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ABRASIVE JET DRILLING FLUID

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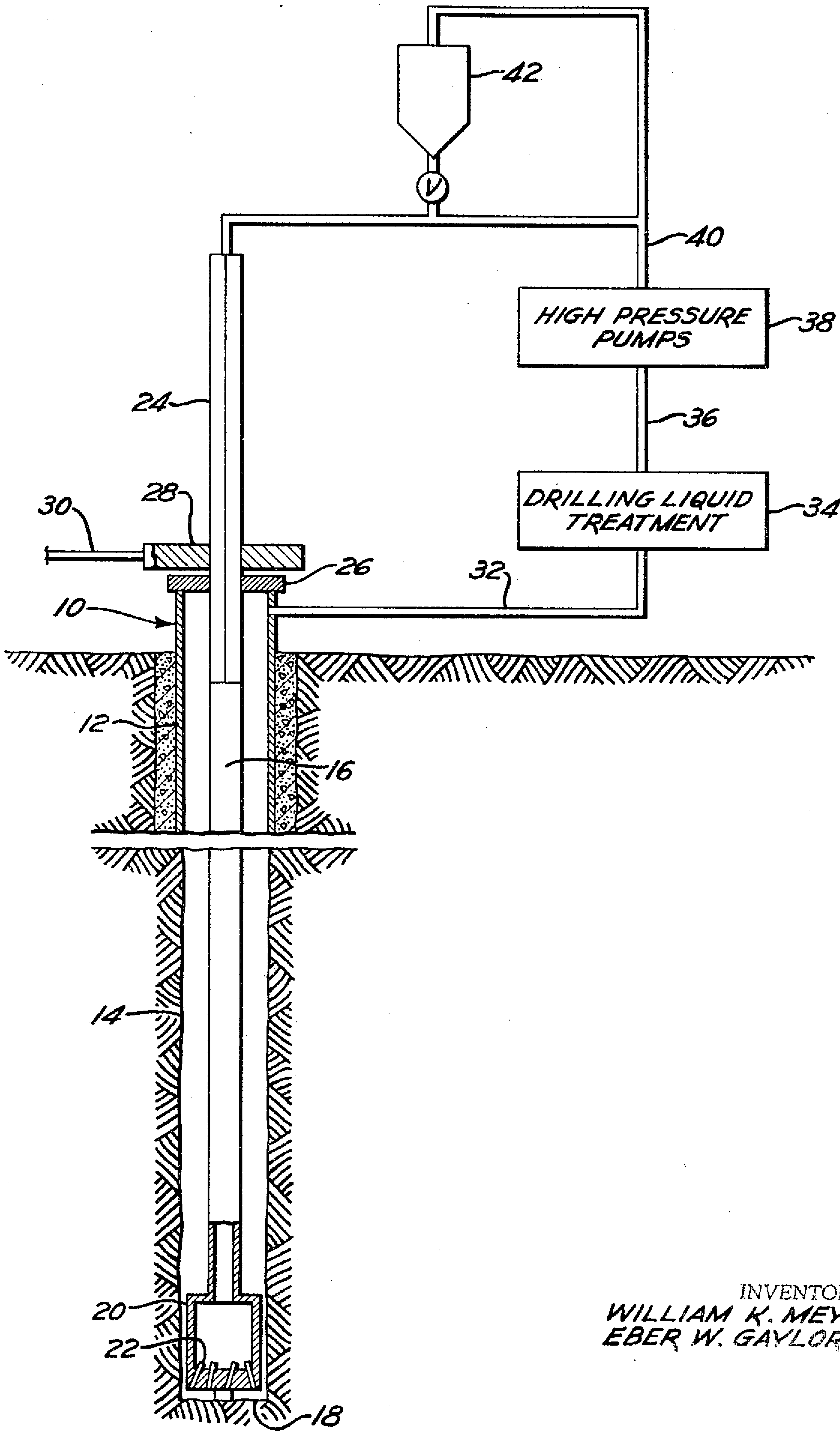

