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METHOD OF RELEASING IMMOBILIZED DRILL PIPE

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This invention relates to the drilling of wells into the earth and relates more particularly to a method for releasing drill pipe which during the drilling operation has become immobilized in the well borehole.

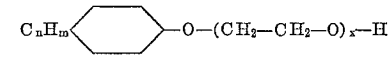
In the drilling of wells into the earth, the drill bit is rotated by means of a drill string which extends from the drill bit to the surface of the earth. The drill string consists of sections of drill pipe and, variously at joints between sections of the drill pipe, drill collars are employed to add weight to the drill string and thus to the drill bit. The diameter of the drill bit is greater than that of the drill pipe and of the drill collars in order to effect rotation of the pipe and collars within the well borehole. However, by necessity, in order to provide a weight greater than that of an equal length of drill pipe, the drill collars have a diameter greater than that of the drill pipe.

During drilling, a drilling fluid is continuously circulated downwardly through the drill pipe, out at the drill bit, and upwardly through the well borehole within the annular space between the drill string and the walls of the well borehole. The purpose of the drilling fluid is mainly the removal of the cuttings from the well borehole although the drilling fluid performs other functions. Various of the strata, or formations, penetrated by the well borehole may be porous and the hydrostatic pressure of the drilling fluid may be higher than the fluid pressure within the porous formations. Complete loss of the drilling fluid into the porous formations under this pressure differential is prevented only by the inclusion in the drilling fluid of solid materials which form a relatively impermeable filter cake on the walls of the well borehole.

Occasionally, drilling operations are halted temporarily and the rotation of the drill string is discontinued. At these times the pressure differential between the drilling fluid and a porous formation, plus the component of weight of the drill string normal to the walls of the well borehole, causes the drill string, and particularly the larger diameter drill collars, to press against the filter cake lining the walls of the well borehole. Additionally, filtration from the drilling fluid into the porous formation continues with the result that further filter cake builds up in the area of contact between the drill collar and the original filter cake. Moreover, contraction of the filter cake between points of contact with the drill pipe effects a further build-up of the filter cake. As a consequence, the total pressure, i.e., the pressure differential multiplied by the contact area plus the weight of the drill stem normal to the walls of the well borehole, on the drill string, increases tremendously and the force required to rotate the drill string when drilling operations are to be resumed is similarly increased. Thus, it can occur that the force required to rotate the drill string may be so high that breakage of the drill string occurs before the drill string becomes unstuck. This type of sticking of the drill string is commonly known as "differential pressure sticking." Various proposals have been made to eliminate the problem of pressure differential sticking of the drill string. However, many of these proposals excessively increase the cost of drilling or otherwise leave much to be desired.

It is an object of the invention to provide a method for releasing immobilized or stuck drill pipe in a well borehole. It is another object of this invention to provide a method for reducing the force required to overcome differential pressure sticking of drill pipe. It is another object of this invention to reduce the cost of releasing stuck drill pipe. These and other objects of the invention will become apparent from the following detailed description.

In accordance with the invention, there is spotted into a well borehole containing drill pipe immobilized by differential pressure sticking a body of liquid comprising a mixture of a liquid hydrocarbon and an alkyl aryl polyethylene oxide. This body of liquid is spotted into the well borehole adjacent to the wall of a permeable formation where the drill pipe is stuck and is permitted to remain thereat for a suitable period of time. Thereafter, a torque or tension, or both, is applied to the drill string. The alkyl aryl polyethylene oxide must contain an alkyl group connected to a benzene nucleus and the alkyl group must contain at least six but not more than ten carbon atoms and the polyethylene oxide chain must contain at least six but not more than eleven ethylene oxide groups on the average. The general formula for the alkyl aryl polyethylene oxide is as follows:



where n has a value between 6 and 10 and x has a value between 6 and 11.

In the practice of the invention, a body, or slug, of liquid comprising the mixture of a liquid hydrocarbon and an alkyl aryl polyethylene oxide is passed into the well borehole. The body, or slug, of liquid, as a separate liquid entity, is moved to the desired location in the well borehole by forcing behind it another body of liquid. The body of liquid comprising the mixture of liquid hydrocarbon and the alkyl aryl polyethylene oxide can be injected into the drill pipe. It can then be forced downwardly through the drill pipe, out of the drill pipe at the drill bit, and thence upwardly through the annular space between the drill pipe and the wall of the well borehole to the desired location or locations. Alternatively, the body of liquid can be passed into the annular space between the drill pipe and the wall of the well borehole at the top of the well borehole and passed downwardly to the desired location or locations.

