Dec. 25, 1962 L. H. ROBINSON, JR., ET AL 3,070,011

DIRECTIONAL DRILLING WITH EXPLOSIVE CHARGES

Filed July 11, 1960

3 Sheets-Sheet 1

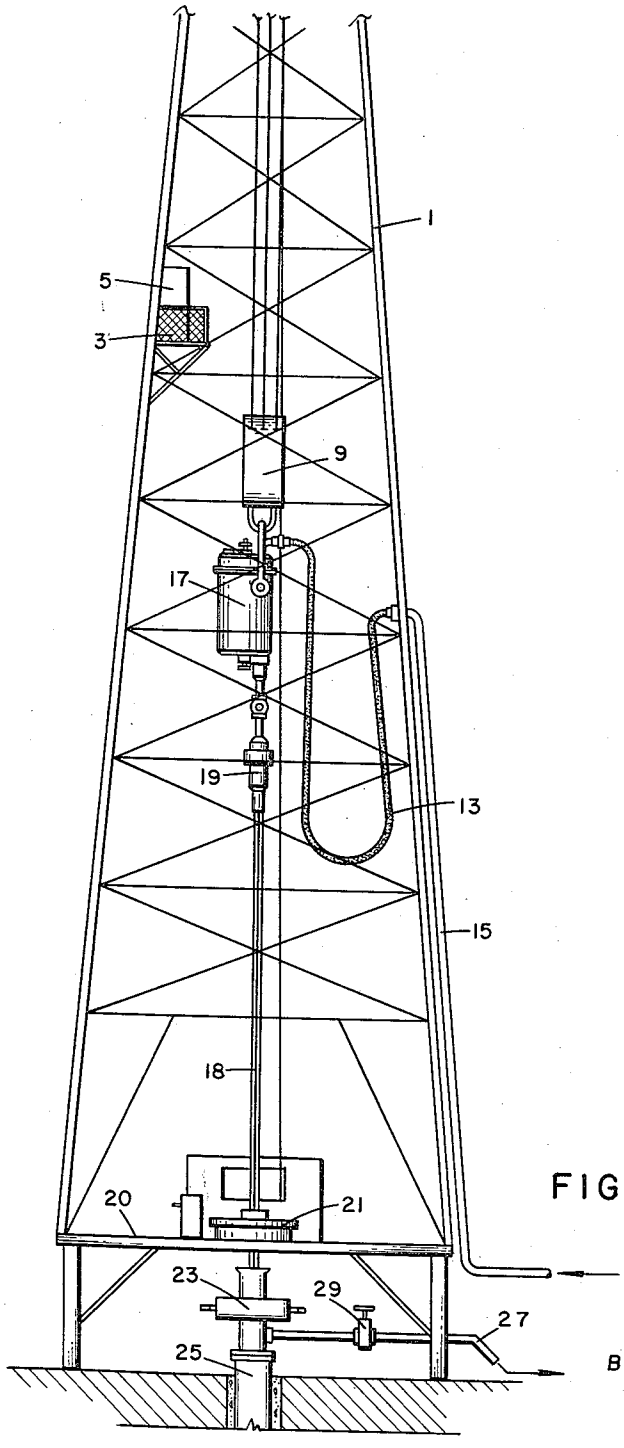



FIG. 1.

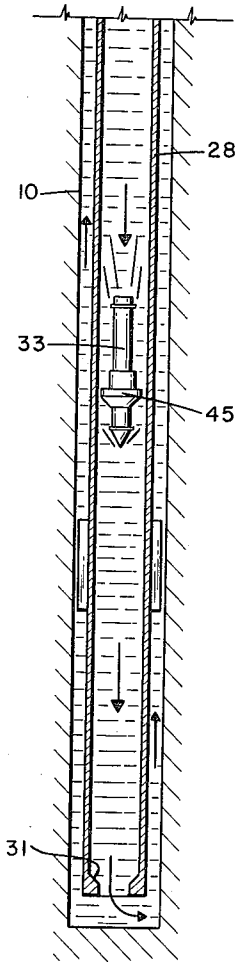



FIG. 2.

INVENTORS.
LEON H. ROBINSON JR.,
ROBERT H. FRIEDMAN,
BY John B. Davidson
ATTORNEY.

