United States Patent

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[54] **METHOD AND APPARATUS FOR DIRECTIONAL DRILLING**
9 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **175/4.5,** 175/4.51, 175/61
[51] **Int. Cl.** **E21b 7/04**
[50] **Field of Search** 175/2, 3.5, 4.5, 4.51, 4.54, 61

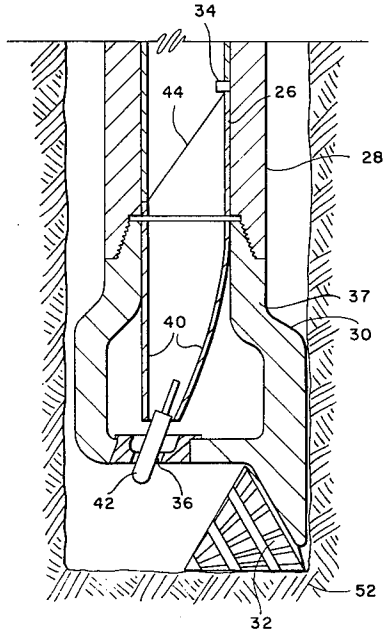
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ABSTRACT: Method and apparatus for directional drilling using explosive devices. The drill bit used for directional drilling has a bottom opening which is orientated on the side of the wellbore in the radial direction to which the borehole is to be deflected. An explosive device is carried by the drilling fluid out the bottom opening whereupon it explodes upon contacting the formation. When drilling commences, the drill bit will follow the path of least resistance, that being the area fragmented by the explosive device.



