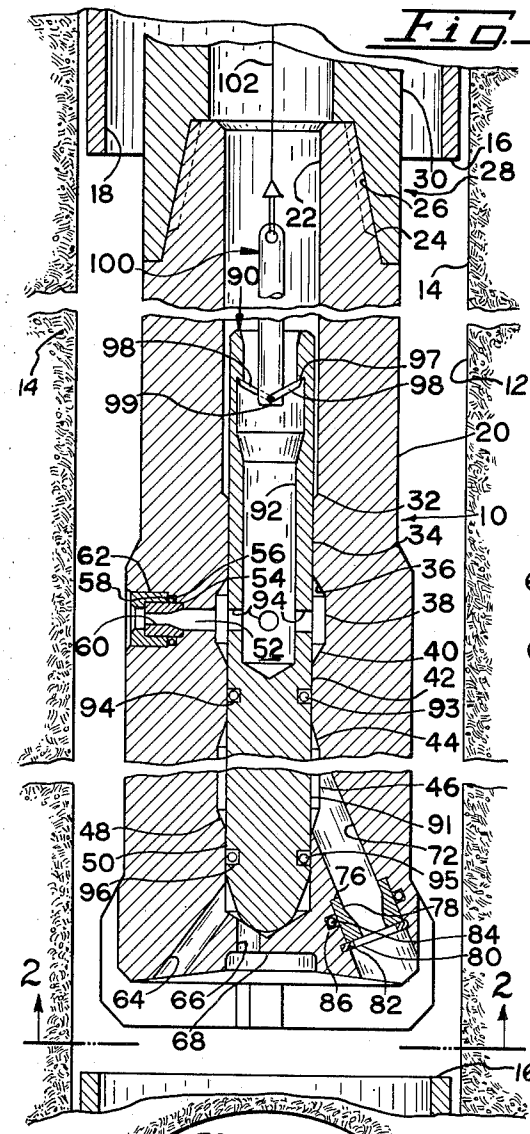
Oct. 12, 1965 B. J. CORDARY 3,211,244

METHOD AND APPARATUS FOR PERFORMING MULTIPLE OPERATIONS IN WELL BORES

Filed Sept. 14, 1962

3 Sheets-Sheet 1

Fig. 1



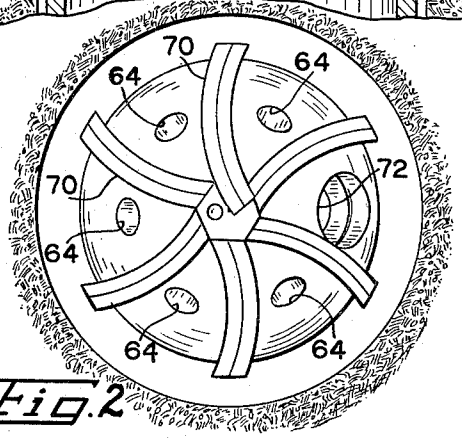
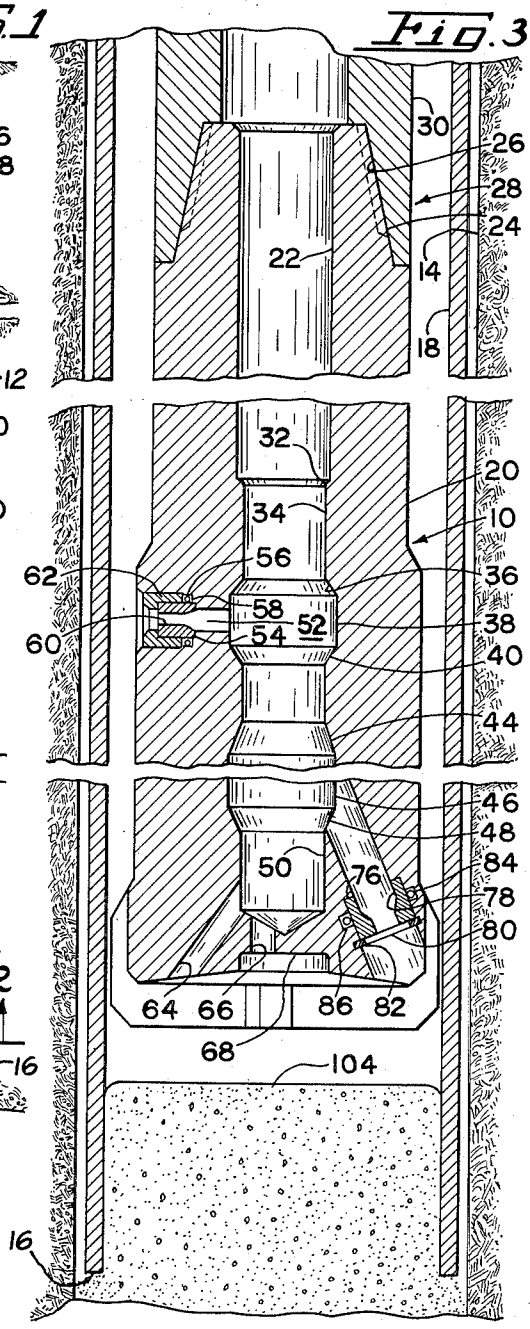


