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Jackson

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[54] **WELL DRILLING METHOD AND APPARATUS**

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[52] **U.S. Cl.** **175/69;** 175/215; 175/243; 175/317; 166/309

[51] **Int. Cl.²** **E21B 21/04;** E21B 43/00

[58] **Field of Search** 175/69, 72, 215, 218, 232, 175/236, 243, 317, 318, 56, 309, 205, 324; 166/309, 311

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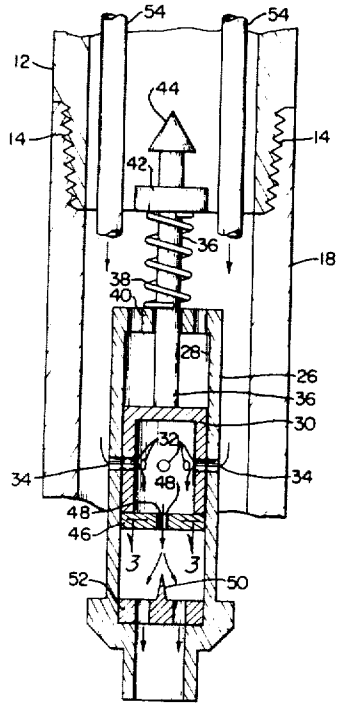
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[57] **ABSTRACT**

Method and apparatus for use in well drilling, such as well completion and reworking, characterized by a foam generator disposed adjacent the bit on the lower end of a drill string to which the foam making materials are delivered for forming foam adjacent the drill bit under controlled differential pressure between the drill pipe fluid column and surrounding drill pipe annulus. In one modification the foam making materials are delivered to the upper end of the drill string for flow to the lower end thereof without combining to form foam. In another modification they may be delivered through pipes directly to the lower end of the drill string. In either modification the foam making materials are discharged at high velocity and pressure conditions are maintained to prevent migration of the foam into the surrounding fluid producing formation which will usually be at relatively low back pressure.

