

[54] **METHOD AND APPARATUS FOR
ISOLATING THE BOTTOM OF A
BOREHOLE FROM AN UPPER
FORMATION**

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175/92; 173/59, 63, 73, 60

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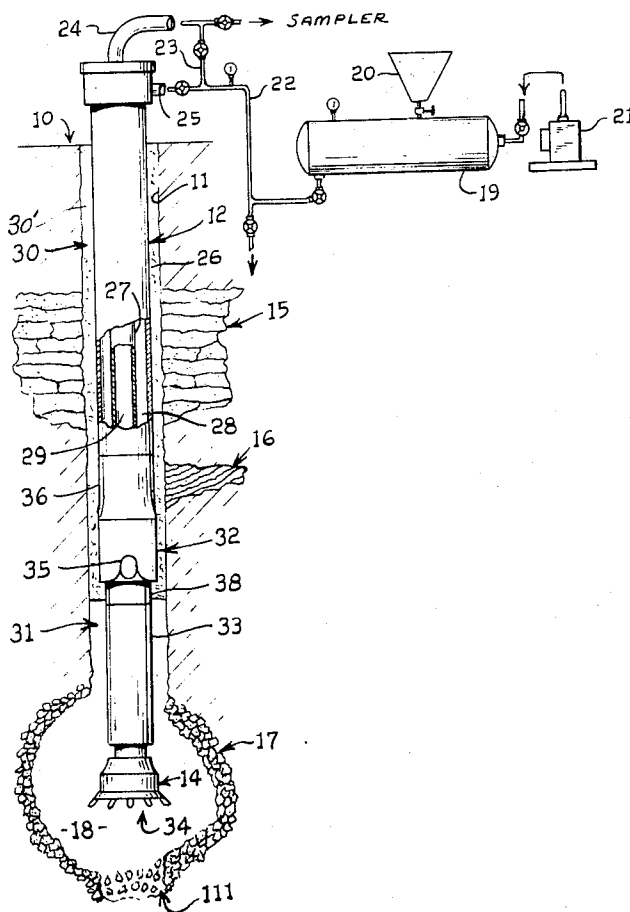
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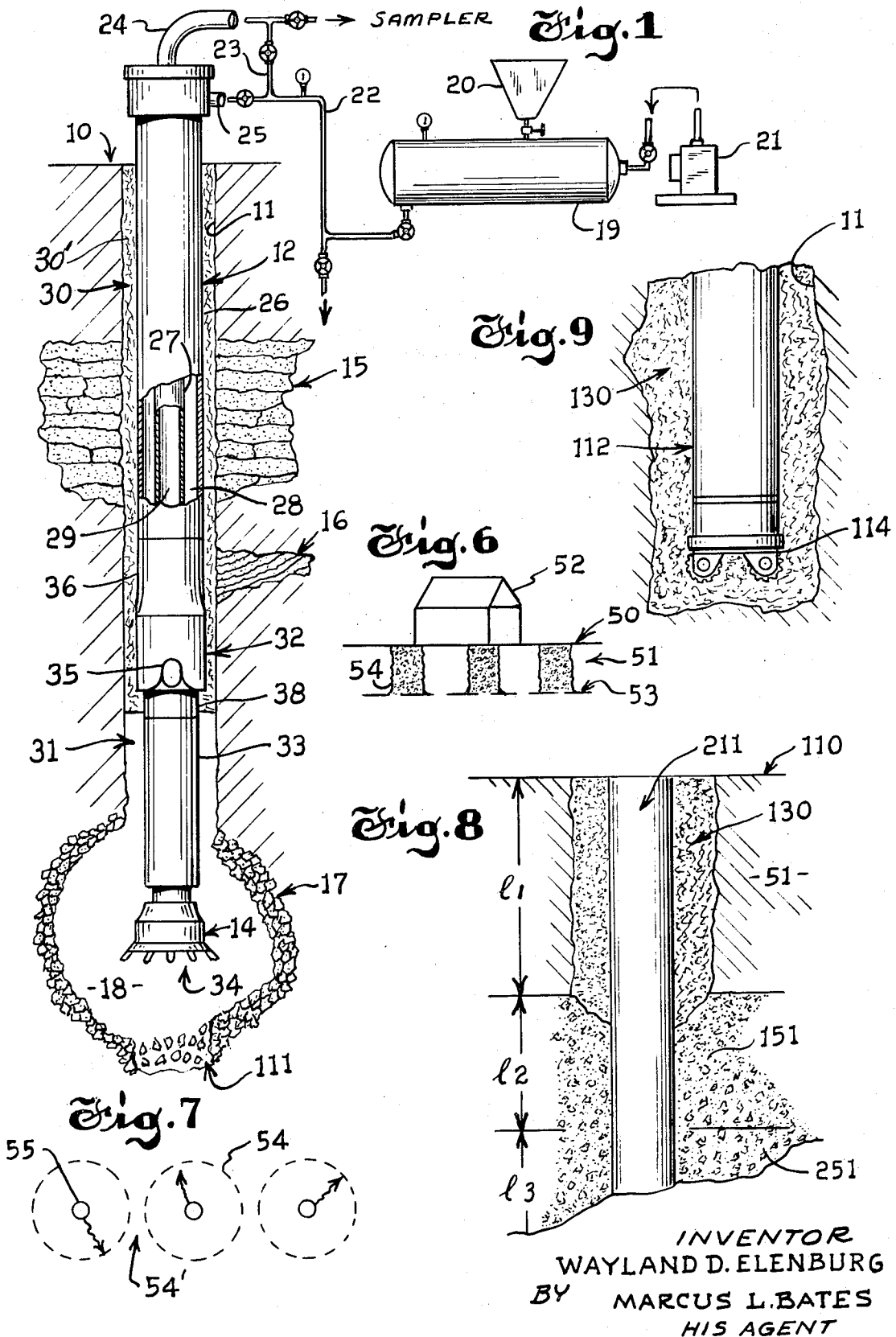
[57] **ABSTRACT**

