

July 26, 1960

P. S. WILLIAMS

2,946,565

COMBINATION DRILLING AND TESTING PROCESS

Filed June 16, 1953

4 Sheets-Sheet 1

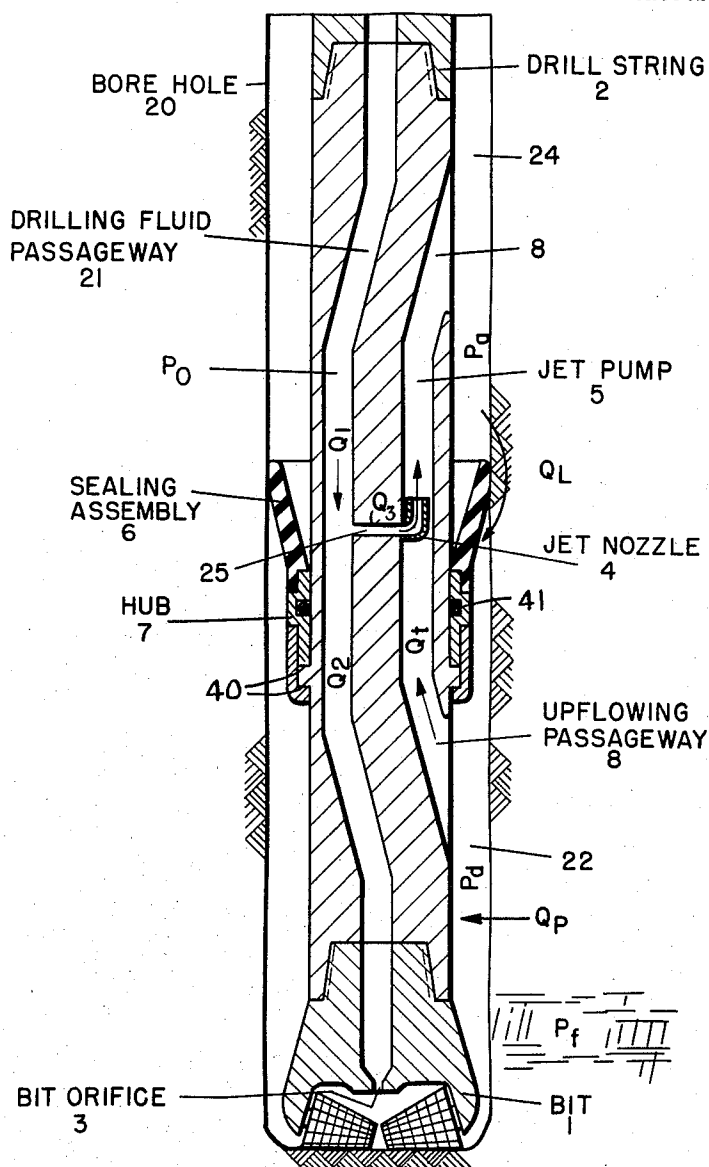


FIG. - I

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4 Sheets-Sheet 2

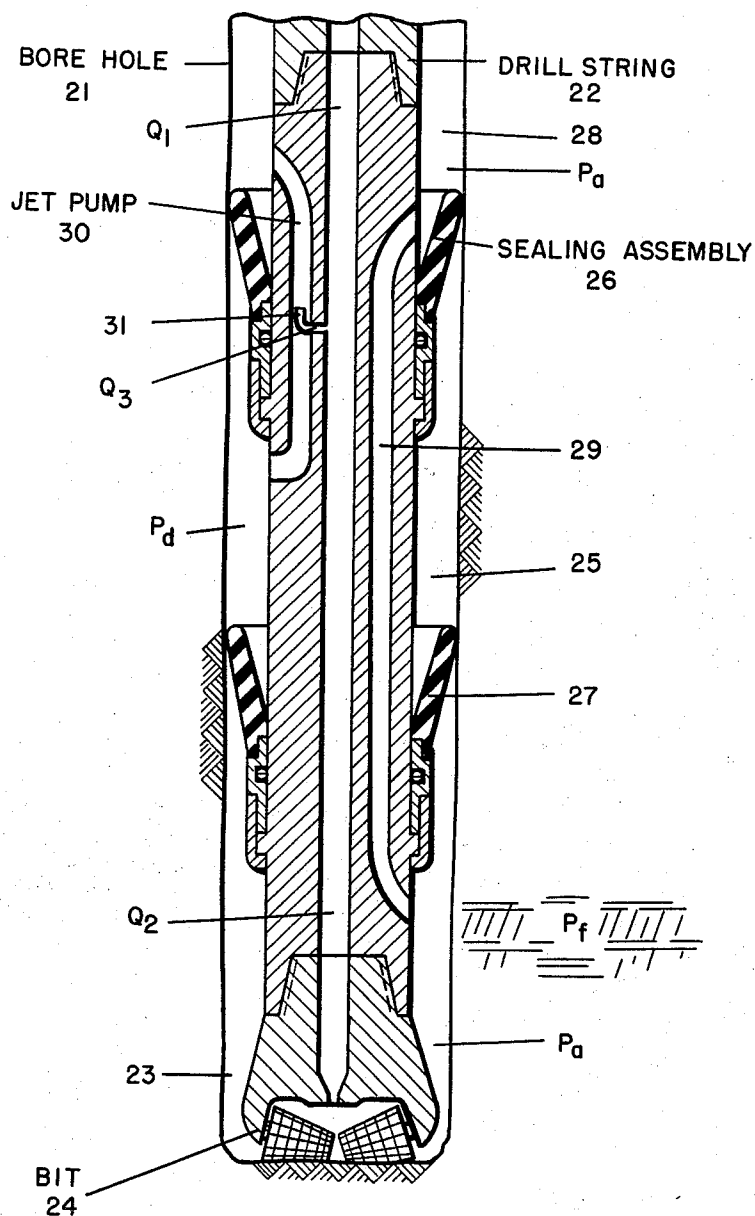


FIG.- 2

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4 Sheets-Sheet 3

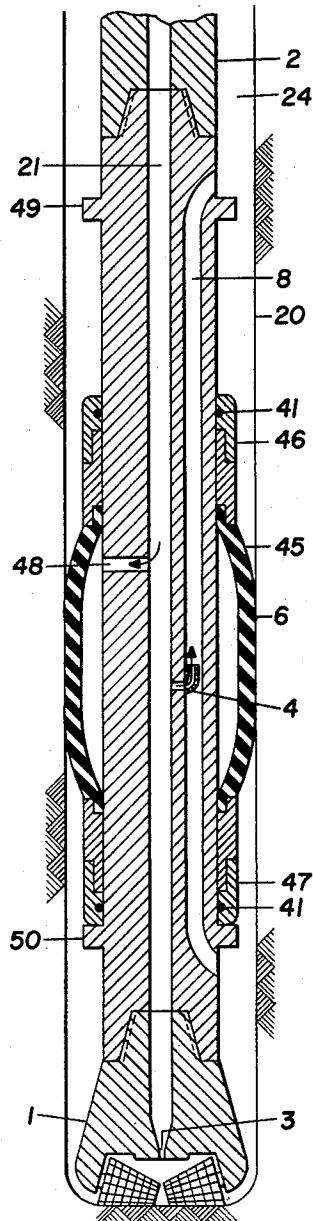


FIG-3

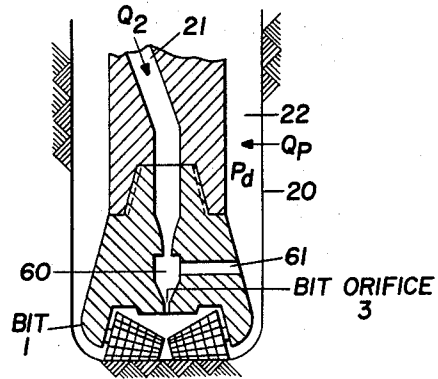


FIG-4

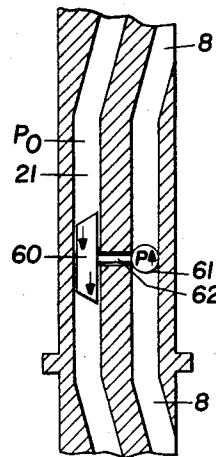


FIG-5

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4 Sheets-Sheet 4

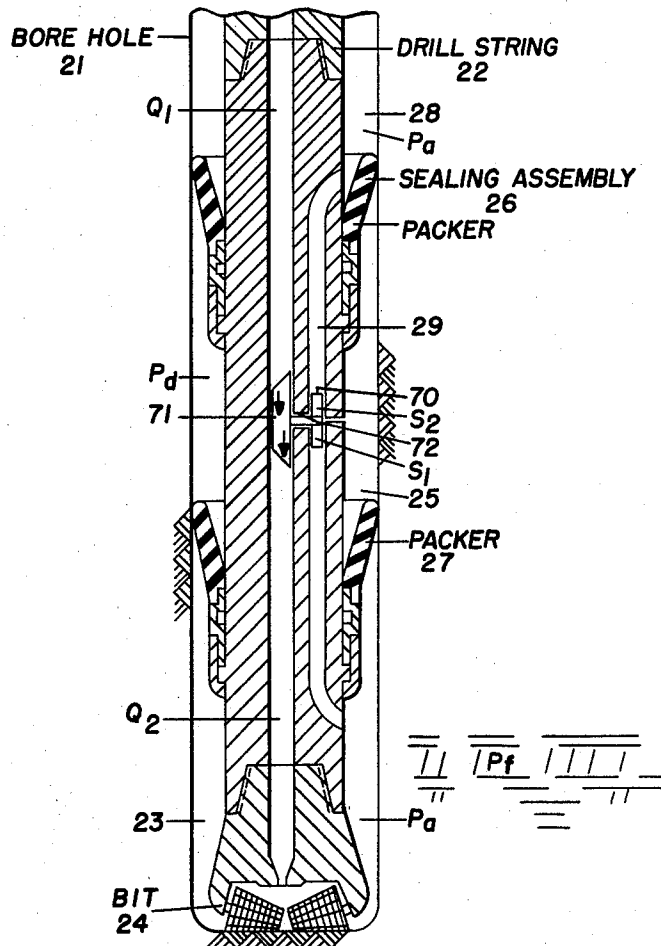


FIG. -6

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2,946,565

COMBINATION DRILLING AND TESTING PROCESS

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7 Claims. (Cl. 255-1.8)