9 Claims, 3 Drawing Figures



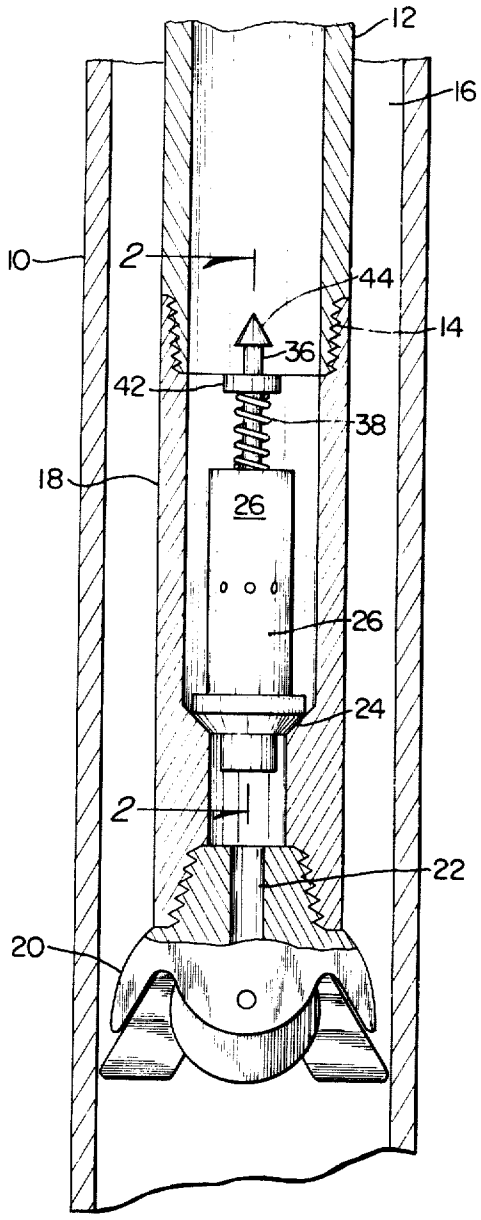


FIG. 1

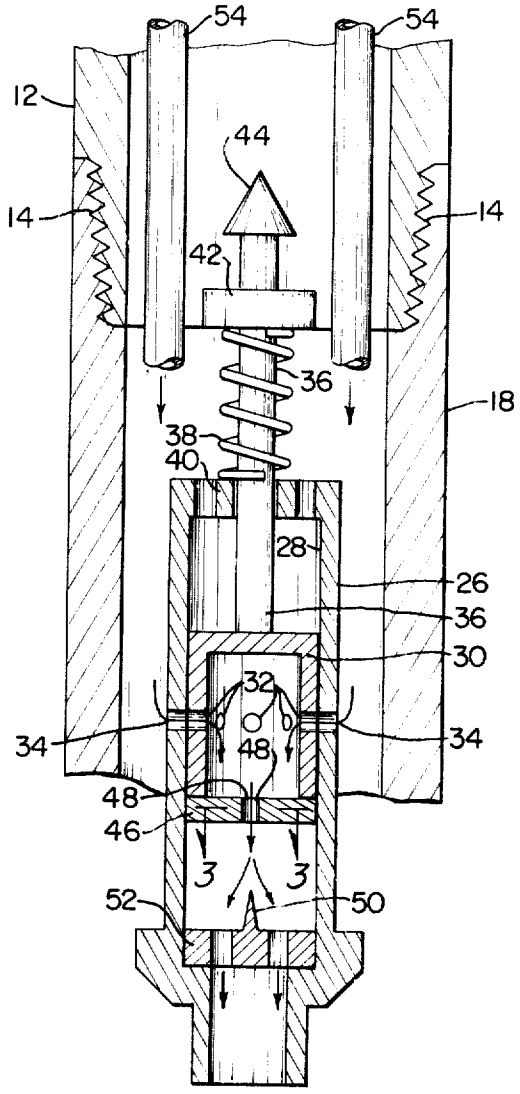


FIG. 2

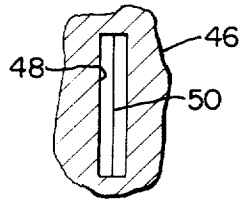


FIG. 3

WELL DRILLING METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

In the drilling of wells for extracting fluids contained in sub-soil formations, it has long been the practice to flow a fluid downwardly through a tubular drill string for delivery to a drill bit at the lower end thereof and return same to the surface through the surrounding annulus, the returning fluid carrying cuttings, sand, or other debris. Originally, drilling mud was employed for this purpose; later, air at high velocity was employed; and more recently, foams have been employed. Each type of fluid, often referred to as the circulating fluid, has its advantages, the selection of which depends upon various conditions in or adjacent the well bore. In the completion of a well bore or the reworking of a producing well, the production of which has been depleted, the principal problem is the removal of accumulated sand in the well bore which reduces the flow rate from the surrounding formation containing the fluid desired to be extracted therefrom. When the pressure in the surrounding formation is only slightly above pressure in the well bore, this presents further problems. For example, if the fluid pressure of the circulating liquid exceeds the formation fluid pressure, the circulating fluid may flow into the formation and reduce its permeability, thus reducing the rate of flow of the desired extracted fluid therethrough. Thus, ideally, a pressure drop between the formation and well bore is desirable to obviate outward flow of the circulating fluid into the formation. This, of course, means that the static pressure at the lower end of the annular column surrounding the drill string must be less than the fluid static pressure within the formation. If the well is relatively deep and the formation fluid pressure is less than the static head of the fluid columns within the drill string or the surrounding recirculating column, it becomes apparent that outward flow of the circulating fluid into the formation is inevitable.

While the use of foam as a circulating medium has been employed, which, of course, reduces the static heads in the columns just referred to, there has been no control of the foam pressure in the locus of the drill bit and surrounding pressure. Generally, the foam is formed at the ground surface above the well and pumped into the drill string.

