bolt 61, which actuating means is preferably a fluid pressure actuated structure.

The bolt 61 in the case illustrated is round in cross section and is slidable carried in a bore 65 formed radially in the sub 10 at a point where the sub is surrounded by the sleeve 11. A suitable fluid pressure seal 66 is carried by the bolt and seals the bolt in the opening 65. The opening 65 provided in the sleeve 11 is shown as formed completely through the sleeve, and it is of such length as to receive the bolt when the sleeve is set in various positions lengthwise of the sub.

In accordance with the present invention the bolt is located at a particular point around the sub, as related to other parts of the mechanism, and the opening 62 is located in a particular manner with reference to the shoe so that when the bolt is engaged in the opening 62 locking the sleeve against rotation on the sub, the shoe is in a predetermined rotative position with reference to the string S.

The actuating means for the bolt 61 involves the core 67 which is slidably carried in the cylindrical portion 41 of the passageway 40 of the sub 10. The core 67 is normally yieldingly held in an up position by a helical compression spring 68 that engages the lower end of the core and is seated on the upper end of a rest 143 seated on the pin 38 of the bit. A stop 69 limits upward movement or travel of the core 67 and is shown as an extension of a lock pin 70 which locks the stop 48 on the sub 10. The core 67 is a plunger or piston-like element subject to reciprocation in the sub and it is provided with a central passage 71 which extends through it from one end to the other. The passage 71 in the core is preferably such as to pass the instrument E, as does the opening 40 in the sub.

In accordance with the present invention a flow actuated check or choke is preferably provided in connection with the core to retard downward flow of fluid through the core so that such flow of fluid operates the core down in the sub 10. The passage 63 of the sub is shown in Fig. 2 of the drawings. Within this depending portion of the case there is a direction indicator which may be a magnetic

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needle 92, and it is preferred, also, to provide an inclination indicator which may be in the form of a plumb bob 93. A recorder 94, preferably a suitably time controlled photographic unit, is carried in the case and is related to the indicators 92 and 93 so that their actions are suitably recorded in the manner common to instruments of this general character. A marker or indicator 130 is provided in a fixed position in the case so its image or position is recorded with the other data.

From the foregoing description and from the drawings, it will be apparent how the case of the instrument is passed through the sub 10, the core 67 and to and through the body of the bit A. The bit employed in carrying out the invention is preferably of the type commonly termed a "trigger" or "trap door" bit, being a bit wherein there is a large vertical opening through the bit, and at the center of the structure there is pivoted central cutter 96, as indicated in Fig. 6 of the drawings. This structure serves to pass the case of the instrument in the manner shown in Fig. 13. Cutter 96 normally projects across the opening that passes the instrument and serves to cut away the core left by the cutters 17. This type of bit is illustrated in United States Letters Patent No. 2,179,010, issued November 7, 1939.

In accordance with the present invention a suitable stop means is provided for limiting downward passage or movement of the instrument relative to the tool on the lower end of string S. In the case illustrated an enlargement or stop 100 is provided on the exterior of the case at the upper portion thereof and engages a stop shoulder 101 provided in the sub 10 at the upper end portion thereof.

In practice it is convenient to handle or operate the instrument E by means of a line L and under normal operating conditions it is merely necessary to lower the instrument by means of the line until the instrument is stopped in the position shown in Figs. 2 and 13 of the drawings. In accordance with the present invention the instrument E, as above described, is cooperatively related to the tool at the lower end of the string S, and more specifically with the shoe B, so that the operator can ascertain the rotative position of the shoe. For this purpose the instrument includes one or more indicators. In the present case I show indicators in the forms of one or more magnetic elements or needles 110 and 111 which may be mounted one above the other on a central vertical pivot 112. These needles are alike and each has an end 113 pointed and the other end in the form of a tail 114. Being like magnetically the needles normally assume a position where the point end of one overlies the tail end of the other in a manner such as is shown in the record illustrated in Fig. 16 of the drawings.

