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PELLET RETENTION METHOD AND APPARATUS FOR PELLET IMPACT DRILLING

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3 Sheets-Sheet 1

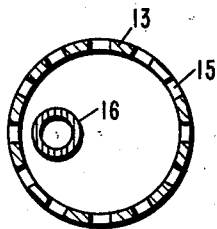


FIG.-2

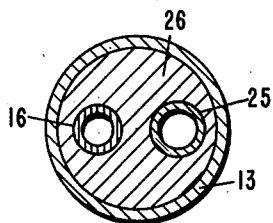


FIG.-3

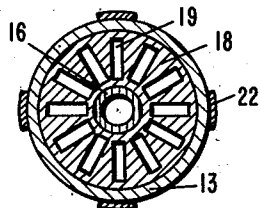


FIG.-4

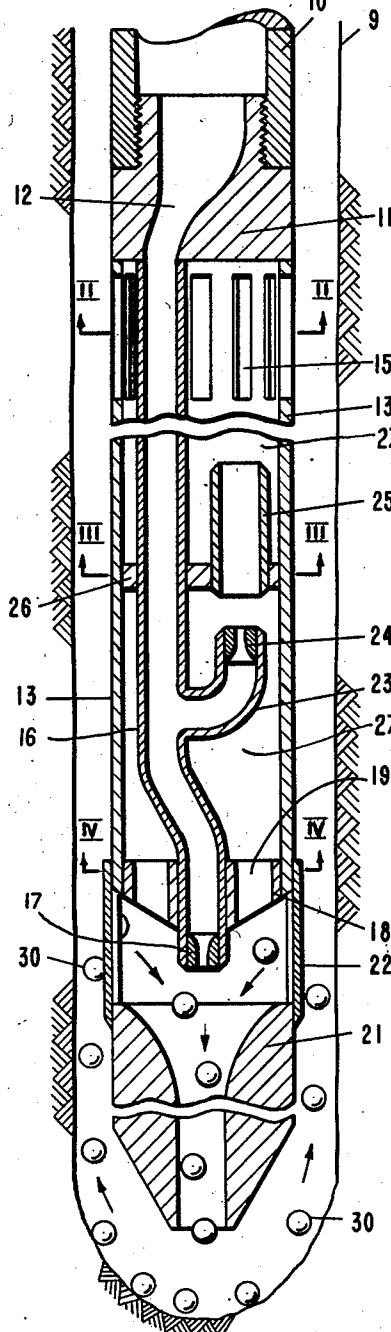


FIG.-1

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3 Sheets-Sheet 3

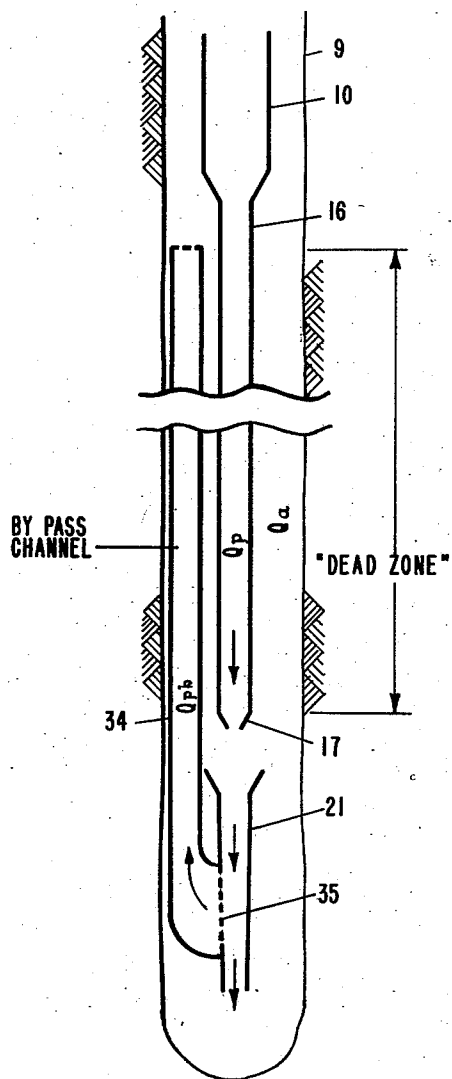


FIG. -7

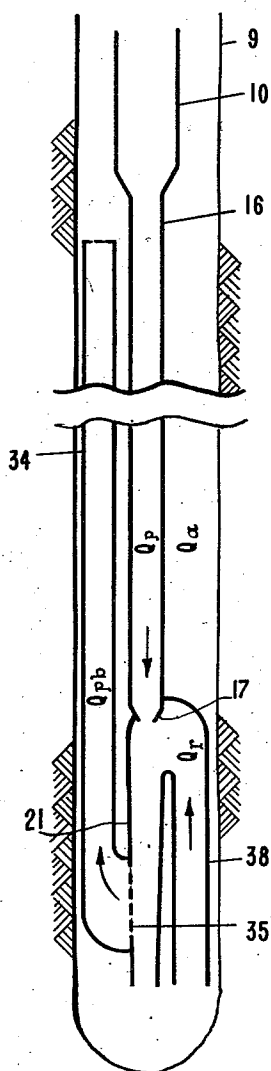


FIG. -8

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2,815,931

PELLET RETENTION METHOD AND APPARATUS FOR PELLET IMPACT DRILLING

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Application April 1, 1954, Serial No. 420,348

6 Claims. (Cl. 255—1.8)

The present invention relates to improved methods and apparatus for drilling boreholes in the earth by what may be described as pellet impact drilling. In particular the invention is directed to a novel means and method for controlling the circulation of pellets and drilling fluid in a bore hole so as to maintain the pellets in the vicinity of the drilling apparatus at the bottom of the bore hole. In accordance with this invention a portion of the returning stream of drilling fluid is directed through a by-pass channel that is inaccessible to the pellets so that the velocity of the remaining fluid stream is considerably reduced and the pellets are thereby prevented from being carried up the bore hole annulus away from the vicinity of the drill bit.

The basic principles of the pellet impact technique for the drilling of bore holes in the earth involve the use of a stream of fluid pumped from the surface of the earth through a tubular member to a nozzle adapted to provide a high velocity jet of fluid directed downwardly toward the bottom of the bore hole. Means are provided to entrain in the high velocity fluid jet a multitude of hard, dense pellets which are accelerated to high velocity in the jet stream and thereby acquire considerable kinetic energy so that when the pellets impinge against the formation the resulting impact and fracturing forces exert a drilling action. Means are also provided for separating pellets from the upflowing returning stream of fluid and reintroducing the pellets into the jet stream. Preferably the pellets that are employed are smooth, non-abrasive, essentially