Feb. 10, 1959 R. P. DWYER 2,873,092

JET DEFLECTION METHOD OF DEVIATING A BORE HOLE

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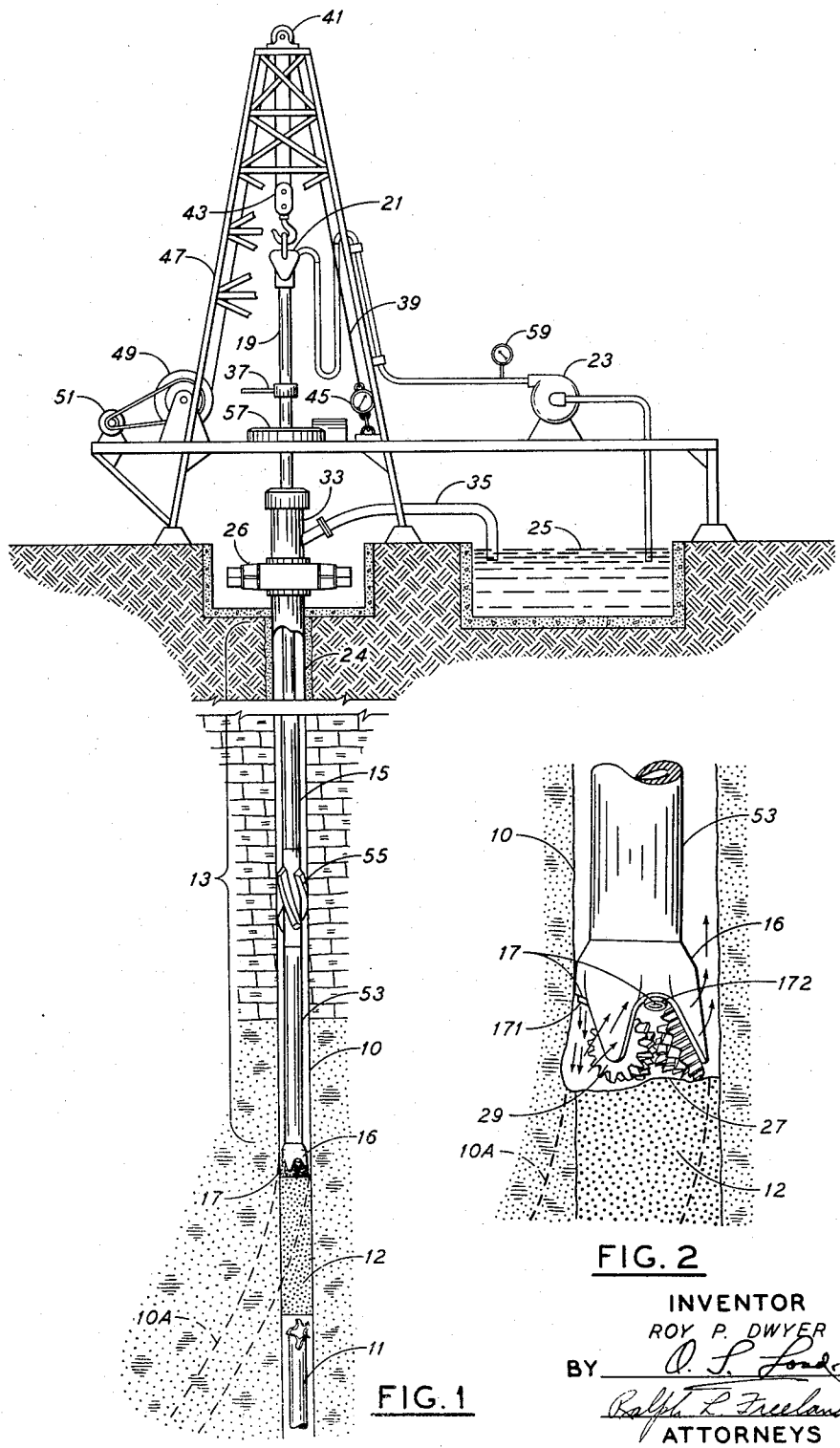

