Sept. 20, 1971 J. D. BENNETT 3,605,918

DRILL BIT AND METHOD FOR EXPLOSIVE DRILLING

Filed Dec. 15, 1969 2 Sheets-Sheet 1

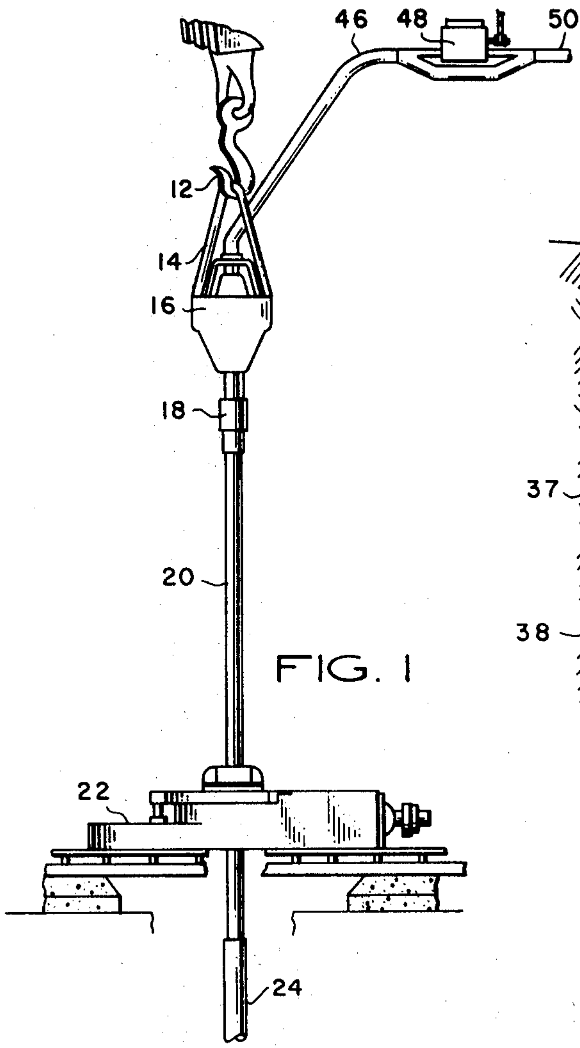

FIG. 1

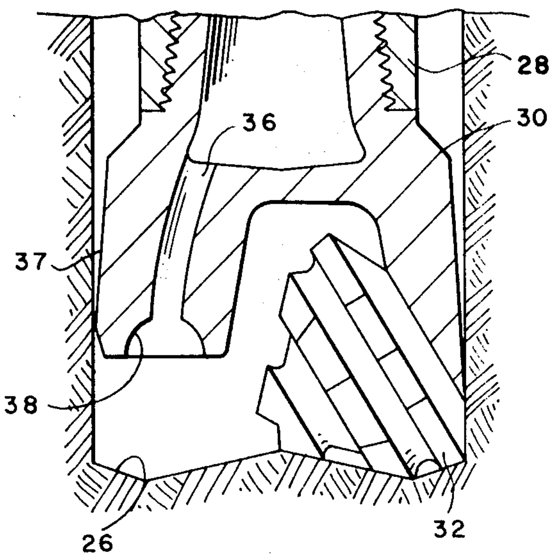

FIG. 2

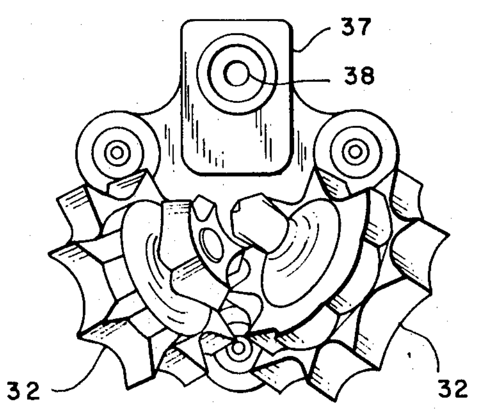

FIG. 3

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DRILL BIT AND METHOD FOR EXPLOSIVE DRILLING

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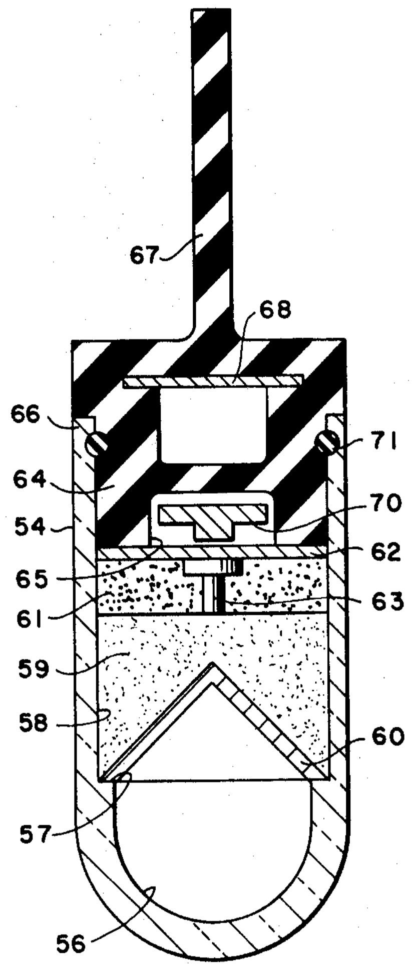

FIG. 4

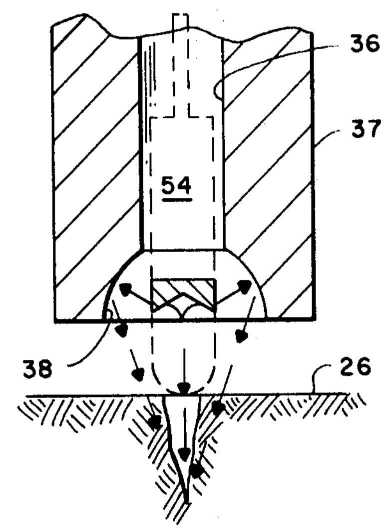

FIG. 5

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DRILL BIT AND METHOD FOR EXPLOSIVE DRILLING

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U.S. Cl. 175—2 9 Claims

ABSTRACT OF THE DISCLOSURE

The particular embodiment described herein as illustrative of one form of the invention utilizes a drill bit having a fluid exit for passing drilling fluids from the interior of the drill pipe to the exterior of the drill bit. The surface surrounding the exit is formed in the shape of a parabola. Explosive capsules are placed in the drilling fluid stream and then moved with the drilling fluid through the drill stem and out the opening in the bit for impact with the formation, whereupon the explosive capsule is detonated. Primary energy in the form of a shaped jet charge is directed into the formation to penetrate the bottom of the borehole and cause fracturing of formation materials. In addition, upwardly directed energy from the shaped explosive charge is reflected from the parabolic-like surface of the drill bit to provide a secondary energy source directed against the formation at the bottom of the borehole.

BACKGROUND OF THE INVENTION

This invention relates to a new and improved method and apparatus for explosive assisted drilling, and more particularly to the use of a capsule which is moved through the eye of the drill bit for detonation upon impact with the borehole, with such detonation developing a primary and secondary source of explosive energy for assisting the drilling of the borehole.

U.S. Patent No. 3,130,797, issued to Ford L. Johnson, and dated Apr. 28, 1964, describes shaped charge devices which may be moved through a hollow drill stem and projected through the jet openings in a conventional roller or other type bit to effect shattering of formations and thereby facilitate drilling. Prior to the use of such devices, it was found that the rate of drilling, for example, by rotary tools, may vary greatly depending upon the formation which is being drilled. In drilling through extremely hard rock, the progress may be slow and consequently costly, because the costs of drilling are at least roughly proportional to time expended.