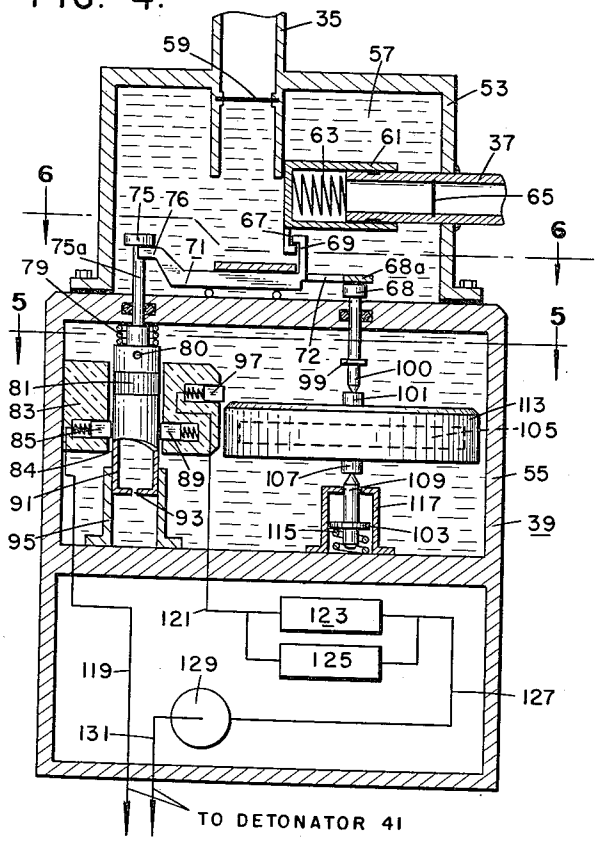
Dec. 25, 1962 L. H. ROBINSON, JR., ET AL 3,070,011

DIRECTIONAL DRILLING WITH EXPLOSIVE CHARGES

Filed July 11, 1960

3 Sheets-Sheet 2

FIG. 4.



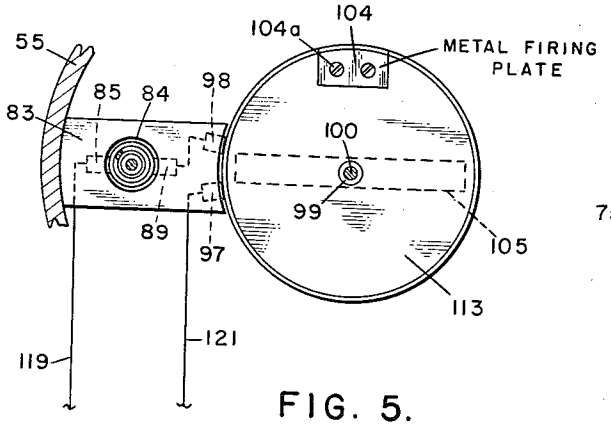




FIG. 5.

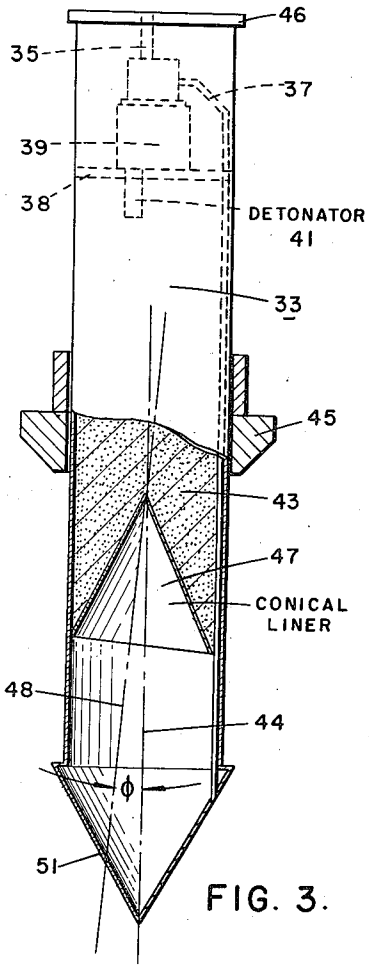



FIG. 3.

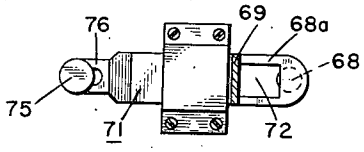



FIG. 6.