FIG. 1

FIG. 2

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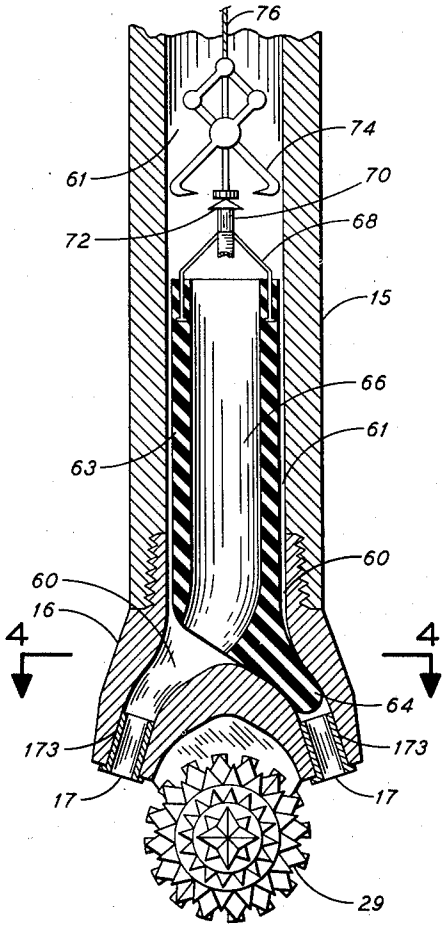

FIG. 3

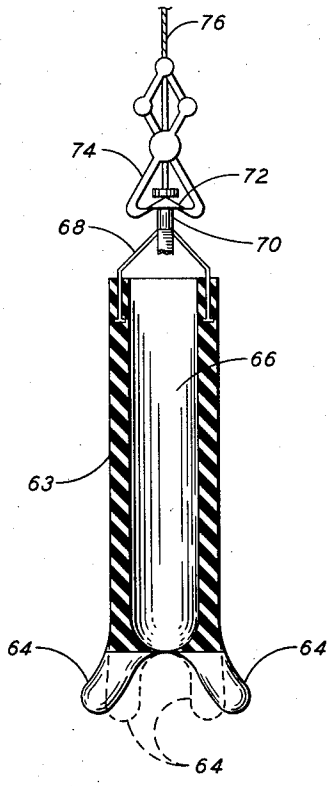

FIG. 5

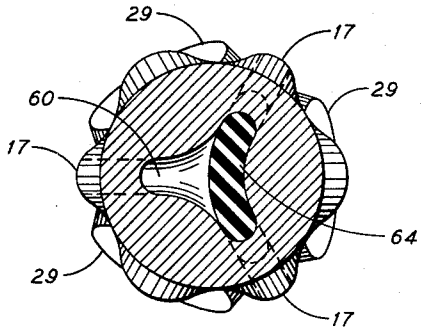

FIG. 4

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JET DEFLECTION METHOD OF DEVIATING A BORE HOLE

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6 Claims. (Cl. 255—1.6)

The present invention relates to a method of directional drilling, and more particularly to a method of directional drilling using a jet drilling apparatus including a drill string and a jet drill bit having one or more fluid nozzles adapted to hydraulically jet directly against the bottom and sides of a well bore.

It is a particular object of the present invention to provide an improved method of directionally drilling a well bore in formations wherein hydraulic washing and mechanical cutting are combined to direct a borehole in predeterminable manner away from true vertical without requiring the use of whipstocks or other conventional downhole accessories. In accordance with said method, one of the hydraulic nozzles carried by a jet drill bit is oriented with regard to the earth's surface, or the well bore, and a greater amount of fluid is circulated therethrough by restricting, plugging or blanking off flow to the remaining nozzles, so that only said single nozzle oriented off-center with respect to the hole drives the drill bit in a desired direction. Desirably, the drill bit is reciprocated, while at the same time fluid is preferentially supplied under high pressure to said single off-center nozzle to drive the well bore in the same direction as that in which said nozzle is pointed. Where other than multiple-cone drill bits are used with said nozzle, the borehole is advantageously maintained cylindrical by oscillation of the bit as it rests on the bottom of the borehole by alternate starting and reversing the rotary table to turn the bit through a few degrees of movement.

In directional drilling, it is common practice to use a hole deflector tool, known as a whipstock set in a borehole drilled to a sufficiently large diameter to accept the whipstock body. The whipstock then guides a normal rotary bit against a side wall of the borehole and causes the bore to be deflected away from the original hole. In such directional drilling, this requires that the borehole be opened from the surface downward to an earth formation that is sufficiently consolidated to accept the whipstock which then must be set, using orienting and directional survey equipment to assure the driller that the whipstock is properly aligned in the hole.

