RETRIEVABLE REVERSE CIRCULATION PELLET IMPACT DRILL

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FIG.-1

FIG.-2

FIG.-3

FIG.-4

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This invention concerns a novel drilling apparatus for the drilling of bore holes in the earth. The drill of this invention embodies the principles of what has been called “pellet impact drilling” and concerns the manner in which solid pellets are circulated in a bore hole so as to forcibly impinge on the bottom of the hole securing a drilling action. The drill of this invention is particularly intended to control fluid flow so as to direct pellets in an annular area about the axis of the bore hole and so as to return the pellets in an upward path along the axis of the bore hole. The drill of this invention is also advantageous in permitting wire line replacement of operative elements of the drill during drilling operations.

In pellet impact drilling, means are required to secure the effective impingement of hard, dense pellets on the bottom of a bore hole propelled by a high velocity fluid jet. The apparatus required to employ this drilling procedure is fundamentally simple in nature. Tubing connected to fluid pumps at the surface of the earth is extended downwardly into a bore hole for connection to a jet nozzle assembly. As will become apparent, the requisite properties of the tubing employed are considerably less stringent in nature than those controlling selection of tubing in rotary drilling. Thus it is not necessary that the tubing be rotated under high torque, nor that the tubing contribute any substantial weight to the jet nozzle assembly. Consequently, for many applications it is practical to use a flexible hose, and, in any case, lighter weight tubing may be employed than that employed in rotary drilling.

Again, as will become apparent, the fluid to be employed as a propulsive and recirculating agent for the pellets may be selected from a wide range of gases or liquids. In this connection it is not necessary that the fluid possess properties to lubricate a drill bit or to affect the cutting action of a drill bit. Consequently a reasonable flexibility exists in selecting the type of fluid to be employed. Particularly in the case of shallow hole drilling, it is possible to successfully use a gas as a fluid, for example, air. In other cases it becomes desirable to employ liquids which may range in character from ordinary water to drilling fluids of the character conventionally employed in rotary drilling operations. However, as will be emphasized, it is an important requirement of this drilling procedure that the fluid employed have a low density as compared to the pellets employed.

The drilling fluid is pumped from the surface of the earth through the tubing referred to, to a jet nozzle assembly. The jet nozzle is so designed as to convert the available pumping pressure to the form of velocity energy. Thus a substantial pressure drop is imposed on the fluid passing through the jet nozzle so as to cause the fluid to be ejected at a high velocity fluid jet. In this connection, when employing a liquid as the drilling fluid, it is generally preferred that the nozzle employed impose a pressure drop of more than about 100 pounds per square inch on the fluid.

The fluid jet referred to is positioned adjacent the bottom of the bore hole at a spaced distance above the bottom. Pellets of a suitable character are then directed into the fluid jet so as to be entrained in the jet. These pellets are then borne by the jet so as to forcibly impinge against the bottom of the bore hole.

The pellets to be employed must have certain critical characteristics. It has been found that the drilling action obtainable from the impact of pellets is largely controlled by the size of the pellets employed. Thus in the case of very small pellets, relatively little drilling action can be obtained. It is therefore necessary to employ the largest pellets practical dependent upon the size of jet nozzle which may be employed, and the ability of the pellets to withstand fracturing. These limitations require that the pellets to be employed have a size in the general range of about ⅜ of an inch to ⅛ of an inch when employing as gas as the drilling fluid, and about ¼ of an inch to ⅛ inch when employing liquid drilling fluid.

The pellets to be employed must also have a high density. The drilling action depends upon the kinetic energy of the pellets, which in turn is proportional to the density of the pellets. Again, as will be brought out, in order to recirculate the pellets in the manner contemplated by this invention, it is necessary that the pellets rapidly settle from the drilling fluid employed. Since settling rate depends in part upon the density of the pellets, this requirement again dictates use of high density pellets.

The configuration and surface characteristics of the pellets are again critical. It is important that the pellets be substantially spherical in nature and that they have a smooth non-abrasive surface. It is necessary that the pellets be non-abrasive in nature so as to limit wear of the jet nozzle assembly through which the pellets are ejected. The same considerations control the configuration of the pellets since sharp corners or edges of any character would cause undue wear of the jet nozzle. In this connection it is fundamental that a spherical body possesses the best resistance to fracture due to impact.