As described in the above patent, the explosive shaped charge is used as an adjunct to what is otherwise essentially conventional drilling procedure. Applied to rotary drilling by means of a bit driven through a hollow drill stem, the invention involves the utilization, as required, of explosive members which may be dropped or propelled through the hollow drill stem and guided into or through one or more passages in the bit, the members being exploded to shatter the formation at the bottom of the hole through which the drilling is proceeding. During this operation, the conventional drilling may be carried out with the circulation of the mud to remove the cuttings, which circulation also acts as a fluid to carry the explosive member into contact with the borehole at the bottom of the well. The use of such explosives in the drilling operation may be on an intermittent basis, such as when the progress of drilling is notably slowed down during the encountering of an extremely hard formation. In addition, it may be found that certain formation materials may be more susceptible to the use of explosives. Therefore, during the drilling of such formations, explosives may be routinely used.

If hard and unfractured rock is being drilled, there is a tendency for the drill to rotate on the surface of the rock, with a relatively low rate of rock removal despite heavy pressure exerted on the bit, the action then being largely one of abrasion. However, if the bit encounters rock which has been fractured, the cutting edges of the bit will enter openings due to fractures, and tend to split the rock along with the production of impacts between the loosened portions of the rock, with the result that comminution is rapidly effected, to produce rock segments of small size removable to the surface by the circulating mud. It is therefore evident that the use of explosives in accordance with this invention is not primarily for the purpose of having the explosive actually produce and shape the hole, rather the objective is to break up the rock so as to cause the bit to function more effectively. Nevertheless, there is advantage in using the shaped charge explosives which have generally as their objective the production of holes.

In the present instance, the primary function of the charge is to produce violent shocks which will effect fracturing of the formation, and such shocks are best obtained through the use of shaped charges. In addition, shaped charges give a greater depth penetration, and will permit the pressure exerted by the hydrostatic mud column within the drill stem to be exerted to underlying portions of the formation below the face of the drill bit. This extension of the pressure into the formation effects a pressure equalization as opposed to a hold-down pressure of the mud which affords a greater rate of removal of the fractured formation. During the drilling operation, mud penetrates exposed interstices or crevices of the formation, to which the cut is being made. This intrusion of mud which is in the form of a mud cake about the borehole wall, serves to hold formation pressure in check, and also prevents the walls of the bore from caving or breaking down. Such "mudding off" of the bore during drilling operations maintains the well in a dead condition throughout the drilling operation, with the mud cake and circulating pressure of the mud preventing the inflow of formation gas, oil, or other formation fluids. Normally, the weight or gravity of the mud is maintained at a level such that the hydrostatic head produced by the column of mud in the wellbore will be sufficient to maintain a positive differential back pressure over the expected downhole formation pressure.

It has been found by experiment that not only does the mud cake form about the borehole wall, but also at the bottom of the borehole which is being drilled by the drill bit. Normally, as the bit grinds into the earth formation, the mud is continuously being applied to the bottom of the hole, so that a positive back pressure is maintained against the formation being drilled at all times. Such positive pressure on the formation at the bottom of the borehole is a direct deterrent to the removal and lifting of cuttings from the borehole, with the pressure tending to hold the cuttings down rather than permitting the removal to the surafce with the mud column. Therefore, if by means of such holes made into the bottom of the formation by shaped charges, the mud pressure can be communicated into the formation a balancing of the pressures will occur across the bottom face of the borehole which will neutralize the hold-down pressure of the mud column.

It is evident that the deeper and greater the penetration of the explosive, the greater will be the magnitude of fracturing of the formation, and thus the more effective of the pressure equalization across the formation portions at the bottom of the wellbore.

I is therefore an object of the present invention to provide a new and improved apparatus for enhancing the effectiveness of explosive charges in a drilling operation.

SUMMARY OF THE INVENTION

With this and other objects in view, the present invention contemplates in a drilling system having a drill stem and a bit and provisions for passing a drilling fluid stream through the drill stem and out an eye within the bit. The bit configuration is arranged to provide a surface for reflecting upwardly directed explosive energy emanating from an explosive charge which is detonated just below the eye of the bit between the bit and the formation being drilled. More particularly, the exit end of the opening through the bit has a parabolic-like surface surrounding the opening and facing downwardly towards the formation being penetrated by the drill bit. The parabolic-like surface is such that when an explosive capsule is passed through the eye of the bit and detonated upon impact with the formation therebelow, secondary energy which emanates upwardly from the explosive charge will be reflected from the parabolic-like surface downwardly toward the formation being drilled. In addition, the explosion will momentarily stop the descending mud column in the drill pipe to store energy in the fluid column. As the force from the explosive energy collapses, a water hammer effect is created in the mud column which imparts a force therefrom to the bottom of the borehole after the primary and secondary energy of the explosive charge has fractured the formation material.