*INVENTORS.*
LEON H. ROBINSON JR.,
ROBERT H. FRIEDMAN.,

Dec. 25, 1962 L. H. ROBINSON, JR., ET AL 3,070,011

DIRECTIONAL DRILLING WITH EXPLOSIVE CHARGES

Filed July 11, 1960

3 Sheets-Sheet 3

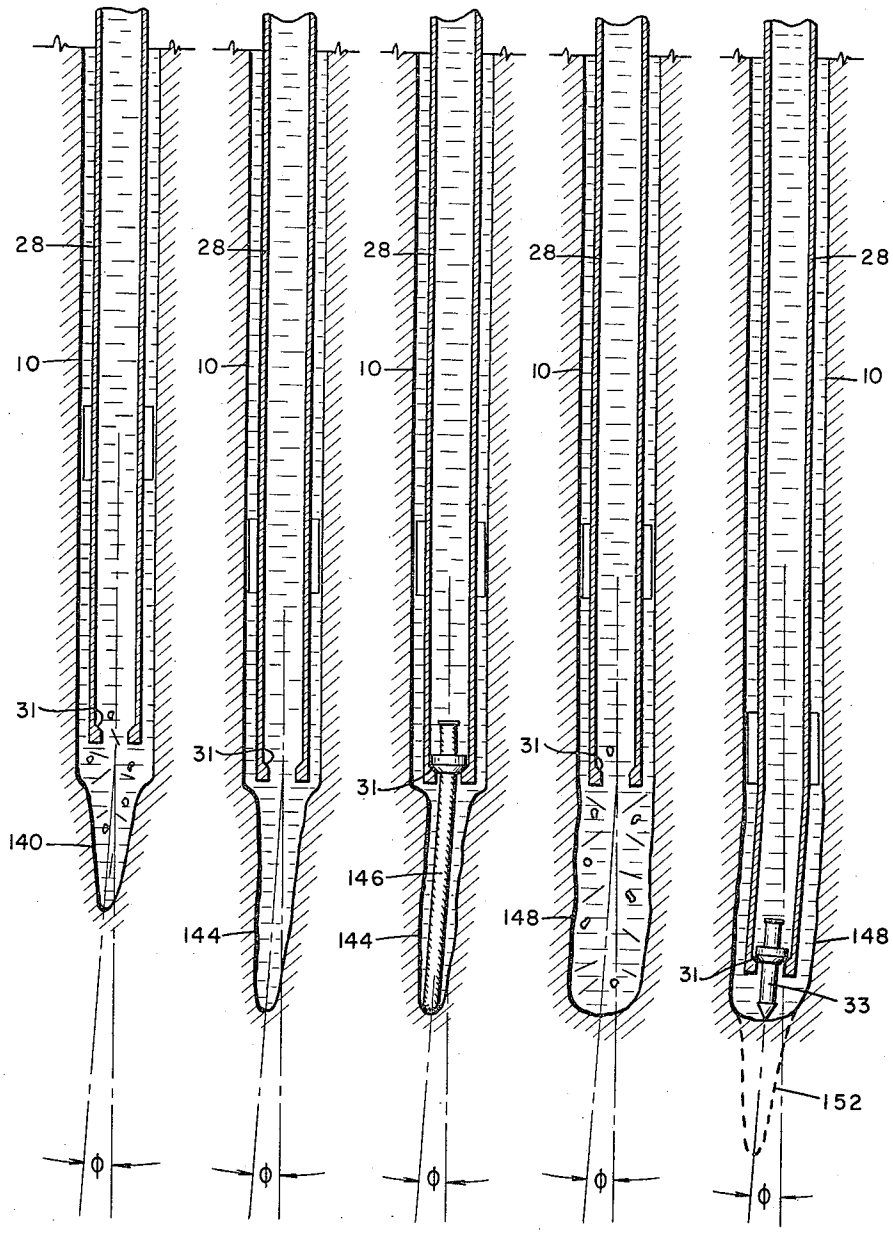



FIG. 7. FIG. 8. FIG. 9 FIG. 10 FIG. 11.

*INVENTORS.*
LEON H. ROBINSON JR.,
ROBERT H. FRIEDMAN,

United States Patent Office

3,070,011

Patented Dec. 25, 1962



# 3,070,011
# DIRECTIONAL DRILLING WITH EXPLOSIVE CHARGES

Leon H. Robinson, Jr., and Robert H. Friedman, Houston, Tex., assignors, by mesne assignments, to Jersey Production Research Company, Tulsa, Okla., a corporation of Delaware

Filed July 11, 1960, Ser. No. 42,089
7 Claims. (Cl. 102—21.6)

This invention relates to directional drilling of boreholes, and more particularly to deviating boreholes, or drilling boreholes in given directions at an angle from the vertical, utilizing a succession of explosive charges including shaped-jet charges.

In connection with the drilling of boreholes in the earth for the purpose of exploiting possible hydrocarbon deposits therein, often it is desirable to drill boreholes at an angle from the vertical and in given directions. This technique may be necessary in order to by-pass sections of drill pipe that have become stuck in the bottom of the borehole, or to more economically penetrate given earth formations as when the earth formations are covered by a body of water.

When directional drilling is necessary, it has been the practice to set a whipstock in a borehole and to utilize the whipstock either to deflect a drill stem in a given direction or to aim a shaped charge in a given direction and at an angle from the vertical. It is manifest that setting whipstock to deflect drilling direction is an expensive procedure that should be avoided if possible.

In U.S. patent application Serial No. 855,681 for "Apparatus for Drilling Boreholes with Explosive Charges," filed on November 27, 1959, now U.S. Patent No. 3,014-423, by Leon H. Robinson, Jr., and Robert H. Friedman, there is described a drilling technique utilizing a succession of explosive charges including shaped-jet charges. The explosive charges are pumped down a drill stem to the bottom of a borehole, are seated by suitable landing apparatus at or near the bottom of the drill stem, and are detonated to deepen and enlarge the borehole. The drilling technique described in this patent application will be found to be very flexible and to almost eliminate the necessity of "round trips" for the purpose of replacing drilling apparatus at the bottom end of the drill stem. The present invention may be advantageously used in connection with the technique described in patent application Serial No. 855,681, now U.S. Patent No. 3,014,423, in order to avoid the necessity of a round trip when it is desired to deflect the borehole from the vertical.