The present invention provides one or more actuators, such as magnets M, in the tool, preferably in the upper end portion of the sub. The magnets are preferably located diametrically opposite each other and one has its positive pole innermost while the other has its negative pole innermost. The magnetic needles 110 and 111 are so located in the instrument E as to occur opposite the magnets M when the instrument is properly located or seated, as shown in Fig. 13. The magnets M, being considerably stronger magnetically, than the needles, immediately position the needles so that their positions coincide or, in other words, so that the pointed ends are in register and the tail ends are also in register, as shown in Figs. 14, 17, 18 and 19 of the drawings.

In connection with the needles 110 and 111 I may provide an inclination indicator such as a gravity actuated ball 120 on a convex surface, or a plumb bob 121, or both. The instrument E further includes means, such as a photographic unit 122, which may be time controlled and which serves to make a record of the needles 110 and 111, as well as the indicators 120 and 121. A further indicator is provided in the form of a projection 130 in the case, which makes a record of the rotative position of the case in the tool at the time the various records are made by the instrument. Indicators 130 and 130 are in line vertically.

In accordance with the present invention the magnets M are in a predetermined rotative position with reference to the lock means D and consequently with reference to the shoe B, and it is through this knowledgment of parts that the readings obtained from or through the instrument E, upon its being withdrawn from the drill string following actuation, can be observed or interpreted to enable the operator to know the rotative position of the shoe B in the bore at the time the instrument E operates.

As a result of the structure just described, when the instrument E makes a record having its lower end portion properly depending from the bit A, the recording includes a record of the needles 110 and 111 showing these needles coincidental, as shown in Figs. 14, 17 and 18. However, should the instrument be in other than the proper position, the recording or reading obtained will show the needles 110 and 111 oppositely related, as shown in Fig. 16 of the drawings.

From the foregoing description it will be apparent how the instrument E can be rapidly lowered to operating position by means of the line L and through proper actuating or timing of the instrument records are made as by the photographic units 94 and 122, the unit 94 recording the inclination and rotative position as by reference to the earth's magnetism, while the unit 122 records the rotative position of the tool. With these factors known or recorded the operator can either leave the string S in the position at which the records were made, if that position is satisfactory, or the strings can be rotated the desired amount to bring the shoe to the desired rotative position, all as will be described in the following description of operation. Information from unit 94 is relayed to unit 122 through indicators 130 and 130.

The stop means F, provided by the present invention, is provided as a means that positively stops or positions the instrument E in the location shown in Fig. 13 at a time when the means D is released so that the shoe B is not necessarily in a given rotative position with reference to the magnets M or string S. The stop means F is shown as including a stop member 140 operable into and out of the passage that extends through the tool to pass the instrument. The stop member 140 is preferably a pivoted member carried on a pivot pin 141 mounted in a recess 142 provided in the core 67. The pivoted stop member 140 normally hangs or depends in a position clear of the passage through the tool.

An actuator 143 is provided to operate or actuate the stop member 140 into the passage or into the path of the instrument E when the core 67 is in other than its uppermost position. The actuator, as shown in the drawings, is in the form of an extension or seat 143 above the upper end of the pin 38. The seat has an inclined operating shoulder 144 which engages the pivoted member 140. When the core 67 is lowered from its uppermost position the inclined shoulder 144 causes the member 140 to be swung inwardly and finally to a position such as is shown in Fig. 7. Inward movement of the member 140 from the position shown in Fig. 6, even though slight, will stop passage of the instrument downward to the proper operating position and, therefore, unless the core 67 is up, in which position the bolt 61 is engaged in the opening 62, the instrument cannot be passed downward to the position shown in Fig. 13.

