

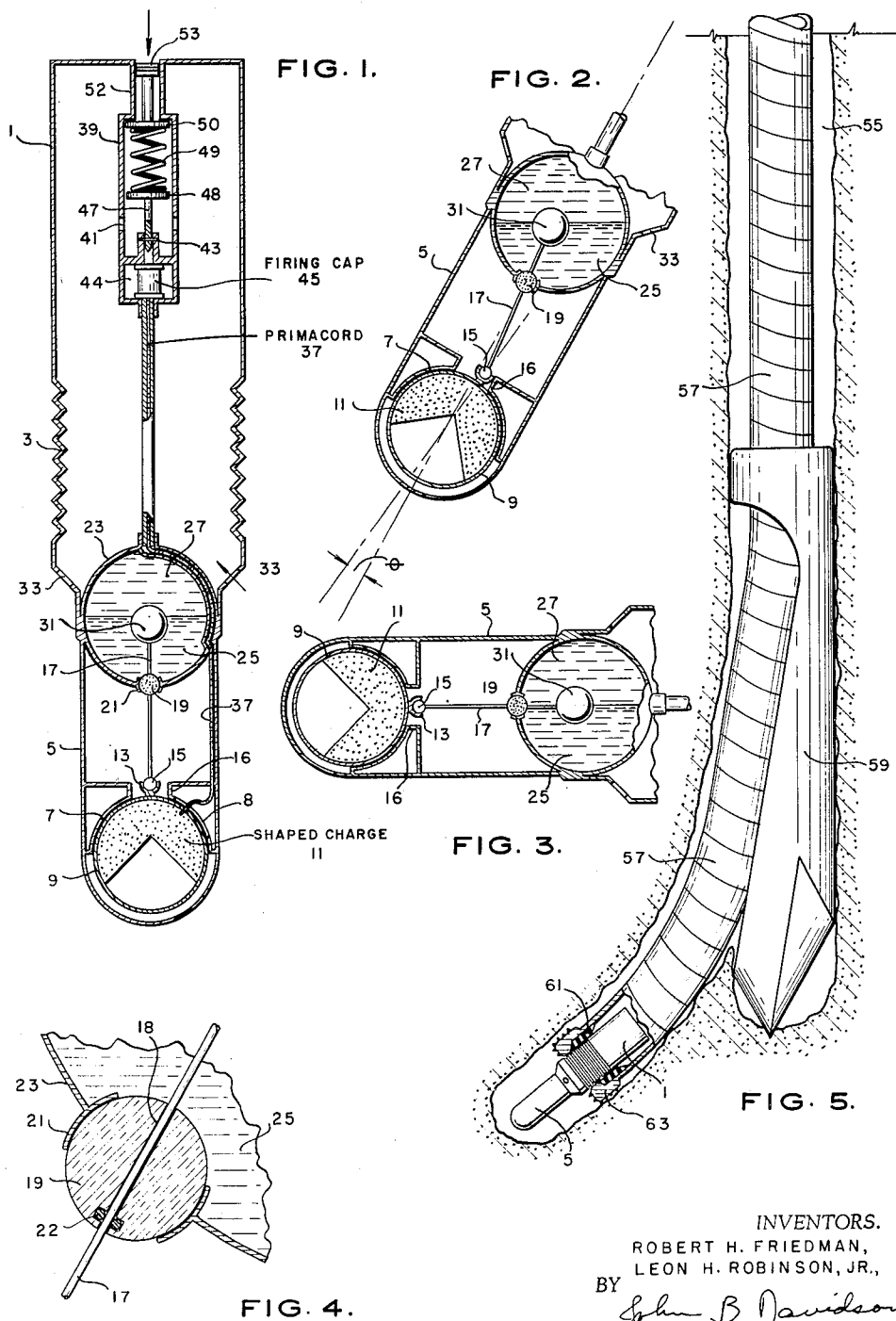
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DRILLING OF OFF-VERTICAL BOREHOLES

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DRILLING OF OFF-VERTICAL BOREHOLES

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This invention relates to off-vertical drilling of boreholes, and more particularly to apparatus for drilling substantially horizontally utilizing directional jet explosive charge means.

In conventional oil and gas wells, the bore-hole presents to oil or gas bearing formations a contact of only 25 to 30 lineal inches, the circumference of the borehole. In order to increase the effective circumference of the borehole, various techniques have been developed, such as the hydraulic fracturing process. The most efficient oil well would be a hole drilled vertically to slightly below the top of the oil producing sand and thereafter drilled horizontally in all directions until the top several inches of the reservoir contain only enough rock to support the overlying strata. The more closely this ideal is approached, the more efficient a single oil well will become.