The present invention generally relates to the production of oil and is particularly concerned with an improved continuous procedure by which formation fluids can be readily detected. In accordance with the present invention a drilling technique is utilized in which the fluid pressure of the drilling mud in the annulus about the drilling bit is less than the formation pressure through which the bit is penetrating. This reduced pressure is secured by providing a pressure seal assembly immediately above the bit and providing a jet pump effect about this assembly so as to maintain the pressure above the pressure seal assembly in excess of formation pressure and to maintain the pressure in the annulus below the pressure seal assembly less than the formation pressure. By this technique, formation fluids are produced into the hole whenever encountered as the bit penetrates the formation, before mud plugging of the formation occurs. These formation fluids flow along with the drilling mud to the surface, and are there detected by conventional mud logging methods.

It is well known in the art to drill bore holes into the earth's substrata in the search for oil. Usually the operation comprises utilizing a drill string having attached to the lower end thereof a suitable bit which is rotated by rotating the drill string. During the operation drilling fluid or mud is pumped down within the drill string through the bit and upwardly in the annulus between the bore hole and the drill string. This drilling fluid serves among other things to remove the drill cuttings; to maintain the bore hole wall structure and to maintain sufficient pressure against the formation in instances where high formation pressures are penetrated, thus preventing blow-out with resultant possible damage to equipment and personnel.