In accordance with the teachings of the present invention, a directional, explosive jet-shaped charge is utilized wherein having an elongated, preferably substantially cylindrical housing, encloses a directional explose jet-shaped charge wherein the conical liner is tilted away from the longitudinal axis of the housing so that, when it is detonated, it will direct an explosive jet in a direction offset from the longitudinal axis of the housing. Manifestly, it is necessary to provide means for orienting the direction of the explosive jet. In accordance with the teachings of the invention, this may be done by including in the firing circuit of the shaped charge a pair of spaced-apart electrical contacts which must be closed in order to detonate the shaped charge. The spaced-apart contacts are bridged by an electrical conductor mounted on a pivoted carrier member to which is affixed a bar magnet. The carrier member is held against rotation and is released by apparatus responsive to the exertion of a predetermined differential pressure across the housing. When the differential pressure is exerted, the carrier is free to rotate and will so rotate in accordance with the force exerted on the bar magnet by the earth's magnetic field. When the bar magnet has aligned itself, the drill pipe and shaped charge housing are rotated until the electrical contacts are bridged by the electrical conductor. At this point the jet-shaped charge will be detonated. In order to change the direction of detonation of the shaped charge it is only necessary to change the position of the electrical conductor with respect to the north pole of the magnet.



The objects and features of the invention will be more completely appreciated upon consideration of the following detailed description thereof taken in connection with the accompanying drawings wherein:

FIG. 1 is a schematic representation of a drilling rig including apparatus suitable for use in accordance with the explosive drilling technique;

FIG. 2 is a schematic representation of the bottom of the borehole containing a drill stem wherein the explosive drilling technique is being practiced;

FIG. 3 is an elevational view, partially in cross-section, of explosive charge drilling apparatus in accordance with the present invention;

FIG. 4 is an illustration, partially in cross-section and partially in schematic form, of the firing mechanism detonated in FIG. 3;

FIG. 5 is a sectional view of a fragmentary portion of the apparatus of FIG. 4 taken along the line 5—5 of FIG. 4;

FIG. 6 is a sectional view taken along section 6—6 of FIG. 4; and

FIGS. 7, 8, 9, 10, and 11 are schematic representations of the bottom portion of a borehole in the earth illustrating the various steps of directional drilling in accordance with the teachings of the present invention.

In FIG. 1 there is shown surface equipment for use in connection with the present invention. The usual drilling rig **1** is provided with an explosive charge loader's platform **3** at a distance above the drilling floor **20** determined by the length of well or drill pipe to be run into the hole to be drilled with the apparatus. An explosive charge housing **5** for storing explosive charges is located on the loader's platform **3**.

The usual traveling block **9** is suspended in the usual manner from a crown block (not shown) by cables. Located between the swivel **19** and block **9** is an explosive charge magazine housing **17**. The function of the charge injector housing is to accommodate a number of explosive charges so that individual explosive charges need not be manually inserted by the loader as the drilling progresses. However, this latter technique may be employed if it is so desired.

Connected to the swivel **19** is a Kelly joint **18** which extends through the rotary table **21** into the surface casing **25**. Drilling fluid is circulated through the magazine housing **17** into the swivel **19** and Kelly joint **18** from the usual stand pipe **15** and hose connection **13**. A mud pump (not shown) supplies pressurized drilling fluid to the stand pipe **15**. Below the drilling floor **20** is located the usual mud return line **27** and blowout preventer **23**. The mud return line **27** may be controlled by a valve **29**. The mud control line is hydraulically coupled to the annular space between the surface casing **25** and the drill pipe in the usual manner.

As is shown most perspicuously in FIG. 2, the drill or well pipe **28** is provided with a landing nipple of landing seat **31** at or near its lower end. The purpose of the landing seat **31** is to receive a collar **45** or seating ring fitted around an exposive charge housing **33** which is pumped down the well through the drill pipe **28**. When the collar **45** lands on the seat **31**, flow of drilling fluid down through the drill pipe and out of the lower end thereof will either be stopped or substantally reduced so that a differential pressure will be built up across the explosive charge. As will be described below, differential

pressure is used for the purpose of firing the explosive charge.

At this point, it is advantageous to briefly describe the explosive drilling technique set forth in detail in the aforementioned patent application Serial No. 855,681, now U.S. Patent No. 3,014,423. This technique makes use of directional explosive jet-shaped charges along with nondirectional gauging exposive charges. The function of the gauging explosive charges is to enlarge the borehole to predetermined gauge after one or more jet charges have been detonated to deepen the borehole. The reason that the gauging charges are necessary is that the hole made by the shaped charges is elongated and tapered. After a shaped-jet charge has been detonated, the drill pipe can be lowered only a short distance. The shaped-jet charges and the gauging charges are injected into the stream of drilling fluid going down the well pipe according to a predetermined sequence. First, a shaped charge is pumped down the well pipe after it seats on the landing seat **31**, the explosive portion of the jet charge is spaced a predetermine distance from the bottom of the borehole. A differential pressure of predetermined magnitude is built up across the shaped charge. Responsive to the differential pressure, the charge is detonated so as to blast a hole in the earth at the bottom of the well bore. This may be done one or more times until the hole is to desired depth. A gauging charge is then landed on the seat **31** so as to extend into the hole produced by the preceding shaped-jet charge or charges. Preferably, the gauging charge is long enough to penetrate substantially the entire length of the hole blasted by the shaped-jet charge. The gauging charge, which may be of a brisant or unbrisant explosive material or a combination thereof, is detonated while tamped with drilling fluid and preferably while under a hydrostatic pressure of at least 1000 p.s.i. Drilling fluid is circulated after each detonation of an explosive charge so as to remove earth fragments and fragments of the explosive charge housing from the bottom of the borehole. Preferably, the explosive charges are injected into the drilling stream so as to be spaced apart substantially 100 to 4000 feet, and the drilling fluid is circulated so the particles therein are traveling at the rate of between 100 and 400 feet per minute so that the successive explosive charges are detonated between 1 and 10 minutes apart.