The critical requirements of the pellets to be employed may be emphasized from a somewhat different viewpoint. In order to secure an effective impact-pulverization effect, pellets entrained in a high velocity fluid jet must separate readily from the fluid so as to depart from fluid circulation paths and so as to overcome any fluid cushioning effect. Again, in the circulation system employed in this invention, rapid settling of pellets from the fluid is required. These factors may be referred to as the “separation characteristics” of the pellets in the fluid employed. The separation characteristics of the pellets in large part depend upon the properties of the pellets which have been emphasized: size, density, smooth surface, and spherical configuration. Inasmuch as the separation characteristics of the pellets depend in part upon the drilling fluid employed, the drilling fluid is preferably a low viscosity, low density fluid consistent with other requirements of the fluid. Practically the pellets must have a density substantially greater than the fluid employed.

Materials which may be used to prepared suitable pellets include iron, steel and other ferrous alloys. Due to the impact resistance required, hardness and toughness are essential and brittle materials cannot be employed. Thus, for example, finished ball bearings have been found to be impractical for use in this invention although ball bearing “blanks” obtained prior to surface hardening are satisfactory. Due to their high density, tungsten carbide alloys of the less brittle character are attractive for use in the pellets to be employed. Alloys of this character or other dense metals, may be employed as a core material, surfaced by ferrous alloys having the requisite toughness.
The principal feature of this invention is the manner in which pellets are entrained and directed in the fluid jet employed. The drill of this invention causes pellets to be outwardly and downwardly directed so as to exert primary drilling action on an annular area about the bottom of a bore hole. The pellets are swept inwardly and upwardly in a return circulation path causing secondary drilling effects to remove the central portion of the bore hole. This pellet circulation principle may be considered to be reverse circulation in the sense that normal circulation would be considered to direct primary drilling forces at the center of the bore hole. It may be appreciated that the reverse circulation pellet direction, obtained as indicated, serves to effectively concentrate the primary drilling action on the outer portion of a bore hole where the greatest volume of material must be removed, per foot of advance of the bit.

The drill of this invention is also particularly advantageous in making practical a wire line retrievable drill arrangement so as to facilitate drilling with casing. It is possible to replace the drill itself as desired without necessity for removing the drill string, casing, or other support from the bore hole.

A preferred embodiment is illustrated in the attached drawings, in which:

Figure 1 illustrates the operative features of the drill in cross-sectional, elevational detail; and

Figure 2 is a fragmental cross-sectional view of Figure 1 taken along the lines 2-2 of Figure 1; and

Figure 3 is a plan view of Figure 2; and finally

Figure 4 is a view of the apparatus of Figure 1 looking upwardly from the bottom of the drill.

The drill illustrated in the drawings essentially constitutes two principal elements. The first element is a tubular support structure identified by the numeral 25 which may be constituted a conventional drill string or a drill casing. Tubular support 25 preferably terminates at its lower end in an outward and downward flare 30. Ports 19 are cut through the tubular support 25. In the particular drill illustrated, immediately above the outwardly flared portion of the tubular support, an inwardly extensive shoulder 14 is provided.

The second principal element of this drill constitutes what may be identified as a body element 2. This body element is adapted to fit within the lower termination of the tubular support 25 so as to seat on the shoulder 14. Seat 26 may be provided on the body so as to effectively maintain the body within the drill string in fluid-tight relation.

The body 2 is provided with particularly designed fluid channels which can be understood by reference to both Figure 1 and Figure 2 since these channels are not symmetrically arranged within the body. A first channel system 3 extends from an upper portion of the body along both sides of the body to communicate with an internal annular cavity identified by numeral 5. Cavity 5 is in fluid communication with the primary nozzles 6 which are spaced about the lower termination of the body so as to direct fluid flow downwardly and outwardly from the axis of the body.

A second fluid channel 28 extends from the lower and central portion of the body upwardly and outwardly to terminate in the passages 4. Passages 4 are positioned at the central portion of the body or near the shoulder 14. Seat 26 may be provided on the body so as to effectively maintain the body within the drill string 25. Fluid passing through ports 4 can therefore flow through the ports 19 by passage through cavity 29.

Beneath the central portion of the body is positioned a central passage or nozzle 10. The passage may be positioned by means of the bars 9 or may be constructed so as to be integral with the body assembly. Return cylinder 10 provides a central passage permitting upflow of fluid along the axis of the drill, as will be described, while forming an annular space defined between the external surface of the cylinder 10 and the flared portion of the tubular support.