A complete understanding of this invention may be had by reference to the following detailed description, when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 2 is an enlarged view of a drill bit embodying principles of the present invention;

FIG. 3 is a bottom view of the bit of FIG. 2;

FIG. 4 is a sectional view illustrating the construction of an explosive capsule; and

FIG. 5 illustrates primary and secondary energy emanating from an explosive capsule in accordance with the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1 of the drawings, portions of a conventional drilling apparatus are shown for practicing the invention. There is illustrated at **12** a hook which is connected to the usual traveling block supported by cables and controlled by the draw-works of a derrick (not shown). A bail **14**, on the hook, supports the conventional swivel **16**, modified only to the extent that its drilling mud entrance opens upwardly and its interior is provided with means for guiding the explosive members as will be shown hereinafter. The swivel is joined at **18** with the usual kelly **20**, passing through the rotary table **22** by which the kelly is driven and supporting the sectional drill stem **24** in conventional fashion. The drill stem terminates in the usual drill collar **28** (FIG. 2). Various conventional parts of the assembly are not indicated, but it will be understood that they are provided as in usual drilling practices. The drill collar **28** carries a bit **30**, which is illustrated as of the multiple cone type, of which one of the cones is indicated at **32**. A jet opening is provided between the cones of the bit at **36**, the hole being drilled is indicated at **26**. The mud flows to the swivel **16** through the flexible hose **46**, the mud being supplied from the usual high-pressure mud pumps which are not shown. The main flow takes place through a connection **50**, but by-pass flow to carry the explosive members into the hose

46, swivel **16**, and the hollow drill stem takes place through the feeding means for explosive members generally indicated at **48**. Such a feeding system is described in greater detail in the aforementioned United States Pat. No. 3,130,797.

A typical explosive member which may be used in conjunction with the present invention is shown in section in FIG. 4. In the particular form illustrated, the explosive member comprises an elongated cylindrical housing **54**, which has one end enclosed by a rounded portion thereof. The interior of the cylindrical housing is hollow, with the lower end having a first diametered portion **56** which forms a stand off space at the lower end of the capsule. A shoulder **57** is formed at the upper end of the first diametered portion. This shoulder supports a liner **60** which in turn maintains the charge in its shaped configuration. The charge is positioned directly above the liner within a second diametered portion **58** of the housing. Positioned directly above the charge in the portion **58** is a primer **61**, having a detonator **63** molded therein. A cap **62** is positioned over the primer **61** and is arranged to be detonated upon impact of a hammer and firing pin assembly **70** with the cap.

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

In the operation of the apparatus described above, when it is desired for various reasons to aid the usual drilling operation so as to increase the rate thereof, an explosive member is introduced into the mud line by means of a device **48**. During the period of introduction of the explosive member, and during its descent to the bottom of the drill stem, the rotary drilling is normally continued, or of course can be interrupted as desired. Continuation of rotation has no adverse significance with respect to the explosive operation. The explosive member passes downwardly within the mud stream as the pumping of mud is continued during the operation. When the member reaches the end of the drill stem, it is directed along with the flowing mud through the eye of the bit whereupon it impacts the bottom of the borehole to be exploded. During its downward descent in the drill stem and also in the flow lines at the surface, the downwardly extending cylindrical portion of the end cap **64** will prevent the charge and firing device from moving upwardly within the housing of the explosive apparatus, so that the explosive members are not inadvertently moved into contact with the firing pin and hammer assembly during acceleration of the device within the drill stem or upon the even greater acceleration due to propulsion through the eye of the drill bit. Thus, premature detonation is prevented by this arrangement of parts. Thereafter, when the explosive member strikes the bottom of the borehole, the firing pin and hammer mechanism **70** is free to continue its downward movement within the space **65** whereupon the inertia of its movement ruptures the firing cap **62** and initiates the detonator **63** within the primer **61** to cause detonation of the jet charge.