spherical, and of substantial size, in the range of about one-eighth inch to about one inch or so in diameter. The basic principles of the technique of drilling by pellet impact are set forth in co-pending application Serial No. 268,873, filed by Philip S. Williams on January 29, 1952, and now abandoned, and entitled "Pellet Impact Drilling Method and Apparatus."

In drilling bore holes by the pellet impact technique it is generally desirable to employ an assembly of a primary and a secondary nozzle. The primary nozzle serves to convert the pressure of the circulating fluid to velocity energy by subjecting the fluid to a substantial pressure drop through the primary nozzle so as to provide a constricted high velocity jet of fluid. A secondary nozzle is positioned directly below and concentric with the primary nozzle and the high velocity jet is directed into the secondary nozzle. In order to accommodate the total volume of fluid from the primary nozzle as well as the volume of pellets and recycle fluid that are admixed with the primary fluid in the secondary nozzle, it is necessary that the secondary nozzle have a substantially greater diameter than the primary nozzle. This configuration and arrangement of primary and secondary nozzles by its nature creates an aspirating effect which plays some part in the proper recirculation of the pellets. This pellet recirculation is also aided by the fact that the secondary nozzle, having a larger exterior diameter than

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the primary nozzle, defines with the bore hole wall an annular channel that is more confined than the annular channel about the primary nozzle. Thus the drilling fluid in travelling up the bore hole annulus will have a relatively high linear velocity adjacent the secondary nozzle and it will have a lower linear velocity as it reaches the vicinity of the primary nozzle. Thus with the proper rate of fluid circulation the fluid will carry pellets up the annulus about the secondary nozzle but will permit the pellets to settle out and re-enter the secondary nozzle by force of gravity as the fluid velocity decreases when the vicinity of the primary nozzle is reached. Thus effective recirculation of pellets in a pellet impact drill bit of the type disclosed in the aforementioned Williams application is brought about by a combination of gravity and aspiration forces.