With reference now to FIG. 3, there is shown a directional exposive jet-shaped charge adapted to deflect a borehole in a predetermined direction. In accordance with the teachings of the present invention, the directional charge includes an elongated housing having a generally pointed, conical head **51**. Fitted about the elongated body portion of the shaped charge housing is a seating ring **45**, the function of which is to seat on the landing seat or nipple **31** so as to prevent the housing from being circulated out the bottom of the drill pipe, and to permit building up of differential hydrostatic pressure across the housing. A flange **46** is provided at or near the upper end of the housing to prevent the seating ring **45** from slipping off of the housing. Explosive charge material **43**, which is preferably brisant, is packed into the middle portion of the housing. A conical liner **47** is provided for the purpose of shaping the exposive jet produced by the explosive charge material **43** in the usual manner. The axis **48** of the conical liner **47** does not coincide with the longitudinal axis **44** of the elongated housing In other words, the conical liner is tilted so that the explosive jet will be directed at an angle $\phi$ from the longitudinal axis of the housing. The explosive charge material **43** is packed between the baffle or partition **38** and the conical liner **47**.

As mentioned above, the exposive charge material is detonated by the exertion of differential pressure across the housing. Preferably, an electrically actuated detonator **41** is used to detonate the shaped charge material. A mechanical firing mechanism, which will be described in detail with reference to FIGS. 4, 5, and 6, electrically energizes the detonator **41** responsive to differential pressure hydrostatically communicated through upper pressure tube **35** and lower pressure tube **37**. Upper pressure tube **35** is in communication with the upper end of the explosive charge housing and lower pressure tube **37** extends from the firing mechanism **39** to the lower end of the housing at the housing head **51**.

With reference now to FIGS. 4, 5, and 6, there is illustrated the details of the firing mechanism **39**. The housing for the firing mechanism comprises two sections **53** and **55** which are bolted or otherwise connected together. The upper pressure tube **35** and the lower pressure tube **37** extend through the walls of the upper housing section **53**. The interior of the upper housing section **53** is filled with a suitable fluid such as water or glycerine. Flexible seals **59** and **65**, which may be of neoprene, are provided within the presseure tubes **35** and **37**, respectively, so that hydrostatic pressure may be communicated to the fluid **57** within the upper housing section **53** and yet physically isolate the interior of the upper housing section **53**. The reason for such physical isolation is to prevent entry of dirt and other extraneous material which could impair the operation of the apparatus to be described below. A release collar **61** is in sliding fit over the end of lower pressure tube **37** that extends into the upper housing section **53**. A spring **63** normally biases release collar **61** away from the lower pressure tube **37** so that it engages the end of upper pressure tube **35**. A flange **67** extends downwardly from the end of the release collar **61** for purposes which will become apparent below.

Electrical energy for energizing detonator **41** is derived from a mercury cell **129**. The electrical circuit which provides a surge current sufficient to activate the detonator includes a resistor **123** and a capacitor **125** connected to the mercury cell by electrical lead **127**, and a pair of spaced-apart electrical contacts **97** and **98**. Contact **97** is connected to resistor **123** and capacitor **125** by electrical lead **121**. The circuit further includes electrodes **85** and **89** spaced apart on either side of a bore **84** through contact housing or carrier **83**, contacts **89** and **98** being connected together, an electrical conductor **119** connecting the electrode **85** to detonator **41**, and electrical conductor **131** connecting detonator **41** to mercury cell **129**. The contact housing **83** is affixed to lower housing section **55**.

The spaced-apart electrical contacts **97** and **98** are adapted to be bridged by a metal firing plate or conductor **104** which is mounted on a substantially cylindrical magnet carrier member **113**. Magnet carrier member **113** is pivotally supported by pivot bearings **100** and **109** which engage bearing seats **101** and **107**, respectively. Pivot bearing **109** is housed in a housing **117** and is urged upwardly by a coil spring **115** engaging a flange **103** affixed to the pivot bearing **109**. The spring **115** is sufficiently strong to prevent the magnet carrier **113** from rotating when the apparatus is in the position shown in FIG. 4. The pivot bearing member **100** is held in the position shown in FIG. 4 by a release mechanism **71** having a flange **68***a* against which the head **68** of the pivot bearing member **100** bears to hold the pivot bearing **100** in place. The magnet carrier **113** houses a bar magnet **105** and carries the metal firing plate **104**. The metal firing plate **104** may be slid around the periphery of the magnet carrier **113** and may be set in various positions thereabout by set-screws **104***a*.