The stand off distance which is provided by the space between the lower end of the capsule and the jet charge permits the charge to form into a shape which is conducive to maximum penetration of the formation at the bottom of the well bore. This usual stand off space which is provided has been recognized as desirable in the use of shaped charges. The resulting explosion of the shaped charge will provide a penetration of the formation in the wellbore beneath the rotary bit. For the various reasons described above, this will effect an increase in the drilling rate. While moving through the flow lines in the drill stem, the capsule which is provided with an elongated tail member is prevented from over-turning within the system because of the added length provided by such tail. If the overall length of the apparatus is made greater than that of the diameter of the flow lines and drill stem through which it moves, overturning of the device is virtually impossible.

The apparatus and method described above represents the conventional method of detonating explosives in a wellbore during a drilling operation. Referring next to FIG. 2 of the drawings, an improved drill bit for enhancing the effectiveness of an explosive drilling operation is described. In a conventional drill bit, the jet for passing mud out of the bit is normally several inches away from the formation, and the explosive capsule is transported to the formation in the jet of mud and explodes on impact with the bottom of the borehole. This invention relates to the use of a jet bit whereby one of the cones has been removed from the conventional three-cone bit and a large shank extended downwardly to bring the jet exit closer to the formation being drilled. This type of bit is normally used in directional drilling or "big eye drilling" where mud is jetted out of the bit close to the formation in order to erode away the formation when the bit is not being turned. In directional drilling, such use of the bit erodes away the formation on one side of the borehole to thereby start a deflected hole. Later, when the bit is rotated it follows the eroded spot and causes a change in the direction of the hole.

Referring to FIG. 2, a shank **37** on the bit not having a cone attached thereto may be made of sufficient mass that repeated explosions in the vicinity of the shank will not cause damage sufficient to render the bit inoperative. The lower end of the shank is provided with a concave parabolic surface **38** which communicates with the channel **37** carrying mud from the interior of the drill stem to the exterior of the bit. FIG. 3 shows a bottom view of the bit in FIG. 2 which features the arrangement described above wherein the cones **32** are mounted in semi-opposed positions on the bit with the shank **37** and parabolic surface **38** assuming a position normally occupied by one of the cones in a conventional bit. The other jet openings normally formed in the bit housing are plugged off. The bit of course can be designed with such openings omitted.

The operation of the apparatus described above is best shown with respect to FIG. 5 of the drawings, which illustrates that portion of the bit featuring the parabolic surface just described, and showing in dotted lines the position of an explosive capsule as it would engage the bottom of the borehole and at the instant that it would be detonated. Upon impact with the bottom of the borehole, the device is detonated, and a perforating jet is formed which moves in a downward direction shown by the center arrows in the diagram. This jet will generally create a substantially vertical fissure or

fracture within the formation beneath the charge. During the explosion of such a device, a substantial amount of energy is reacted upwardly away from the downwardly directed jet. This upwardly directed energy will strike the parabolic surface at the end of the shank **37**, and then be reflected downwardly. Such energy reflection will come at a time lag behind the primary energy wave which is directed longitudinally downwardly in the formation. The reflecting surface on the bit is located relative to the bottom of the borehole such that the explosive charge is in the proximity of the focal point of the parabola with respect to the shaped charge and the bottom of the borehole. Actually the charge should be spaced slightly downwardly of the focal point so as to converge reflected energy off of the reflecting surface. Thus, the secondary, reflected energy wave should hit in the vicinity of the edge of the hole which has been made by the penetration of the primary charge. Since the primary charge has already created a fissure at this instant in time, the reflected charge is then able to accomplish greater fracturing because of lateral room available within the formation to receive displaced materials which may be moved by the secondary energy wave.

