Jan. 20, 1959 F. W. CRAWFORD 2,869,825

EARTH BORING

Original Filed Feb. 25, 1946 2 Sheets-Sheet 1

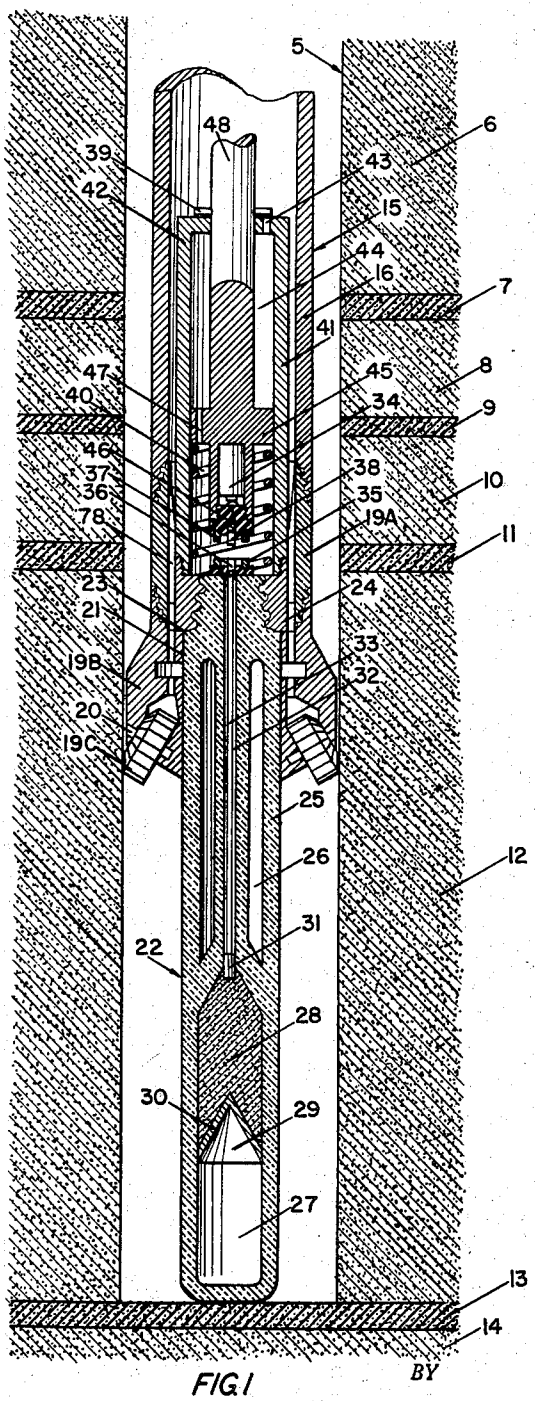


FIG 1

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EARTH BORING

Original Filed Feb. 25, 1946 2 Sheets-Sheet 2

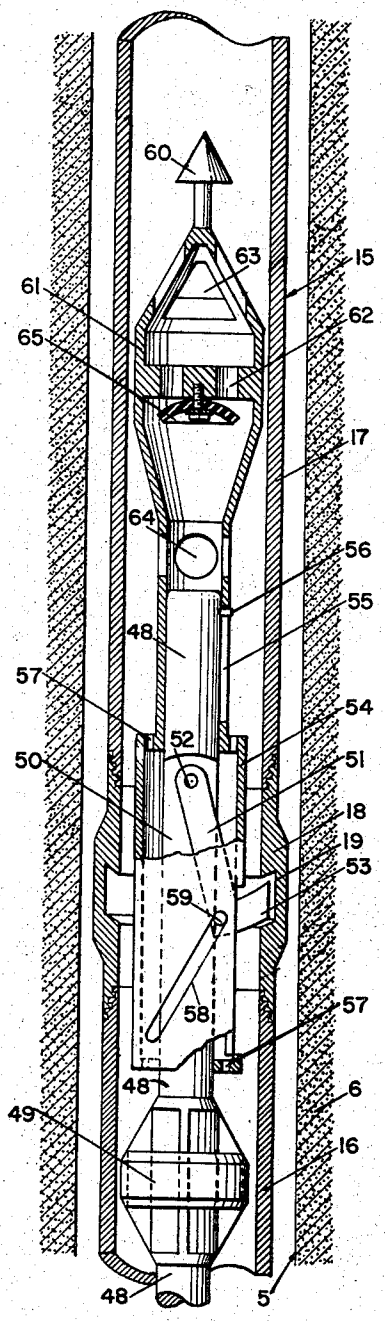


FIG. 2

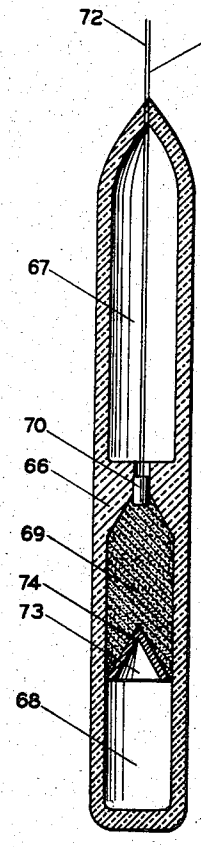


FIG. 3

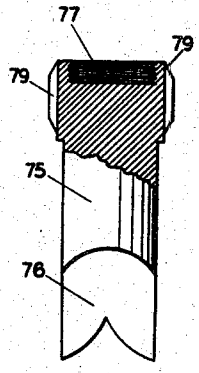


FIG. 4

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United States Patent Office 2,869,825 Patented Jan. 20, 1959

2,869,825

EARTH BORING

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Continuation of application Serial No. 650,105, February 25, 1946, now abandoned. This application October 26, 1953, Serial No. 388,175

15 Claims. (Cl. 255—1.8)

This invention relates to methods and means for earth boring. In a more specific aspect it relates to advancing the earth bore into the ground by one or more explosions in which the explosive force is directed downwardly, with or without mechanical rotary drilling operations before or after the explosion or explosions. In another specific aspect it relates to a method and means of lowering an explosive through the rotary drill string and bit so that a downwardly directed explosion may be produced in the well without removing the rotary drilling string.

This application is a continuation of my copending application Serial No. 650,105 filed February 25, 1946, for "Earth Boring," now abandoned.

In the art of earth boring considerable difficulty has been experienced because of the existence of very hard formations often encountered in rotary drilling deep oil wells. Often such hard formations are so dense that only a foot or two can be rotary drilled in a day or sometimes even a week. Such formations wear out the rotary drilling bit so that it is necessary to pull out the rotary drill string to replace the worn out bit. When the well is deep, considerable time and expense is involved in removing the rotary drill string. Therefore, ordinary rotary drilling methods become very expensive when such hard formations are encountered, and in some instances rotary drilling progress has become so expensive and slow that the well has been abandoned before reaching the depth desired by geologists.

The present invention is useful in rotary drilling all formations whether they are soft or hard. The advantages of the present invention increase, relative to mechanical rotary drilling methods, rapidly as the hardness of the formations encountered increases. While the present invention is useful in rotary drilling into a very thick hard formation it is particularly useful when one or more relatively thin hard formations are encountered, a situation illustrated in Figure 1 of the drawings.

One object of this invention is to provide means and methods for penetrating hard formations that are encountered in earth boring.

Another object is to provide means and methods for earth boring.

Another object is to provide means and methods for earth boring employing one or more downwardly directed explosions each of which may or may not be preceded or followed by mechanical rotary drilling.

Another object is to provide means and methods for placing the explosive charges and causing downwardly directed explosions without removing the rotary drill string from the well.

A further object of the invention is to provide methods and means for inserting downwardly directed explosions into the usual rotary drilling systems employed.