The electrical contacts **97** and **98** and the electrodes **85** and **89** are supported in a contact housing which is constructed of an electrically insulative material such as Plexiglas. The contacts and electrodes are housed in recesses within the contact housing and are spring-biased outwardly therefrom, as shown. The electrodes **85** and **89** engage a dashpot piston **91** which has a band **81** of electrically conductive metal affixed thereto. The metal

band 81 is positioned so as to connect together electrodes 85 and 89 when the dashpot is at the lower end of the dashpot cylinder 95. The space within which the apparatus is housed is filled with an incompressible liquid such as glycerin or distilled water. The dashpot piston is provided with a port 93 at the lower end thereof and a port 80 at the upper end thereof, which are hydraulically interconnected through the dashpot piston so as to permit slow passage of fluid therethrough. The dashpot piston is biased downwardly by coil spring 79 at the upper end thereof. The spring also engages the upper wall of the lower housing section 55. Extension 75*a* of the dashpot piston protrudes upwardly through the upper wall of the lower housing section 55 into the spaced defined by the upper housing section 53. A clevis 76 on release mechanism 71 hold the dashpot against the force of coil spring 79 in the position shown.

The release mechanism 71 is mounted on rollers so that it will slide readily to the right, as viewed. A flange 69 on the release mechanism 71 engages the flange 67 of the release collar 61. When the release collar is forced to the right, as viewed, it will drag the release mechanism along with it; when the clevis 76 no longer engages the head 75 the dashpot will begin moving downward. Likewise, when the flange 68*a* moves far enough to the right so that the head 68 of the pivot bearing 100 enters slot 72, the force exerted by spring 115 will be sufficient to move the magnet carrier 113 upwardly and to allow the magnet carrier to pivot freely when flange 99 engages the upper end of housing 55.

The lowermost section of pipe 28 preferably is a section formed of a nonmagnetic material such as that made by Houston Oil Well Equipment Company for orientation of directional drilling deflecting tools and described on page 2402 of the Composite Catalog of Oil Field Equipment and Services, 1958–59 edition.

The operation of the apparatus shown in FIGS. 3 through 6 will be described in conjunction with the stepwise illustrations of FIGS. 7 through 11. Let it be assumed that the borehole 10 has reached a depth at which it is desired to deflect the borehole off vertical and in a given direction, such as due east. The metal firing plate 104 will be moved to the position shown in FIG. 5. Assume that a shape charge, such as is shown in FIG. 3, has been pumped to the bottom of the pipe 28 so that seating ring 45 is landed on seat 31. In order to actuate the device, the pressure within pipe 28 is increased to at least a predetermined pressure. Flexible seal 59 will bulge inwardly under the force of the differential pressure between tube 35 and tube 37 and the incompressible fluid within upper housing section 53 will force the release collar 61 to the right. Release mechanism 71 will be dragged to the right by release collar flange 67. When the release mechanism 71 has moved a sufficient distance, head 68 will no longer be held by the flange 68*a* and will move up into slot 72 under the impetus of spring 115. Simultaneously, clevis 76 will move to the right a sufficient distance to release head 75 so that the dashpot piston will move slowly downwardly under the impetus of spring 79. The magnet carrier 113 will move up relatively quickly as compared to the downward movement of dashpot piston 91. The magnet carrier may now pivot by virtue of the force exerted on the magnet 105 by the earth's magnetic field. In view of the fact that the dashpot piston 91 moves quite slowly, the firing circuit of the detonator will not be completed should the metal firing plate 104 make the electrical connection between contacts 97 and 98 as the magnet carrier pivots. When the rotary movement of the magnet carrier ceases, the metal firing plate 104 will be in the position shown in FIG. 5 relative to the contacts 97 and 98. When the dashpot piston 91 moves down to make contact between electrodes 85 and 89, the circuit will be in condition for firing when metal firing plate 104 makes electrical contact between contacts 97 and 98. The pipe 28 now may be rotated slowly. Contacts 97 and 98 will be moved around the periphery of the magnet carrier 113 until they both contact the metal firing plate 104. This will complete the electrical circuit to energize the detonator 41 and explode the shaped charge 43. A hole, such as is designated by the reference numeral 140 in FIG. 7, will result. The drill pipe 28 may now be lowered a short distance (limited by the tapered shape of hole 140) and a second charge similar to the one shown in FIG. 3 may be circulated to the bottom of the drill pipe and detonated in the same manner as described above. The resulting hole will be similar to that shown in FIG. 8 and designated by the reference numeral 144. As shown in FIG. 9, a gauging charge 146 may now be circulated down the drill pipe. The explosive charge may be contained in a semiflexible container so that it will penetrate to the bottom of the hole 144 and still permit the seating ring thereof to seat on the seat or nipple 31. The detonating charge will be detonated in the manner described in the aforementioned patent application Serial No. 855,681, now U.S. Patent No. 3,014,423. The resulting hole is designated in FIG. 10 by the reference numeral 148. The drill pipe may now be lowered as far as possible and a conventional straight shaped-jet explosive charge may be circulated to the bottom of the drill pipe and detonated to form the hole designated by the reference numeral 152. After the drill pipe has been lowered again, if it is desired to still further deviate the borehole from the vertical, another explosive charge such as that shown in FIG. 3 may be circulated to the bottom of the drill pipe and detonated.