Fig. 2

Fig. 3



INVENTOR.
BRUCE J. CORDARY
BY
Christie, Parker & Hale
ATTORNEYS

Oct. 12, 1965 B. J. CORDARY 3,211,244

METHOD AND APPARATUS FOR PERFORMING MULTIPLE OPERATIONS IN WELL BORES

Filed Sept. 14, 1962

3 Sheets-Sheet 2

Fig. 5

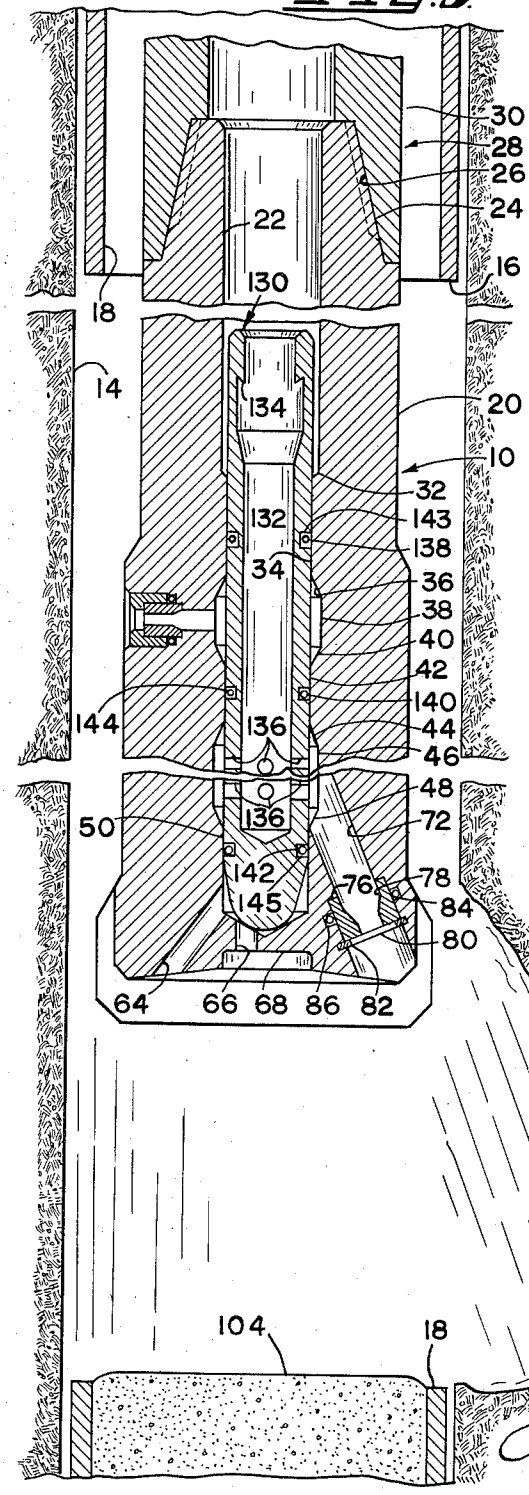
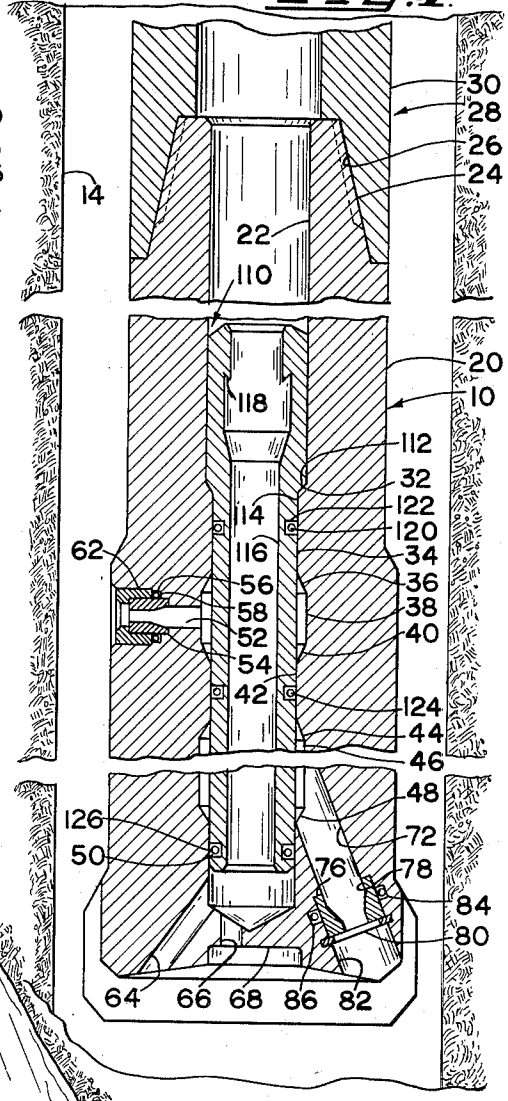