SUMMARY OF THE INVENTION

In the present invention, foam is employed as the circulating medium, generally as heretofore, but with the essential difference that the drill string contains the mixed ingredients for producing foam which are discharged at high velocity in the locus of the drill bit. The pressure at the point of discharge equals the static head of the column within the drill string (plus any pressure applied at the upper end thereof) which pressure is not applied to the formation. The static pressure of the foam formed adjacent the drill bit and delivered thereto is preferably controlled such that it, together with the static head of the recirculated annular foam column, is less than formation static pressure so that fluid flow from the formation is toward the well bore, thus preventing any outward circulating fluid flow into the formation tending to reduce its permeability.

The foam forming apparatus comprises a tubular member having conventional drill pipe connections at the ends thereof, one of which may be secured to a drill bit and the other to the lower end of a drill pipe string. An adjustable spring loaded valve is provided to control the flow of the foam forming materials in the drill pipe to the drill bit in accordance with a desired pressure drop therebetween. A discharge jet operates at sufficiently high velocity and tubulence to produce the desired foam. The control valve and discharge jet are preferably formed within an insert which may be dropped into the tubular member or removed therefrom without removing the drill string from the well bore.

One of the objects, accordingly, is to provide apparatus for use with a well drill string for generating foam adjacent a drill bit from a supply of foam generating materials contained within the drill string above the apparatus.

Another object is to control the pressure drop between the supply and the generated foam.

Another object is to control the pressure drop so that the foam pressure is less than the static pressure of fluid in a surrounding fluid-bearing formation.

Another object is to discharge the foam generating materials through a jet at high velocity and produce turbulence of the jet to form the foam.

Another object is to render the apparatus removable from the drill string without removing the drill string from the well bore.

A further object is to provide a novel method for completing or reworking a well bore with the use of a foam circulating medium.

Still further objects, advantages, and salient features will become more apparent from the detailed description to follow, the appended claims, and the accompanying drawing to now be briefly described.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a central section through the lower end of a drill string and surrounding casing with the subject of the invention disposed between the lower end of the drill string and the drilling bit;

FIG. **2** is a section taken on line **2—2**, FIG. **1**; and

FIG. **3** is a section taken on line **3—3**, FIG. **2**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to the drawing, and first to FIG. **1**, casing **10** may be assumed to be the existing casing of a well, the production of which has been depleted due to clogging or partial clogging by said or other debris which has entered same from the surrounding formation, removal of which is desired to restore productivity. The clogging material may have entered through the lower end of the casing or through perforations therein (not shown). Drill string **12** is of conventional construction, the sections of which are coupled by tapered threads **14**, the upper end of which is rotated by a rotary table or the like (not shown) as understood in the art, an annulus **16** surrounding the drill string through which the material is to be flowed to the surface of the earth.

The subject of the invention comprises a hollow short drill string extension **18**, the upper end of which is threadedly connected to the lower end of drill string **12**, its lower end having a suitable drilling bit **20** threadedly connected thereto which may be of any conventional construction and provided with a conduit **22**

communicating the interior of the extension with annulus **16.** Extension **18** is provided with a tapered seat **24** upon which sealingly rests foam delivery apparatus **26** which contains the operative parts to now be described in detail.

Referring now to FIG. **2,** apparatus **26** is provided with a bore **28** which slideably receives a piston valve **30** having apertures **32** which communicate with apertures **34** in the position shown and which move to non-communicative position (not shown) when the piston valve moves upwardly. A valve stem **36** is affixed to the piston valve and is urged upwardly by a spring **38** disposed between an apertured bulkhead **40** and a collar **42** which may be adjusted axially on the valve stem to provide a desired spring force. The upper end of the valve stem is provided with a conical head **44** which may receive a suitable fishing tool (not shown) which may be dropped into the drill string for engaging the conical head and removing apparatus **26** from the drill string. Bore **28** is also provided with a fixed plate **46** having a rectangular aperture **48** extending therethrough, also shown in FIG. **3,** which delivers fluid therethrough at high velocity for impingement on knife edge **50** affixed to a fixed apertured bulkhead **52.** As will be apparent from the arrows in FIG. **2,** foam making fluid is delivered downwardly through the drill string, its static head (or additional pressure applied thereto at the surface) being sufficient to move the piston valve against the urge of the spring to the position shown. The fluid then flows through apertures **34,32** and **48** at which locus the fluid is flowing at high velocity for impingement on knife edge **50,** the foam produced then flowing through the drill bit and into annulus **16** for upward discharge to the surface along with the foreign material which is to be removed from the casing.