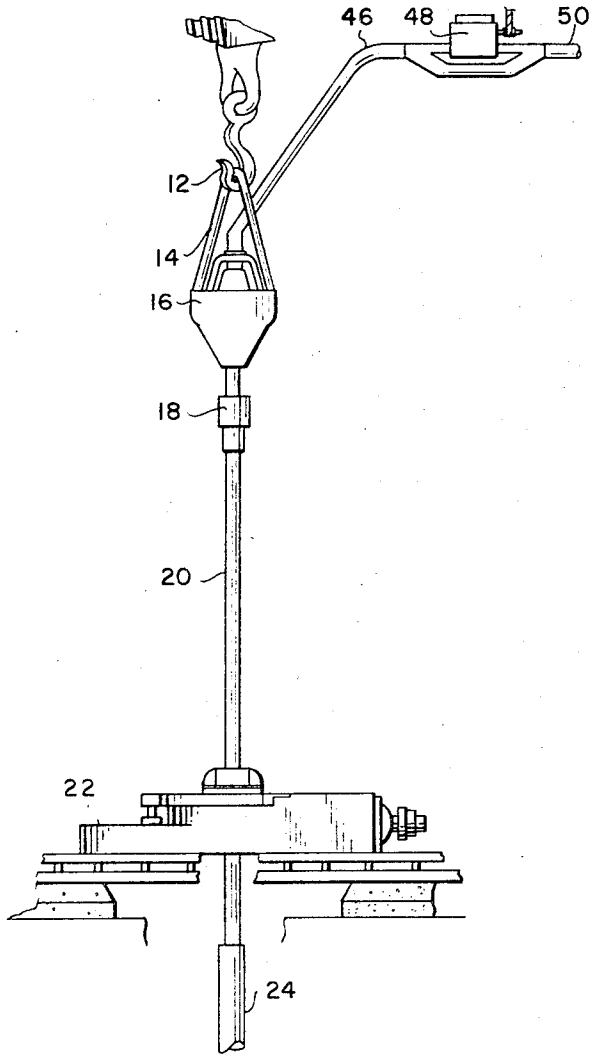


FIG. 1

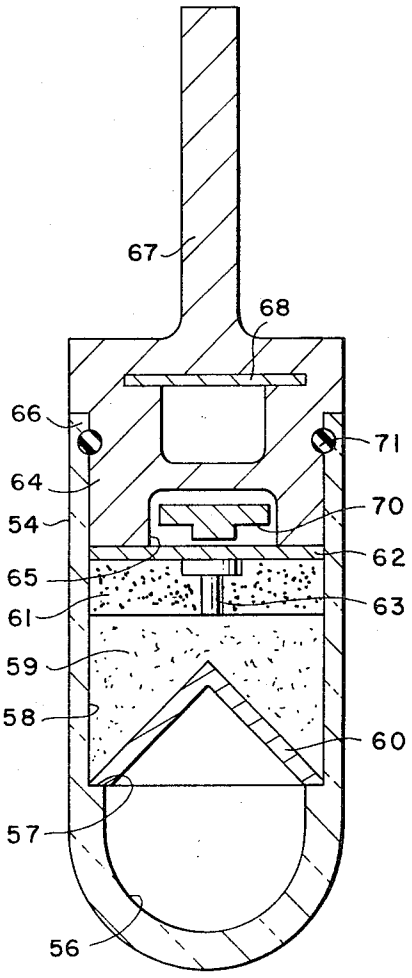


FIG. 3

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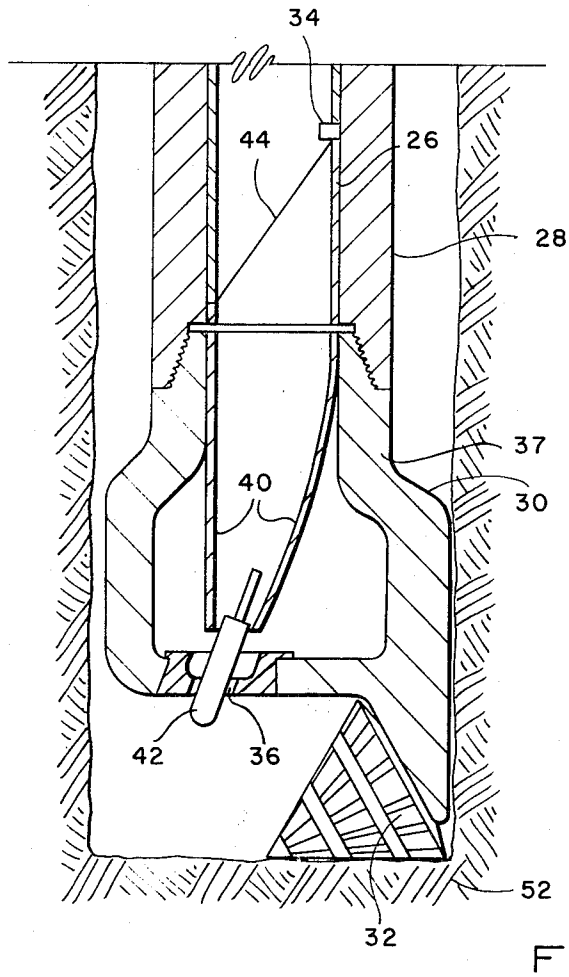


FIG. 2

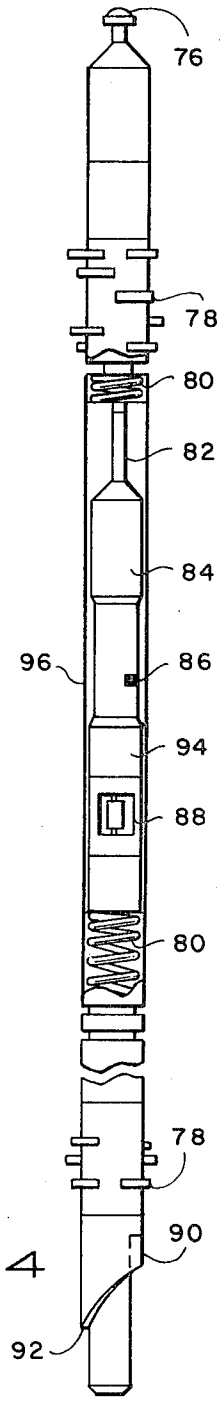


FIG. 4

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METHOD AND APPARATUS FOR DIRECTIONAL DRILLING

BACKGROUND OF THE INVENTION

This invention relates to a new and improved method and apparatus for explosive assisted directional drilling, and more particularly, to the use of an explosive device which is moved through the eye of a drill bit oriented to the side of the borehole toward which the is to be deviated. Upon impact of the explosive device with the borehole bottom, the formation is fragmented and a rotating bit will tend to deflect the borehole toward the fragmented side.