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ABRASIVE JET DRILLING FLUID

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Continuation-in-part of abandoned application Ser. No. 615,205, Feb. 10, 1967. This application Sept. 9, 1968, Ser. No. 758,357
Int. Cl. E21b 7/18
U.S. Cl. 175—67 14 Claims

ABSTRACT OF THE DISCLOSURE

A method of hydraulically jet drilling a well by injecting into drill pipe a novel drilling liquid comprising clay, water, ferrous abrasive particles and fibers derived from wood and plants, discharging the drilling liquid through bit nozzles and against the formation at a high velocity, and circulating the drilling liquid, and pieces of formation removed by the drilling liquid, up the annulus to the surface.

This application is a continuation-in-part of our application Ser. No. 615,205 filed Feb. 10, 1967, now abandoned.

This invention relates to drilling wells, and more particularly to a drilling liquid valuable in a hydraulic jet drilling process in which the drilling liquid is discharged at high velocities against the bottom of the borehole of a well to penetrate hard formations.

Most oil and gas wells are presently drilled by a rotary drilling process in which a bit rotated at the lower end of drill pipe mechanically breaks particles from the bottom of the borehole. A drilling mud is circulated down the well through the drill pipe and up through the annulus surrounding the drill pipe to remove cuttings from the borehole. Clay solids are dispersed in the drilling mud to increase the viscosity and gel strength of the drilling mud to aid in removal of the cuttings from the hole. Another function of the drilling mud is to counteract pressures existing in underground formations and prevent flow from these formations into the borehole during the drilling operations. Weighting agents, particularly barite, are incorporated in the drilling mud to increase its density and thereby create hydrostatic pressure adequate to overcome the formation pressure. Both the barite and clay particles suspended in drilling muds are finely divided. Most of the particles will pass through a 325 mesh screen.

The conventional rotary drilling method described in the preceding paragraph allows extremely fast drilling in shallow and/or soft formations, but the rate of drilling decreases rapidly as both the depth of burial and the hardness of the formation increases. The slow drilling in these formations is aggravated by increased wear of the drill bit which makes necessary frequent interruption of the drilling for replacement of the bit.

A drilling method that has been developed in an attempt to overcome the high cost of drilling hard formations is hydraulic jet drilling. In hydraulic jet drilling, an abrasive-laden liquid is pumped down through drill pipe and is charged at a velocity of preferably 650 feet per second or more through a plurality of nozzles in a drill bit at the bottom of the drill pipe. A preferred abrasive material for use in the hydraulic jet drilling process is iron or steel grit or shot having a particle size of 10 to 80 mesh and preferably 20 to 40 mesh. It is essential that the drilling liquid used in the hydraulic jet drilling process be capable of suspending the abrasive as well as the cuttings when circulation of the drilling liquid is interrupted while adding a joint to the drill pipe or pulling

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the drill pipe to replace a drill bit. The high density and large size of the ferrous abrasives make suspension of the abrasive particles in the drilling liquid difficult. A drilling liquid of suitable suspension properties cannot be obtained merely by the addition of clay solids without increasing the viscosity and gel strength of the drilling liquid to such an extent that the pressure loss in the drill pipe precludes effective drilling by the hydraulic jet drilling method.

This invention resides in a novel hydraulic jet drilling method and drilling liquid in which clay solids, fibers derived from wood and other plant sources, and ferrous abrasive particles are suspended in an aqueous liquid. The resultant drilling liquid is circulated down a well and discharged at high velocities produced by a pressure drop of the order of 4000 pounds per square inch or more across the nozzle against the bottom of the borehole to penetrate the formations being drilled. A preferred drilling liquid of this invention contains additives to reduce fluid loss of the liquid, control the pH and prevent bacterial growth.

The single figure of the drawing is a diagrammatic view, partially in vertical section, of apparatus for drilling by this invention.