In employing the structure or apparatus that I have provided and in carrying out the method of the present invention, an operating string with the tool on its lower end is first lowered into the well bore W, that is, into the bore 205, and is operated to form the seat or counterbore 20 extending from the bottom of bore 205, as shown.
in Fig. 1. It is to be understood that the sub 10, sleeve 11, shoe B and bit A form an assembly on the lower end of the string S that can be conveniently referred to as a tool. The seat opening or counterbore 20 can be drilled, prior to orientation the tool, to a suitable depth such as is illustrated in Fig. 1. If fluid is circulated down through the string S the core 67 will be lowered and the shoe released relative to the bit so that the bit operates without carrying or dragging the shoe around with it. However, if fluid is not circulated the shoe will be carried around with the bit as the counterbore is drilled.

When a suitable seat or counterbore has been established circulation of fluid is stopped and the string rotated slightly causing the sub to turn within the sleeve until the bolt 61 registers with the opening 62, whereupon the spring 68 will elevate the core 67, causing the bolt to be engaged in the opening 62. The shoe is now locked in a predetermined rotative position with reference to the magnets M carried by the sub, and therefore with reference to the string S. The string is then elevated to move the bit to a position well above the bottom of the bore, as shown in Fig. 2.

The line L is then operated in the string S to lower the instrument E into the position shown in Fig. 13, in which position the lower end portion 91 of the instrument case depends a substantial distance below the bit and into the open well bore, so that the action of the needle 92 is not impaired by the presence of the bit and other parts above it.

The instrument E, which is magnetically influenced is then operated, as by means of a ducer or by a suitable wire control or through other control means, recording the positions of the various indicators included in the instrument, particularly the indicators 92, 110 and 111. If it is important to ascertain inclination, then the recordings of the indicators 93, 120 and 121 may be important.

When the sub has been recorded, the instrument E is withdrawn and the recordings made by the instrument are read or interpreted, with the result that the operator is advised as to the rotative position of the shoe in the well. With this knowledge the operator can leave the shoe in the recorded position or can vary it from the recorded position, as circumstances require, following which the string S is lowered without rotation, causing the shoe to be engaged in the seat or counterbore 20 where it is tightly engaged or wedged in a manner such as is indicated in Fig. 3 of the drawings.

With the shoe seated in the counterbore 20 circulation is established, causing the core 67 to be lowered and the lock bolt 61 retracted, thus freeing the sub for rotation in the sleeve. With the sub and sleeve thus freed for relative rotation the string S can be turned or rotated in the manner common to drilling with the rotary method, and pressure can be imparted to the bit with the result that the counterbore is deepened or extended, as indicated in Fig. 4 of the drawings, to become, in effect, an extension of the bore W inclined or at an angle relative thereto as a result of the guiding or deflecting action of guide surface 23 of the shoe. The keys on the shoe embedded in the wall of the extended bore leave slight grooves 130 therein, as indicated in Fig. 4, and they serve to hold the shoe against turning as the bit operates to advance the counterbore.

When the desired extension of the bore has been established the string S can be withdrawn, in the course of which operation the bit can be kept in operation, and when the bit is out of the bore extension or counterbore the string can be removed from the well, carrying the tool with it.

The extended bore thus formed may, in practice, be but slightly smaller than the initial or original bore W, and it is important to observe that it is wholly free of obstructions or undesirable equipment such as whiplstocks, or the like.

If desired, the extension of the bore can be enlarged to correspond in size to the original bore by operating a string S' with a suitable bit A', either alone or equipped with a reamer R, as circumstances require. The enlargement of the extension or counterbore is illustrated in Fig. 5 of the drawings.

At any time in the course of operating the apparatus when the bit is suitably elevated off bottom, if the instrument employed in the course of orientation is lowered to assume the position shown in Figs. 2, 21 and 26, and the string is then lifted without the lowering of the limited level, thereon of the operator knows that the lock means of the shoe is engaged and the shoe at that time is in a predetermined rotative position relative to the string. If the instrument has been released for lowering into the position just mentioned and is not seated, and lifting of the string is accompanied by lowering of the liquid level therein, the operator knows that the instrument has not lowered to stop discharge of liquid and this is probably due to the shoe lock being disengaged.