There are presently several methods of deflecting a borehole. The original method and one still being used is the whipstock. A whipstock is basically a shoe for deviating the drill bit from the direction the bit was traveling to one at an angle to the original direction. Generally, the whipstock is attached to the last joint of drill pipe and provides a long deflecting surface which forces the drill bit to deviate from its original path, along the angle provided by the whipstock member. The upper portion of the whipstock encircles the drill pipe and the remainder is a long wedge-shaped member with the wide portion of the wedge located at the bottom of the borehole. The drill pipe with bit attached thereto extends through the encircling portion of the whipstock and is deviated toward the side of the hole dictated by the wedge portion of the whipstock. The wedge portion of the whipstock is oriented by well-known survey instruments to provide the chosen direction for deflection.

Another method of wellbore deviation is by the use of a big eye jet bit. This bit utilizes a large jet nozzle through which large volumes of fluid exit the drill bit. The nozzle is oriented to one side of the wellbore and as drilling fluid exits the large jet nozzle, it impinges and erodes away the bottom of the borehole. After the borehole has been eroded sufficiently to create a hole on one side of the borehole, drilling is commenced and the drill bit will follow the eroded path created by the impinging drilling fluid exiting the large jet nozzle. The big eye jet bit method of directional drilling is limited to the softer earth formations, because of the slow erosion rate in harder formations. No special downhole equipment, such as used with the whipstock method is necessary. The wellbore can be surveyed, the bit reoriented, and further deflection attempted without having to come out of the hole or reposition other equipment. With the use of a whipstock, it is much more difficult to adjust the angle of inclination of the borehole because of problems related to bypassing the point of original deflection with the whipstock, and the necessity of removing the whipstock from the wellbore.

Knuckle joints have also been used for wellbore deflection. This deflection tool has a ball and socket joint acting as a universal joint. The drill bit which is located below the knuckle joint can be positioned at one side of the wellbore to initiate a deflected borehole. This tool has very erratic directional control and therefore, its primary use is for side tracking obstructions in the wellbore.

Another tool utilized in directional drilling is a spudding bit. This tool is chisel shaped with an opening at the bottom for discharging drilling fluids. A combination of spudding the tool up and down and the jet action of the mud out the bottom of the spudding bit provides a deflected hole 1 to 4 feet deep. This tool is often followed by a whipstock or knuckle joint. This bit is used only in soft formations such as sands and soft to medium shales.

U.S. Pat. No. 3,130,797 issued to Ford L. Johnson, and dated Apr. 28, 1964, describes shaped charge devices which may be moved through a hollow drill stem and projected through a jet opening in a conventional roller or other type bit to effect shattering of formations and thereby facilitate drilling. In this patent, the explosive shaped charge is used as an adjunct to what is otherwise essentially conventional drilling procedure. Applied to rotary drilling by means of a bit driven through a hollow drill stem, the invention of Johnson involves the utilization as required of explosive members which are dropped or propelled through a hollow drill stem and guided into or through one or more passages in the bit, the members being exploded to shatter the formation at the bottom of the borehole. This drilling procedure is especially adaptable to hard and unfractured rock where there is a tendency for the drill to rotate on the surface of the rock with a relatively low rate of rock removal, despite heavy pressure exerted on the bit. If the bit encounters rock which had been fractured, the cutting edges of the bit will enter the openings due to the fracture and more easily produce rock segments of small size for removal to the surface by the circulating mud. The object of using an explosive is to break up the rock so as to cause the bit to function more effectively. It has also been found that the shaped charges permit the pressure exerted by the hydrostatic mud column to be exerted to underlying portions of the formation below the face of the drill bit. This extension of the pressure into the formation effects a pressure equalization as opposed to a holddown pressure of the mud on the borehole bottom. This pressure equalization affords a greater rate of removal of the fractured formation. Experimentation shows that not only does the mud cake form about the borehole wall, but it also forms at the bottom of the borehole being drilled. This mud is continuously being applied to the bottom of the hole so that a positive back pressure is maintained against the formation being drilled at all times. Such positive drilling fluid pressure on the formation at the bottom of the borehole is a direct deterrent to the removal and lifting of cuttings from the borehole because the pressure tends to hold the cuttings down rather than allowing their removal to the surface with the drilling fluid. Therefore, the holes made by shaped charges in the bottom of the formation allow the mud pressure to be communicated into the formation so that a balancing of the pressure occurs across the bottom face of the borehole, thereby neutralizing the holddown pressure of the mud column. This the explosive devices provides for much improved drilling rates, especially in hard formations.