In drilling relatively softer formations it is conventional to drill with rotary equipment that includes a drill string having a jet bit secured to the lower end of the drill string. Jet bits are normally characterized by having two or three rock bit cones, or cutters, that rotate when the drill string is driven and in addition, have a plurality of hydraulic nozzles positioned so that drilling fluid pumped downwardly through the drill string passes between adjacent rotary bit cones and strikes the bottom near the sides of the borehole. The nozzles are either set to strike the bottom of the borehole at about the same diameter as the outer diameter of the drill bit cones or strike slightly to the outer edge of the borehole during drilling. In such drilling the hydraulic action of the drilling fluid passing through the nozzles at high velocity does not actually drill the formation, since in general

the rock is too hard for more than slight erosion by the drilling fluid jets. However, at least in theory, it is believed that the jets assist in the removal of chips formed by the drill bit cutters so that the cutting edges are in contact with fresh surfaces at the bottom of the hole at all times. Such jet drill bits have been used in conjunction with whipstocks where it is desired to drill deflected boreholes, such as in directionally drilling under bodies of water, or to change the course of a drilling well, for example, to by-pass "junk" (pieces of drill string or other undrillable material lost in the hole), sealed off in an original borehole by cement plugs or to straighten crooked holes.

It is also common practice to drill pilot holes deflected from the bottom of a full size drill hole using both a flexible drill pipe and flexible connectors. However, such pilot holes are normally guided in the desired direction by complex orienting equipment located in a full-size drill string wherein the pilot bit and pilot drill string are supported.

In accordance with the present invention, a simplified method is provided for performing deflected drilling using the jet drilling technique that does not require whipstocks or other auxiliary deflecting equipment either in starting the well bore or in deflecting the bore after the well has been drilled to any desired depth. In said method, deflection of the jet drill string is obtained by directing a substantial portion of the drilling fluid through one nozzle of a jet drill bit. In a preferred method of carrying out the invention, said single jet is eccentric to the center of the drill string and said jet is oriented in the direction and on the same side of the bore that deviation of the borehole is to take. With the single preferred hydraulic nozzle oriented in said desired direction, the well bore is started by applying sufficient weight to the bit and supplying drilling fluid to said preferred jet nozzle under pressure through the drill string. After sufficient penetration has been obtained to permit vertical movement of the drill string therein, the drill bit is reciprocated up and down by increasing and decreasing the weight applied thereto by the drill string and drill collars. Deviation of the borehole then proceeds in the direction that the jet is oriented and said directional drilling will proceed at least through the softer portions of the earth. Without full rotation of the drill bit and drill string until after the desired deviation of the borehole is obtained, the drill string may advantageously be oscillated so that the cutters can maintain the borehole generally cylindrical in form. Such oscillation is particularly useful with a drag-type bit. Desirably, but not necessarily, the jet drill bit is supported on the lower end of a flexible length of drill pipe below a section of normal drill string including a plurality of drill collars. After full, desired deflection is obtained, the drill string is rotated and if desired, the remaining jets in the drill bit unplugged so that conventional jet drilling may proceed.

Further objects and advantages of the present invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings which form an integral part of the present specification:

In the drawings:

Fig. 1 is a schematic representation of one arrangement of apparatus suitable for carrying out directional drilling with jet drilling apparatus;

Fig. 2 is a detailed view of the lower end of drilling apparatus illustrated in Fig. 1, particularly showing the flow of drilling fluid directly against the bottom of the borehole through one eccentric nozzle of a conventional jet bit;

Fig. 3 is a vertical sectional view through the lower

end of a drill bit illustrating an alternative arrangement for preferentially blocking drilling fluid flow from all but one of the nozzles in a jet drill bit;

Fig. 4 is a sectional plan view showing the blocking arrangement in the bit's flow passages taken in the direction of arows 4—4 in Fig. 3;

Fig. 5 is a front elevation view, partially in section, of the flow directing member shown in the embodiment of Figs. 3 and 4.

Referring now to the drawings, and in particular to Fig. 1, there is indicated a borehole **10** that has been started into the earth. In the present example it is desired to by-pass the lower portion of borehole **10** wherein a "fish," such as broken drill string **11**, is stuck in the borehole. As indicated schematically, a plug **12** has been set above the top of "junk" or "fish" **11** and it is desired to by-pass the lower part of borehole **10** by a deflected borehole, proposed by the well bore outline indicated as **10A**, starting from a point directly above plug **12**. In accordance with the method of the present invention, the deflected borehole **10A** is to be drilled by a jet drill string **13** that includes a series of drill collars **15** and a hydraulic jet drill bit **16** that includes a plurality of jet nozzles **17**. As indicated schematically in Fig. 1, a jet drill string normally drills well bore **10** by rotary table **57** turning drill string **13** while drilling fluid is supplied by mud pump **23** to the hydraulic nozzles **17** under high pressure through Kelly bar **19**, and swivel **21**. Fluid is drawn from sump **25**.