In the embodiment of the invention illustrated in Figs. 20 to 24, inclusive, the drilling string S is provided at its lower end with a bit A having a shoe B previously described. In this form of the invention a hole opening mechanism or reamer R' is combined with or cooperatively related to bit A and is located in or on the string S. In the particular case illustrated, the reamer R' is located on the lower end of string S so that it occurs between the string S and the sub on the bit A and is, therefore, above and immediately adjacent the bit A.

The reamer R' is in the general nature of a reaming tool, that is, it is a tool having a body 200 carrying cutters 201 and the cutters are supported by body 200 so that they will cut or drill the formation penetrated by bit A, so that the extension of the well bore made by bit A is enlarged an appreciable amount and, preferably, so that it is either the size of the well bore 205 or is of a size slightly smaller than the bore 205.

It is contemplated that in practice the reamer R' may be varied widely in form of construction. In the case illustrated in the drawings, reamer R' is of conventional construction and the body 200 has legs that carry a plurality of circumferentially spaced cutters 201 so that they project downwardly and radially outward, as clearly illustrated in the drawings.

With the equipment just described the string S with the bit A and reamer R' carried thereby is lowered into the well bore 205 and operated as shown in Fig. 20, so that the shoe B wedges against one side of the counterbore 20 made by the bit A. The bit A depends a substantial distance below the reamer R' and far enough so that a counter bore or seat 20 may be established sufficient to carry out the orienting and drilling operations hereinafore described, the operation illustrated in Fig. 21 being comparable to the operation illustrated in Fig. 2. Fig. 21 shows the bit and shoe removed from the counterbore and scoring 158, such as may be left by the shoe, is shown on or in the wall of the counterbore.

After the orienting operation is executed, while the bit is out of the counterbore, so that the shoe B is located in the desired rotative position, the bit A is returned to the counterbore 20, as shown in Fig. 22. The shoe is wedged into the counterbore 20 at the desired location and established grooves in the wall, as clearly illustrated in Fig. 22. The drill string 90 in the core is then rotated and advances as the extension of the bore is formed and as this deepening operation is carried out the bit A advances and the reamer R' follows the bit, with the result that bore extension is established, as shown in Fig. 23 of the drawings.

Since the shoe B wedges against the side of the hole adjacent the bit A and continues to do so as the hole is drilled, the hole or extension of the bore that results is somewhat curved rather than straight.
If the reamer R' is of a size corresponding to the bore 205 of well W the extension formed by the bit A and reamer R' in the manner just described, will correspond in size to the well bore 205 and will be, in effect, a continuation thereof deflected in a predetermined manner from the axis of the well bore. If, on the other hand, the reamer R' is somewhat smaller than the bore 205 as the bore 206 is advanced, as illustrated in Fig. 23, the extension of the bore continuing from the bore 205 will be somewhat smaller than the bore 205. In this case, the operation of the equipment illustrated in Figs. 20 to 23, inclusive, is for convenience by the operator of a drilling string S' carrying a conventional bit A' and a reamer R'. The conventional bit and reamer will advance in the extension of the bore established by the bit A and reamer R' so that the extension becomes a full size continuation of the well bore.

By employing the steps above described, a bit A of small size, say, for example, a bit A for cutting a hole 75% inches in diameter is effective for use in the course of drilling a well bore from that size up to, say, 125% inches in diameter, assuming, of course, that what may happen to be of the maximum diameter the reamer R' is used in connection with the bit A, and conventional bit A' and reamer R' are run in accordance with the steps illustrated in Figs. 20 to 24, inclusive.

In the case illustrated in Figs. 25 to 27, inclusive, equipment such as illustrated in Figs. 1 to 5, inclusive, is used, however, the operation instead of being a mere simple single deflection of the well bore is the deflection of the well bore and a following correction or second deflection. In this case, as shown in Fig. 25, an extension of the well bore is drilled ahead of the well bore 205 in accordance with the procedure illustrated in Figs. 1 to 4, inclusive. The scoring 159 of the wall of the counterebore is shown in Figs. 25, 26 and 27.