Referring to the drawing, a well indicated generally by reference numeral **10** is illustrated with casing **12** set in the upper end of the well and with open hole **14** at the lower end of the well. Drill pipe **16** extends downwardly through the well substantially to the bottom **18** of the borehole. A drill bit **20** having a plurality of nozzles **22** opening through its lower end is connected to the lower end of the drill pipe **16**.

A kelly **24** connected to the upper end of drill pipe **16** extends through a suitable closure **26** and rotary table **28**. Power is supplied to the rotary table **28** through a suitable shaft **30** to rotate the drill pipe **16** and the drill bit **20** secured to the lower end of the drill pipe **16**.

Opening from the casing **12** below closure **26** is a discharge line **32** extending to apparatus **34** indicated generally by the legend "Drilling Liquid Treatment." Ordinarily, the treatment consists of removing from the drilling liquid large-size cuttings and very fine particles and cooling the liquid before passing it to the high-pressure pumps. A treated mud line **36** from the drilling liquid treatment apparatus **34** delivers treated drilling liquid to high pressure pumps **38** which recirculate the drilling liquid through an injection line **40** to the upper end of the kelly **24**. A pressure transfer case **42** may be provided for injecting the abrasive into the high pressure drilling liquid delivered to the upper end of kelly **24**.

In the performance of the hydraulic jet drilling method of this invention, an aqueous suspension of plant fibers and clay solids is delivered by high pressure pumps through injection line **40** into the upper end of kelly **24**. The drilling liquid passes from kelly **24** downwardly through drill pipe **16** into the drill bit **20** from which the drilling liquid is discharged through nozzles **22**. The high flow rate of te drilling liquid provided by high pressure pumps **38** causes a pressure drop across nozzles **22** of at least 4000 and preferably 5000 p.s.i. The high-velocity jets discharged from the nozzles cut the bottom **18** of the borehole and the cuttings from the bottom of the borehole are circulated upwardly through the annulus between the borehole wall and the drill pipe to the top of the well.

Drilling liquid discharged through discharge line **32** is delivered to apparatus **34** in which the drilling liquid is treated before it is recirculated in the well. Preferably, after one circulation of the aqueous suspension of plant fibers and clay solids, the ferrous abrasive particles are introduced into the suspension to form the desired drilling liquid. The incorporation of the ferrous abrasive particles can be accomplished in the drilling liquid treatment and the abrasive-laden drilling liquid delivered to the high-pressure pumps **38**. Another method of incorporating the abrasive particles is to add the abrasive particles to the abrasive-free liquid discharged from the pumps **38**. Such addition can be accomplished by means of the high pressure transfer case **42**. The abrasive-laden liquid is then pumped down through the drill pipe and discharged through the nozzles **22** to cut the bottom of the borehole. Clay solids, plant fibers, ferrous abrasives, fluid-loss additives, bacterial inhibitor and water are added to the system as required to maintain the desired volume of drilling mud of the desired composition.

In the hydraulic jet drilling method, it is essential that the abrasive-laden drilling liquid be discharged from the drill bit at a high velocity against the bottom of the borehole. In a preferred method, a plurality of jet streams cut the major portion of the bottom of the borehole as the jet bit **20** is rotated. Because of the extremely high velocity at which the drilling liquid is discharged from the drill bit and the necessity of a large number of jet streams, usually 10 to 20, to cut substantially the entire bottom of the borehole, the flow rate of the drilling liquid pipe and annulus is high. Unless the drilling liquid has a unique combination of strong solids suspension characteristics and low pressure drop, it cannot be used effectively in hydraulic jet drilling with ferrous abrasives. Clay alone, in an aqueous suspension having a viscosity and gel strength adequate to suspend ferrous abrasives, causes an excessive pressure drop in the drill pipe and annulus.

The plant fibers used in the drilling liquid of this invention are finely divided. The length of these fibers varies with the type of plant from which they are obtained. Suitable fibers may be obtained from either soft or hardwood trees or by fibrous plants such as sugar cane. Fibers derived from wheat straw or rice straw can be used.