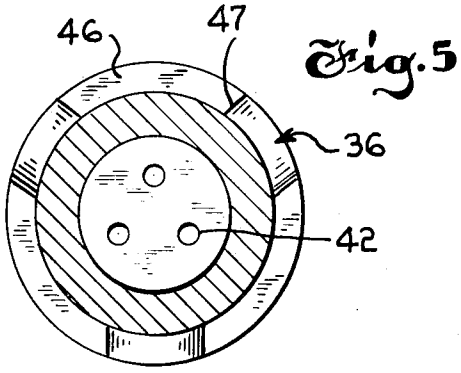
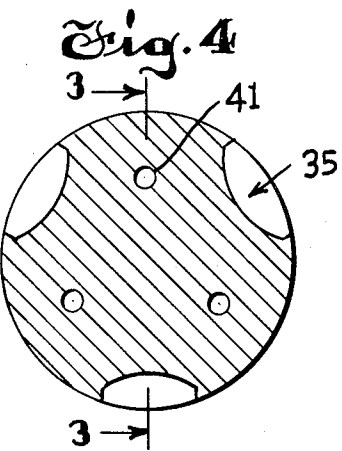
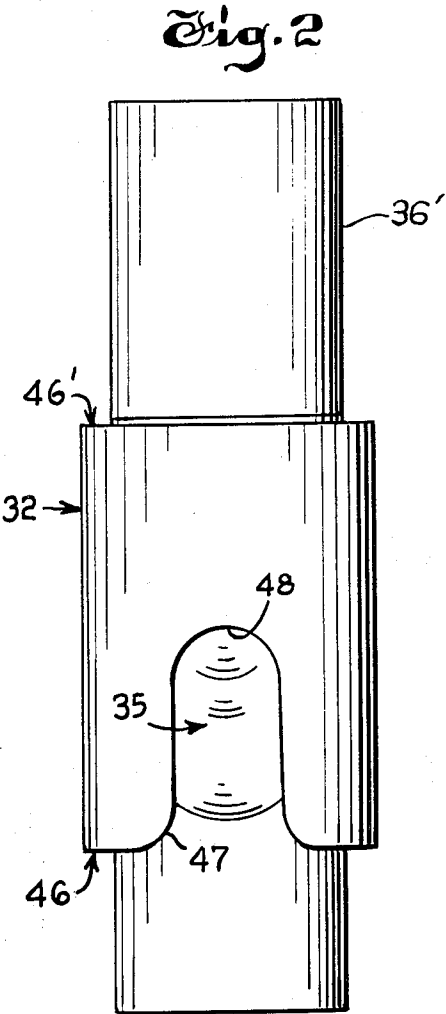
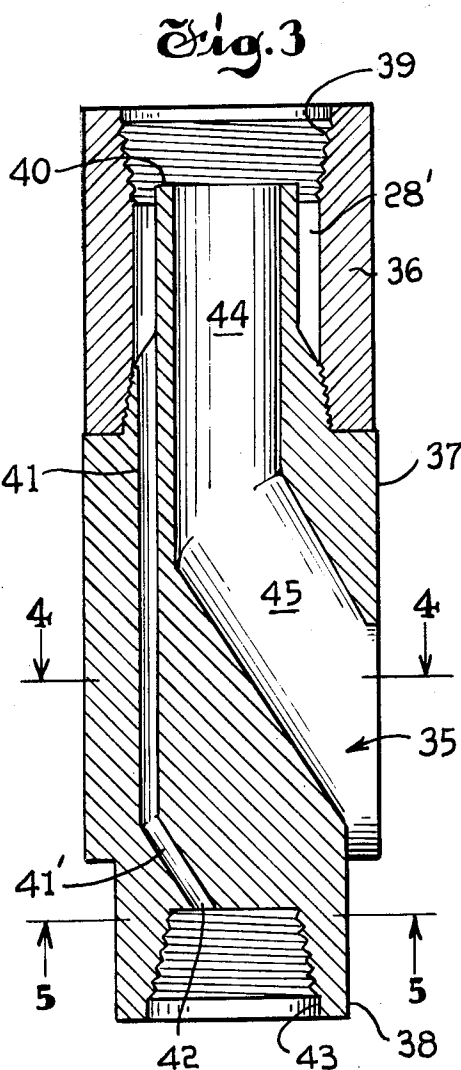
Improved drilling method for isolating the bottom of a borehole from an upper formation by the provision of a cross-over sub which is used in conjunction with a concentrically arranged dual pipe string. A bit is connected to the pipe string by the sub, and drilling fluid is circulated down the drill string annulus, through the sub, and to the bit, while cuttings are returned along with the drilling fluid from the bit, through a radial passageway formed in the sub, and to the inner tubing of the drill string.