Fig. 4



INVENTOR.
BRUCE J. CORDARY

BY

Christie, Parker & Hale

ATTORNEYS

Oct. 12, 1965 B. J. CORDARY 3,211,244

METHOD AND APPARATUS FOR PERFORMING MULTIPLE OPERATIONS IN WELL BORES

Filed Sept. 14, 1962 3 Sheets-Sheet 3

Fig. 7

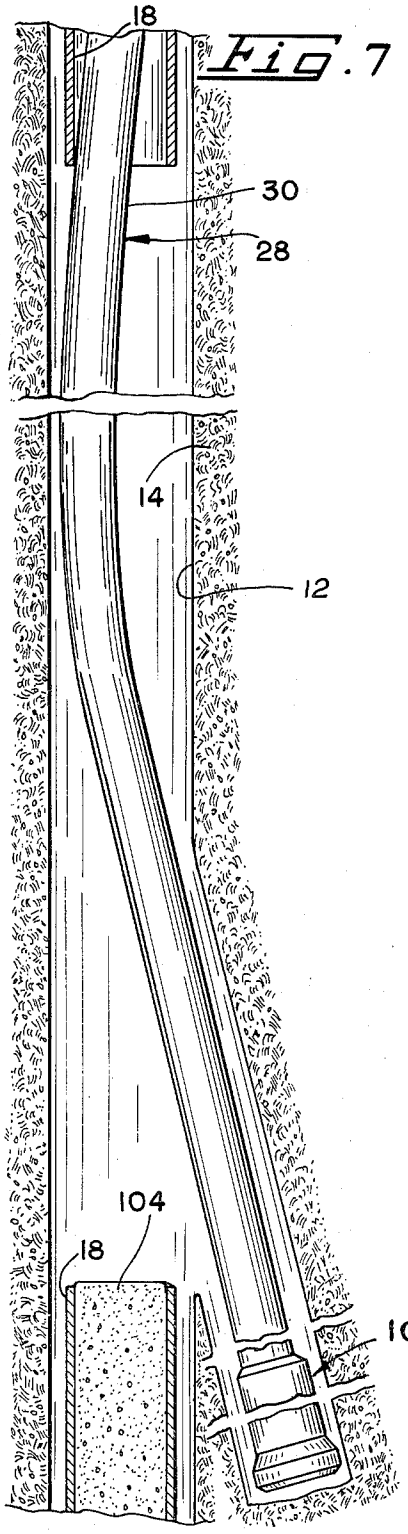
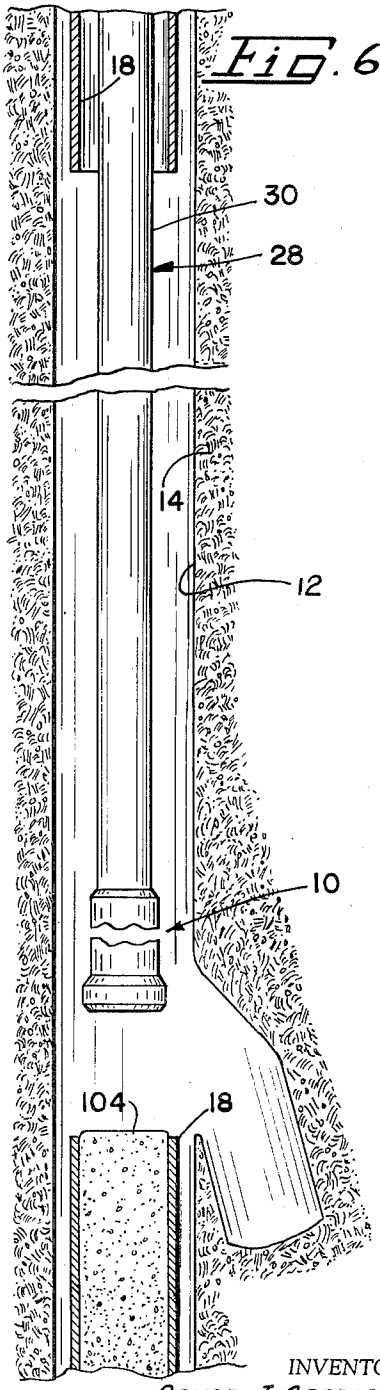