In drilling operations of this character the practice of maintaining a fluid pressure in the bore hole above the pressure of formation fluids is well established for the reasons given heretofore. However, in rotary drilling procedures it is very difficult and almost impossible to tell when potential gas formations or oil containing sands are encountered until special logging and testing procedures are subsequently carried out. However, even under these special testing conditions the formations are sometimes so plugged by drilling fluid as to reduce production of formation fluids or even mask or entirely hide their presence.

In accordance with the present invention the pressure of the drilling fluid about the bit is reduced to a value below the formation pressure thus permitting gas or other formation fluids to flow into the bore hole about the bit. These formation fluids are then pumped along with the drilling mud to the surface at which point their presence can be detected by mud analysis and other equivalent logging techniques. By the present invention the conventional heavy mud head is maintained throughout the hole except in the annulus about the bit. Thus the up-hole and surface conditions remain substantially unaltered. This ensures safety for the hole, for the rig and for the

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personnel, and reduces maintenance cost. It is realized that under certain conditions the quality of the mud may be impaired and contaminated by these inflowing formation fluids. However, this contamination may be substantially reduced and eliminated by conventional mud treatments which are economically feasible in most operations.

The process of the present invention may be fully appreciated by reference to the drawings illustrating embodiments of the same.

Figure 1 illustrates an operation utilizing one sealing assembly wherein the pressure in the annulus adjacent the bit is maintained below the formation pressure.

Figure 2 illustrates an operation wherein two sealing assemblies are employed and wherein the low pressure area is maintained somewhat above the area adjacent the bit.

Figure 3 illustrates an operation in which an intermittently advancing packer assembly is employed.

Figure 4 illustrates an operation in which an additional jet pump is employed in the vicinity of the bit.

Figure 5 illustrates an operation in which a turbine and pump combination is employed in the apparatus of Figure 1 in place of the jet pump illustrated there.

Figure 6 illustrates an operation similar to that illustrated in Figure 1 but employing two vertically spaced sealing assemblies in place of one such assembly. This figure also illustrates the use of a turbine-driven two-stage pump interposed between the two sealing assemblies.

Referring specifically to Figure 1, the drill stem, or drill collar 2, is shown positioned in the bottom of bore hole 20. Attached to the lower end of drill stem or drill collar 2 is shown an assembly device by which the pressure of the drilling fluid in the annulus about the drill bit and immediately above it is reduced below the formation pressure and by which the pressure in the annulus above this area is maintained above the formation pressure.

The assembly device comprises a down flow passageway 21 by which down-flowing drilling fluid may pass from the lower end of the drill stem 2 down and through bit orifice 3 of bit element 1 attached to the lower end of the assembly device. The down-flowing mud which passes through the drill bit flows upwardly in the annulus 22 along with cuttings, through upflow passageway 8 in the assembly device and back into the annulus 24 above sealing assembly 6. In accordance with the present invention a portion of the down-flowing fluid in passageway 21 is passed through passage 25 and jetted upwardly through jet nozzle 4. Jet nozzle 4 comprises an integral part of jet pump 5 which in turn comprises the upper area of passageway 8.

The assembly device comprises a packer sealing assembly 6 positioned about the circumference of the device and sealed against the bore hole wall. In operation the drilling fluid is pumped downwardly through the drill stem or drill collar 2 and into passageway 21. In normal operations the pressure of the drilling fluid P_0 in the drill stem is higher than the pressure P_a of the drilling fluid in the annulus in the lower end of the hole. This is customary to give a high jet velocity through bit orifices 3 in the drill bit. The drilling fluid, in amount Q_1 (gals. per minute) passing down passageway 21, is divided into two portions, Q_2 (gals. per minute) which quantity passes downwardly through the drill bit and upwardly in annulus 22, and a quantity of drilling fluid Q_3 (gals. per minute) which passes through passageway 25, through jet nozzle 4 and upwardly through jet pump 5.