In a pellet drilling bit of the type described where pellet recirculation depends on the combination of gravity and aspiration effects the upper limit of net fluid flow through the bore hole, that is down through the drill string and up through the bore hole annulus, is reached when the upward flow of fluid past the several feet of drill pipe and associated structure above the top of the secondary nozzle is sufficient to carry the pellets to the top of that zone, since when the pellets reach the top of that zone they will then go into a region of smaller annulus area and hence of even greater fluid velocity and will not be available for drilling purposes since they cannot again enter the secondary nozzle. This phenomenon is known as "wash-over." Thus the "gravity aspirator" bit of the type disclosed in the aforementioned application presents a limitation that may be undesirable since in some instances the rate of fluid flow necessary to keep the bore hole open may be greater than that permissible to keep the pellets in the vicinity of the secondary nozzle entrance.

It is an object of the present invention to provide for a greater velocity contrast of fluid flow above the secondary nozzle entrance as compared to annular fluid flow below the secondary nozzle entrance than can be obtained with the prior configuration of primary and secondary nozzles so that the pellets will not be carried up the bore hole annulus any appreciable distance above the secondary nozzle entrance. In accordance with the present invention a by-pass channel, inaccessible to pellets, is provided that extends to a zone in the bore hole annulus an appreciable distance above the secondary nozzle entrance so that a large portion of the returning fluid will flow through this by-pass channel and very appreciably lower the velocity of the remaining fluid in the bore hole annulus and thereby limit the pellet carrying capacity of the fluid in the annular region between that zone and the secondary nozzle entrance.

The nature and objects of the invention and the advantages obtained by the method and apparatus of the invention will be more fully appreciated when reference is made to the ensuing description and the accompanying drawings in which:

Figure 1 is a sectional elevation of one embodiment of the invention shown in drilling position in a bore hole;

Figure 2 is a sectional view taken on line II—II of Figure 1;

Figure 3 is a sectional view taken on line III—III of Figure 1;

Figure 4 is a sectional view taken on line IV—IV of Figure 1;

Figure 5 is a schematic diagram of the embodiment of Figure 1;

Figure 6 is a schematic diagram of an alternate embodiment of the invention;

Figure 7 is a schematic diagram of a second alternative embodiment of the invention; and

Figure 8 is a schematic diagram of a fourth embodiment of the invention.

Referring specifically to Figure 1 one embodiment of the invention is shown in drilling position in the bore hole 9. The apparatus is suspended from a conventional drill string 10 the lower portion of which is shown. The uppermost portion of the apparatus consists of a support member that threadably attaches to the drill string. This support member comprises a plug element 11 having a central passage that communicates with the interior of the drill string and terminates in a throat 12. Depending from and attached to the plug member is a cylindrical housing 13 having at its upper end a slotted section provided with a plurality of circumferentially distributed slots 15. The lower end of housing 13 is blocked off by a deflector 18 having a plurality of vertical slots 19 and centrally receiving the lower end of a tube 16 positioned within the housing 13. The upper end of the bore of tube 16 mates with the throat 12 in sealing relation as shown. The lower end of the tube 16 terminates in a primary nozzle 17.

Positioned below the primary nozzle 17 and supported from the housing 13 by suitable means such as the straps 22 is a secondary nozzle element 21. The latter nozzle is of substantially greater internal diameter than the primary nozzle and is preferably elongated so as to ensure the effective entrainment and acceleration of pellets in the fluid stream that passes from the primary nozzle into the secondary nozzle. Preferably at least three of the straps 22 are employed equally spaced about the circumference of the housing 13 in order that the secondary nozzle will be supported with sufficient rigidity. If desired extensions may be fastened to the lower end of secondary nozzle 21 for positive off bottom spacing in the manner disclosed in application Serial No. 268,873.

Positioned within the housing 13 and connected to the tube 16 is an upwardly directed branch tube 23 that terminates in an auxiliary primary nozzle 24. Supported above the auxiliary primary nozzle within the housing is an auxiliary secondary nozzle 25, a baffle 26 being also positioned within the housing intermediate the ends of the auxiliary secondary nozzle so that all of the fluid that moves upwardly within the housing will be directed through the auxiliary secondary nozzle. The baffle also serves as suitable support means for the auxiliary secondary nozzle.