Another object is to provide means and methods of running explosives to a point below the bit by means of a wire line tool, or pump-up pump-down tool, used in

place of the usual rotary core barrel or core buster of the same type.

Numerous other objects and advantages will be apparent to those skilled in the art upon reading the accompanying specifications, claims and drawings.

In the drawings:

Figure 1 is an elevational, cross sectional, view of an earth bore containing one embodiment of the present invention.

Figure 2 is an upward extension of Figure 1.

Figure 3 is a cross section, elevational, view taken through a modified embodiment of the present invention.

Figure 4 is an elevational view, with parts broken away, showing a core buster which may be substituted for portions of Figure 1 in practicing certain embodiments of the present invention.

In Figure 1, an earth bore or well generally designated as 5 is shown extending down through a number of natural earth formations 6, 7, 8, 9, 10, 11 and 12. An earth formation 13 has been uncovered and it is desired to penetrate formation 13 and such formations as 14 which lie below 13.

While the operation of the present invention is not limited by the hardness, or softness, or thickness of the formations, the invention has particular advantages in the situation shown in Figure 1 in which formations 6, 8, 10, 12 and 14 are relatively soft, and formations 7, 9, 11 and 13 are particularly hard.

In Figure 1, a rotary drill string generally designated as 15 may be of any type old in the art of earth boring. As such it may be a rotary drill string composed of pipe sections 16 and 17 (Figure 2) connected by couplings or tool joints 18. The particular tool joint shown, joint 18, is a special joint in that it contains an annular groove 19 not present in the other tool joints (not shown). The pipe section 16 may be provided with a rotary drill collar or coupling 19A to which a rotary drill bit 19B may be secured.

While rotary drill bit 19B is shown as a roller bit, having rollers 19C mounted to rotate on bearings 20, it is obvious that other types of bits employing fixed blades or rotatable discs may be employed in the practice of the invention, as rotary drill bit 19B may be any bit found useful in the prior art as the present invention will operate the same with any type bit.

Bit 19B however, should contain a large, preferably centrally located, passage 21 so that the explosive charge generally designated as 22 may be lowered therethrough. Explosive charge 22 is also generically called a tool in the claims along with the other mechanical tools, such as the rotary drilling fish tail bit 75, 76, and the rotary core barrel (not shown), which tools are adapted to be placed in series, one at a time, on seat 23 in rotary drill bit 19B and used at different times during the drilling of a well. The use of first one tool and then another produces a unitary result of drilling a single well bore 5 through varying formations 6, 7, 8, 9, 10, 11, 12, 13 and 14, with the greatest possible speed, and therefore cannot be said to be an aggregation. In hard formations 7, 9, 11 and 13 explosive tool 22 should be used first, and in soft formations 6, 8, 10, 12 and 14, it is recommended that mechanical tools be employed, the combination of these tools having a unitary result of a single straight well bore 5 produced in minimum time.

When explosive charge 22 is not inside rotary drill string 15, rotary drill bit 19B may be operated with space 21 empty, or space 21 may be filled with the usual core barrel or core buster, removable through the rotary drill string as will be explained further with relation to Figure 4.

As shown in Figures 1 and 2, the explosive charge 22 is insertable and removable through rotary drill string 15 by any of several methods common in the art of core barrels which are removable through the rotary drill string, the embodiment shown in the drawing being capable of operation in the same manner as a wire-line rotary core barrel, or a pump-up pump-down rotary core barrel, as will be explained below under "Operation." In the position shown, explosive charge 22 is supported by shoulder 23 of coupling 24 on a corresponding upwardly facing shoulder of rotary drill bit 19B. The lower part of the charge 22 is preferably made of relatively easily drillable material such as glass or Bakelite body 25. Numerous suitable materials have been enumerated in the art of earth boring, and in the art of wells for use in drillable cementing shoes and collars and for drillable plugs for floating casing into the hole, such material being strong but easily rotary drilled through. While body 25 might be made of a light metal such as magnesium or aluminum, it is preferable to use some glass or plastic composition because such non-metallic materials are more easily rotary drilled up and disposed of, and yet have sufficient strength for the operations to be described later.