Of the deflection tools described above, only the whipstock has provided to be efficient in the hard formations. Use of whipstocks require substantial additional rig time because of trips to run and retrieve the tool. It is therefore an object of the present invention to provide new and improved method and apparatus for directional drilling using explosive charges.

SUMMARY OF THE INVENTION

With this and other objects in view, the present invention contemplates orienting a jet nozzle to the side of the borehole to which the hole is to be deviated, and once oriented, passing a drilling fluid containing an explosive device through the jet nozzle and into contact with the borehole. Several explosive devices can be passed through the nozzle and into contact with the formation to fracture one side of the wellbore bottom and thereby produce and shape a hole so that the drill bit will deviate toward that fractured area when drilling is commenced. After drilling has commenced and several feet have been drilled, a survey instrument can be run to determine the amount of deviation obtained. If further deviation is necessary, the jet nozzle is again oriented and shaped charges are passed through the nozzle and into contact with the formation. The process is repeated until the proper deviation has been obtained. A complete understanding of this invention may be had by reference to the following detailed description, when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of surface equipment for introducing explosive capsules into a drilling apparatus;

FIG. 2 is a cross section of a drill bit attached to drill pipe showing a shaped charge exiting a jet nozzle;

FIG. 3 is a sectional view illustrating the construction of an explosive capsule; and

FIG. 4 is a partial cross-sectional view of a gyroscopic wellbore survey tool.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1 of the drawings, portions of a conventional drilling apparatus are shown for practicing the invention. There is illustrated at 12 a hook which is connected to the usual traveling block supported by cables and controlled by the draw-works of a derrick (not shown). A bail 14, on the hook, supports the conventional swivel 16 modified only to the extent that its drilling mud entrance opens upwardly and its interior is provided with means for guiding the explosive members as will be shown hereinafter. The swivel is joined at 18 with the usual kelly 20, passing through the rotary cable 22 by which the kelly is driven in supporting the sectional drill stem 24 in conventional fashion. The drill system 24 terminates in the usual drill collar (not shown). Various conventional parts of the assembly are not indicated, but it will be understood that they are provided as in usual drilling practices. The drill stem 24 carries a bit 30 shown in FIGS. 2 and 3 which is illustrated as of the multiple cone type, of which one of the cones is indicated at 32. A jet opening is provided between the cones of the bit at 36, and the hole being drilled is indicated at 52 (FIG. 2). The mud flows to the swivel 16 through the flexible hose 46, with the mud being supplied from the usual high-pressure mud pumps which are not shown. The main flow takes place through a connection 50, but bypass flow to carry the explosive members into the hose 46, swivel 16, and the hollow drill stem takes place through the feeding means or explosive members generally indicated at 48. Such a feeding system is described in greater detail in the aforementioned U.S. Pat. No. 3,130,797.

A typical explosive member which may be used in conjunction with the present invention is shown in section in FIG. 3. In the particular form illustrated, the explosive member comprises an elongated cylindrical housing 54, which has one end enclosed by a rounded portion thereof. The interior of the cylindrical housing is hollow, with the lower end having a first diametered portion 56 which forms a stand off spaced at the lower end of the capsule. A shoulder 57 is formed at the upper end of the first diametered portion. This shoulder supports a liner 60 which in turn maintains the charge in its shaped configuration. The charge is positioned directly above the liner within a second diametered portion 58 of the housing. Positioned directly above the charge in the portion 58 is a primer 61, having a detonator 63 molded therein. A cap 62 is positioned over the primer 61 and is arranged to be detonated upon impact of a hammer and firing pin assembly 70 with the cap.

A capsule end portion or end cap 64 is sized to fit within the second diametered portion 58 in the interior bore of the housing, and it has a cylindrical portion extending downwardly therefrom into contact with the upper end of the charge and primer assembly positioned within such portion 58 of the housing. An O-ring seal 71 is provided between the outer cylindrical surface of the end cap 64 and the interior bore of the housing, to provide a fluidtight seal therebetween. The lower end of the end portion has a hollow cylindrical portion 65, which provides a space for receiving the firing pin and hammer assembly 70, with such assembly being free to move within the hollow portion of the end cap. The end cap has an outwardly extending shoulder which rests upon the upper end 66 of the housing 54. Hydrostatic pressure of the fluid within the system provides a means for holding the end cap within the housing and maintaining its assembly therewith. Extending upwardly from the upper end of the end cap is a tail section 67. The length of the tail section 67 is sufficient to render the overall length of the capsule greater than the internal diameter of the drill stem. The tail section 67 is made of resilient material such as rubber, to facilitate its movement within curved or elbowed sections of piping at the surface of the drilling apparatus. A strength insert 68 of a substantially rigid material, is also provided within the end cap to prevent deformation of the end cap and breaking of the seal to thereby prevent exposure of the interior of the capsule to moisture within the drilling system.