In operation the drilling apparatus described performs in essentially the same manner as the drilling apparatus described in the aforementioned application Serial No. 268,873. Drilling fluid pumped down through the drill string passes through primary nozzle 17 and is directed into secondary nozzle 21. The fluid leaves the primary nozzle in the form of a high velocity jet stream and combines with aspirated fluid entering the secondary nozzle from the bore hole annulus adjacent the secondary nozzle and with pellets 30 that enter the top of the secondary nozzle. The pellets that are accelerated and entrained in the fluid while passing through the secondary nozzle will strike the bottom of the bore hole and exert a drilling action and will then be forced outwardly and upwardly through the bore hole annulus along with the returning stream of drilling fluid and formation particles. The pellets will be drawn back into the top of the secondary nozzle and again entrained in the down-flowing stream of fluid.

A portion of the fluid flowing from the drill string through the tube 16 will be diverted through the auxiliary primary nozzle 24 and will be directed into the auxiliary secondary nozzle 25, thereby exerting a jet pump action which will direct a portion of the returning stream of fluid through the slots 19 in the deflector 18. These slots are sufficiently narrow that pellets will not pass therethrough.

The up-flowing fluid will leave the housing 13 through the slots 15.

The purpose served by the fluid stream that is diverted through the by-pass channel 27 in housing 13 will be more fully appreciated when reference is made to Figure 5 which is a schematic diagram of the structure shown in Figure 1. The fluid flow per unit of time from the pumps at the earth's surface that passes down through the drill string consists of a primary drilling jet supply, Q_p plus a by-pass jet supply Q_b . The by-pass jet of fluid causes aspiration of a portion Q_{pb} of the up-flowing primary fluid stream into the by-pass channel 27. The amount of fluid flowing through the secondary nozzle in a unit of time will be the sum of the primary fluid and the recycle fluid that is aspirated into the secondary nozzle, i. e. $Q_p + Q_r$. The nozzles can be so designed that essentially all of the returning fluid stream will be by-passed through the by-pass channel, in other words so that Q_{pb} will be equal to Q_p . The result will be that the net flow of fluid in the bore hole annulus between the bottom and top of the by-pass channel 27, i. e. Q_a , will be zero. Thus the annular space in the bore hole between the bottom and top of the housing can be considered a dead zone and no pellets will be carried into this annular space. If the by-pass flow Q_{pb} is reduced to some extent the annular flow Q_a will be slowly upward. As long as Q_a is kept at a sufficiently low value that it will not effectively lift pellets through the so-called dead zone some reduction in the amount of fluid that needs to be pumped down through the drill string can be effected. If the auxiliary primary nozzle 24 is so designed that it will aspirate a quantity of fluid Q_{pb} that is greater than the primary fluid flow Q_p the annular flow Q_a will be downward. Although this will increase the pump load it has the advantage of ensuring that the pellets will always tend to be forced down into the secondary nozzle and also of forcing the formation cuttings to be recycled through the secondary nozzle until they are small enough to pass through the slots 19 of the deflector, thereby minimizing the chance of plugging those slots. It will be noted from Figure 1 that with the deflector 18 in the position shown the pellets will tend to bombard the deflector and keep it free of cuttings, thereby minimizing plugging.

A schematic diagram of an alternative embodiment of the invention is shown in Figure 6. In this embodiment no auxiliary primary nozzle is employed. Instead a shroud 31 is positioned below the primary nozzle to divert a part of the jet stream from the primary nozzle into a by-pass channel 32 so as to cause aspiration of the by-pass stream Q_{pb} through slots in a deflector member 33. In order that a portion of the jet stream will be diverted into channel 32 it is only necessary that the outlet 40 in the deflector member be sufficiently small that the outer periphery of the jet stream will impinge on the edge of the outlet. It will be seen that the operating principle involved in this embodiment is essentially the same as that in the embodiment of Figure 1.

In Figure 7 is shown a schematic diagram of a second alternative embodiment of the invention. In this embodiment a by-pass tube 34 communicates with an opening in the secondary nozzle so as to divert through the by-pass channel a quantity Q_{pb} of the combined primary and recycle streams. A perforated baffle 35 positioned in the opening to the secondary nozzle prevents entry of pellets into the by-pass channel. This opening should be near the lower, high pressure end of the secondary nozzle. To produce the desired diversion of fluid through the by-pass channel it may be necessary to reduce the diameter of the secondary nozzle 21 gradually but uniformly from top to bottom, rather than to have the nozzle truly cylindrical, in order to present a slight restriction in fluid flow through the nozzle.