Fig. 6



INVENTOR.
BRUCE J. CORDARY

BY

Christie, Parker & Hale

ATTORNEYS

United States Patent Office 3,211,244
Patented Oct. 12, 1965

3,211,244

METHOD AND APPARATUS FOR PERFORMING MULTIPLE OPERATIONS IN WELL BORES

Bruce J. Cordary, Los Alamitos, Calif., assignor to The Servco Company, Long Beach, Calif., a corporation of Nevada

Filed Sept. 14, 1962, Ser. No. 223,713
3 Claims. (Cl. 175—61)

This invention relates to apparatus and methods for changing the direction of holes drilled in the ground.

While in ordinary drilling operations, a hole, such as an oil well, is drilled straight and vertically, circumstances sometimes require that the hole depart from vertical or that the direction of the hole be otherwise changed. For example, a producing formation may underlie a body of water in a position such that it is more economical to drill an angled well or "slant hole" from the shore to the formation. Occasionally errors in the orientation of the hole require correction by a change in direction. In still other instances, accidents, such as twisting off portions of the drill string in the well make it necessary that the well be plugged back and sidetracked, or improved production rates make advantageous drilling of an angled hole to intersect the maximum possible length of the producing formation.

Prior systems for changing the direction of a well include the setting of a whipstock or its equivalent and drilling of a pilot hole with a small diameter rock bit in the new direction. Thereafter, the drill string is withdrawn from the well and a conventional bit is placed on the drill string, which is then again lowered into the well. Another technique for changing the direction of a hole is to utilize a so-called "one-eyed" bit consisting of an aperture from which a fluid is ejected at high pressure to form by jetting action a pilot hole angled in accordance with the orientation of the tool and its aperture. These prior techniques have the disadvantage of requiring one or more round trips i.e. withdrawal from the well and return to the well of the entire length of drill string, to replace the pilot hole bit with a conventional bit in order to resume normal drilling. Round trips are time consuming and expensive, particularly in deep wells.

This invention provides drilling apparatus and methods for performing a combination of steps in the hole without requiring round trips to change from one type of bit to another. By the present invention, a directional hole is formed and drilling is continued with the same bit without need for round trips to make bit changes. Furthermore, in accordance with a preferred form of the invention, other steps may also be performed within the hole as required and without round trips.

In terms of method, the invention changes the direction of an elongated hole drilled in the earth with a hollow drill string and an elongated drilling tool on the lower end of the string. The drilling tool includes a longitudinal bore opening into the hollow drill string. An orienting bore opens into the longitudinal bore through the lower portion of the tool at an angle to the longitudinal axis of the tool. At least one circulating bore opens into the longitudinal bore through the bottom of the tool. The method includes the steps of disposing the drill string and tool in the hole and pumping a circulating fluid down through the drill string into the longitudinal bore of the tool. Flow of fluid through the circulating bore is restricted, and the orienting bore is opened so that fluid is jetted against the side of the hole to form a cavity extending at an angle to the hole. The drilling tool is then disposed in the cavity, the circulating bore is opened and fluid is jetted from it as drilling extends the

length of the cavity in a direction substantially collinear with the longitudinal axis of the tool. Preferably, after the tool is disposed in the cavity, the orienting bore is closed to increase the effectiveness of the jetting action through the circulating bore.