Body 25 may or may not be lightened by hollow spaces such as annular space 26 as will be described in the operations below. A hollow space 27 is also provided for purposes to be described and an explosive charge 28 of any suitable explosive is positioned in body 25 preferably substantially as shown.

Explosive charge 28 is provided with a depression 29 preferably in the form of a cone, which depression acts to concentrate most of the force of the explosives downwardly as will be explained later. Depression 29 is preferably lined with a relatively thin layer 30 of any malleable, ductile, and preferably tenacious metal, such as copper, tin, silver, or gold, or alloys having similar properties. Copper or copper alloys are preferable, as obviously such metals as gold are too expensive to be economically employed. This metal layer on explosion of charge 28 seems to aid the blast of gases coming out of cone 29 to penetrate formation 13, but layer 30 is not essential to such operation but is merely preferable.

Many alternative methods and means for exploding charge 28 can obviously be conceived, and the present invention may be practiced with any such means. For purposes of illustration, however, a much preferred method and means of exploding charge 28 has been illustrated which has obvious advantages as pointed out under the operation of the device. This means comprises a detonation cap or detonator 31 preferably electrically fired by current passing through wires 32 and 33 from dry cell battery 34 when annular contact 35 connected to wire 32 and central contact 36 connected to wire 33 completes the circuit by contacting similar contacts 37 and 38 connected to opposite poles of battery 34. While only one cell is shown in battery 34, obviously many cells may be used in series.

Premature contact is prevented by shear pin 39 which will only shear off under a load of several tons. A helical compression spring 40 may be provided for holding the contacts apart during assembly, if desired.

Coupling 24 connects body 25 with stand-off body 41. Body 41 has an upper shoulder or inwardly directed flange 42 for shearing shear pin 39 and a fluid passage 43 is provided therethrough in order to obviate any hydraulic lock caused by liquid in space 44.

Battery 34 is retained in the end of piston 45 by means of a threaded cap 46 made of insulating material and containing contacts 37 and 38 and the connecting wires. Contact 38 is spring pressed. As all these details are obvious from the drawings no further discussion of minor parts is given.

Piston 45 contains a fluid passage 47, similar to passage 43 in flange 42, and piston 45 is attached to piston rod 48 which continues upwardly in Figure 2 where it is preferably provided with guide means 49. Guide 49 is provided with water passages. In many instances guide 49 is unnecessary and may be eliminated. Rod 48 continues upwardly as shown in Figure 2 and has a portion of one side removed to form a plane at 50 to provide space for L-shaped latch 51 which is pivoted to rod 48 by means of pivot 52. The lower projecting end 53 of the L-latch 51 may be inserted and removed from the groove 19 as will be described.

Slideably mounted on rod 48 is a sleeve 54. In sleeve 54 is a straight slot 55 cooperating with pin 56 driven into a mating hole in rod 48 to prevent rotation between rod 48 and sleeve 54. Sleeve 54 may or may not be provided with water passage 57. Sleeve 54 has a slanting slot 58 which acts to guide pin 59. Pin 59 is either integral with the latch or is driven into a hole therein so that as sleeve 54 moves upwardly relative to rod 48, the slot 58 will engage pin 59 and withdraw end 53 from grooves 19 by pivoting movement around pivot 52 and vice versa when sleeve 54 moves downward. The sleeve 54 may be provided with a fishing-head 60 for engagement with an overshot on a wire line for operation as a wire line tool. However, an enlarged head 61 is provided, having water passages 62, 63 and 64, the center water passage 62 being adapted to be closed by excess flow valve 65 so that the entire device may be pumped to the surface by the drilling fluid if desired as will be explained under the operation.

While a particular type of tool removable through the rotary drill string has been shown for supporting charge 28, it is obvious that any such means old in the art may be substituted in place thereof in the practice of the invention, except that such devices which are capable of the preferred operation of the invention are preferred.