Wood pulp fibers from deciduous trees range in length generally from 1 to 1½ mm. while fibers from coniferous trees range in length generally from 3.5 to 5 mm. While fibers of either coniferous or deciduous origin may be effectively utilized in the drilling liquid of this invention, it is preferred that the wood pulp fibers be obtained from coniferous trees. The long fibers of soft wood trees demonstrate more suspending power than deciduous wood pulp fibers. Any ordinary commercial wood pulp fiber usually produced in sheet form is an example of a suitable source of wood pulp for use in this invention.

The wood pulp fibers are suspended in a concentration in the range of ½ percent to 5 percent by weight of the drilling liquid, where long coniferous derived wood pulp fibers are employed, or 1 percent to 5 percent where short deciduous wood pulp fibers are used. The term "long wood pulp fibers" is defined in this application as wood pulp fibers whose length is in excess of 2 mm. A preferred concentration of wood pulp fiber for use in this invention would be in a range of 1½ to 2½ percent by weight of long fibers or a range of 2 to 4 percent by weight if short fibers are used.

The lower limits of wood pulp fiber concentration are controlled by the optimum viscosity of the mud system prior to adding the fibers. During jet drilling, it is desirable to keep the mud viscosity as low as possible. By depending on the suspension properties of the wood pulp fibers to suspend the ferrous abrasive particles a high viscosity, high gel strength mud system is not needed.

A preferred plant fiber for use in this invention is bagasse fiber derived from sugar cane. Drilling liquids of this invention in which the plant fiber is bagasse fiber have better ability to suspend ferrous abrasive particles than drilling liquids containing the same concentrations of wood fibers. Moreover, drilling liquids containing bagasse fibers have a lower filtrate loss than drilling liquids containing wood fibers. Because of the better suspending properties resulting from the bagasse fibers, lower concentrations of bagasse fibers can be used. Bagasse fibers have a length in the range of 1 to 4 mm. They generally have a higher ratio of length to thickness than wood fibers.

Clay solids are incorporated in the aqueous suspension of aqueous fibers as a dispersing agent aiding in dispersion of the fibers in the liquid. The clay solids also aid in the suspension of the abrasives by increasing the viscosity of the drilling liquid. A clay such as attapulgite is preferred over high-yield clays such as bentonite which produce a fluid with a higher friction drop. Either type clay will however be satisfactory to use in the mud system of this invention.

Where attapulgite is employed to form a fresh or salt water mud system, the attapulgite clay should represent 2 to 7 percent by weight of the resultant aqueous mud system. A preferred attapulgite system would be a suspension in which this clay is present in the mud system in a range of approximately 4 to 6 perecnt by weight.

Bentonite is employed only in fresh water mud systems. The bentonite clay should represent 1 to 4 percent by weight of the resultant aqueous mud system. It is preferred in this invention however that the bentonite should be present in the mud system in a range of approximately 2 to 3 percent by weight.

The aqueous suspension of plant fiber and clay solids will in many instances be an adequate drilling lquid without further modification. When drilling some formations, the loss of liquid from the liquid phase of the drilling fluid, called filtrate, may be excessive. To prevent excessive loss of drilling liquid, sodium carboxymethyl cellulose, pregelatinized starch, small portions of oil, or other additives well known to reduce filtrate may be added to the drilling liquid. Because of their lower filtrate loss, drilling liquids containing bagasse fibers require less fluid loss reducing additives. In the instance where conditions are favorable to bacterial growth which will attack the wood fibers or fluid-loss agents, various bacterial inhibitors may also be added to the drilling liquid. Examples of such bacterial inhibitors are Formalin, substituted phenols and hypochlorite.

When making up the initial drilling liquid for the hydraulic jet drilling process, the aqueous suspension of plant fibers is preferably circulated at least once through the drill bit to adequately disperse the plant fibers and give a drilling liquid capable of suspending the ferrous abrasive. Although this first pass of the abrasive-free drilling fluid is not mandatory, it does however function to further mix the wood fibers in the liquid, produce a more uniform concentration, and increase the suspending power of the drilling liquid.