The jet pump 5 is positioned between the regions above and below the packer assembly 6. The packer assembly is either of the umbrella or the inflatable variety and is designed to withstand a few hundred lbs. per sq. in. in

pressure thrust exerted downwardly. It is preferably mounted on a mandrel, hub or equivalent means 7 fitted in the bearings 40, and contains fluid seals 41 so that the drill pipe assembly can turn within it, i.e. so that the packer assembly does not turn with respect to the earth. It is, however, designed to slide down the hole as it is drilled, keeping at a fixed distance above the bit. If the packer assembly is of the inflatable type it may be inflated by diverting a small amount of drilling fluid through or into it by conventional means. Of whatever type, the packer assembly should wear as long as a drill bit, and stand the trip down the hole without damage.

One concept of the present process is to use an intermittently advancing packer. For example, a conventional packer may be constructed which is inflated or expanded, and also locked to the wall against the vertical fluid load by the application of pump pressure. Release of such pump pressure will deflate the packer and thus release the locking dogs. The entire packer will be mounted on, for instance, a 10-foot section of tubing in such a manner that the tubing can both rotate and slide lengthwise within it. In operation, the packer at the start will be at the bottom of the tubing section. The pumps are started and, for example, a ten-foot hole is drilled. When the pumps are stopped, the packer will fall to the bottom of the tubing. The pumps are then started and, for example, another 10 feet of hole are drilled.

An operation employing an intermittently advancing packer is illustrated in Figure 3. Referring to this figure, it will be observed that the apparatus depicted there is very similar to the apparatus of Figure 1 with the main exception being the type of sealing assembly employed. As in Figure 1, the main components illustrated in Figure 3 include drill string 2, up-flowing passageway 8, drilling fluid passageway 21, jet nozzle 4, bit orifice 3, and bit 1—all positioned within bore hole 20. The sealing assembly 6 in Figure 3 differs from the assembly in Figure 1 in that it utilizes an inflatable packer 45 which is provided at its upper and lower ends with hub members 46 and 47. The packer is sealed to the hub members, and the hub members in turn are adapted to move vertically and rotationally with respect to the bit, the drill string and the other rotating parts. Each hub member is provided with a liquid seal 41 which prevents liquid from communicating between the bore hole and the internals of the packer.

A port 48 is provided to establish fluid communication between passageway 21 and the internal portion of the packer 45. Thus, when the pressure of the fluid within the passageway 21 is increased to a predetermined value, packer 45 becomes inflated and exerts a fluid tight seal against the wall of the bore hole.

With respect to the port 48, it will be apparent that this port should continuously communicate with the internal portion of packer 45. Accordingly, two shoulders or stops 49 and 50 are provided to limit the vertical travel of the over-all sealing assembly 6. Thus, as the drill bit 1 travels vertically downward through the earth, sealing assembly 6 slides relatively upward until hub 46 strikes against shoulder 49. At this point the pressure in passageway 21 is decreased and packer 45 is deflated. The entire assembly 6 then drops until it strikes against stop 50. The packer is then reinflated by increasing the pressure in passageway 21 and the drilling operation is resumed. This intermittent advance of the sealing assembly can be repeated as often as is desired or necessary.

In operation, and referring to the drawing, the jet pump creates a pressure differential P_a minus P_d across the packer assembly, where P_a is greater than P_d while delivering a net amount of fluid Q_t , where Q_t is greater than Q_3 . The pump 5 is designed to give a value of P_a minus P_d such that P_d (the pressure below the packer) is less than P_f (the fluid pressure within the formation). P_a is normally somewhat greater than P_f to eliminate spontaneous flow into the hole. For example, if P_a minus

P_f equals 500 p.s.i. and if P_f minus P_d equal 100 p.s.i., then P_a minus P_d equals 600 p.s.i. This represents one suitable figure for a typical 10,000 ft. hole. For shallower holes both absolute and difference pressures are lower, and fluid friction losses are less. It is to be understood that P_a as used here is static mud pressure plus friction drop up the annulus, which latter figure is of the order of about 100 p.s.i. in a 10,000 ft. hole.