In addition to the importance of the vertical spacing as described above, the lateral position of impact of the explosive is of consequence. If the eye of the bit is positioned at too large an angle with respect to the vertical axis of the bit, and if the exit of the eye is spaced too far from the bottom of the borehole, the explosive capsule will strike the bottom in the vicinity of the edge of the bottom. It has been found that the rate of drilling is enhanced if the impact zone of the explosive device is spaced laterally inwardly from the outside wall of the hole a sufficient distance to insure that the maximum zone of influence of the explosive is on the bottom of the hole.

In addition to the energy imparted to the formation as a result of the primary and secondary energy waves, the column of mud that is traveling down the drill pipe has, when the explosion occurs, a considerable amount of velocity. At that instant that the explosion takes place, the column of mud is momentarily stopped, and the energy that builds up thereafter from the water hammer effect above the explosion is instantly released into the fractured crater generated by the primary and secondary energy waves at the explosion, thus providing a substantial amount of power or hammering action which is imparted to the formation as a result thereof. It is readily seen that the effect of the charge, including the primary and secondary energy waves together with the hammering effect of the mud column will naturally be greater with an increase in the size of the explosive charge that is used in the apparatus. Additionally, the effectiveness of water hammer phenomena is related to the distance which the exit end of the bit opening is spaced from the bottom of the borehole. A spacing of from 2–5 times the diameter of the bit opening will place the hammer effect close enough to the bottom of the borehole to be effective in imparting energy to the already fractured formation.

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

What is claimed is:

1. A drill bit for use in explosive assisted drilling of boreholes wherein an explosive device is passed within a fluid stream through the bit and explodes upon contact with the bottom of the borehole, including: a housing having cutting means mounted on one end thereof; means for passing fluid into and through said housing; fluid exit means on said housing adjacent said cutting means; and means forming a part of said exit means for maximizing the drilling effect of reflected energy from an explosion occurring near the exit means.

2. The drill bit of claim **1** wherein said maximizing means is a parabolic-like surface which is arranged to reflect upwardly directed explosive energy downwardly in a directed manner to aid primary explosive energy.

3. The drill bit of claim **1** wherein said exit means is comprised of a single external opening on the lower face of the drill bit.

4. The apparatus of claim **2** wherein said parabolic surface is arranged on the bit to be spaced from the borehole bottom when said cutting means are in working contact with the borehole bottom so that when an explosive device is detonated upon contact with the borehole bottom said explosion is just below the focal point of the parabolic surface relative to said explosive device and said borehole bottom.

5. A drill bit for use in boring holes in earth formations, including: a body having means for attaching said body to a string of pipe; cutting means on said body; an opening in said body for passing drilling fluids from the interior of said body outwardly into contact with the earth formations; and a parabolic surface formed about said opening.

6. The apparatus of claim **5** wherein said opening is arranged on the bit so that it is spaced from the bottom of the boreholes a distance of 2–5 times the diameter of the opening when the cutting means of the bit are in working contact with the bottom of the borehole.

7. A method of drilling earth formations including the steps of: suspending an earth boring apparatus, including a drill pipe having a restricted bottom opening, in

a borehole; positioning said earth boring apparatus in the borehole so that the bottom opening is spaced 2–5 diameters of the opening from the bottom of the borehole; passing a drilling fluid through the drill pipe and out such bottom opening in the earth boring apparatus; and passing an explosive device with the drilling fluid through the bottom opening for generating an explosion below such opening upon contact of such explosive device with the borehole bottom.

8. The method of claim **7** and further including reflecting upwardly directed energy from such explosion downwardly into contact with the borehole bottom.

9. The method of claim **7** wherein said earth boring apparatus includes a drill bit having the restricted opening and further includes the step of rotating the drill bit while passing the explosive device with the drilling fluid through.

References Cited

UNITED STATES PATENTS

1,852,843	4/1932	Greve	175—339X
3,022,729	2/1962	Robinson, Jr.	174—4.5X
3,190,372	6/1965	Johnson	175—4.5
3,231,031	1/1966	Blom	175—2X
3,329,222	7/1967	Neilson	175—376X
3,419,092	12/1968	Elenburg	175—339X
3,516,502	6/1970	Bennett et al.	175—4.5

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U.S. Cl. X.R.

175—4.5, 339