As better indicated in Fig. 2, nozzles **17** direct the stream of hydraulic fluid under high pressure directly against the bottom **27** of borehole **10** in such manner that as the cones **29** rotate on the bottom of the well bore, chips are immediately flushed away by the hydraulic stream and rise through the mud column in borehole **10** to return to the sump **25** through well head **33** and return line **35**.

In accordance with the present invention, deflected well bore **10A** is drilled in the direction indicated by the dotted lines with the apparatus indicated hereinabove, but with the conventional jets **17** modified so that a major portion of the drilling fluid leaves only one of the plurality of jet nozzles **17**. The remainder are either blanked off, plugged, or flow restricted so that fluid flowing down the drill string **13** will be ejected from that jet which is oriented in the direction that borehole **10A** is to be sidetracked. In practice each nozzle of a conventional jet bit is lined with a hardened insert formed of a wear-resistant material, such as tungsten carbide. These inserts reduce wear by sand and rock particles recirculated with the drilling fluid. The size of said inserts can be varied to take advantage of the capacity of different sizes of mud pumps, such as pump **23**. In a preferred manner of carrying out the present invention, one oversized or larger opening insert **171** is pressed into one of the three eccentric nozzle openings **17** and two undersized inserts **172** into the other openings **17**. Insert **171** is selected to give maximum jet action with the available mud pump, but the remaining inserts are intended to serve as auxiliary flushing jets to keep cones **29** clean. Additionally, by using flow in all three jets, even though purposefully unequal, normal rotary jet drilling can be resumed without requiring a round trip to unplug the remaining jets or other corrective action to activate the non-directional jets.

Drill string **13** is then lowered into borehole **10** and nozzle **17** oriented by conventional orienting methods, well known in the field of directional drilling, but indicated herein schematically by bar **37** clamped to Kelly bar **19**. This bar is normally held in alignment by optical instruments (not shown) using a part of derrick **47** as a base line.

With the single or preferred jet **17** oriented, a predetermined weight is then applied to drill bit **16**, for example, by releasing a portion of the weight supported by cable **39**, threaded through crown block **41** and travelling block **43**. Adjustment of said tension is indicated by weight meter **45**, located in the deadline and anchored to the floor of derrick **47**. Lifting and lowering of drill string **13** is performed by drawworks drum **49** driven by motor **51**.

With the single oversized, or unplugged, nozzle **17** directed toward one side of the borehole bottom, the weight thereon is alternately decreased and increased, and desirably bit **16** is raised and lowered in the well bore so that reciprocating, or churning, action occurs as nozzle **171** operates against one side of the bottom and the wall of borehole **10**. The lateral erosion of the borehole in this manner is indicated in Fig. 2. Although conventional drill collars (heavy-walled drill pipe) will deflect sufficiently to follow the deviated borehole, drill bit **16** is assisted in following directly after, and in the direction of single nozzle **17**, by supporting it upon a short section of regular drill pipe, known as a "pup joint," **53**. Section **53** is preferably thin-walled so that there is more transverse flexibility in the drill string directly above the bit. To prevent undue, or too rapid, deflection of borehole **10A** away from the direction of original borehole **10**, drill string **13** is provided with a stabilizer **55** secured to the outer surface of drill collar **15**. This stabilizer assists the drill pipe to remain in the center of the borehole **10A** and maintains a large radius of curvature while the lower end is deflecting in the desired direction of deviated borehole **10A**.

When deflected borehole **10A** has achieved the desired angle of deflection, the jet drill apparatus may be returned to normal rotary jet drilling. When restricted circulation has been permitted through the remaining jets, this can be done merely by starting rotation of the rotary table **57** in conventional manner.