Such a pressure balance as indicated permits formation fluids to produce into the hole below the packer and to mix with the drilling fluid for return up the annulus to the surface, where these formation fluids are detected by conventional or improved "mud logging" techniques. The present process also avoids flushing fluid from the formation ahead of the bit, which means that the cuttings go into the mud stream carrying their original fluids. While some of these formation fluids are released into the drilling mud when pressure is reduced near the surface, some formation fluids remain in the cuttings. This is of real value upon examination of the cuttings.

The quantity Q_t of fluid handled by the jet pump 5 is defined by Q_t equal Q_2 plus Q_L plus Q_p , where Q_L is fluid leaking past the packer and Q_p is that produced from the formation. Q_L will be held as low as possible but need not be zero. The amount of fluid produced, even for Q_L equals 0, is self-regulating in that as Q_t increases, P_a minus P_d decreases eventually to where P_d equals P_f , whereupon Q_p equals 0.

The drilling rate will be reduced somewhat by diversion of the fluid Q_3 to the pump. Reduction of "plastering" on the surface by reversal of pressure gradient acts to help the drilling rate, though the compensation may not be complete. If the fluid Q_2 proves to be insufficient to keep the bit clean when used directly, it may be used as the primary fluid in another jet pump near the bit as is illustrated in Figure 4. Turning to this figure, fluid Q_2 flowing down through passageway 21 enters additional jet pump 60 and educts secondary fluid through passageway 61 from annular space 22. The outflow of this pump may then be directed on the bit cutters and the hole bottom for cleaning purposes. Such a jet pump could deliver the desired amount of fluid and at considerable pressure since P_o minus P_d is large. (Several hundred p.s.i. more than the pressure P_o minus P_a which actuates the main pump.)

In accordance with the present process the formation between the packer and the bit is never exposed to the normal direction of mud pressure unless the pumps are shut down. Damage to the formation while adding drill pipe will usually be negligible. The distance from the packer assembly to the bit will vary and will be a function of a number of factors such as the thickness and presumed tightness of strata of interest. Normally this distance will vary between about 5 and 50 feet. The present process can profitably be used through most earth strata of potential interest in most wildcat wells, since essentially the only penalties (relative to ordinary drilling) are a slight reduction in drilling rate and some mud contamination. The gains secured are reduced logging and drill stem costs, and above all increased assurance of not missing producing horizons.

The advantages of the jet pump shown in the figure, for maintaining the desired pressure differential, is its simplicity and low cost. It is also adapted to handling the solid-laden fluid from around the bit. Its disadvantage is its relatively low efficiency, which increases the total horsepower requirement for a given pressure differential and fluid delivery to the bit. Thus in some applications, e.g. extremely deep wells, it may be desirable to use instead an axial flow turbine and pump combination, or even a piston type assembly. It is also within the concept of the present invention to use a conventional two-stage or tandem jet. A suitable turbine-pump combination is illustrated in Figure 5 where turbine 60 positioned within drilling fluid passageway 21 drives pump 61 positioned

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within upflowing passageway 8. Power is transmitted from the turbine to the pump as by means of shaft 62. It will be appreciated of course that fluid must not be permitted to flow along shaft 62 between passageways 8 and 21, and prevention of such flow can be attained by conventional means.