Where reworking of a well cased with tubular steel conduit requires drilling of a slant hole, a conventional milling tool is used to cut away the casing in the vicinity of the formation of which the well direction is to be changed. Under these conditions, the drilling tool includes a washing bore extending laterally from the longitudinal bore through the side of the tool. A method embodiment according to the invention includes the added step of jetting fluid from the washing bore against the exposed portion of the formation to wash it clean of mud cake, milled pieces of casing and the like. Cement is then pumped into the well to form a cement plug extending above at least the lower portion of the milled out part of the casing. After the cement is set, it is partially drilled out with the tool to the level where the deviation of the well is to begin. Thereafter, fluid is jetted from the orienting bore to form the cavity at an angle to the axis of the well. The tool is then disposed in the cavity, the circulating bore is opened, and the length of the cavity is extended to the required depth or until wear of the bit makes it necessary to change the drilling bit on the lower end of the tool.

In terms of apparatus, the drilling tool includes an elongated body having a longitudinal bore opening through one end. Drilling means are mounted on the other end of the body. An orienting bore opens at one end into the longitudinal bore and passes through the drilling end of the body at an angle to the longitudinal axis of the body. A circulating bore opens at one end into the longitudinal bore and passes through the drilling end of the drilling tool. Means are provided for opening the orienting bore and restricting flow through the circulating bore, and means are also provided for restricting flow through the orienting bore and opening the circulating bore.

A presently preferred embodiment of the tool of the invention includes a washing bore opening at one end into the longitudinal bore and passing through the side of the tool. Means are provided for opening and closing the washing bore. The various bores in the tool are opened and closed by elongated selector plugs which are dropped down through the drill string into the drilling tool. The selector plugs are removed as required by a lifting tool lowered on the end of a wire line.

These and other aspects of the invention will be more fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is a longitudinal sectional view of the drilling tool disposed in a well and adapted to wash the part of a formation exposed through a milled out section of casing;

FIG. 2 is a view taken on line 2—2 of FIG. 1;

FIG. 3 is a longitudinal sectional view of the drilling tool without any selector plug in place;

FIG. 4 is a longitudinal sectional view of the drilling tool adapted for conventional drilling;

FIG. 5 is a longitudinal sectional view of the drilling tool adapted for circulation of fluid through the orienting bore;

FIG. 6 is a schematic view showing the beginning of a cavity inclined to the longitudinal axis of the well; and

FIG. 7 is a schematic view showing the tool in the cavity in a position to extend the length of the well in a new direction.

With particular reference to FIG. 1, an elongated drilling tool 10 is disposed in a well 12 adjacent a portion of a formation 14 exposed through a milled out portion 16

of a casing 18 set in the well. The milling out of the casing is done by conventional apparatus and techniques which form no part of this invention, and therefore is not described in detail.

The drilling tool includes an elongated vertical body 20 having a longitudinal cylindrical bore 22 opening through the upper end of the body. External threads 24 on the upper end of the body engage internal threads 26 on the lower end of a drill string 28 made up of sections of drill pipe 30. The upper end of the drill string (not shown) is supported in the conventional manner by a rotary drilling rig (not shown) so that drilling tool 10 may be rotated by rotation of the drill pipe.

The longitudinal bore in the drilling tool is tapered inwardly at 32 to form a cylindrical reduced diameter bore section 34 of slightly smaller diameter than the main portion of the longitudinal bore. Reduced diameter section 34 tapers outwardly at 36 to an enlarged section 38 of greater diameter than the major portion of the bore. An inwardly tapering portion 40 of the longitudinal bore merges into another reduced diameter section 42, which is of the same diameter as reduced section 34. The lower end of section 42 tapers outwardly at 44 and merges with another enlarged section 46, the lower end of which tapers inwardly at 48 to merge with a reduced diameter section 50 of the same diameter as reduced diameter sections 34 and 42.

A washing assembly includes a horizontal washing bore 52, opening at its inner end into the enlarged section 38 and extending outwardly through the side of the tool. The outer end of the washing bore is stepped to form a first annular shoulder 54 and a second annular shoulder 56 on which is disposed on O-ring gasket 58. A washing jet nozzle 60 is held against shoulder 54 by an annular retaining nut 62 threaded into the outer end of the washing bore and sealing at its inner end against gasket 58. Although not shown, the drilling tool includes two other washing assemblies identical with the one shown in FIG. 1 and spaced at equal intervals around the circumference of the tool.