A schematic diagram of still another embodiment, similar in principle to that of Figure 7, is shown in Figure 8. In this embodiment the by-pass tube 34 is positioned as

in Figure 7 and in addition a pellet return conductor tube 38 is provided through which all of the recycle fluid Q_r and the recycled pellets are carried back into the top of the secondary nozzle. This embodiment has the advantage of more positively keeping the pellets in the vicinity of the drilling zone. For proper operation of this embodiment the by-pass flow must be such that Q_a is downward in order to keep the pellets in the drilling zone.

This invention provides a method and apparatus for retaining pellets in the vicinity of a pellet impact bit by providing an upward by-pass flow of return fluid so that the remaining fluid velocity in the bore hole annulus is too low to lift pellets upwardly in the annulus beyond the recycling zone. The invention has two principal advantages: first, having balanced out the annulus flow in a section above the drilling zone, it makes no difference what the annulus area is, so that hole enlargements and constrictions have no effect on pellet behavior as far as wash-over is concerned; second, pellets can pass downward through this zone without restriction.

The scope of the invention is defined by the following claims and is not to be limited merely to the specific embodiments hereinbefore described by way of example.

What is claimed is:

1. A method of drilling a bore hole in the earth comprising the steps of circulating a quantity of fluid downwardly through the bore hole in a central channel and upwardly through an annular channel, converting at least a portion of the downflowing fluid into a high velocity jet, directing said jet against the formation to be drilled, introducing into and entraining in said fluid jet a plurality of essentially spherical pellets of substantial size whereby said pellets are impinged against the formation, circulating at least a portion of the upflowing fluid and said pellets, after impact, upwardly in a restricted channel to a re-entry zone, directing said pellets from said re-entry zone into said fluid jet, and reducing the velocity of upward flow of fluid in said annular channel in a region extending from the vicinity of said re-entry zone to a selected point above said re-entry zone by diverting a portion of the total fluid flowing upwardly out of said bore hole through a by-pass channel leading from a zone in the vicinity of said re-entry zone to said selected point in said annular channel.

2. An apparatus for drilling bore holes in the earth by entraining pellets in a high velocity stream of fluid which comprises a support member adapted to be positioned in a bore hole in a manner defining an annular space therewith, said support member having a vertically extending fluid passage terminating at its lower end in a nozzle adapted to provide a downwardly directed high velocity jet of fluid, a tubular member positioned below and supported by said support member in a manner positioning the bore of said tubular member in substantial alignment with said nozzle while maintaining a pellet entry opening sufficiently large to permit the passage of pellets into the top of said bore, and a by-pass channel

in the apparatus extending from the vicinity of the pellet entry opening to a region exterior of the apparatus a selected distance above said pellet entry opening, whereby a portion of a stream of fluid normally flowing upwardly in the bore hole annulus when the apparatus is in use will be diverted through said by-pass channel.

3. Apparatus as defined by claim 2 wherein the lower end of said by-pass channel terminates within the bore of said tubular member.

4. Apparatus as defined by claim 3 including a pellet return conduit extending from a region adjacent the lower end of said tubular member and terminating in said pellet entry opening.

5. An apparatus for drilling a bore hole in the earth by entraining pellets in a high velocity stream of fluid which comprises a support member attachable to the lower end of a drill string, said support member having a passage for fluid therewithin communicating with the interior of said drill string, a downwardly directed primary nozzle connected to the lower end of said passage, an open-ended secondary nozzle of larger diameter than said primary nozzle supported by and positioned below said support member in a manner substantially aligning the bore of said secondary nozzle with said primary nozzle while maintaining an opening for pellet entry into the top of said bore, a by-pass conduit held by said support member and having a lower opening terminating exteriorly of said support member in the vicinity of said pellet entry opening and an upper opening terminating exteriorly of said support member a selected distance above said lower opening, an upwardly directed primary nozzle positioned within said by-pass conduit and a conduit connecting said last named nozzle with said fluid passage within said support member.

6. A method of drilling a bore hole in the earth comprising the steps of circulating a fluid within a bore hole by passing the fluid downwardly through a central channel and upwardly through an annular channel in the bore hole, converting at least a portion of the down flowing fluid into a high velocity jet, directing the jet against a formation underlying the bore hole, introducing and entraining within said jet a plurality of essentially spherical pellets of substantial size and thereby impinging the pellets against the formation, recirculating into the jet the impinged pellets together with a portion of the fluid flowing upwardly in the annular channel from the formation, reducing the velocity of the non-recirculated fluid in said annular channel by bypassing at least part of the non-recirculated fluid from a point in the vicinity of the jet to a second point in the annular channel vertically above and spaced from the fluid jet.

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