

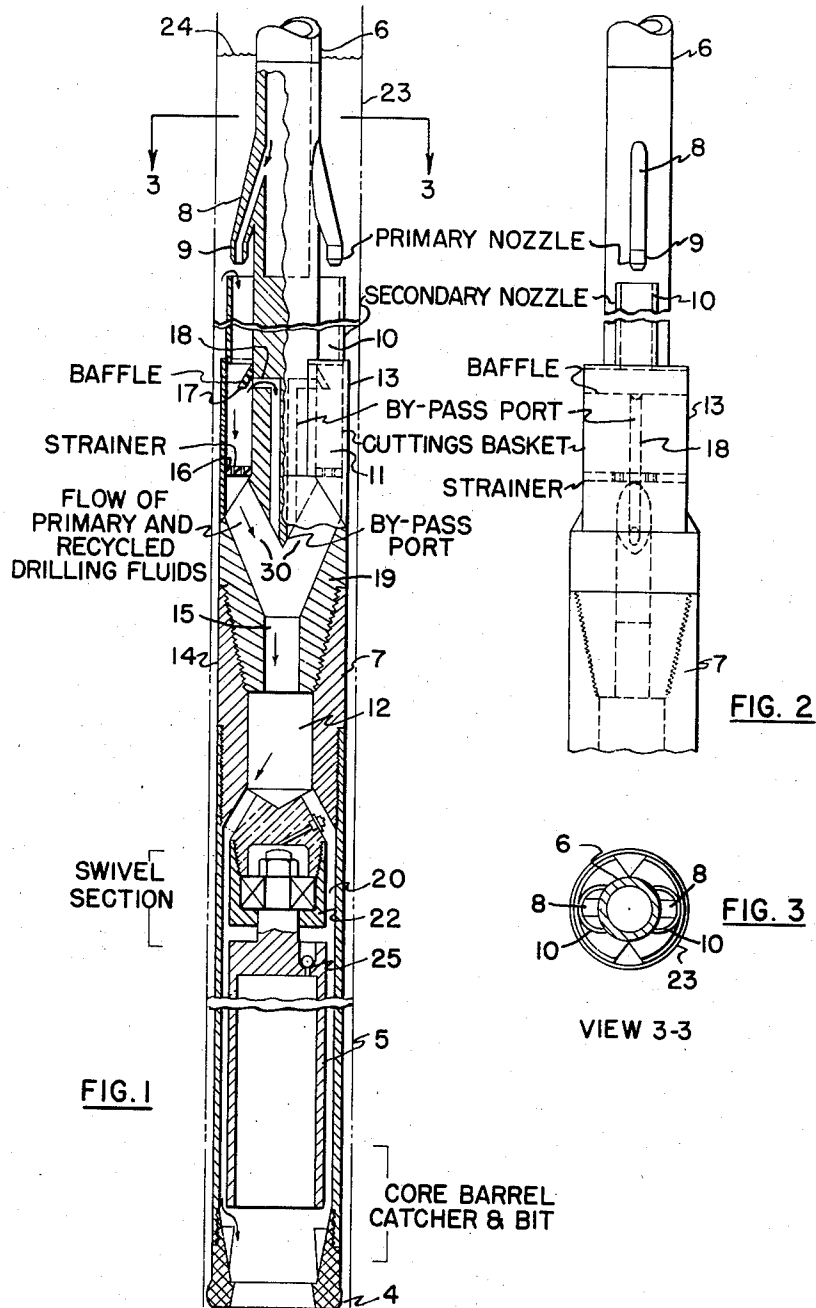
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METHOD OF DRILLING

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METHOD OF DRILLING

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The present invention is generally concerned with the sampling of underground formations. The invention particularly relates to means for obtaining samples of earth substrata from the bottoms of well bores that have been drilled through the earth's crust in an effort to reach petroleum accumulations. It is especially directed toward means for obtaining core samples from rotary drilling operations wherein the samples are substantially uncontaminated by the drilling muds that are conventionally employed in such operations. The invention has particular application to the obtaining of uncontaminated core samples from subterranean formations that are characterized by low formation pressures.

In the field of geology it is desirable to obtain samples of subterranean earth formations for the purpose of ascertaining the nature and structure of the formations. This is particularly true in petroleum geology where detailed information concerning the earth's substrata is a vital factor in the search for oil. Here data relative to the age of a particular formation, its porosity, fluid content, oil content, permeability, lithology, etc. are obtained from core samples which in turn are obtained from the bottom of a well bore that has penetrated the formation.