There is shown in Figs. 3, 4 and 5 an alternative arrangement for directionally controlling the flow of drilling fluid to a single jet nozzle. As best seen in Fig. 3, flexible plug element **63** forms a flow directing means with bit **16** and drill collar **15**. Plug **63** includes a pair of ears **64** adapted to fit into two of the three flow passageways **60** in bit **16**. As best seen in Fig. 5, the ears **64** are flexible and normally turn outwardly so that they generally conform to molded passageways **60** and terminate just above nozzle inserts **173**. In the present arrangement each of the nozzles **17** have inserts **173** of the same diameter so that upon removal of plug unit **63** from main passageway **61** through pipe collar **15** and bit **16**, flow of drilling fluid will be equal through all three nozzles **17**. As further shown in both Figs. 3 and 5, a central passageway **66** is formed in plug member **63** to funnel drilling fluid into a single, unstopped passageway during directional drilling. This flow passageway is best seen in Fig. 4.

Since it is desirable to retrieve the plug member **63** after directional drilling as described hereinabove and the borehole has attained desired deviation, a plug snatcher arrangement **74** is lowered on cable **76** to engage knob **72** on the end of shaft **70**. Shaft **70** is connected to plug **63** by bale **68** molded into the plastic or rubber body of flow directing plug **63**. As indicated in Fig. 5, when the fingers on snatcher **74** lift plug unit **63**, ears **64** are deformed to the position indicated by the dotted lines. Thus, the entire unit can be pulled out of the drill string so that conventional jet drilling can proceed with equal fluid flow through nozzles **17**.

Drilling can be performed with only a single jet open, by rotating the drill bit **16** with the remaining one or two other jets plugged, but, of course, it is preferable to remove the plugs in the remaining jet nozzles **17**.

Alternative to the arrangements shown in Figs. 3 to 5, individual plugs can be used in the nozzles that are removable in several different ways. For example, the entire drill bit assembly can be lifted out of the borehole and the plugs moved manually, or the individual

plugs can be made of a frangible material that will burst through the nozzles that have been blanked off upon sufficient increase of mud pressure above a predetermined value, that can be indicated by gauge **59** on the output of mud pump **93**. Alternatively, reversed circulation of drilling fluid in the borehole can be used to recover the plugs from within drill string **13**.

While the present method has been described as applied to by-passing a previously drilled hole, it will be understood that the present method is particularly adapted to drilling of offshore wells wherein it is desired to position as many producing wells as possible on a single platform by deflecting the wells to cover a large lateral area below the earth's surface. In some operations, it is desirable to be able to begin deflecting the well bore at the underwater bottom. For this purpose, the directional hydraulic jet bit is oriented in the desired direction when the drill string is lowered into contact with bottom. Adequate pressure is then applied to drill bit **16** so that drilling will be started by hydraulic action in the direction of the single oriented nozzle. As soon as the bit has been drilled several feet into bottom by this technique, the bit is alternately raised and lowered while circulation continues.

Preferably a continuing survey of the well orientation is made while directional jetting action continues. This deviation can be surveyed with conventional equipment. In such borehole surveying a record is made either by a continuous indicator or by a so-called "one-shot" camera method wherein a single photo of the angle and direction of deflection is made at any desired point in the well bore. In such method, the directional recording instrument is recovered at the earth's surface without removal of the drill string.

In using the foregoing system, I have found it possible to deflect a borehole through 24° of angle from true vertical in a borehole only 2035 feet deep. In said well bore, the angle of deflection was found to be 2¾° in the first 17 feet of penetration and 8¼° at a depth of 47 feet after deflecting. Additional deflection could have been obtained by the above-described method, but in the particular well being drilled, it was desired to maintain the deflection not greater than about 24° at the 2000 foot depth.

It will be apparent that the present method is not confined to any particular form of bit since jet bits, and jet drilling methods are commonly known that use either two or three cones and have a comparable number of jet nozzles, each directed against the bottom of the well bore, intermediate the cutting surfaces of the bit cones. Additionally, drag bits having jet nozzles can be used in the method described. Further, the degree of flexibility of the drill string can be varied considerably depending upon the direction and amount of deviation desired in a completed well bore by insertion or omission of a flexible length of pipe below the drill collars.

Various other modifications in the apparatus and in the method of applying the concept of the present invention will become apparent to those skilled in the art from the foregoing description. However, it is intended that all such modifications falling within the scope of the appended claims are to be included therein.