In Figure 3, a much simpler embodiment of the invention is shown, comprising a body 66 preferably made of materials similar to that described for body 25. Body 66 may contain air spaces 67 and 68 similar respectively to spaces 26 and 27. Similarly an explosive charge 69, a detonator 70 and wires 71 and 72 are provided which are similar to corresponding parts 31, 32 and 33. A depression 73 and a metal layer 74 are provided similar to depression 29 and layer 30 of Figure 1 except that the lower edge of 74 is shown lying in a plane which is perpendicular to the longitudinal axis of the apparatus of Figure 3.

Body 66 may be suspended in the well and lowered into the well or rotary drill string by means of wires 71 and 72. Wires 71 and 72 may be made into a cable if desired. Detonator 70 may have a percussion cap (not shown) extending to the top of body 66, in which case, an ordinary rope or cable could replace wires 71 and 72 and the explosive be actuated by a go-devil (not shown) which could be a short piece of pipe dropped down around the cable. Electric firing is preferred because of less chance of an accident.

Figure 3 is adapted to be used with both rotary drill strings and other hollow drill strings, such as shown in Figure 1, in which case it may be lowered through the string or with cable tools. In the later case the cable tools are preferably raised or removed from the well to allow the passage of body 66.

In Figure 4, a typical core buster 75 is shown having a fish-tail type rotary bit 76 thereon and having a coupling 77 adapted to replace coupling 24 of Figure 1. Obviously other forms of rotary bits including roller or disc cutters may be used.

It will be noted in Figure 1, that a number of keyways 78 are provided in collar 19A, generally 6 or 8 in number, for the passage of rotary drilling fluid; and core busters 75, of Figure 4, has two or more splines 79 to engage in keyways 78. Obviously the number of splines

The operation of Figure 4 has already been described with relation to Figures 1 and 2 above.

While this invention has been described in connection with certain specific embodiments, the principle involved is susceptible of numerous other applications that will readily occur to persons skilled in the art. The invention, is therefore, to be limited only as indicated by the scope of the appended claims.

Having thus described the various features of the invention, what I claim as new and desire to secure by Letters Patent is:

1. During the rotary drilling of a borehole with a rotary bit having a longitudinal passage therethrough, the steps comprising lowering into said borehole through said bit an explosive charge having a depression provided therein to direct the force of the explosion, raising said bit to a point spaced above said charge, positioning said explosive charge so that said depression will direct the force of said explosive into the earth in the direction of the earth boring, and exploding said charge while so positioned, whereby the force of said explosion has a substantial earth boring effect and other effects are reduced.

2. During the rotary drilling of a borehole with a rotary bit having a longitudinal passage therethrough, the steps comprising lowering into said borehole through said bit an explosive charge having a depression provided therein to direct the force of the explosion, raising said bit to a point spaced above said charge, positioning said explosive charge so that said depression will direct the force of said explosive into the earth in the direction of the earth boring, exploding said charge while so positioned, whereby the force of said explosion has a substantial earth boring effect and other effects are reduced, and rotary drilling again with a drilling bit.

3. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge by downward movement of said drilling string comprising an electric circuit actuated by lowering said drill string and a detonator in said circuit located in the upper portion of said charge, said tool being constructed to dispose said explosive charge a predetermined spaced distance outside said drilling bit and drill string when said tool is positioned on said seat, said explosive charge being connected when so disposed by said tool to said drill string and drill bit.

4. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge by downward movement of said drilling string, said tool being constructed to dispose said explosive charge a predetermined spaced distance outside said drilling bit and drill string when said tool is positioned on said seat, said explosive charge being connected when so disposed by said tool to said drill string and drill bit.

5. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge comprising an electric circuit actuated by lowering said drill string and a detonator in said circuit located in said charge, said tool being constructed to dispose said explosive charge a predetermined spaced distance outside said drilling bit and drill string when said tool is positioned on said seat, said explosive charge being connected when so disposed by said tool to said drill string and drill bit.

6. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge, said tool being constructed to dispose said explosive charge a predetermined spaced distance outside said drilling bit and drill string when said tool is positioned on said seat, said explosive charge being connected when so disposed by said tool to said drill string and drill bit.

7. The method of earth boring comprising rotary drilling with a mechanical tool secured to and removable through a rotary drill string, removing the rotary drilling tool and substituting an explosive charge secured to and positioned a spaced distance in advance of said drill string without removing the drill string from the earth bore, exploding the explosive charge to advance the earth bore, replacing the mechanical tool in place of the explosive charge and continuing the drilling with the mechanical tool.

8. The method of claim 7 in which a plurality of explosive charges are placed and exploded in series before continuing with the mechanical rotary drilling.

9. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive an explosive charge removable through the drill string, a seat in said drill string for positioning said explosive charge, an explosive charge removable through said drill string and positionable in said seat in such a manner that the lower end thereof extends below said drilling bit, said explosive charge comprising an elongated member having an explosive charge in its lower end with a depression therein for directing the force of the explosive downwardly, said elongated member also having a cylinder at its other end, a piston adapted to reciprocate in said cylinder, a piston rod extending from said piston out of said cylinder, a shear pin attached to said piston rod and adapted to press against the upper end of said cylinder and to be sheared off when said drill string is lowered to exert its weight through said piston to cause said piston to be forced into said cylinder, a latch mechanism associated with said piston rod and adapted to coact with said drill string to hold said piston and piston rod at a predetermined fixed location therein and a firing mechanism for said charge comprising a detonator in the end of said charge opposite said depression, a pair of contact points connected to said detonator and located in the lower end of said cylinder, and a short circuiting means attached to said piston and adapted to connect said contact points when said piston is forced into said cylinder after said shear pin is sheared.

10. During the rotary drilling of a borehole with a bit having a longitudinal passage therethrough, the steps comprising lowering into said borehole completely through said bit an explosive charge having a depression provided therein to direct the force of the explosion, raising said bit to a point spaced above said charge, positioning said explosive charge so that said depression will direct the force of said explosive into the earth in the direction of the earth boring, exploding said charge while so positioned, whereby the force of said explosion has a substantial earth boring effect and other effects are reduced, and rotary drilling again with a rotary drilling bit.

79 is less than the number of keyways 78 so that water circulation continues.

Obviously other core busters and rotary core barrels old in the art of earth boring may be substituted in place of Figure 4 and I do not claim Figure 4 to be novel except when employed with my invention, and any other rotary core barrels and core busters may be so employed.

Operation

The operation of the structure shown in Figures 1 and 2 is as follows:

The well driller is rotary drilling with rotary drill string 15 and bit 19B through relatively soft formation 12. During this rotary drilling the center opening 21 may be empty or may be filled with a usual rotary core barrel (not shown) or a core buster such as 75 of Figure 4.

Hard formation 13 is then encountered, as in the past hard formations 7, 9 and 11 were also encountered. By many indications at the surface, such as reduction of cuttings and failure of the rotary drill string to advance, the driller realizes that he has encountered a relatively hard formation 13. In the prior art, he would merely proceed to wear rollers 19C and 76 out on the hard formation, but in the practice of the present invention the driller raises rotary drill string 15 to a position a little higher than that shown in Figure 1. The driller may continue the circulation of a rotary drill fluid down through rotary drill string 15 and up the annular space between bore 5 and rotary drill string 15, or may discontinue circulation as he sees fit. Generally it is preferable to continue circulation.

Obviously, charge 22 is then lowered into the hole by any of several well known methods. It can be lowered on a wire line (not shown) attached to 60, or it can be merely dropped into the rotary drill string 15. Drill string 15 being full of liquid, the dropping is a gentle process and may be further checked by a flexible cup 65 which will tend to close hole 62 if the progress downward is too rapid. However, with hole 62 completely closed the apparatus may still be pumped down.