Core samples in a rotary-type oil well drilling operation are generally obtained by the use of a drilling apparatus that utilizes special coring bits. Such bits are connected to the lower end of a conventional drill string, and the string and bit are then rotated to cut a cylindrical-shaped core sample in the bottom of the bore hole. The sample, as it is cut, is forced up within a core barrel; and when the sampling operation has been completed, the bit along with the core barrel and the core sample are withdrawn from the bore hole.

During the coring operation, the bore hole is conventionally filled with drilling mud which is continuously circulated from the earth's surface to the bottom of the bore hole and thence back to the earth's surface. The mud serves several functions such as to remove any cuttings from the bore hole, to lubricate the bit and to provide a hydrostatic head within the hole.

While the use of drilling mud offers many advantages, its presence during coring operations often occasions difficulties that seriously interfere with the operation. For example the hydrostatic head of the drilling mud very often contaminates the core sample, since it tends to drive the drilling mud directly into the sample and to displace connate fluids from the sample. Furthermore, the head of drilling mud also tends to cause the mud to penetrate the pores of some of the oil reservoir formations and may even flood these formations to such an extent that oil in the formations remains undetected. This is especially true when the formations are low pressure ones and are characterized by pressures less than the hydrostatic head of drilling mud which extends throughout the length of the bore hole.

In view of the aforementioned difficulties that have been encountered in coring bore holes in rotary drilling

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operations, it is an objective of the present invention to circumvent these difficulties. Thus, it is a particular object of the invention to afford means for reducing the degree of contamination which presently characterizes many core samples that are obtained in rotary drilling operations. It is further a particular object of the invention to reduce the contamination of core samples as it is presently occasioned by the presence of extensive columns of drilling mud.

These and other objects are realized in accordance with the invention by employing a coring technique which is characterized by the utilization of a two-fluid drilling mud system. This system is further preferably characterized by possessing relatively high viscosities and relatively low densities. The coring operation is additionally marked by the use of a greatly reduced amount of drilling mud in comparison with presently conventional practice.

In a process embodiment, the invention may broadly be described as a rotary coring operation wherein a relatively small head of drilling mud is present in the bore hole and is recirculated in the immediate vicinity of the coring bit. The recirculation of the mud is achieved by passing a stream of a gasiform fluid to a point below the surface of the drilling mud and there passing it through an eductor adapted to direct the drilling mud and the gasiform fluid toward the bottom of the bore hole. The gasiform fluid thus simultaneously circulates and aerates the drilling mud; and it not only retains the advantages that characterize the use of the mud but also affords additional ones. The additional advantages result from the fact that the gasiform fluid by aerating the drilling mud is considered to effectually reduce its density and its head without materially affecting its effective viscosity. Thus, it is possible to employ highly viscous muds for coring operations and yet retain good conditions of mud fluidity and circulation rate. This feature is an important one since the more viscous the drilling mud is, the less the core sample is likely to experience contamination.

In an apparatus embodiment, the invention comprises a jet pump unit and associated conduits for insertion within a conventional coring apparatus between the core barrel unit and the drill string. The jet pump unit cooperates with the conventional parts to provide new and valuable features.

The invention may be best presented and described by reference to the drawings that accompany this description.

Figure 1 illustrates in a vertical, partial cross-sectional view an embodiment of the invention which is contemplated to constitute the best mode for realizing the objectives of the invention.

Figure 2 is a side view of an upper portion of the apparatus that is illustrated in Figure 1.

Figure 3 is a top sectional view of the apparatus of Figure 1 as taken along the lines 3—3 of Figure 1.

Turning now to the figures, it may be seen that the apparatus illustrated there includes a conventional coring bit 4, core barrel 5 and drill string 6 in addition to a jet pump section 7 which cooperates with the aforementioned conventional members to provide the desired objectives.

The jet pump section 7 includes one or more conduits 8; one or more primary nozzles 9; one or more secondary nozzles 10 each of which is in substantially vertical alignment with a corresponding primary nozzle; baskets 11; and conduit means 12 which provides a continuous fluid passageway from the exit end of each one of the secondary nozzles to the bottom of the bore hole in the immediate vicinity of the coring bit.