Referring next to FIG. 2, a shank 37 has attached thereto a cone 32, which is in contact with the formation 52. The shank 37 is part of a drill bit 30 which is attached to muleshoe-orienting sub 28. Located inside the drill bit 30 is a guide 40. The guide 40 is used to direct a shaped charge 42 to a large jet opening 36. The guide 40 does not extend to the bottom of the drill bit interior so that drilling fluids flowing into the drill bit 30 will not only exit the large jet opening 36, but also will reach other jet openings not shown herein. The other jet openings are arranged as in a conventional drill bit.

Located above the drill bit 30 in muleshoe-orienting sub 28 is a muleshoe sleeve 26, muleshoe key 34, and muleshoe 44. This muleshoe arrangement mates with orientation equipment such as that shown in FIG. 4. The muleshoe sub is made up so that there is a known correlation with the guide 40 such that when an orientation tool is seated in muleshoe 44, the orientation tool is in a fixed position relative to the jet opening 36.

The apparatus described above can also be used for straight hole explosive drilling. The explosive devices are used to fragment the formation to aid the drill bit teeth to grind up the formation so that it can be carried to the surface by the drilling fluid. For the purpose of directional drilling, it is necessary to orient the drill bit 30 so that the jet opening 36 is positioned at the side of the hole to which the hole is to be deviated. This orientation can be accomplished with several commercially available orientation tools. A typical orientation tool is described in FIG. 4. The guide 40 may aid in such orientation and will be discussed further herein.

Once the drill bit 30 has been properly positioned, drilling fluid is continuously circulated out the large jet opening 36 and the other jet openings, and explosive devices are injected into the drilling fluid stream. The guide 40 directs the explosive device out the large jet opening 36 so that the explosive device will be directed to the bottom of the borehole 52. Upon contact with the bottom of the borehole 52, the explosive device penetrates and fractures the formation. Several explosive charges may be necessary to sufficiently fragment the bottom of the borehole 52 such that upon commencement of rotary drilling, the drill bit will follow the track initiated by the explosive devices. Once substantial footage has been drilled, a surveying instrument such as is shown in FIG. 4 can be run to determine the angle and direction of the deviation. If further corrections are necessary, the drill bit is reoriented, whereupon explosive devices carried by the drilling fluid once again fragments the formation at one side of the bottom of the borehole and thereby creates a new track for the drill bit. These steps can be repeated until the proper deviation is obtained.

Several orientation tools can be utilized, including magnetic and gyroscopic tools. A gyroscopic tool is shown in FIG. 4 and has an indexing cam 92 and key slot 90 which engages muleshoe 44 and muleshoe key 34. The gyroscopic orientation device 96 usually consists of a gyrocompass 88 and a gyrobattery pack 94 for supplying energy for operation of the gyrocompass 88. Film 86 is provided to record the position of the gyrocompass 88 and is supplied with energy by a film battery pack 84. The film is activated by a timer 82 which usually provides sufficient time for the gyroscopic device to be lowered into the borehole. Additionally, the instruments are mounted between shock absorbers 80 and the tool is centered in the wellbore by centralizers 78. The orientation tool 96 can be retrieved from the wellbore by fishing neck 76. If surface recording through the use of conductor cable is used, the tool 96 would not have to be retrieved each time a survey was taken.

Alternatively, a magnetic orientation device can be used, and requires nonmagnetic drill collars. This orientation device usually consists of a compass-angle unit, film to record indications of the compass-angle unit, a power supply to activate the

film, and a time device for initiating filmed recordings. The compass-angle unit will measure the angle and direction of the borehole and the position of the deflecting tool, which in this case is the drill bit itself. Since both the gyroscopic and magnetic orientation tools can determine angle and direction of the hole and the direction of the deflection tool, any orientation device commercially available could be used with the apparatus disclosed herein.