It has been proposed in the past to approach the ideal by drilling "weep holes" extending more or less horizontally out laterally from a borehole extending from a productive earth formation to the earth's surface. It is extremely expensive to drill such horizontal holes utilizing conventional drilling techniques. Furthermore, in practice the drilling of horizontal holes has been only rarely successful.

In accordance with the teachings of the present invention, holes are drilled horizontally out from a vertically drilled borehole by utilizing shaped jet explosive charge means rotatably supported in one end of an elongated housing adapted to land in the lower end of a drill string. Included within the elongated housing is a leveling apparatus connected to the shaped charge means for urging the shaped charge means to a position whereat the line of fire thereof is substantially horizontal. Also included in the housing may be means for limiting the angle of attack between the longitudinal axis of the housing and the line of fire of the shaped charge means to a predetermined maximum. Connected to the shaped charge means is apparatus for firing the shaped charge means when the housing is landed in the landing means. A succession of such apparatus is landed at the lower end of the drill pipe string to successively deviate the borehole from the vertical. When the borehole is substantially horizontal, a desired number of such apparatuses are successively detonated at the end of the drill string until the hole is extended away a desired distance from the vertical portion of the borehole.

Objects and features of the present invention not apparent from the above discussion will become evident upon consideration of the following detailed description thereof taken in connection with the accompanying drawing, wherein:

FIG. 1 is a sectional elevational view of apparatus in accordance with the invention;

FIGS. 2 and 3 are fragmentary views of a portion of the apparatus of FIG. 1 illustrating the operation of the apparatus of FIG. 1;

FIG. 4 is an enlarged fragmentary view of the ball bearing pivot illustrated in FIG. 1; and

FIG. 5 is a view of the lower end of a borehole illustrating the apparatus of FIG. 1 in position for use in extending a borehole.

With reference now to FIG. 1, there is illustrated an elongated housing comprising an upper elongated section

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1 of large diameter, and a lower elongated section 5 of small diameter. The sections 1 and 5 are interconnected so as to form a unitary structure. The upper housing section 1 contains pleats 3 near the lower end thereof to make it slightly flexible for passage through nonlinear sections of a borehole. While under certain circumstances these pleats are not absolutely necessary from a flexibility viewpoint, they have an additional useful function that will be described below.

Near the lower end of housing section 5 is positioned a ball socket 7 for supporting a ball housing 9. Within the ball housing 9 there is formed a shaped jet explosive charge 11 formed in accordance with prior art techniques, for directing an explosive jet, when detonated, along a line of fire from the lower end of housing section 5. The ball socket 7 contains a slot 8 therein through which extends a line explosive such as Primacord for igniting the shaped charge.

At the upper end of housing section 5 there is positioned a container 23 for liquids, which may be constructed in substantially the form of a ball. Disposed within the container 23 are fluids of different specific gravity such that a stable horizontal interface is set up thereby. The fluids should be substantially immiscible and preferably should be substantially incompressible. However, under certain circumstances, one of the fluids may be a gas provided that it is immiscible with and insoluble in the other fluid. For example, the fluids may be oil and water, oil and mercury, or mercury and a liquid explosive such as nitromethane or nitric acid-nitrobenzene-water (Dithekite).

A ball socket 21 is formed in the container 23 for receiving a ball bearing pivot means 19 therein. As is most perspicuously illustrated in FIG. 4, the ball bearing pivot means has a linear passageway 18 extending there-through, within which is slidably positioned an elongated connecting rod 17. The ball bearing pivot means 19 preferably is formed of sintered glass or metal so as to be slightly permeable, thereby equalizing the pressure thereacross. This has the advantage, as will become apparent below, that the walls of the container 23 may be made of thin metal, and that the seal provided by O-rings 22 does not have to be absolutely tight, thereby making it possible for the connecting rod 17 to slide more freely through the passageway 18. The connecting rod is rigidly connected at its upper end to a float 31 in container 23. The float may be constructed of wood, plastic, or any solid material whose density is less than one liquid but greater than the density of the other liquid, and is adapted to float at all times at the interface of the fluids in container 23. At the other end thereof the connecting rod 17 is connected to ball housing 9 by a ball and socket joint comprising socket 13 and ball 15. Socket 13 is connected to the ball housing 9 opposite to the line of fire of the shaped charge 11.