The ferrous abrasive is added in a concentration of 1 to 20 percent and preferably 1½ to 10 percent by volume of the drilling liquid. Concentrations of ferrous abrasives in the range of 10 to 20 percent are used when a drilling liquid of high density is desired for drilling through formations at high pressures. The ferrous abrasives used in hydraulic jet drilling are commercially available abrasives widely used in cleaning metal castings. It is preferred that the abrasive particles have a Rockwell C hardness of at least about 55 and have a particle size in the range of 10 to 80 and preferably 20 to 40 mesh. Either cast iron or steel particles are suitable and the particles can be either in the form of shot or grit.

The drilling liquid used in hydraulic jet drilling is subjected to severe shear as it passes through the nozzles in the drill bit. Many of the organic compounds, such as starches, gums, carboxymethyl cellulose, and acrylonitriles, that have been added to drilling muds to thicken them and reduce the fluid loss of the drilling mud, are degraded when subjected to the severe shear in the drill bit nozzles. In contrast, the novel drilling liquids of this invention have little tendency to degrade as they are subjected to the severe shear in the drill bit nozzles. Owing to the inherent strength of the individual plant fibers, the fibrous particles in the drilling liquid remain substantially unbroken and therefore require only moderate fiber additions to the system to maintain the optimum concentration of long fibers in the system.

The ferrous abrasive particle suspension characteristics of this drilling mud are believed to be produced by the physical entanglement of the plant fibers and the electrostatic attraction between the fibers to form a brush-type network. The particle suspension produced by the plant fibers thereby allows the operator to utilize a liquid system which possesses a low viscosity. By maintaining the viscosity of the drilling mud at a low level the operator is able to pump the aqueous suspension at high velocities while maintaining a relatively low pressure drop both within the drill pipe and within the annulus between the drill pipe and the borehole wall. The reduction of pressure losses in the system permits a greater portion of the energy imparted to the drilling liquid to be expended in the cutting of the borehole. The reduction of pressure losses in the annulus also reduces the danger of formation fracturing. The problem of formation fracturing often occurs where pressure losses are high and high fluid velocities are maintained. High borehole pressure also increases sloughing during periods of quiescence when the differential pressure between the well bore and the formation pressure is reduced or the direction of the differential pressure is changed.

The drilling mud of this invention is not affected by salt, calcium chloride, hydrogen sulfide or calcium sulfate contamination. Salts such as sodium chloride or calcium chloride may therefore be added to make this mud system inert to drilling solids and thereby decrease treating costs. These salts may also be added to increase the density of the mud of this invention without the corresponding viscosity increase accompanying density increases where solids are added. In contrast to conventional muds, the viscosity of the liquid phase of the mud of this invention can be controlled without altering its suspending ability. The addition of sodium chloride or calcium chloride will also reduce sloughing of the formation and damage to the formation caused by mud invasion.

Owing to the low liquid viscosity of the mud of this invention, solids can easily be separated. This mud possesses high suspension characteristics which allows addition of large amounts of density increasing materials without increasing the viscosity to such an extent that drill pipe pressure losses will be excessive.

To illustrate the increased suspension properties and decreased pressure drop of the mud of this invention, three example muds were tested in the laboratory. Although there is no method of absolutely measuring the suspension properties of mud, torsion type rotating viscosity meter tests at three revolutions per minute are commonly utilized in the oil industry to quantitatively indicate a mud's suspendibility properties. Drill pipe pressure loss tests were made by passing the mud through 411 feet of 3.8 inch ID pipe at 600 gallons per minute. Mud A was a 6 percent bentonite-water conventional rotary type drilling mud. Mud B was an invert emulsion old type, jet drilling mud comprising 34 percent diesel oil, 1 percent emulsifier detergent and 65 percent water. Mud C is an example of the new jet drilling mud of this invention comprising 3 percent attapulgite clay, 3 percent hardwood fibers, ½ percent soft wood fibers and 93½ percent water. The test results are as follows:

Mud	3 r.p.m. fann reading	Pressure drop, p.s.i./100 ft.
A	2	14.1
B	21	16.5
C	10	9.0

In the jet drill method of this invention it is desirable to maintain the pressure drop in 3.8 inch ID drill pipe

below 12.5 p.s.i./100 ft. The viscosity tests indicated that mud A would not suspend the jet drilling ferrous abrasive particles. Muds B and C would adequately suspend the ferrous abrasive particles, but mud B had a pressure drop approximately 25 percent in excess of the desired maximum. Mud C, an example of the mud of this invention, therefore proved to have suspension and pressure drop properties superior to heretofore employed jet drilling muds.