A plurality of inclined circulating bores 64, peripherally spaced in the lower end of the tool, as particularly shown in FIG. 2, provide flow communication between the lower end of longitudinal bore 22 and the outside of the tool. A vertical circulating bore 66 opens at its upper end into the lower end of longitudinal bore 22 and at its lower end into a circular recess 68 formed in the center of the drilling end of the tool. A plurality of cutting blades 70 are mounted on the bottom of the bit to provide a drag-type bit. Although the cutting blades shown are of the drag-type, it will be understood that other suitable cutting elements, such as roller cones, may also be used within the scope of the invention.

A relatively large diameter orienting bore 72 opens at its upper end into enlarged section 46 of the longitudinal bore, and passes through one side of the drilling tool so that the longitudinal axis of the orienting bore forms an acute angle with the longitudinal bore of the drilling tool. The orienting bore is stepped outwardly to form an annular shoulder 76 to receive a jet nozzle 78, which is held in place by a snap ring 80 fitted into an annular groove 82 in the outer end of the orienting bore. An O-ring 84 in an annular groove 86 in the larger diameter portion of the orienting bore makes a sealing fit around the intermediate portion of jet nozzle 78.

As shown in FIG. 1, a washing selector plug 90 is disposed in the lower end of longitudinal bore 22 in the drilling tool. The plug is an elongated cylindrical body 91 which is rounded at its lower end and has an external diameter to make a close sliding fit inside the reduced diameter sections 34, 42, and 50. A longitudinal bore 92 opens through the upper end of the washing selector plug, and a plurality of horizontal bores 94 near the bottom of bore 92 open into enlarged diameter section 38 of longitudinal bore 22. Accordingly, when a fluid is

pumped from the surface down through the drill string, it successively passes through longitudinal bore 22, longitudinal bore 92 in the washing selector plug, horizontal bores 94 and out through washing bores 52. A high pressure hydraulic jet stream flows from jet nozzles 60 against the exposed surface of the formation to wash away mud cake, milled pieces of casing, soft cement, and other detritus.

An O-ring 93 in a peripheral groove 94 of the washing selector ring makes a seal against section 42 of the longitudinal bore, and an O-ring 95 in a peripheral groove 96 makes a seal against section 50 of the longitudinal bore.

The upper portion of bore 92 in selector plug 90 is stepped to form an upwardly and outwardly inclined shoulder 97 for engagement by the outer ends of fingers 98 secured at their inner ends by a pivot pin 99 to the lower end of a pickup tool 100 suspended from a wire line 102. When the washing operation is completed, the washing selector plug is removed by lowering the pickup tool into the upper end of bore 92 to a point below the shoulder 97. As the pickup tool is raised, fingers 98 extend outwardly due either to the action of gravity or to a spring (not shown) until the outer ends of the fingers bear against the inside of bore 92. When wire line 102 is raised, the fingers of the pickup tool slide upwardly until they engage shoulder 97. The washing selector plug can then be lifted from the interior of the tool to leave the tool as it appears in FIG. 3.

After the formation is washed and the washing plug withdrawn, cement is pumped down the drill string and out the lower end of the tool to form a cement plug 104, as seen in FIG. 3. In pumping cement through the tool, adapted as shown in FIG. 3, the cement flows out through circulating bore 64, orienting bore 72 and washing bore 52. The top of plug 104 is slightly above the milled out section of casing. The drilling tool is raised a short distance above the top of the cement, and held in that position until the cement sets.

After the cement sets, an elongated drilling selector plug 110 is dropped down the drill string and into longitudinal bore 22 of the drilling tool, as shown in FIG. 4. The upper end of the drilling selector plug has an enlarged diameter to make a close fit against the interior of bore 22 above tapered portion 32. The exterior of the drilling selector plug includes an inwardly tapered section 112 which merges at its lower end with a cylindrical section 114 to form a close sliding fit inside reduced diameter sections 34, 42, and 50 of longitudinal bore 22. The tapered portion 112 on the drilling plug seats on the tapered portion 32 in the longitudinal bore and suspends the lower end of the drilling plug above the bottom interior of the longitudinal bore.