Further provided in the elongated housing section 5 is means for limiting the angle of attack between the housing and the line of fire of the shaped charge means to a predetermined maximum. By "angle of attack" is meant the angle θ shown in FIG. 2 that results when the ball housing 9 is rotated such that the axis of the cone formed by the shaped charge 11 is off the longitudinal axis of housing section 5. As illustrated, the means for limiting the angle of attack may be a section of the ball socket structure 7, or may be an annular metal member 16 affixed to the socket structure 7. However, other means may be provided for this purpose. The size of the circular central opening in the annular metal member 16 determines the extent to which the ball housing 9 can rotate in the socket formed by ball socket structure 7.

For the purpose of firing the shaped charge 11, there is positioned in the upper elongated housing section 1 a

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detonator housing 39. This detonator housing is affixed to the upper end of housing section 1 by a narrow neck 52 defining a piston chamber for a piston 53. A firing cap 45 is positioned in a chamber 44 at the lower end of detonator housing 39. A firing pin 47 is held in place above the firing cap 45 by a shear pin 43. A compression spring 49 is positioned between a plate 48 at one end of firing pin 47 and a plate 50 affixed to the lower end of piston connecting rod 51 of piston 53. Ports 41 and ports 33 are respectively provided in detonator housing 39 and at the lower end of housing section 1 so that hydraulic pressure from outside the housing section 1 below the pleated section 3 will appear within the detonator housing 39. Thus, when a differential pressure appears across piston 53, plate 50 will be forced downwardly to place compression spring 49 even more in compression until shear pin 43 shears. Shear pin 43 will be driven against firing cap 45 to fire the cap, thus igniting Primacord 37 and shaped charge 11.

The technique for making hole with the apparatus described above will be described with reference to FIGS. 1, 2, 3, and 5. In FIG. 5 there is illustrated a substantially vertical borehole 55 drilled according to prior art techniques. Whipstock 59 is positioned at the lower end of the borehole to deviate from the vertical a flexible drill pipe 57, which is lowered into the well. It will be apparent from an inspection of FIG. 1 that when the apparatus is positioned vertically, the line of fire of shaped charge 11 likewise will be substantially vertical inasmuch as float 31 will not exert a horizontal force component on the ball and socket connection 13, 15 so as to rotate ball housing 9. At the lower end of drill pipe 57 there is provided means for landing the apparatus shown in FIG. 1 to prevent the apparatus from going out of the lower end of the pipe string. This landing means is illustrated in FIG. 5 as an annular rubber sleeve 61 which may contain grooves on the inner surface thereof adapted to mate with the pleats 3 so as to hold the apparatus at the lower end of the drill pipe. The drill pipe may also be provided with a reamer 63 to ream out the hole, if necessary, formed by shaped charge 11, so that the pipe may extend as far thereinto as possible.

The apparatus illustrated in FIG. 1 is inserted into the drill pipe at the upper end thereof and is circulated down the drill pipe in the drilling fluid in the usual manner. Means for injecting the apparatus into the drilling fluid during the normal course of explosive drilling operations is described in U.S. patent application Serial No. 855,899 of L. H. Robinson, Jr., now U.S. Patent No. 3,070,010.

When the apparatus lands in the bottom of the drill pipe, the shaped charge 11, float 31, connecting rod 17, and the associated apparatus will be as illustrated in FIG. 2. The float 31 will remain on the interface between fluids 27 and 23 and will exert a rotative force on ball housing 9 until socket 13 strikes annular metal member 16. The hydraulic pressure in the drill pipe thereupon is quickly increased to actuate the firing mechanism and detonate shaped charge 11. The borehole will be extended a substantial distance. The housing sections 1 and 5 and the other apparatus illustrated in FIG. 1 will be destroyed by the explosion. The remnants of the apparatus and the earth detritus left by the explosive jet are circulated out of the well by the drilling fluid. A gauging charge may then be lowered into the borehole to enlarge the hole formed by the shaped charge 11, following the technique described in U.S. patent application Serial No. 855,899. Thereupon, a succession of apparatuses such as illustrated in FIG. 1, and gauging charges are injected into the pipe string and detonated at the bottom of the pipe string. The borehole formed thereby will become increasingly horizontal in increments determined by the angle θ (see FIG. 2). Eventually, the angle of attack θ again will become zero when the borehole is substantially horizontal so that the apparatus is as illustrated in FIG. 3. It is to be appreciated that after

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the apparatus is as illustrated in FIG. 3, the angle θ will remain substantially zero after successive firings, it being impossible for float 31 to exert a torque on ball housing 9 that will direct the line of fire of shaped charge 11 above the horizontal. The borehole therefore may be extended horizontally as far as desired from vertical borehole 55.