OPERATION

General

As an example of the operation of the construction so far described, it will be assumed that a producing well, which may be gas, oil, or water, is to be reworked because of production depletion resulting from said clogging of the well bore. It will also be assumed that the fluid pressure in the surrounding formation is relatively low which precludes use of a high pressure fluid in the well bore which would force said or other debris outward into the formation, thus tending to clog same and reduce its permeability. It thus becomes apparent that the applied pressure at the bottom of the bore should be less than formation fluid pressure. Now, if foaming ingredients, such as water, air and a foaming agent, were mixed at the surface to form foam and introduced into the upper end of the drill string, the static head of the foam column could well be less than the formation fluid pressure, thus requiring pumping pressure to be added at the top of the foam column. In the present invention, and in contra-distinction to the procedure just referred to, the foaming ingredients, but in unfoamed and more dense form, are introduced into the upper end of the drill string and foaming occurs at the bottom of the drill string rather than at the surface. The static head of the unfoamed mixture is, of course, considerably greater than a foam column as in the prior art. This static head will often be sufficient for producing the foam and desired pressure differential at the bottom of the well bore, but if not, only a relatively small pressure need be added to the unfoamed mixture at the top of the column.

Normally, the foam producing ingredients may be delivered to the upper end of the drill string as just described. In some instances, however, it may be found desirable to introduce some or all of the ingredients at the bottom of the drill string. FIG. **2** includes this modification in which pipes **54,54** extend from the surface to near the lower end of the drill string and through which some or all of the ingredients may be introduced without flowing downwardly through the entire length of the drill string thus minimizing some foaming which might occur therein. Ordinarily, the foaming agent would be introduced through one of these pipes and water or air through the other, the drill string forming the conduit of the normally third ingredient. This modification, however, introduces mechanical and other complications which would normally be avoided.

Control Valve

Valve **32,34** and spring **38** control the rate of discharge of the foam producing ingredients to the lower end of the well bore. The spring is so chosen (or its spring pressure adjusted by collar **42**) to control the differential pressure between the foam producing ingredients and foam discharge pressure at the bottom of the well bore so that the latter is somewhat less than formation fluid pressure. This, of course, prevents flow of foam or entrained debris outwardly into the formation tending to clog same.

Foam Ingredient Discharge

When the foam producing ingredients are discharged at relatively high velocity into a region of low pressure they form a foam mixture of very low density as compared to their former state. Various discharge orifices may be employed but the type illustrated is preferred, this type sometimes being known as a sonulator which generates ultrasonic acoustic energy, resulting in production of a foam having improved characteristics. Such devices are well known as exemplified by those manufactured by Sonic Engineering Corporation, Norwalk, Conn.

Foam Producing Mixtures

There are many foaming agents available for rendering water and other liquids "foamable," some of which are noted in the U.S. Pat. to Schramm, No. 3,130,798 and Schneider, U.S. Pat. No. 3,313,362. Some which are available on the market are conventional detergents and trade-secret agents such as "Triton QS-15" sold by Rohm and Haas Co. of Philadelphia, Pa., and "Snyfoam" sold by Swift and Co. of Chicago. An agent for stiff foam is marketed under the trade name "Magcobar," and an agent for foaming oily liquids is marketed under the trade name "AMBIDEX" by Carlisle Chemical Works of Reading, Ohio. No invention resides in the foaming agent as most if not all of the conventional foaming agents on the market can be used.