The drilling selector plug has a longitudinal bore 116 extending through it. The upper end of the bore is stepped to form an internal lifting shoulder 118 identical in structure and function to that in the washing selector plug so that the drilling selector plug can be lifted by a wire line as previously described. An O-ring 120 in an annular groove 122 around the exterior of the drilling selector plug makes a seal against reduced diameter section 34 of longitudinal bore 22 in the drilling tool. Similarly mounted O-rings 124 and 126 make seals against reduced diameter sections 42 and 50, respectively.

With the drilling selector plug in the position shown in FIG. 4, the washing bores and the orienting bore are sealed. The circulating bores are open so that drilling fluid, pumped down through the drill string and through bore 22 of the tool and longitudinal bore 116 of the drilling selector plug, is ejected as a plurality of high pressure jets from circulating bores 64. The drill string is rotated to drill out the top of the cement plug to the desired depth adjacent the exposed portion of the formation. Thereupon, the drilling selector plug is removed with the wire line tool as described with reference to

FIG. 1, and, if required, the washing plug (FIG. 1) is again dropped into place to wash the sides of the formation. The washing selector plug, if used, is removed with the wire line.

An orienting selector plug **130** is then dropped down the drill string and into the drilling tool to the position shown in FIG. 5. The orienting plug is an elongated cylindrical body having an external diameter which makes a close sliding fit inside the reduced diameter sections **34**, **42**, and **50** of the longitudinal bore **22** in the drilling tool. The lower end of the plug is rounded and rests on the bottom of the longitudinal bore **22**. A longitudinal bore **132** opens through the top of the orienting plug and is stepped at its upper end to form an internal lifting shoulder **134** identical with that in the washing selector plug. A plurality of horizontal bores **136** in the lower end of the orienting plug provide communicating between the interior of the plug and the enlarged diameter section **46** of longitudinal bore **22**. Section **46** is in flow communication with orienting bore **72**. O-rings **138**, **140**, and **142** in exterior peripheral grooves **143**, **144**, and **145**, respectively, in the orienting plug provide seals against reduced diameter sections **34**, **42**, and **50**, respectively, of longitudinal bore **22** of the drilling tool.

With the tool adapted as shown in FIG. 5, pumping of drilling fluid through the drill string ejects a high pressure jet from the orienting bore at an acute angle with respect to the longitudinal axis of the well and of the drilling tool. No flow of fluid occurs through the circulating bores. The high pressure jet from the orienting bore digs or washes out a cavity **150** at an acute angle to the original direction of the well, as schematically shown in FIG. 6. The direction of the cavity is controlled by orienting the drilling tool with conventional directional surveying equipment so that the orienting bore is positioned to form a cavity in the required angle. Deflection of a hole by jetting is known to those skilled in the art of drilling. After the drilling tool is oriented, all practical weight is placed upon the bit so that the inherent flexibility of the drill string produces a deflection in the direction of the cavity that is created by the high pressure jet. This causes the bit to be forced into the cavity, as is schematically shown in FIG. 7. Jetting is continued until the cavity extends a suitable distance in the desired direction. Thereafter, the orienting selector plug is withdrawn by the wire line pickup tool, and the drilling selector plug **110** is dropped into the position shown in FIG. 4. Drilling fluid is circulated out of the bottom of the drilling tool, which is rotated by the drill string to extend the well in the direction of cavity **150**. Drilling proceeds as far as desired, or until it is necessary to withdraw the bit for replacement or dressing.

It will be apparent from the foregoing description that the apparatus and method according to the present invention enable the performance within a hole of a combination of steps which required by former techniques a number of round trips. As a consequence considerable savings in the expense of well drilling become possible.

I claim:

1. A method for changing the direction of an elongated hole drilled in an earth formation with a hollow drill string with an elongated drilling tool on the lower end of the drill string, the tool including a longitudinal bore opening into the hollow drill string, a lateral washing bore opening from the longitudinal bore out through the side of the tool, an orienting bore opening from the longitudinal bore through the lower portion of the tool at an angle to the longitudinal axis of the tool, and at least one circulating bore opening from longitudinal bore through the bottom of the tool, the method comprising the steps of:

(a) Disposing the drill string and tool in the hole;

(b) circulating fluid down the drill string and into the longitudinal bore of the tool;

(c) inserting a first closure means into the drilling tool to restrict flow of fluid through the orienting and circulating bores;

(d) jetting fluid from the washing bore against the side of the hole to wash the formation;