When it is desired to isolate the upper borehole annulus or a formation from the bottom of the borehole, a blocking agent is forced down the inner tubing, out through a radial passageway of the sub, and against or into the formation adjacent to the borehole. Drilling is then resumed with the bottom of the borehole being isolated from the upper borehole annulus.

12 Claims, 9 Drawing Figures







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METHOD AND APPARATUS FOR ISOLATING THE BOTTOM OF A BOREHOLE FROM AN UPPER FORMATION

BACKGROUND OF THE INVENTION

In drilling a borehole with a dual pipe string which provides counter-current flow of fluid to and from the bit, an aquifer is often encountered which complicates some drilling operations. At other depths, voids or formations with large pores may be encountered which causes loss of circulation or sample hold-up. At still other depths, rubble lacking sufficient structure to form a self supporting borehole wall may be encountered.

In drilling with air and using a rotary bit, encountering some of these difficulties necessitates the substitution of a less desirable method of drilling.

When using an air hammer in borehole forming operations, penetration of an aquifer often forces one to abandon the air hammer and resort to rotary bit operation. This is also true when circulation is lost, or when a loose or non-supporting formation is encountered with an air hammer.

Where the formation is being sampled, lost samples or sample hold-up will occur when some of the above conditions are encountered. Therefore, means by which the continued use of an air hammer drilling operation under the above described adverse conditions is desirable. Provision of method and apparatus enabling continued use of an air hammer drilling operation in unfavorable formations is also desirable.

Throughout this specification the term "drill bit assembly" includes an air hammer which is connected to a bit; rotary drill bits; air drills together with their bits, as well as other type drilling apparatus which can be used in conjunction with concentric drill pipe.

The term "drilling fluid" is intended to mean drilling mud, water, air, and various other gaseous or liquid substances used in the art of borehole formation.

The term "cuttings" is intended to mean portions of a formation which are removed from the bottom of the borehole as the bit penetrates the various strata of the earth. The cuttings may include material associated with the chip drilling process wherein large sample particles are obtained for subsequent analysis, as well as broken lengths of core.

SUMMARY OF THE INVENTION

The present method enables drilling through difficult types of formations to be continued by the provision of a sub assembly which connects a drill bit assembly to concentrically arranged drill pipe. A blocking agent can be pumped downhole to the sub and into the borehole at any time, thereby isolating the lowermost portion of the borehole from any formation which has been penetrated by the bit. Formation of the borehole can then be continued until other troublesome formations are subsequently encountered.

This method also provides the means by which a foundation can be made in the surface of the earth when the upper strata of the earth is comprised of materials exhibiting low bearing pressure, such as sand, for example.

In carrying out the above method, an improved sub assembly is provided in combination with a dual pipe string and borehole forming apparatus.

It is a primary object of this invention to provide both method and apparatus which enables the bottom of a borehole to be isolated from a formation through which the borehole extends.

Another object of this invention is to provide a method of drilling past an aquifer when using concentric drilling string.

A further object of this invention is to enable the continued use of an air hammer regardless of the formation being penetrated.

A still further object of this invention is to provide a method and apparatus to enable borehole penetration of a non-supporting formation.

An additional object of this invention is to provide a method and apparatus to enable continued drilling through lost circulation zones.

The above objects are attained in accordance with the present invention by the provision of a drilling method and apparatus fabricated in a manner substantially as described in the above abstract and summary.

These and various other objects and advantages of this invention will become readily apparent to those skilled in the art upon reading the following detailed description and claims and by referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cross-sectional view of a portion of the upper crust of the earth, with apparatus made in accordance with the present invention being diagrammatically disclosed in association therewith;

FIG. 2 is an enlarged side elevational view showing a sub assembly made in accordance with the present invention;

FIG. 3 is a longitudinal cross-sectional view of the sub, taken along line 3—3 of FIG. 4, while FIG. 4 is a cross-sectional view taken along line 4—4 of FIG. 3;

FIG. 5 is a cross-sectional view taken along line 5—5 of FIG. 3;

FIG. 6 is a schematical representation which discloses another form of the present invention;

FIG. 7 is a top plan view of FIG. 6;

FIG. 8 is an enlarged cross-sectional diagrammatical representation of part of FIGS. 6 and 7; and

FIG. 9 is a fragmentary enlarged part cross-sectional representation of another embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Throughout the various figures of the drawings, wherever possible, like or similar numerals refer to like or similar parts.

As seen in FIG. 1, in conjunction with the remaining figures, a cross-section of the upper crust of the earth 10 has been penetrated by earth boring apparatus to form a borehole 11, within which is axially disposed a drill string 12 having a bit 14 disposed at the lower extremity thereof.

Still looking at FIG. 1, it is seen that the borehole has penetrated an aquifer 15; a void 16, also called a "lost circulation zone;" and a strata of rubble 17, such as a fractured unconsolidated zone which has collapsed and partially filled the borehole at 111. Cavity 18 has been formed by the collapsed rubble.