As particularly illustrated in Figure 1 the jet pump

section 7 consists of an upper body portion 13 and a lower body portion 14 which are connected together by suitable means such as threaded, welded or flanged joints. The upper body portion 13 includes a central body member 19, conduits 8, primary nozzles 9, secondary nozzles 10, baskets 11, baffles 17, strainers 16, by-pass passageway 18, branch conduits 30, and common conduit 15. The lower body portion 14 contains conduit 12 which transmits liquid from the upper body portion to the core barrel and the coring bit.

The jet nozzles 9 are positioned at the very top of the upper body portion and are secured to the central body member 19. They are vertically disposed and are supported in the annular space between the outer surface of the upper body portion and the inner surface of the bore hole. Two such primary jet nozzles are indicated in the figure, but it will be appreciated that more than this number may be readily incorporated within the apparatus as desired.

Each one of the primary nozzles 9 is arranged to convey gasiform fluid from within the drill string 6 and to direct this fluid in a vertically downward direction. The discharge end of each primary nozzle is additionally positioned in vertically spaced relation with the entrance to a secondary nozzle 10. As in the case of the primary nozzles, the secondary nozzles are supported from central body member 19; and they are also vertically disposed and are positioned within the annular space between the upper body portion 13 and the inner surface of the bore hole. The secondary nozzles 10 discharge at their lower ends into baskets 11. The discharged fluid then passes into a common conduit 15 through branch conduits 30 and empties into the upper portion of conduit 12. Spaced from the discharge end of each secondary nozzle and forming the bottom of basket 11 is a strainer 16 or other perforated member which is adapted to remove solid particles from the fluid stream as it flows through the secondary nozzles. Each strainer 16 and basket 11 is supported from the central body member 19.

Also spaced from each one of the secondary nozzles 10 is an angularly disposed baffle or deflector member 17 which is secured to the wall surface of central body member 19 and inclined angularly downward. Immediately below each such baffle 17 is a fluid passageway 18 formed in central body member 19 which constitutes a bypass around each strainer 16. The baffle and bypass combination is preferably included in the jet pump section in order to maintain fluid flows through the section in the event that the strainer 16 becomes plugged. The baffle members provide a change in flow direction for the fluid sufficient to divert any solid particles into the baskets 11. The baskets lie vertically intermediate the baffles and the strainers. The solid particles referred to here are cuttings and the like.

It has been mentioned above that each one of the secondary nozzles 10 discharges via a basket 11, strainer 16 and branch conduit 30 into a common conduit 15. The conduit 15 in turn discharges through conduit 12 into an annular conduit 20 which extends down and around the core barrel 5 and thence discharges at the bottom of the bore hole in the immediate vicinity of the coring bit 4.

Core barrel 5 may be a conventional core barrel and may be attached in a conventional manner as by means of a swivel section 22 to the lower body portion 14 of the jet pump section 7.

Having described the structural features in the figures, attention is now directed toward the manner in which this apparatus should be operated in accordance with the present invention. To begin with the apparatus is assembled at the top of the bore hole 23 and is then lowered to the bottom of the hole. At this time the amount of drilling mud within the bore hole is ad-

justed such that its upper level 24 is just slightly above the discharge ends of the primary nozzle 8.

At this point two operations are initiated substantially simultaneously. First, the entire apparatus is rotated in a conventional manner so that the cutting surfaces of the coring bit 4 are driven into the bottom of the hole. Second, a gasiform fluid such as air, methane, ethane, natural gas, etc. is passed downward through drill string 6 and thence through each one of the primary nozzles 8. In the description that follows it will be assumed that the gasiform fluid is air.

In discharging from the primary nozzles, the air educes drilling mud from within the bore hole, and both the air and the drilling mud then pass vertically downward through the secondary nozzles 10. In passing through the secondary nozzles, the air and drilling mud become thoroughly mixed with the result that an aerated fluid consisting of air and mud is formed.

The aerated mud flows downwardly through each one of the secondary nozzles, passes through the strainers 16 and ultimately to the bottom of the bore hole. In the latter location the aerated mud picks up any cuttings or other solid particles and conveys them upwardly through the annular passageway between the overall apparatus and the bore hole back up to the level of the primary nozzles. At this point the air is disengaged from the liquid mud and solid particles and flows back to the atmosphere through the annular space between the drill string 6 and the wall of the bore hole. It will be noted at this point that the level of drilling mud within the bore hole will ordinarily be substantially raised due to the increase in volume that it experiences as a result of its aeration.