(e) removing the first closure means and then pumping cement slurry down the drill string and out at least the circulating bore to place a cement plug in the hole;

(f) inserting a second closure means into the drilling tool to restrict flow of fluid through the washing bore and the circulating bore while leaving open the orienting bore;

(g) jetting fluid from the orienting bore against the side of the hole to form a cavity at an acute angle to the hole;

(h) forcing the drilling tool into the cavity;

(i) removing the second encloure means and inserting a third closure means into the drilling tool to restrict flow of fluid through the washing bore and the orienting bore while leaving open the circulating bore; and

(j) jetting fluid out of the circulating bore as drilling extends the length of the cavity.

2. A method for changing the direction of an elongated hole drilled in an earth formation with a hollow drill string with an elongated drilling tool on the lower end of the drill string, the tool including a longitudinal bore opening into the hollow drill string, a lateral washing bore opening from the longitudinal bore out through the side of the tool, an orienting bore opening from the longitudinal bore through the lower portion of the tool at an angle to the longitudinal axis of the tool, and at least one circulating bore opening from longitudinal bore through the bottom of the tool, the method comprising the steps of:

(a) disposing the drill string and tool in the hole;

(b) circulating fluid down the drill string and into the longitudinal bore of the tool;

(c) inserting a first closure means into the drilling tool to restrict flow of fluid through the orienting and circulating bores;

(d) jetting fluid from the washing bore against the side of the hole to wash the formation;

(e) removing the first closure means;

(f) pumping cement slurry down the drill string and out at least the circulating bore to place a cement plug in the hole in the vicinity of the washed formation;

(g) raising the drilling tool above the cement while it sets to a solid plug;

(h) drilling away the top portion of the set cement plug with the drilling tool;

(i) inserting a second closure means into the drilling tool to restrict flow of fluid through the washing bore and the circulating bore while leaving open the orienting bore;

(j) jetting fluid from the orienting bore against the side of the hole to form a cavity at an acute angle to the hole;

(k) forcing the drilling tool into the cavity;

(l) removing the second closure means and inserting a third closure means into the drilling tool to restrict flow of fluid through the washing bore and the orienting bore while leaving open the circulating bore; and

(m) jetting fluid out of the circulating bore as drilling extends the length of the cavity.

3. A drilling tool comprising:

(a) a vertical elongated body having a longitudinal bore of a first cross-sectional area opening out of the upper end of the body,

(1) the longitudinal bore being adapted to accommodate individually one of three selector plugs at a time and having first and second spaced sections of enlarged cross-sectional area;

(b) drilling means mounted on the bottom end of the body;

(c) an orienting bore opening at one end into the said first enlarged section and extending through the drilling end of tthe body at an acute angle to the longitudinal axis of the body;

(d) a washing bore opening at one end into the said second enlarged section and extending through the body transversely to the longitudinal axis;

(e) a circulating bore opening at one end out of the drilling end of the body and at its other end into the longitudinal bore at a point spaced from the said first and second enlarged sections;

(f) a washing selector plug adapted for slidable insertion within the first cross-sectional area of the longitudinal bore and to seal the first enlarged section and circulating bore from the second enlarged section and having a first opening into the upper portion of the longitudinal bore, and a second opening coinciding with said second section, the first and second openings being in flow communication within the plug;

(g) an orienting selector plug adapted for slidable insertion within the first cross-sectional area of the longitdinal bore and to seal the second enlarged section and circulating bore from the first enlarged section and having a first opening into the upper portion of the longitudinal bore and a second opening

coinciding with said first section, the first and second openings being in flow communication within the plug; and

(h) a circulating selector plug adapted for slidable insertion within the first cross-sectional area of the longitudinal bore and to seal the first and second enlarged sections from the circulating bore and having a first opening into the upper portion of the longitudinal bore and a second opening coinciding with the circulating bore opening, the first and second openings being in flow communication within the plug;

(i) each of said selector plugs including means to enable removal of said plugs from a point remote from the drilling tool.

References Cited by the Examiner

UNITED STATES PATENTS

2,167,194	7/39	Anderson	175—61 X
2,324,102	7/43	Miller	175—231
2,873,092	2/59	Dwyer	175—61
2,903,239	9/59	Standridge	175—321

CHARLES E. O'CONNELL, *Primary Examiner.*

BENJAMIN BENDETT, *Examiner.*