With this description and identification of the principal elements of the drill, the manner in which this drill is operated can be understood. In operation a plurality of pellets 31 are placed at the bottom of the bore hole. Drilling mud or other fluid is then forced downwardly through the drill string 25 from the surface of the earth. The drilling fluid enters the fluid channel 28 so as to pass into the cavity 5 for ejection through the primary nozzles 6. The passage of the fluid through these primary nozzles causes the jetting of a high velocity fluid stream from each of the nozzles. This fluid stream is directed downwardly through the secondary nozzle arrangement provided by the annular space 32 between the cylinder 10 and the flared portion of the tubular support. The jetted fluid is therefore directed downwardly and outwardly to contact the walls of the bore hole and to be circulated inwardly and upwardly through the cylinder 10. This fluid flow is effective to pick up and entrain the pellets 31 referred to so that these pellets are forcefully directed against the outer portion of the bore hole for return inwardly and upwardly through the cylinder 10.

The lower termination of the central fluid passage 28 is provided with a blocking element 11 which is perforated by slots 13 so that fluid can pass through channel 28 for exhaust to the bore hole annulus through ports 19. Blocking means 11 is provided to provide passage of the pellets and to deflect these pellets into a return circulation path in the fluid jetted from nozzle 6.

In this manner continuous drilling action can be effectively obtained.

In an operative form of the drill described it is desirable to position a seal 15 about the lower termination of the tubular support 25 so as to prevent fluid flow between the bore hole and the support 25 at this point. This fluid seal serves to ensure the most effective circulation of the drilling fluid as described.

A spearhead 1 or similar device is preferably fixed to the body 2 so that the entire body can be lowered into place or recovered by use of a wire line as desired in order to replace the nozzle elements as wear occurs during drilling.

It is apparent that the drill described is subject to many modifications within the scope of this invention.

What is claimed is:

1. A pellet impact drill comprising in combination a tubular support member including port elements adjacent its lower termination and having an inwardly projecting shoulder member below said port elements, a removable body element adapted to fit within the lower portion of said tubular support member in fluid-sealed relation therewith and laterally adjacent said port elements and being further adapted to rest upon said shoulder member, wireline engaging means attached to said body element whereby a wire line may be attached thereto for raising and lowering said body element, a plurality of primary nozzles positioned at the lower termination and spaced about the axis of the body element directed downwardly and outwardly with respect to the body element, a secondary nozzle positioned around and below said primary nozzles and longitudinally aligned therewith, a first channel in said body element providing fluid communication between the interior of said tubular support member and said primary nozzles, a second channel in the central lower portion of the body element to provide fluid communication from below said body element to said port elements, a passageway interconnecting said second channel with the interior of said tubular support member and said secondary nozzles, and said body element being characterized by having pellet-blocking means therein adapted to deflect any pellets flowing threethrough into said secondary nozzle and a return nozzle supported within said secondary nozzle and establishing fluid communication from the exterior of said secondary nozzle to said passageway.
2. The drill defined by claim 1 including an outwardly and upwardly extending seal member fixed about the external termination of the tubular support and below said port elements.

3. A pellet impact drill comprising in combination a tubular support member including port elements adjacent its lower termination and having an inwardly and upwardly projecting shoulder member below said port elements, a removable body element adapted to fit within the lower portion of said tubular support in fluid-sealed relation therewith and laterally adjacent said port elements and being of a character to be supported by said shoulder member, wire-line engaging means attached to said body element whereby a wire line may be attached thereto for raising and lowering said body element, a plurality of primary nozzles positioned at the lower termination and spaced about the axis of the body element and directed downwardly and outwardly with respect to said body element, a secondary nozzle constituting an annular opening positioned around and below said primary nozzles in longitudinally aligned relation therewith, a first channel in said body element providing fluid communication between the interior of said tubular support and said primary nozzles, a second channel in the central lower portion of said body element to provide fluid communication from below said body element to said port elements, a return nozzle supported within said secondary nozzle, a passageway interconnecting said second channel with the entrance to said secondary nozzle and said return nozzle with said passageway being characterized by having pellet-blocking means therein and of a character to deflect any pellets flowing therethrough into said secondary nozzle.

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