Upon being recirculated to the level of the primary nozzles, the drilling mud is once more educted or aspirated by the down flowing air issuing from each one of the primary nozzles and is recycled through the same fluid path. Any solid particles are trapped within the baskets by the strainers 16, and solid-free aerated mud is therefore always available at the bottom of the bore hole. If the strainers become plugged, the down flowing mud is disengaged from solid particles by the baffles 17; and the solid-free mud then flows through the bypass passageway 18 into the conduit member 15.

As the operation continues, a core sample is gradually forced up within core barrel 5. Any fluid within the core barrel is released therefrom as by means of a ball check valve 25 which discharges any such fluid into the annular conduit 20 which lies outside the core barrel.

The coring operation is continued until the desired amount of sample has been collected within the core barrel 5. At this point the sample and the entire apparatus are withdrawn from the bore hole in a conventional manner. The core sample is then handled in any manner desired for obtaining analytical data and information concerning the formation sampled.

In describing the operation of the present invention, air has been assumed to be the gasiform fluid that is sent to the bottom of the bore hole through the drill string 6. It will be noted, however, that a number of such fluids may also be used. For example, light hydrocarbon gases of a type that are usually found in co-existence with petroleum are especially suitable. Such gases include natural gas, methane, ethane and the like. In general the fluid need be characterized by being gaseous under the prevailing conditions and chemically inert toward the mud and oil. Nitrogen and the other inert gases are therefore also suitable.

In so far as the choice of a drilling mud is concerned, it will be noted that any conventional hydrocarbon-base or aqua-base mud may be used. The best operation, however, is obtained by employing drilling muds that are characterized by a relatively high viscosity and low density. Conventional muds may have densities

from about 70 to 100 or more lbs./cu. ft., but lower densities than these are now possible by the use of synthetic lubricants which have densities less than that of water. Typical of these lubricants are polyalkylene glycol, polypropylene oxide ether, polybutene, polyalkylene oxide, etc. The viscosities of conventional muds may range from about 5 to 30 or more centipoises.

It will be understood that the present invention is not to be limited in its scope to the particular specific examples that have been presented in this description. A number of modifications and variations may be employed without materially changing or altering the invention. Thus, any type of conventional coring bits or core barrels may be employed, and the arrangement of the nozzles and fluid passageways may be altered to meet particular conditions. For example, it may be desirable with some drilling muds to vary the vertical spacing between the discharge ends of the primary nozzles and the entrance ends of the secondary nozzles. Furthermore, the arrangement and location of the strainers, the bypass passageways and the like may be altered or changed slightly as desired.

It will be further understood that, while the present description has been directed toward a procedure wherein the height of drilling mud in a bore hole is positioned just above the height of the discharge ends of the primary nozzles, the height of the mud may be extended above this level where it is necessary to counteract relatively high subterranean formation pressures. In general, however, it is desirable to maintain the height of the drilling mud such that the hydrostatic pressure exerted by this height of mud is just slightly greater than the formation pressure in order that mud contamination and penetration of the well formations are minimized. In this connection, it will be appreciated that in conventional drilling operations the drilling mud in a bore hole extends completely throughout the hole. This height of mud is therefore preferably reduced in accordance with the present invention by bailing or otherwise removing some of the drilling mud down to the height of mud desired for the coring operation.

What is claimed is:

1. In a process for drilling a borehole wherein a drilling tool having a longitudinal passageway therein is actuated at the lower end of a string of drill pipe and a stream of gasiform drilling fluid is circulated down through the drill string and up through the annulus between the drill string and the wall of the borehole, the improvement which comprises filling the bottom of the borehole with a drilling mud to a height such that the hydrostatic head of the mud is slightly greater than the pressures of the surrounding formations, and jetting the downflowing stream of gasiform fluid into the mud which educts mud into the longitudinal passage of the drilling tool so as to circulate and aerate the mud within the drilling tool and the bottom of the borehole.

2. In a method of drilling a borehole wherein a drilling tool having a longitudinal passageway therethrough is actuated at the lower end of a string of drill pipe and a stream of gasiform drilling fluid is circulated down through the drill string and up through the annulus between the drill string and the wall of the borehole, the improvement which comprises filling the bottom of the borehole with a drilling mud to a height such that the head of the drilling mud is slightly greater than that of the pressures within the formations surrounding the borehole, educting mud into the drilling tool by the downflowing stream of gasiform drilling fluid so as to circulate and aerate said mud, and removing cuttings from the circulating mud.

3. A method as defined in claim 2 with the further improvement wherein the cuttings are removed from the circulating mud by straining the down flowing aerated mud within said drilling tool.

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