Regarding the explosive device shown in FIG. 3 and illustrated as exiting the large jet opening 36 and identified as 42 in FIG. 2, consideration must be given to premature detonation. During the downward descent in the drill stem and in the flow lines, the downwardly extending cylindrical portion of the end cap 64 will prevent the charge and firing device from moving upwardly within the housing of the explosive apparatus, so that the explosive members are not inadvertently moved into contact with the firing pin and hammer assembly during acceleration of the device within the drill stem or upon the greater acceleration due to propulsion through the eye of the drill bit. Thus, premature detonation is prevented by this arrangement of parts. Thereafter, when the explosive member strikes the bottom of the borehole, the firing pin and hammer mechanism 70 is free to continue its downward movement within the hollow cylindrical space 65 whereupon the inertia of its movement ruptures the firing cap 62 and initiates the detonator 63 within the primer 61 to cause detonation of the jet charge.

The standoff distance which is provided by the space between the lower end of the capsule in the jet charge permits the charge to form into a shape which is conductive to maximum penetration of the formation at the bottom of the wellbore. This usual standoff space which is provided has been recognized as desirable in the use of shaped charges. While moving through the flow lines and the drill stem, the capsule which is provided with an elongated tail member is prevented from overturning because of the added length provided by such tail. If the overall length of the apparatus is made greater than that of the diameter of the flow lines in the drill stem, overturning of the device is virtually impossible.

With the use of explosive devices, well bores drilled through hard formations can be deflected without having to use special downhole equipment requiring trips to run and retrieve such equipment. The drill bit employed herein for explosive directional drilling can be utilized for conventional rotary drilling and/or explosive rotary drilling, therefore, rig time for wellbore deflection is held to a minimum.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects, and therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A method of directional drilling in earth formations including the steps of: suspending an earth boring apparatus, including drill pipe having a restricted bottom opening, in a borehole; orienting the bottom opening to the side of the wellbore to which the wellbore is to be directed; passing a drilling fluid through the drill pipe and out the bottom opening; and passing an explosive device with the drilling fluid through the bottom opening for generating an explosion below such opening upon contact of the explosive device with the borehole bottom.

2. The method of claim 1 wherein the earth boring apparatus includes a drill bit having the restricted opening and further including the steps or rotating the drill bit to drill the earth formation and subsequently measuring the inclination of the wellbore to determine if the wellbore direction is satisfactory.

3. The method of claim 2 including repeating the steps of orienting the bottom opening, detonating the explosive device, drilling, and borehole inclination measurement, until the proper well direction is attained.

4. A method for deflecting the direction of a wellbore including the steps of: lowering into the wellbore on drill pipe a drill bit, having a bottom opening; locating the drill bit adjacent the point where the borehole is to be deflected; orienting the bottom opening so that the opening is on the side of the borehole to which the borehole is to be deflected; passing a drilling fluid through the drill pipe and out the bottom opening; and injecting an explosive device into the drilling fluid so that it passes with the fluid out the bottom opening for generating an explosion upon contact of the explosive device with the wellbore.

5. The method of claim 4 including the steps of rotating the drill bit for drilling of the wellbore area contacted by the explosive device, and surveying the wellbore drilled after said drilling to determine the direction and inclination of the borehole.

6. The method of claim 5 including repeating the steps of orienting the bottom opening, generation of an explosion, drilling and surveying the new drilled wellbore until desired wellbore deflection is achieved.

7. In a directional drilling apparatus, the combination of means for orienting the apparatus and directing explosives into earth formations at an oriented positional attitude, which means comprises: drill pipe having a drill bit attached to its lower end, said drill bit having a plurality of bottom openings; means for guiding explosive device into one of said bottom openings; means for directing drilling fluids through all of said openings; and means for receiving an orientating device located within said pipe and having a predetermined positional relationship with one of said openings.

8. The drill bit of claim 7 wherein the guide means is funnel shaped, spaced from the bottom of the drill bit interior and secured to the interior wall of the drill bit.

9. A drill bit for use in explosive directional drilling of earth formations including: a housing having a plurality of bottom openings; cutting members attached to said housing; guide means in said housing arranged so that there is a substantially smooth direct passageway to one of said bottom openings; means for permitting drilling fluid to exit through the remainder of said bottom openings; and means for receiving an orienting device which is located above the guide means.

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