The present invention is broadly concerned with a drilling procedure whereby the pressure of the drilling fluid adjacent the drilling bit is maintained less than formation pressure thereby permitting formation fluids to flow into the drilling mud and to be removed to the surface along with the upflowing drilling mud. In accordance with the present invention a sealing assembly is utilized somewhat above the bit which is sufficient to withstand a differential pressure between the fluid immediately above the sealing element and the fluid below the sealing element. The precise apparatus to secure this result may be varied appreciably. For instance to reduce the pressure differential across a packer, two or more packers may be used in tandem as illustrated in Figure 6. If two packers are utilized the space between these packers may be connected to the intermediate level of a two-stage pump 70 as further illustrated in Figure 6 for reducing the pressure about the bit. Pump 70 has two stages S_1 and S_2 both disposed within passageway 29 and driven by a turbine 71 positioned within the stream of drilling mud Q_1 . Port 72 is provided to establish fluid communication between the suction side of S_2 and the annular space 25 between the packers of sealing assemblies 26 and 27. These respective packers may be designed to leak before they break, thus constituting an automatic "pressure limiter." Furthermore separate pressure limiters, set above working differential but below rupture pressure, may be installed about each packer.

It is within the concept of the present invention to employ suitable means to stop or reduce the flow of drilling fluid through the bit, thereby increasing the capacity of the jet pump and increasing the rate and quantity of formation fluids entering the bore hole. Also, since it will be possible to continuously analyze for formation fluids in accordance with the present process it will be unnecessary to unduly consider the formation plugging characteristics of the drilling mud, thus reducing mud engineering costs.

As pointed out heretofore, the quantity of mud Q_3 employed in jet pump 5 will vary depending upon, among other factors, mud density and depth of the bore hole. For instance, at about 10,000 feet the quantity of mud Q_3 passing through the bit comprises about 20% to 25% of the total mud flow. In fast drilling areas, where various types of jet bits are utilized, this possibility may reduce or decrease the drilling rate to an undesirable figure. This situation can be overcome to a large degree by the utilization of two packers as illustrated in Figure 2. Referring specifically to Figure 2, the entire assembly is shown disposed in the bottom of borehole 21 and attached to the end of drill string 22. A quantity of mud Q_1 is pumped down the drill string. A quantity of mud Q_2 passes downwardly through the jet bit and into the area 23 about the bit 24. An area 25 in the annulus just above the bit is sealed off by means of packer elements 26 and 27 which are similar to those described with respect to Figure 1. A quantity of mud Q_2 which passes through the bit 24 into the annulus area 23 passes into the annulus 28 above packer 26 through mud up-flow 29. A portion of the mud quantity Q_1 designated as Q_3 is diverted into jet pump 30 through jet 31. Thus, the pressure in annulus 25 P_a is maintained below the formation pressure P_f . Therefore, any fluids in the formation about area 25 will flow into area 25 and be pumped into area 28 by means of jet pump 30. These formation fluids will flow to the surface with the upflowing drilling mud and thereupon be detected by conventional mud logging techniques.

Under the conditions of operation as described with

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respect to Figure 2, the annulus area about the bit is at annulus pressure while the annulus area between the packing is at a pressure below formation pressure. The quantity of mud flowing through the bit will vary depending upon depth and other operating factors. An operation can be designed to pass from about 70% to 80% of the mud through the bit and to use only 20% to 30% of the total down-flowing mud Q_1 to actuate the jet pump. While this adaptation of the present invention does flush out chips, as in conventional drilling, and may tend to force some drilling mud into the formation as the bit is penetrating the formation, this will not be a serious condition since the mud exposure time will be at a relatively low level. Furthermore, the use of 80% of the fluid for actual drilling will result in no appreciable loss of drilling rate as compared to the standard practice.

What is claimed is:

1. In rotary-type drilling apparatus, the improved combination for simultaneously drilling a borehole and testing a formation penetrated by the borehole which comprises a string of drill pipe adapted to be positioned within the borehole, an assembly device attached to the lower end of the drill string, a drill bit attached to the lower end of the assembled device and adapted to rotate with the drill string and the assembly device, a downflow fluid passageway within said assembly device communicating with the drill string and the drill bit, a sealing device rotatably mounted about said assembly device and adapted to form a seal against the wall of the borehole, a by-pass passageway within said assembly device extending around said sealing device and communicating at each end with the borehole annulus about said assembly device, a jet pump comprising a jet nozzle positioned within said by-pass passageway and adapted to pump fluid upward within said by-pass passageway, and a jet fluid passageway communicating between said jet nozzle and said downflow fluid passageway.