A steel tank 19 has a hopper 20 supported and valved thereto, and further includes a compressor 21 flow connected thereto by the illustrated valve. Flow lines and valves 22, 23, 24, and 25 are interconnected between the tank, the outflow from the swivel, and the outflow from the inner tubing string to enable cross-feeding from one to the other in any number of arrangements, as is known to those skilled in the art.

The drill string includes a drill pipe 26 within which there is concentrically arranged a longitudinally disposed inner tubing 27, which cooperate together to form a counter-current flow path comprised of drill string annulus 28 and an inner tubing passageway 29. The upper borehole annulus 30 is separated from the lower borehole annulus 31 by a blocking agent seen disposed therein at 30'. Below the blocking agent is seen a sub assembly 32, hereinafter called a "sub," which is connected to the lower terminal end of the drill pipe.

Air hammer 33 forms part of the bit assembly and connects the bit to the sub. Spent power fluid, in the form of compressed air, flows from the hammer and exhausts at 34. The blocking agent forces the spent power fluid, which is also the drilling fluid, to flow up the lower borehole annulus and into each of the three radial passageways 35 of the sub.

The details of the sub disclosed in FIG. 2 include a reduced diameter portion 36' which threadedly engages a threaded reduced diameter portion of an enlargement 37.

In the preferred embodiment of FIG. 3, the sub is seen to include a reduced diameter portion 38 which is diametrically opposed to the removable member 36. Threaded passageway 39 forms a box which is adapted to engage the pin formed at the lowermost extremity of a drill pipe in the usual manner. An inner tubing connector 40 is axially aligned with respect to the longitudinal axis of the sub and is adapted to sealingly engage the lower terminal end portion of the before mentioned inner tubing of the tubing string.

The inner tubing connector cooperates with member 36 to form the illustrated inner sub annulus 28'.

Passageways 41 are radially spaced apart from one another and flow connected at one extremity to the annulus 28'. The opposite end of the passageways each terminate at 42 within the box 43 and provide a flow path from 28' to 42.

The inner tubing connector provides a passageway 44 which branches into a plurality of passageways 45, each of which form one of the three spaced apart radial passageways 35.

The lower reduced diameter portion terminates at the enlargement to form a circumferentially extending shoulder 46. The shoulder is upwardly undercut or milled to form the illustrated inverted U-shaped passageway at 47 and 48, hereinafter called a ramada. The ramada communicates the lower hole annulus with a passageway 35.

Looking now to the details of FIGS. 6-8, there is seen a surface 50 of the earth which is made up of material 51 that exhibits a bearing pressure inadequate for support of a structure 52. Below the surface of the ground is located a hard pan 53 which is adequate for support of structure 52. A plurality of cement columns 54 are spaced apart from one another as seen at 55 so

as to provide vertical support for a platform which rests on the upper extremity of the columns for supporting structure 52.

In FIG. 8, borehole 211 has been formed below the surface of the ground 110. Formation 51 is inadequate to form a self supporting borehole wall, and accordingly, a blocking agent 130 has been pumped into the formation and into the illustrated relative position of FIG. 8: The blocking agent extends downhole a distance indicated by L-1. A second blocking agent 151, which may be in the form of cement or cementitious material, extends a distance L-2 below the blocking agent 130. Blocking agent 251, which preferably is identical to blocking agent 151, extends a distance L-3 downhole.

FIG. 9 illustrates a borehole 11 having irregular surface walls, and through which there depends a drill string 112 connected to a rotary type rock bit 114. The rotary bit preferably is made in accordance with my previously issued U.S. Pat. No. 3,439,757, issued Apr. 22, 1969, but can take on several different forms so long as it is connected to the string by a sub made in accordance with the present invention. A blocking agent 130 fills the borehole annulus.