The invention is not to be restricted to the specific structural details or arrangement of parts herein set forth, as various modifications thereof may be effected without departing from the spirit and scope of the invention.

The objects and features of the invention having been completely described, what we wish to claim is:

1. Apparatus for off-vertical drilling at the lower end of a drill pipe string having landing means at said lower end, comprising:

an elongated housing adapted to land in the landing means;

shaped jet explosive charge means rotatably supported in one end of said housing for directing an explosive jet along a line of fire from said one end;

leveling means in said housing connected to said shaped charge means for urging said shaped charge means to a position whereat said line of fire is substantially horizontal; and

means connected to said shaped charge means for firing said shaped charge means when said housing is landed in the landing means.

2. Apparatus for off-vertical drilling at the lower end of a drill pipe string having landing means at said lower end, comprising:

an elongated housing adapted to land in the landing means;

shaped jet explosive charge means rotatably supported in one end of said housing for directing an explosive jet along a line of fire from said one end;

leveling means in said housing connected to said shaped charge means for urging said shaped charge to a position whereat said line of fire is substantially horizontal;

means in said housing for limiting the angle of attack between the longitudinal axis of said housing and the line of fire of said shaped charge means to a predetermined maximum; and

means connected to said shaped charge means for firing said shaped charge means when said housing is landed in the landing means.

3. Apparatus for off-vertical drilling at the lower end of a drill pipe string having landing means at said lower end, comprising:

an elongated housing adapted to land in the landing means;

a ball socket in said elongated housing at one end thereof;

a ball housing in said ball socket;

a shaped charge in said ball housing having a given line of fire relative to said ball housing;

leveling means in said elongated housing connected to said ball housing for urging said ball housing to a position whereat said line of fire of said shaped charge is substantially horizontal; and

means connected to said shaped charge for firing said shaped charge when said elongated housing is landed in the landing means.

4. Apparatus for off-vertical drilling at the lower end of a drill pipe string having landing means at said lower end, comprising:

an elongated housing adapted to land in the landing means;

a ball socket in said elongated housing at one end thereof;

a ball housing in said ball socket;

a shaped charge in said ball housing having a given line of fire relative to said ball housing;

a container for liquids in said elongated housing;

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first and second substantially immiscible, substantially incompressible fluids of different specific gravity in said container such that a stable horizontal interface is set up between the fluids;

a second ball socket in the wall of said container; 5

a ball bearing pivot means in said second ball socket;

a float in said container adapted to float at the interface of said fluids;

a connecting rod slidably connected through said ball bearing pivot means, rigidly connected at one end to said float, and pivotally connected at the other end to said ball housing opposite to the line of fire of said shaped charge; and 10

means connected to said shaped charge for firing said shaped charge when said elongated housing is landed in the landing means. 15

5. Apparatus for off-vertical drilling at the lower end of a drill pipe string having landing means at said lower end, comprising:

an elongated housing adapted to land in the landing means; 20

a ball socket in said elongated housing at one end thereof;

a ball housing in said ball socket;

a shaped charge in said ball housing having a given line of fire relative to said ball housing; 25

a container for liquids in said elongated housing;

first and second substantially immiscible, substantially incompressible fluids of different specific gravity in 30

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said container such that a stable horizontal interface is set up between the fluids;

a second ball socket in the wall of said container;

ball bearing pivot means in said second ball socket;

a float in said container adapted to float at the interface of said fluids;

a connecting rod slidably extending through said ball bearing pivot means, rigidly connected at one end to said float;

a ball and socket joint connecting the other end of said connecting rod to said ball housing opposite to the line of fire of said shaped charge; and

means connected to said shaped charge for firing said shaped charge when said elongated housing is landed in the landing means.

6. The apparatus of claim 5 wherein is further included means in said elongated housing for limiting the angle of attack between the longitudinal axis of said elongated housing and the line of fire of said shaped charge to a predetermined maximum.

7. Apparatus as defined in claim 6 wherein said ball bearing pivot means is constructed of sintered metal.

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