What is claimed is:

1. In well drilling apparatus for use in a formation having relatively low fluid pressure, such as a debris clogged and production depleted well, said apparatus including a drill string and a drilling bit at the lower end thereof adapted to drill a well bore of a diameter to form an annulus surrounding the drill string, the improvements, in combination, comprising:

a. a tubular member disposed adjacent the lower end of said drill string and forming a part thereof for rotating the bit;

b. a foam generator disposed within said tubular member;

c. said generator having a normally closed control valve means so constructed and arranged to open upon application thereto of predetermined pressure of a mixture supply of substantially unfoamed foam producing ingredients, such as air, water and a foaming agent;

d. a mixture discharge orifice communicating with said valve and the lower end of said annulus; and

e. means for delivering said mixture to said valve;

f. whereby said valve is adapted to open in response to differential pressure between mixture supply pressure and pressure at the lower end of said annulus and deliver said mixture to said orifice, said orifice being so constructed to pass said mixture therethrough at high velocity and convert same to a foam, the foam pressure static head at the lower end of said annulus being controlled to be insufficient for any substantial flow thereof into said formation but sufficient to cause upward flow thereof in said annulus to thereby carry debris cut by said bit to the upper end of said annulus for discharge therefrom.

2. Apparatus in accordance with claim **1** wherein the means for delivering said mixture to said valve means consists of the drill string bore.

3. Apparatus in accordance with claim **1** wherein the means for delivering said mixture to said valve means includes at least one conduit within the drill string bore extending from the surface to near the lower end thereof.

4. Apparatus in accordance with claim **1** wherein said control valve means comprises a hollow piston slideable within a bore and having ports in the wall thereof adapted to communicate with ports in the wall of the bore, a valve stem affixed to the head of the piston, a spring for urging the valve stem toward valve closed position, and a head on the valve stem adapted to be grasped by a fishing tool for removing the valve means through the bore of the drill string.

5. Apparatus in accordance with claim **1** wherein said mixture discharge orifice is rectangular in cross section and discharges the mixture onto a knife edge at ultrasonic velocity to affect ultra-sonic vibrations and cavitation within the liquid and produce small stable gas bubbles therein.

6. Apparatus in accordance with claim **1** wherein said tubular member is constructed as a relatively short drill string extension having conventional couplings at the ends thereof for connection to the drill string and the drill bit.

7. Apparatus in accordance with claim **6** wherein said foam generator is so constructed to sealingly engage the tubular member by mutually cooperating surfaces against unauthorized mixture flow to the annulus, said generator being removable through the drill string without removing same from the well bore.

8. Method of drillling or reworking a well having a bore extending into a formation having relatively low fluid pressure and containing debris, such as sand, which it is desired to remove with a circulating foam, comprising the steps of:

a. drilling into said debris with a conventional hollow rotatable drill string having a drill bit at its lower end adapted to produce an annulus surrounding the drill string,

b. introducing foam producing ingredients, such as air, water and a foaming agent through the drill string for delivery at the lower end thereof,

c. flowing the delivered ingredients through a control valve to maintain a discharge pressure less than the surrounding formation fluid pressure to obviate flow of the debris into the formation, and

d. discharging the ingredients through an orifice adjacent the drill bit to convert the ingredients into a lighter density foam adapted to carry the debris through said annulus to the surface.

9. A well drilling process for use in a formation having relatively low fluid pressure, such as a debris clogged and production depleted well, and with a drill string and a drilling bit at the lower end thereof adapted to drill a well bore of a diameter to form an annulus surrounding the drill string, comprising;

a. rotating the bit by a tubular member forming a part of the lower end of the drill string, and having a foam generator therein;

b. delivering a mixture supply of substantially unfoamed foam producing ingredients, such as air, water and a foaming agent to said tubular member under predetermined pressure;

c. delivering the mixture supply through a pressure control valve in the generator;

d. delivering the mixture supply from the control valve through a mixture discharge orifice at high velocity to convert same to foam; and

e. delivering the foam to the lower end of said annulus at a controlled static pressure head insufficient for any substantial flow thereof into said formation but sufficient to cause upward flow thereof in said annulus to thereby carry debris cut by said bit to the upper end of said annulus for discharge therefrom.

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