The blocking agent may be any substance which provides a self-supporting wall, but preferably is selected from the following substances: (1) Dowell J 170 polomer together with water and a catalyst. The polomer is referred to by the trade name "Protectorzone," and is marketed by the Dow Chemical Company as a water based viscosity plug for fluid diversion. The catalyst is M6 Cololist, also a trade name belonging to Dow Chemical Company.

(2) AM9 grouting material which is an oilfield product.

(3) Portland Cement and other similar cementitious substances. (4) Dowell Chemical Seal Ring No. 300, an elastic polymeric seal which sets into a rubber-like material, and which swells upon imbibing water.

OPERATION

The operation of the present method will be explained in conjunction with an air hammer, such as a "4210 Mission Hammer" fabricated by Mission Manufacturing Company of Houston, Texas. One drill string which can be employed with this hammer is 4½ inch O.D. having a 2¼ inch O.D. inner tubing string disposed therein, with the sub having an enlargement which is 4 ⅞ inch O.D. by 12 inches in length, with the total length of the sub being 24 inches. The drilled passageways are ⅝ inch I.D. while the return fluid inlet 35 is 1 ¼ inch I.D. Drilling fluid in the form of compressed air is forced into the annulus 28 at a rate of 300 to 600 c.f.m. at 60 to 120 p.s.i.

In operation the drill string is rotated four to eight revolutions per minute to avoid boring a crooked hole, while air is pumped down the drill string annulus, through the cross-over sub, and to the air hammer. The action of the compressed air flowing through the motor of the hammer causes the bit to reciprocate, thereby progressively forming the borehole.

After the borehole has been formed to a depth of several feet a blocking agent is placed into the borehole annulus, as seen at 30', and the drilling resumed after a suitable time delay to enable the agent to "set" or un-

dergo any necessary chemical reaction. The first application of the blocking agent can be flowed directly into the upper open end of the borehole annulus, or alternatively can be flowed down through the inner tubing string to the sub, as will be described in greater detail later on herein.

As drilling is resumed, the blocking agent effectively packs off the upper and previously formed annulus from the formation being penetrated. Since the polomer is a resilient, rubber or jel-like substance, it adequately adheres to the borehole wall and also sealingly engages the outer periphery of the drill pipe. Accordingly, it will now be obvious to those skilled in the art that absolutely no uphole flow can occur except along the following flow path: the compressed air exhausts from the lower bit surface and carries formation cuttings up the lower borehole annulus and into the ramada. The exhaust power fluid, or compressed air, along with the cuttings enter each of the ramadas of the return inlets 35, and continue to flow through passageways 45 where the passageways converge into the inner tubing connector. The cuttings along with the air, continue to flow up the inner tubing to the surface of the earth where the cuttings may be separated from the air and stored for subsequent analysis, if deemed desirable.

Accordingly, contamination of the cuttings being formed by the bit can only occur from the wall of the lower borehole annulus at 31, and for this reason the polomer is continuously applied by increments of about 100 feet as the borehole is sunk into the ground.

Once the initial column of polomer has been implanted into the borehole annulus, subsequent treatment of increments of the borehole annulus with additional polomer may be effected at increased pressures so as to force or squeeze the polomer against or into the formation. This "squeeze" is made possible because of the presence of the blocking agent in the upper borehole annulus, which effects a packer.

Where deemed desirable, a resilient ball having an O.D. of slightly less than the I.D. of the inner tubing string can be used so as to avoid wasting the polomer, or to avoid aeration of the blocking agent as it is being placed in the annulus. The ball is dropped into the inner tubing behind the polomer and pumped downhole where it becomes seated at 40. A pressure increase indicates that the ball has arrived at the seat and that all of the polomer has been forced into the annulus. The ball is automatically returned uphole upon resumption of the drilling operation.

Assuming that an aquifer is encountered by the bit, water is produced as the bit penetrates the water bearing zone, and eventually a hydrostatic head will be produced by the aquifer which renders the air hammer progressively ineffectual as the pressure differential across the air hammer continues to decrease due to the hydrostatic head. When this condition is encountered, a blocking agent must be added to the annulus in order to continue drilling under dry conditions.