Assuming an extension to have been drilled to a position as shown in Fig. 26, and assuming orienting operations or a survey is made at this point in the procedure, it may be found that the extension of the well bore is not that which is desired, due possibly to error in calculation or a change in program, or to any one of several different factors. In such event the bit A, as provided by the invention, with the shoe B combined therewith, is operated, as shown in Fig. 27, after surveys and orientation have been carried out as hereinabove described, causing the extension to have an advanced portion 20A deflected to extend in the desired manner. This can all be carried out without removal of the equipment from the well, since it is possible as a result of the present invention to set and release the shoe B relative to the bit A whenever desired, and as often as necessary.

The practical significance of the procedure just pointed out and which is shown in Figs. 25 to 27, inclusive, will be appreciated when it is realized that to execute such an operation with standard methods or ordinary equipment, for instance, with whipstocking, would require numerous runs or return trips, complicated survey and orienting operations, and it is doubtful whether it could be executed practically under the most ideal conditions.

Having described only a typical preferred form and application of my invention, I do not wish to be limited or restricted to the specific details herein set forth, but wish to reserve to myself any variations or modifications that may be suggested by those skilled in the art and fall within the scope of the following claims:

Having described my invention, I claim: 1. A well deflecting tool comprising a rotatable drill bit having a longitudinally extending axis of rotation, a bit guiding shoe having an external guide surface thereon, and means coupling said bit and said shoe to each other for relative rotation about said axis with said guide surface located in a fixed axial and radial relationship to said axis, said guide surface having a lower edge extending partially around the circumference of said bit adja-
said last mentioned means comprises a member pivotally connected to the lower end of said piston at a location wherein said member may normally hang in a position clear of said passageway, and an inclined surface on said bit adapted to cam said member into said passageway upon movement of said piston toward said second position.

9. A well deflecting tool as recited in claim 7 including means biasing said piston toward said first position, said piston being movable to said second position upon the application of fluid pressure thereto, and means responsive to application of fluid pressure to said piston for restricting said passageway.

10. The combination with a well drilling bit having a bit guiding shoe rotatably mounted thereon, means for latching said shoe to said bit at a predetermined rotative position, and means operatively associated with said shoe for establishing a localized magnetic field having a known relationship to said predetermined rotative position; of a surveying instrument comprising an elongate casing axially positioned within said bit, cooperating means on said casing and said bit locating said casing at a known axial position within said bit, first indicating means operable when said casing is at said known axial position to indicate the direction of the earth's magnetic field with respect to a reference point within said instrument, and second indicating means comprising a first and a second magnetized needle mounted for independent rotation within said casing at spaced axial locations upon a common pivotal axis, the axial spacing of said needles being such that the respective magnetic fields of said needles mutually attract said needles to assume and maintain a first rotative orientation with respect to each other, said needles being so located within said casing as to lie within said localized magnetic field when said casing is at said known axial position to thereby indicate the direction of the magnetic field of said magnetic means with respect to a reference point within said instrument, the field of said magnetic means being of a strength sufficient to overcome the mutual attraction of said needles and to force said needles into a second rotative orientation with respect to each other whereby the rotative position of said shoe and the location of said casing at said known axial position may be simultaneously determined.

11. The combination with a well drilling bit having a bit guiding shoe rotatably mounted thereon, means for latching said shoe to said bit at a predetermined rotative position, and means operatively associated with said shoe for establishing a localized magnetic field having a known relationship to said predetermined rotative position; of a surveying instrument comprising an elongate casing axially positioned within said bit, cooperating means on said casing and said bit locating said casing at a known axial position within said bit, a first and a second magnetized needle mounted for independent rotation with said casing at spaced axial locations upon a common pivotal axis, the axial spacing of said needles being such that the respective magnetic fields of said needles mutually attract said needles to assume and maintain a first rotative orientation with respect to each other, said needles being so located within said casing as to lie within said localized magnetic field when said casing is at said known axial position to thereby indicate the direction of the magnetic field of said magnetic means with respect to a reference point within said instrument, the field of said magnetic means being of a strength sufficient to overcome the mutual attraction of said needles and to force said needles into a second rotative orientation with respect to each other whereby the rotative position of said shoe and the location of said casing at said known axial position may be simultaneously determined.