However it is lowered, the shoulder 23 takes its seat on the top of bit 18 and then sleeve 54 moves downwardly relative to rod 48. Slot 58 swings latch 51 by means of pin 59 around pivot 52 so that end 53 is inside annular groove 19. At this time the bottom of body 25 is a short distance above the top of formation 13.

The rotary drill string 15 is then lowered until the bottom of body 25 contacts formation 13 lifting coupling 24 off bit 18 and transmitting compressive force through shear pin 39, rod 48, pivot 52 and latch 51 to catch end 53 in groove 19. As the lowering continues no further relative movement is possible and the load increases on shear pin 39 until it reaches a relatively large value. While shear pin 39 could be made easily shearable and the invention still be operable, it is believed a better factor of safety is provided against premature explosions in the rotary drill string by making shear pin 39 quite strong. Obviously shear pin 39 should be weaker than all the other parts, such as pivot 52, for example. As the pressure increases, pin 39 shears and sleeve 41 moves upwardly until contacts 35, 36, 37 and 38 complete the circuit between detonator 31 and battery 34.

Detonator 31 thereupon explodes setting off explosive charge 28. A flame front or explosive wave passes from detonator 31 downwardly through charge 28 progressively increasing in force and due to the presence of conical depression 29 the force of the explosion is directed along a vector down the axis of core 29 into hard formation 13.

While the effect of the explosive charge on the formation depends a lot on the character of the formation, in many instances the result is that the explosive charge will blow a hole into the formation and melt the formation somewhat along the outer edges and the bottom of the hole. The extent of the hole depends of course on the thickness and resistance characteristics of formation 13, but in most cases the situation as to drillability has been improved thereby.

While not absolutely essential to the invention, it is preferable to have an air space 27 spacing explosive 28 from the formation 13 in order to obtain the maximum penetrating effect of explosive 28, and while space 27 could be filled with a liquid such as water, it is preferred to have space 27 filled with a gas, it being contemplated to have the gas under subatmospheric, atmospheric or superatmospheric pressure. So far as the explosion is concerned, it is better to have space 27 under subatmospheric pressure, but in a very deep well, in order to reduce the thickness of 25 it may prove desirable to have the gas in space 27 highly compressed in order to aid the walls of 25 in resisting the hydrostatic pressure. On the other hand, it is simplest and cheapest to have space 27 at atmospheric pressure and filled with air, although an inert gas or a mixture of explosive gases could be employed if desired in all three pressure cases mentioned above.

It has been found that the force of explosive 28 is also increased by the use of a malleable, ductile and tenacious metal layer 30. The action during the explosion is that the layer of metal 30 is turned inside out, and either in whole, or generally as a number of metal beads, or shot, is driven forcibly into formation 13 increasing the penetration of the explosion.

Space 26 may be provided to lighten the body 25 and to reduce upward shock on the rotary drill bit 19B. However, in many cases space 26 is unnecessary.

The explosion having occurred, the driller may proceed to remove what remains of 25 by pumping up, or pulling up, head 61 in the manner normal to tools removable through the rotary drill string, such as by a wire line (not shown) attached to 60. As sleeve 54 moves up relative to rod 48, slot 58 will remove 53 from groove 19, and as 25 had been shattered there is no pressure opposing the removal. When pin 59 reaches the bottom of slot 58, rod 48 then is pulled along after head 61 and the remains of the device removed. An annular ridge may be provided around the top of sleeve 41 to form a cup to retain the broken ends of shear pin 39 if it is necessary to keep them out of the well. Body 25 has been shattered and the portions thereof remaining in the well being made of easily drillable material are no obstacle for further rotary drilling.

The driller then replaces his former rotary core barrel (not shown) or core buster 75 and proceeds to rotary drill with them. Or he may rotary drill merely with bit 18 leaving opening 21 empty.