The blocking agent is placed in hopper 20, the tank is then decompressed, and the valve into tank 19 opened to admit the agent into the tank. The tank is then sealed, pressured up by the compressor 21, and the proper valves opened to enable the blocking agent to be forced down the inner tubing, and out the ramadas,

where the blocking agent displaces any water which may be present in the borehole annulus. It is then usually necessary to apply several hundred pounds pressure to the blocking agent so as to "squeeze" the agent back against or into the formation, and to hold the operation in a static condition until the blocking agent has "set."

After a suitable time delay, the valves are again returned to the normal drilling position, and drilling is again resumed. The blocking agent effectively isolates the formation below the bit from the upper borehole annulus adequately to permit air drilling to be resumed under dry conditions. Upon encountering lost circulation, the above described steps may be employed to seal off the void which is stealing the drilling fluid.

As seen in FIG. 1, assuming rubble at 17 has been encountered by the bit, it is desirable to add sufficient structural integrity to the formation so as to enable it to form a self supporting wall. As in the previous instance, the blocking agent is pumped from port 35, where it flows into the lower annulus and into contact with the last applied blocking agent. The previously placed polomer provides a packer which offers resistance to flow uphole so that the new batch of blocking agent, after completely filling the annulus, is forced into the rubble and back up into the formation depending upon the geological structure of the rubble. After the agent has set, the formation of the borehole can be continued at 111.

Where a polomer is employed as the blocking agent, 9 pounds of Protectorzone material along with 30 gallons of water are transferred from the hopper into the tanks after the tank has been equalized with ambient conditions. Air is used to agitate and thoroughly mix the ingredients, after which 0.6 pounds of catalyst is added to the tank through the illustrated valve, to provide a sol. As soon as the various ingredients are all properly mixed together, a sample is taken, the valves rearranged, and air pressure is then employed to force the agent down the central tubing and out the radial passageways. The agent is forced from the central tubing as it flows into the borehole annulus and back up into the formation as the pressure is increased 200-400 p.s.i. The operation is held in a static condition until the surface sample indicates that the sol has turned into a jel, after which the drilling operation is resumed by releasing the pressure on the tubing string, and applying air pressure to the drill string annulus. As the pressure is increased, the chattering of the bit hammer will indicate that the downhole drilling apparatus is back in proper operative condition.

Those skilled in the art will realize that the present invention enables cuttings obtained from the central tubing to be precisely indexed with respect to the specific depth of the hole, since contamination due to hold-up is avoided through the use of the present method.

Since all of the air circulated down the drill string annulus returns back up the central tubing, any water which may be present is continuously cleaned out of the system. The application of a blocking agent to the formation may be repeated each time the drill string is withdrawn from the hole so as to isolate the lowermost portion of the borehole from the upper borehole annulus to thereby avoid sample contamination as well as

continuously adding another packer-like member to the operation.

The present method provides unquestionable quality of samples and enables an air hammer to continue obtaining core samples where water or lost circulation are a problem.

The blocking agent stabilizes the hole as well as the drill pipe and also greatly reduces pipe wear. Generally, the use of a 100 foot length of blocking agent will adequately protect the formation. In a 5 and 1/4 inch hole, 34 gallons of material will treat 100 feet of hole annulus.

I claim:

1. In drilling a borehole using concentrically arranged drill pipe and tubing string to form counter-current flow to and from the bit, with a cross-over sub connecting the drill bit to the drill pipe, a method of isolating the upper borehole annulus from the formation being penetrated by the bit comprising the steps of:

1. forming a first flow path from the drill string annulus, through the sub, and to the bit so as to enable drilling fluid to flow across the face of the bit as the bit penetrates a formation;
2. forming a second flow path from the borehole annulus, through the sub, and into the tubing string so as to enable drilling fluid and cuttings from the bit to return uphole;
3. flowing a blocking agent along either the first or the second flow path and into the borehole annulus in proximity of the sub so as to displace fluid from the borehole annulus and also to isolate the borehole annulus from the formation being penetrated by the bit;
4. resuming the borehole forming operation by flowing drilling fluid along the flow path set forth in steps (1) and (2) after the upper borehole annulus has been isolated from the formation in accordance with step (3).