12. The method of extending a well bore in a predetermined rotative direction comprising the steps of lowering a drill bit having guide means rotatably mounted thereon to the bottom of said bore, moving said drill bit relative to said guide means to form a seat for said guide means, raising said drill bit and said guide means from said seat, locking said guide means against rotation relative to said bit, rotating said bit to orient said guide means to guide said bit in the desired direction, lowering said drill bit and said guide means to said seat formed by said drill bit while said guide means is locked against rotation relative to said bit, unlocking said guide means from said bit and advancing said bit and said guide means to extend said bore in the desired direction.

13. A well deflecting tool comprising a rotatable drill bit having a longitudinally extending axis of rotation, a bit guiding shoe having an external guide surface thereon, means mounting said shoe on said bit for rotation of said bit relative to said shoe about said axis while said shoe is maintained in a fixed axial relationship to said bit, and means releasably coupling said bit and said shoe to each other, said bit and said shoe being rotatable together about said axis when coupled to each other and said bit being rotatable relative to said shoe about said axis when said coupling means is released, and said guide surface being spaced the same radial distance from said axis irrespective of whether said bit is coupled to each other for rotation together about said axis or said coupling means is released to permit said bit to rotate relative to said shoe about said axis.

14. A well deflecting tool comprising a rotatable drill bit having a longitudinally extending axis of rotation, cutting elements mounted on the lower end of said bit, a bit guiding shoe having an external guide surface thereon, means coupling said bit and said shoe to each other to permit said bit to rotate relative to said shoe about said axis, and abutment means engageable between said shoe and said bit to maintain said shoe in fixed axial relationship with said bit during rotation of said bit relative to said shoe, said guide surface having a lower edge extending partially around the circumference of said bit adjacent said cutting elements and having an upper edge extending partially around the circumference of said bit below the upper end of said bit.

15. A well deflecting tool comprising a rotatable drill bit having a longitudinally extending axis of rotation, cutting elements mounted on the lower end of said bit, a bit guiding shoe having an external guide surface thereon, means coupling said bit and said shoe to each other to permit said bit to rotate relative to said shoe about said axis, and abutment means engageable between said shoe and said bit to maintain said shoe in fixed axial relationship with said bit during rotation of said bit relative to said shoe, said guide surface having a lower edge extending partially around the circumference of said bit adjacent said cutting elements and having an upper edge extending partially around the circumference of said bit below the upper end of said bit.

16. A well deflecting tool comprising a rotatable drill bit having a longitudinally extending axis of rotation, cutting elements mounted on the lower end of said bit, a bit guiding shoe having an external guide surface thereon, means coupling said bit and said shoe to each other to permit said bit to rotate relative to said shoe about said axis, and abutment means engageable between said shoe and said bit to maintain said shoe in fixed axial relationship with said bit during rotation of said bit relative to said shoe, said guide surface having a lower edge extending partially around the circumference of said bit adjacent said cutting elements and having an upper edge extending partially around the circumference of said bit below the upper end of said bit.
wardly and inwardly of said axis from said upper edge to a lower edge located above the lower end of the cutting elements of said bit, and means mounting said shoe upon said bit to permit said bit to rotate relative to said shoe about said axis while said shoe is maintained in fixed axial relationship to said bit.

18. A well deflecting tool as defined in claim 17 wherein said guide surface is inclined with respect to said axis of rotation at an angle such that a downward projection of said guide surface intersects the outer circular peripheral path defined by the cutting elements of said drill bit upon rotation of said drill bit about said axis.

19. A well deflecting tool as defined in claim 18 wherein said guide surface is a cylindrical surface having a radius of curvature substantially equal to the radius of said outer circular peripheral path.