The method of drilling hard formations utilizing a drilling water suspension containing, by weight of liquid, 1 to 7 percent clays, ½ to 5 percent plant fibers and 1 to 20 percent ferrous abrasives by volume of the liquid, increases the efficiency of the drilling operation. The drilling efficiency is increased by decreasing the pressure losses within the system, decerasing the mud additives needed to maintain the desired concentration and by maintaining optimum particle suspension.

Therefore we claim:

1. A method of hydraulically jet drilling a well in which is inserted a string of drill pipe having a hydraulic jet drill bit attached to its lower end comprising injecting into the upper end of the drill pipe a drilling liquid comprising clay, water, ferrous abrasive particles and plant fibers; discharging the drilling liquid through the drill bit and against the bottom of the borehole at a rate adequate to produce a pressure drop across the bit of at least 4000 pounds per square inch; and circulating up the annulus formed between the drill pipe and the wall of the borehole, the drilling liquid discharged from the drill bit and the particles of the formation cut and abraded from the bottom of the borehole.

2. A method of hydraulically jet drilling a well in which is inserted a string of drill pipe having a hydraulic jet drill bit attached to its lower end comprising injecting into the upper end of the drill pipe a water-base drilling liquid comprising clay in a concentration between 1 to 7 percent of the weight of the liquid, ferrous abrasive particles having a size in the range of 10 to 80 mesh in a concentration in the range of 1 to 20 percent by volume of the liquid and plant fibers having a fiber length of 1 to 5 mm. and in a concentration of ½ to 5 percent by weight of the liquid; discharging the drilling liquid through the drill bit and against the bottom of the borehole at a rate adequate to produce a velocity of at least 650 feet per second and a pressure drop across the bit of at least 4000 pounds per square inch; circulating up the annulus formed between the drill pipe and the borehole of the well, the drilling liquid discharged from the drill bit and the particles of the formation cut and abraded from the bottom of the borehole; separating from the drilling liquid substantially all of the particles of the formation cut and abraded from the bottom of the borehole; and recirculating the drill liquid down the drill pipe.

3. A method as set forth in claim **2** in which the clay is attapulgite.

4. A method as set forth in claim **2** in which the clay is bontonite.

5. A method as set forth in claim **2** in which the fiber is wood pulp fiber.

6. A method as set forth in claim **2** in which the fiber is bagasse fiber.

7. A method as set forth in claim **2** in which the fiber is from coniferous trees.

8. A method as set forth in claim **2** in which the fiber is from deciduous trees.

9. A method as set forth in claim **2** in which the abrasive has a Rockwell C hardness of at least 55.

10. A water-base hydraulic jet drilling fluid of enhanced suspension properties comprising water; clay in a concentration of 1 to 7 percent by weight of the water; ferrous abrasive particles in a concentration of 1 to 20 percent by volume of the water with a particle size between 10 to 80 mesh; and plant fibers in a concentration of ½ to 5 percent by weight of the water.

11. A water-base hydraulic jet drilling fluid as set forth in claim **10** in which the plant fiber is a wood fiber.

12. A water-base hydraulic jet drilling fluid as set forth in claim **10** in which the plant fiber is bagasse fiber.

13. A water-base hydraulic jet drilling fluid as set forth in claim **10** in which the water is salt water and the clay is attapulgite.

14. A water-base hydraulic jet drilling fluid as set forth in claim **10** in which the abrasive has a Rockwell C hardness of at least 55.

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