The increased rate of rotary drilling in hard formation 13 after the shot has been fired is probably due to the cracking caused by the explosion and the crystallization of the molten formation with the result that rotary drilling or reaming of the formation is less hard on the bit, and is generally productive of more rapid progress than when rotary drilling formation 13 before the explosion.

One or more explosions may be necessary for each one of formations 7, 9, 11 and 13, and there may or may not be mechanical rotary drilling operation between the succeeding explosions depending upon the drillers judgment and experience in rotary drilling such formations. Drilling into a very thick, hard formation may thus consist of more explosions than mechanical rotary drilling, but fortunately real hard formations have often been found to be thin, being sometimes only several inches thick.

The operation of Figure 3 is much simpler. The structure shown in Figure 3 is lowered into the bore hole at any desired time and exploded while standing on the bottom, preferably in an upright position, by current from the surface by wires 71 and 72 or by a go-devil dropped down the supporting cable to set off a percussion cap (not shown). Regardless of the method of setting off the explosion, the operation and effect of the explosion is the same as has been described with relation to Figures 1 and 2.

11. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge by downward movement of said drilling string comprising an electric circuit actuated by lowering said drill string and a detonator in said circuit located in the upper portion of said charge, said tool and rotary drill bit being so proportioned that when said tool is positioned on said seat said entire explosive charge has passed through, below and outside said drill bit, and is disposed a predetermined spaced distance below said drill bit, and means to secure said explosive charge to said drill bit when disposed said spaced distance below said bit.

12. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge by downward movement of said drilling string, said tool and rotary drill bit being so proportioned that when said tool is positioned on said seat said entire explosive charge has passed through, below and outside said drill bit, and is disposed a predetermined spaced distance below said drill bit, and means to secure said explosive charge to said drill bit when disposed said spaced distance below said bit.

13. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge comprising an electric circuit actuated by lowering said drill string and a detonator in said circuit located in said charge, said tool and rotary drill bit being so proportioned that when said tool is positioned on said seat said entire explosive charge has passed through, below and outside said drill bit, and is disposed a predetermined spaced distance below said drill bit, and means to secure said explosive charge to said drill bit when disposed said spaced distance below said bit.

14. Earth boring apparatus comprising in combination a rotary drill string having a rotary drilling bit adapted to receive tools removable through the drill string, a seat in said drill string for positioning said tools, a tool removable through said drill string and positionable on said seat, an explosive charge in said tool having a depression therein for directing the force of the explosive downwardly and self contained means for firing said charge, said tool and rotary drill bit being so proportioned that when said tool is positioned on said seat said entire explosive charge has passed through, below and outside said drill bit, and is disposed a predetermined spaced distance below said drill bit, and means to secure said explosive charge to said drill bit when disposed said spaced distance below said bit.

15. During the rotary drilling of a borehole with a rotary bit having a longitudinal passage therethrough, the steps comprising lowering into said borehole through said bit a glass enclosed explosive charge having a depression provided therein to direct the force of the explosion, raising said bit to a point spaced above said charge, positioning said explosive charge so that said depression will direct the force of said explosive into the earth in the direction of the earth boring, exploding said charge while so positioned, whereby the force of said explosion has a substantial earth boring effect, the glass enclosure is shattered, and other effects are reduced, and rotary drilling again with a drilling bit to remove the shattered glass and cut into the earth to deepen said borehole.

References Cited in the file of this patent

UNITED STATES PATENTS

82,586	Beach	Sept. 29, 1868
494,877	Miller	Apr. 4, 1893
2,265,982	Bolton	Dec. 16, 1941
2,300,823	Whitman	Nov. 3, 1942
2,407,093	Mohaupt	Sept. 3, 1946
2,494,256	Muskat et al.	Jan. 10, 1950
2,629,325	Sweetman	Feb. 4, 1953

OTHER REFERENCES

"The Shaped Charge," by Volta Torrey, pages 160 to 163 of The Explosives Engineer, July-August 1945.