2. The method set forth in claim 1, wherein the drill bit is connected to the sub by an air hammer, and further including the step of flowing the blocking agent through the second flow path; and, using air to power the air hammer; and, using the spent power fluid from the air hammer to provide the drilling fluid.

3. The method set forth in claim 1, wherein the bit is a rotary rock bit, and further including the step of using a liquid drilling mud as the drilling fluid.

4. The method set forth in claim 1, wherein step (3) is carried out at spaced apart locations along the borehole as the borehole is formed, so as to present a continuous column of blocking agent which isolates the borehole annulus from the formation being penetrated by the bit.

5. The method set forth in claim 1 wherein step (3) is carried out by using an agent which is liquid in step (3), and which turns into a self-supporting mass prior to carrying out step (4) so as to form a continuous open hole packer in the borehole annulus.

6. The method set forth in claim 1 wherein step (3) is carried out in order to isolate the drill bit from a lost circulation zone, and further including using a sol as the blocking agent in step (3) which turns into a jel prior to carrying out step (4).

7. The method of claim 1, and further including the step of employing a sol as the blocking agent in step (3)

and, allowing the sol to jel before commencing step (4).

8. The method of claim 1, and further including the following steps:

5. forming the borehole for a limited length by carrying out step 4;
6. flowing cementitious material along the second flow path and forcing the cementitious material radially away from the borehole;
7. repeating step (5) followed by repeating step (6) to thereby provide a vertical cementitious column so as to provide a bearing surface for above the ground structure.

9. The method of claim 8, wherein a plurality of columns defined in step (7) are formed adjacent to one another to thereby form a platform having legs downwardly depending therefrom, wherein the legs are the individual columns of step (7).

10. A bit sub for connecting a drill bit assembly to a concentric dual pipe string for carrying out a drilling operation in a well borehole wherein the pipe string includes a drill pipe having a tubing string axially disposed therein to thereby form a counter-current flow path to and from the bit; the improvement comprising:

said bit sub having a lower threaded passageway for being connected to the drill bit assembly, an upper threaded passageway for being connected to the drill pipe, and an inner tubing connector for being flow connected to the tubing string; said inner tubing connector being coaxially arranged respective to said upper threaded passageway thereby forming a sub annulus; said sub annulus being a continuation of the drill string annulus;

means forming at least one radial passageway in said sub, said radial passageway being flow connected to the interior of said inner tubing connector;

means forming at least one flow path from said drill bit sub annulus to said lower threaded passageway for forming a flow path from the drill string annulus to the bit;

means forming a circumferentially extending enlargement about a marginal length of said sub; a lower edge portion of said enlargement forming a circumferentially extending shoulder; said shoulder having a marginal circumferentially portion thereof upwardly undercut to provide a ramada in the form of an inverted U-shaped passageway for communicating the exterior of the bit with the radial passageway; said ramada having a downwardly opening portion for enabling drilling fluid and cuttings from the bit to flow therethrough and into the radial passageway, through the inner tubing connector, and through the inner tubing string to the surface of the ground.

11. The bit sub of claim 10, wherein said upper threaded passageway is in the form of a removable member, said removable member being cylindrical in form and having a lower threaded surface, threads formed externally of said inner tubing connector for threadedly engaging said lower threaded surface of said removable member.

12. The bit sub of claim 10 wherein said drill bit assembly is in the form of an air hammer having a drill bit connected to a lower portion thereof; said means form-

ing a flow path from said drill bit to said sub annulus being in the form of a plurality of radially spaced apart passageways; each radially spaced passageway being spaced apart from one another by a ramada.

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