The invention is quite advantageous in that it is almost entirely automatic and virtually fool-proof. The shaped-jet explosive charge cannot be detonated until the magnet carrier oscillation has settled down after the magnet carrier is released to pivot.

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

What is claimed is:

1. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated, substantially cylindrical housing having a longitudinal axis; a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped explosive jet charge within said housing for rotation therewith, comprising an explosive charge and a generally conical hollow in the explosive charge, the axis of said generally conical hollow being tilted at an angle to the longitudinal axis of said housing whereby said jet charge when detonated will direct a directional explosive jet at an angle to the longitudinal axis of said housing; and electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; a bar magnet; an electrically insulative carrier disk for said bar magnet, pivotally mounted in said housing and adapted to pivotally rotate with said bar magnet as said magnet aligns itself in accordance with the earth's magnetic field; a contact carrier in said housing; a pair of spaced electrical contacts on said contact carrier; means associated with said contact carrier for urging said electrical contacts against the periphery of said carrier disk; connecting means on said carrier disk for electrically connecting together said electrical contacts when said electrical contacts are at a given orientation relative to said magnet; and circuit means interconnecting said electrical power source, said electrical contacts, and said detonating charge to energize said detonating charge when said

contacts are electrically connected by said connecting means.

2. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated, substantially cylindrical housing having a longitudinal axis; a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped jet charge within said housing comprising an explosive and a conical liner extending upward into said explosive with its axis tilted at an angle with respect to the axis of said housing whereby the explosive jet produced by the explosive charge will be directed substantially along the axis of said conical liner; an electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; a bar magnet; an electrically insulative carrier disk for said bar magnet, pivotally mounted in said housing and adapted to pivotally rotate with said bar magnet as said magnet aligns itself in accordance with the earth's magnetic field; a contact carrier in said housing; a pair of spaced electrical contacts on said contact carrier; means associated with said contact carrier for urging said electrical contacts against the periphery of said carrier disk; connecting means on said carrier disk for electrically connecting together said electrical contacts when said electrical contacts are at a given orientation relative to said magnet; circuit means interconnecting said electrical power source, said electrical contacts, and said detonating charge to energize said detonating charge when said contacts are electrically connected by said connecting means; a bore within said contact carrier; a dashpot mechanism comprising a dashpot cylinder connected to said housing and a electrically insulative dashpot piston positioned for reciprocating movement within said cylinder and said bore; third and fourth electrical contacts within said contact carrier, separated by said dashpot piston; conductive means on said dashpot mechanism adapted to connect together said third and fourth electrical contacts when said dashpot piston is at one extreme of its range of movement; a coil spring on said dashpot piston, engaging a portion of said housing for urging said dashpot piston toward said one extreme of its range of movement; restraining means in said housing connected to said dashpot piston and said carrier disk for holding said dashpot piston away from said one extreme of its range of movement and for holding said carrier disk against pivotal rotation; and means connected to said restraining means and hydraulically coupled to said longitudinally spaced-apart locations at the exterior of said housing, adapted to actuate said restraining means to release said carrier disk and said dashpot piston whereby said carrier disk will be oriented in accordance with the force exerted by the earth's magnetic field on said bar magnet, and said dashpot piston will slowly move toward said one extreme position thereof to connect together said third and fourth electrical contacts.

3. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated, substantially cylindrical housing having a longitudinal axis; a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped explosive jet charge within said housing for rotation therewith comprising an explosive charge and a generally conical hollow in the explosive charge, the axis of said generally conical hollow being tilted at an angle to the longitudinal axis of said housing whereby said jet charge when detonated will direct a directional explosive jet at an angle to the longitudinal axis of said housing; an electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; a bar magnet, an electrically insulative carrier disk for said bar magnet, pivotally mounted in said housing and adapted to pivotally rotate with said bar magnet as said magnet aligns itself in accordance with the earth's magnetic field; a contact carrier in said housing; a pair of spaced electrical contacts on said contact carrier; means associated with said contact carrier for urging said electrical contacts against the periphery of said carrier disk, connecting means on said carrier disk for electrically connecting together said electrical contacts when said electrical contacts are at a given orientation relative to said magnet; restraining means connected to said carrier disk for holding said carrier disk against rotation; means connected to said restraining means and hydraulically coupled to said pair of longitudinally spaced-apart locations at the exterior of said housing, adapted to actuate said restraining means to release said carrier disk whereby said carrier disk may rotate to be oriented in accordance with the force exerted on said magnet by the earth's magnetic field; and time delay means connected to said said connecting means for preventing said connecting means from connecting together said electrical contacts until said magnet is oriented by the earth's magnetic field.

4. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated, substantially cylindrical housing having a longitudinal axis; a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped explosive jet charge within said housing for rotation therewith comprising an explosive charge and a generally conical hollow in the explosive charge, the axis of said generally conical hollow being tilted at an angle to the longitudinal axis of said housing whereby said jet charge when detonated will direct a directional explosive jet at an angle to the longitudinal axis of said housing; an electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; a bar magnet; an electrically insulative carrier disk for said bar magnet, pivotally mounted in said housing and adapted to pivotally rotate with said bar magnet as said magnet aligns itself in accordance with the earth's magnetic field; a contact carrier in said housing; a pair of spaced electrical contacts on said contact carrier; means associated with said contact carrier for urging said electrical contacts against the periphery of said carrier disk; connecting means on said carrier disk for electrically connecting together said electrical contacts when said electrical contacts are at a given orientation relative to said magnet; restraining means connected to said carrier disk for holding said carrier disk against rotation; and means connected to said restraining means and hydraulically coupled to said pair of longitudinally spaced-apart locations at the exterior of said housing, adapted to actuate said restraining means to release said carrier disk whereby said carrier disk may rotate to be oriented in accordance with the force exerted on said magnet by the earth's magnetic field.

5. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated housing having a longitudinal axis; a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential

hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped explosive jet charge within said housing for rotation therewith comprising an explosive charge and a generally conical hollow in the explosive charge, the axis of said generally conical hollow being tilted at an angle to the longitudinal axis of said housing whereby said jet charge when detonated will direct a directional explosive jet at an angle to the longitudinal axis of said housing; an electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; a bar magnet; an electrically insulative carrier disk for said bar magnet, pivotally mounted in said housing and adapted to pivotally rotate with said bar magnet as said magnet aligns itself in accordance with the earth's magnetic field; a contact carrier in said housing; a pair of spaced electrical contacts on said contact carrier; means associated with said contact carrier for urging said electrical contacts against the periphery of said carrier disk; connecting means on said carrier disk for electrically connecting together said electrical contacts when said electrical contacts are at a given orientation relative to said magnet; circuit means interconnecting said electrical power source, said electrical contacts, and said detonating charge to energize said detonating charge when said contacts are electrically connected by said connecting means; and means in said housing connected to said shaped jet charge adapted to detonate said shaped jet charge responsive to exertion of a differential hydraulic pressure of predetermined magnitude between spaced-apart locations on said housing upon rotation of said shaped jet charge to a given orientation with respect to the earth's magnetic field.

6. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated, substantially cylindrical housing having a longitudinal axis, a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped explosive jet charge within said housing for rotation therewith comprising an explosive charge and a generally conical hollow in the explosive charge, the axis of said generally conical hollow being tilted at an angle to the longitudinal axis of said housing whereby said jet charge when detonated will direct a directional explosive jet at an angle to the longitudinal axis of said housing; an electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; first means in said housing including direction sensing means, electrically connected to said power source and to said detonating charge, adapted when activated to electrically energize said detonating charge upon rotation of said housing to a position whereat the axis of said conical hollow is pointed in a given direction; and means connected to said first means adapted to activate said first means when a predetermined differential hydraulic pressure is exerted between a pair of longitudinal, spaced-apart locations on the exterior of said housing.

7. Apparatus for explosive drilling at an angle from the vertical in a borehole traversed by a drill pipe having a seating means at the lower end thereof, comprising: an elongated, substantially cylindrical housing having a longitudinal axis; a seating ring operatively associated with said housing, adapted to seat on the drill pipe seating means so that differential hydraulic pressure may be exerted across said housing between a pair of spaced-apart locations on the exterior of the housing; a shaped explosive jet charge within said housing for rotation therewith comprising an explosive charge and a generally conical hollow in the explosive charge, the axis of said generally conical hollow being tilted at an angle to the longitudinal axis of said housing whereby said jet charge when detonated will direct a directional explosive jet at an angle to the longitudinal axis of said housing; an electrically actuable detonating charge operatively connected to said shaped charge adapted, when electrically energized, to detonate said shaped charge; an electrical power source in said housing; first means in said housing, including a pivotally supported bar magnet, said first means being electrically connected to said power source and to said detonating charge being adapted to electrically energize said detonating charge when said housing is rotated so that said magnet assumes a given position in said housing; and means connected to said first means to hold said bar magnet against rotation within the housing until a predetermined hydraulic pressure has been exerted between a pair of longitudinally spaced apart locations on the exterior of the housing whereby said first means is deactivated.

References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,544,573 | Vincent | Mar. 6, 1951 |
| 2,679,380 | Sweetman | May 25, 1954 |