2. Apparatus for simultaneously drilling a borehole within the earth and for testing a formation penetrated by the borehole which comprises a string of drill pipe adapted to be rotated within the borehole, an assembly device attached to the bottom of the drill string, a drill bit attached to the bottom of the assembly device, a downflow fluid passageway within said assembly device communicating with the drill string and the drill bit, upper and lower sealing devices vertically spaced from one another and rotatably mounted about said assembly so as to seal against the wall of the borehole, an upflow fluid passageway within said assembly device communicating with the borehole annulus below said lower sealing device and above said upper sealing device, a by-pass passageway within said assembly device extending around said upper sealing device and communicating at each end with the borehole annulus about said assembly device, a jet pump comprising a jet nozzle positioned within and adapted to pump fluid upward through said by-pass passageway, and a jet fluid passageway communicating with said jet nozzle and said downflow fluid passageway.

3. In a process for drilling a borehole within the earth wherein a string of drill pipe and a bit supported therefrom are rotated and advanced through the earth, and wherein a drilling fluid is passed down through the drill string to the bit and thence upward within the annular space between the drill string and the wall of the borehole, the improvement which comprises packing off a portion of the annular space between the bit and the surface of the earth, educing fluid from the packed-off portion at a rate sufficient to lower the pressure within said portion to a value below the pressure within the earth surrounding said portion, discharging the educed fluid into the annular space above said portion, by-passing upflowing drilling fluid around each packing-off point, and advancing the packed-off portion down the borehole as the borehole is drilled.

4. In a rotary method of drilling a borehole within the

earth wherein a bit is advanced through the earth at the lower end of a string of drill pipe and wherein drilling fluid is passed down within the drill string, the improvement which comprises directing a first portion of the downflowing drilling fluid toward the drill bit to flush drill cuttings from the bit, packing the borehole annulus at at least one point spaced from and above the bit to pack off a section of the borehole annulus between the drill string and the wall of the borehole from the borehole annulus proper, advancing the packing points at substantially the same rate as the drill bit, by-passing said first portion of drilling fluid containing flushed drill cuttings around each packing point, discharging said by-passed first portion and said cuttings into the borehole annulus proper above said packed-off section, jetting a second portion of the downflowing drilling fluid so as to educe fluid from said packed-off section and so as to maintain the pressure within the packed-off section at a value less than the pressure within the portion of the earth surrounding the packed-off section, discharging the educed fluid and the jetted second portion of drilling fluid into the borehole annulus proper above the packed-off section, and withdrawing said first and second portions of said drilling fluid together with flushed drill cuttings and educed fluid from the borehole annulus.

5. In rotary-type apparatus for drilling a borehole in the earth including a string of drill pipe and a drill bit supported therefrom, the improvement which comprises an assembly device inserted between and attached to the drill string and the drill bit, a downflow passageway providing fluid communication between the drill string and the bit, at least one sealing device rotatably mounted

around said assembly device and adapted to seal off a section of the borehole annulus existing between the assembly device and the wall of the borehole, a by-pass passageway within the assembly device communicating at one end with the borehole annulus above the uppermost sealing device and at its lower end with the borehole annulus below the lowermost sealing device, pumping means adapted to pump drilling fluid down through the drill string to the bit and thence through the borehole annulus and the bypass passageway back to the surface of the earth, education means disposed within said assembly device and adapted to educe fluid from the sealed-off section of the borehole and to discharge the educed fluid into the borehole annulus above the uppermost sealing device.

6. An apparatus as defined in claim 5 in which each sealing device is inflatable and slidable along the length of the assembly device and in which means are provided on the assembly device for limiting the uppermost and lowermost positions of each sealing device relative to the assembly device.

7. A method as defined in claim 3 in which the packed-off portion is advanced intermittently as the borehole is drilled.

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