I claim:

1. The method of directionally drilling a well bore into an earth formation by jet drilling method with a drill bit that includes a plurality of rotary cutters and a plurality of fluid-ejecting nozzles adapted to direct drilling fluid against the bottom and wall of a borehole intermediate said cutters which comprises the steps of restricting drilling fluid flow through all but one of said plurality of nozzles, orienting said drill bit with said one unrestricted nozzle positioned relative to the earth in the direction of desired deviation of the bore-hole, and supplying drilling fluid under pressure through at least said one nozzle to erode said well bottom and wall in the direction of orientation of said unrestricted nozzle, at the same time periodically reciprocating said drill bit into and out of contact with the bottom of the well bore, said reciprocation being performed without rotation of said drill bit.

2. The method in accordance with claim 1 wherein the flow of drilling fluid is restricted to be substantially all through said one oriented nozzle by blocking said flow to the remainder of said nozzles.

3. The method in accordance with claim 1 wherein the flow of drilling fluid is preferentially directed toward the desired direction of deviation by making the flow through said one oriented nozzle substantially greater than that through the other of said nozzles by increasing said flow through said one nozzle and simultaneously restricting flow to the remaining nozzles.

4. The method of directionally drilling a well bore with jet drilling apparatus that comprises a drill string including drill pipe and drill collars, a drill bit secured to the lower end of said drill string, said drill bit including a plurality of cutter members and a plurality of fluid nozzles for directing fluid flow at the bottom of a well bore intermediate said cutter members, means for supplying drilling fluid under pressure therethrough and means for elevating and lowering said drill string to apply a predeterminable weight to said drill bit which comprises the steps of restricting the flow path through said plurality of nozzles so that a substantial portion of the drilling fluid flow will be through only one of said nozzles, orienting said drill string with said one nozzle in the desired direction for deflection of a borehole from said well bore, lowering said drill bit into contact with said well bore bottom, applying a predeterminable weight to said drill bit while pumping drilling fluid under pressure through at least said one nozzle to erode said bottom of said well bore in the direction of orientation of said one nozzle, and maintaining a predetermined rate of circulation of said drilling fluid through said one nozzle while at the same time reciprocating said drill string substantially without rotation thereof.

5. The method of directionally drilling a well bore with jet drilling apparatus that comprises a drill string including drill pipe, drill collars, and a drill bit secured to the lower end of said drill string, said drill bit including a plurality of cutter members, a plurality of fluid nozzles for directing fluid flow at the bottom of a well bore intermediate said cutter members, means for circulaitng drilling fluid through said drill string and means for elevating and lowering said drill string to apply a predeterminable weight to said drill bit which comprises the steps of positioning a relatively flexible section of drill pipe intermediate the lower end of said drill collars in said drill string and said drill bit, restricting the flow path through said plurality of nozzles so that a substantial portion of the drilling fluid will flow through only one of said nozzles, orienting said drill string with said one nozzle in the desired direction for deflection of a borehole from said well bore, lowering said drill bit into contact with said well bore bottom, applying a predeterminable weight to said drill bit, pumping said drilling fluid under pressure through at least said one nozzle to erode said well bore bottom in the direction of orientation of said one nozzle, and maintaining a predetermined rate of circulation through said one nozzle while at the same time reciprocating said drill string without rotation thereof to successively increase the weight on said bit up to a predetermined value and decrease it therefrom.

6. In the method of drilling a well bore with jet drilling apparatus that comprises a drill string including drill pipe, drill collars, and a drill bit secured to the lower end of said drill string, said drill bit including a plurality of cutter members, a plurality of fluid nozzles for directing fluid flow at the bottom of a well bore intermediate said cutter members, means for circulating drilling fluid through said drill string and means for elevating and

lowering said drill string to apply a predeterminable weight to said drill bit, the method of directionally deviating said well bore which comprises the steps of positioning a relatively flexible section of drill pipe intermediate the lower end of said drill collars in said drill string and said drill bit, restricting the flow path through said plurality of nozzles so that a substantial portion of the drilling fluid will flow through only one of said nozzles, orienting said drill string with said one nozzle on the side of the well bore for the desired direction of deviation of said well bore, lowering said drill bit into contact with said well bore bottom, applying a predeterminable weight to said drill bit, pumping said drilling fluid under pressure through at least said one nozzle to erode said well bore bottom in the direction of orientation of said one nozzle, maintaining a predetermined

rate of circulation through said one nozzle while reciprocating said drill string without rotation thereof and while successively increasing the weight on said bit up to a predetermined value and decreasing it therefrom, and then rotating said drill string to advance the drilling of said well bore after the desired deviation of the well bore has been obtained without withdrawing said drill string and bit from the well bore.

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