It is preferred that the body of liquid comprising the mixture of a liquid hydrocarbon and the alkyl aryl polyethylene oxide, upon passage through the well borehole to the desired location or locations, be immiscible with whatever fluid may be in the well borehole at its leading edge and at its trailing edge. Under such circumstances, mixing of the body of liquid with other liquids in the borehole is minimized. Mixing, if any, will be only such as will occur at the interfaces of the body of liquid with other liquid in the well borehole. Thus, where an aqueous drilling fluid is employed, the body of liquid will be immiscible with the drilling fluid in the well borehole and aqueous drilling fluid, or water, may be employed as the liquid for forcing the body of liquid through the borehole. By aqueous drilling fluid is meant a drilling fluid wherein the liquid phase is composed entirely of water or, where oil is present in the liquid phase, the continuous phase of the fluid, as distinguished from the dispersed phase, is water. On the other hand, where the drilling fluid is an oil base drilling fluid, i.e., where the liquid phase is composed entirely of oil or, where water is present in the liquid phase, the continuous phase is oil, the body of liquid is preferably preceded, and followed, through the well borehole by a body of water or by an emulsion wherein the continuous phase is water.

The body of liquid comprising the mixture of a liquid

hydrocarbon and the alkyl aryl polyethylene oxide contains the alkyl aryl polyethylene oxide in an amount at least as great as 2 percent by volume. Amounts greater than 2 percent by volume can be employed. For example, the amount can be 10 percent by volume. Greater amounts than 10 percent by volume can also be employed. Ordinarily, however, satisfactory results can be obtained with amounts between 2 and 10 percent by volume.

The liquid hydrocarbon employed in the body of liquid may be any liquid hydrocarbon that will remain in the liquid phase under the temperature and pressure conditions encountered during the operation of releasing the stuck drill pipe. Satisfactory results are obtained employing liquid hydrocarbons having boiling points at atmospheric pressures between 300° F. and 850° F. The liquid hydrocarbon may be a petroleum distillate fraction. For example, the liquid hydrocarbon may be kerosene, gas oil, or diesel oil. The liquid hydrocarbon may be a petroleum crude oil. Where petroleum crude oils are employed, the higher gravity and non-asphaltic crudes are preferred. Preferably, diesel oil is employed.

The alkyl aryl polyethylene oxide, as indicated, contains not less than six and not more than ten carbon atoms in the alkyl side chain and not less than six and not more than eleven ethylene oxide groups in the polyethylene oxide chain. Preferably, however, the alkyl side chain contains eight to nine carbon atoms and the polyethylene oxide chain contains seven to ten ethylene oxide groups. While the number of ethylene oxide groups in the polyethylene oxide chain must not be less than six and not more than eleven, this number, as indicated, is an average number. It is not essential that each molecule of the compound contain not less than six and not more than eleven ethylene oxide groups. Rather, it is necessary only that the average number of ethylene oxide groups in the compound be not less than six and not more than eleven. Thus, mixtures of alkyl aryl polyethylene oxides may be employed of which only part, or even none, of the individual molecules contain not less than six and not more than eleven ethylene oxide groups so long as the average number of the ethylene oxide groups is not less than six and not more than eleven. For example, it is possible to employ an equimolar mixture of alkyl aryl polyethylene oxides where one-half of the molecules contains four ethylene oxide groups and the remaining one-half of the molecules contains twelve ethylene oxide groups. In this case, the number of ethylene oxide groups on the average is eight. Similarly, other combinations of compounds may be employed to obtain the desired number on the average of ethylene oxide groups.

Suitable alkyl aryl polyethylene oxides which may be employed include:

(1) polyethylene oxide of octyl phenol having 7 to 8 ethylene oxide groups on the average and having the formula

$$C_8H_{17}—C_6H_4—O—(CH_2—CH_2—O)_x—H$$

where x is 7 or 8 on the average;

(2) polyethylene oxide of octyl phenol having 9 or 10 ethylene oxide groups on the average and having the formula

$$C_8H_{17}—C_6H_4—O—(CH_2—CH_2—O)_x—H$$

where x is 9 or 10 on the average; and

(3) polyethylene oxide of nonyl phenol having 9½ ethylene oxide groups on the average and having the formula

$$C_9CH_{19}—C_6H_4—O—(CH_2—CH_2—O)_x—H$$

where x is 9½ on the average.

The body of liquid comprising the mixture of liquid hydrocarbon and alkyl aryl polyethylene oxide is forced into the well borehole to the position or positions therein where differential pressure sticking of the drill pipe has occurred. Contact of the body of liquid is thus effected with the stuck drill pipe and the mud filter cake lining

the wall of the well borehole and any filter cake built up at the area of contact with the drill collar and the wall filter cake. Preferably, the body of liquid should be in contact with the drill pipe and the mud filter cake for a distance on either side of the porous formation where sticking is occurring of about 50 feet.

Following placing of the body of liquid at the desired location or locations, the body of liquid is permitted to remain at this location or locations for a suitable time. While it is not intended to limit the invention to the consequences of any theory, it is believed that contact of the filter cake with the body of liquid allows the filter cake particles under the action of the alkyl aryl polyethylene oxide to become preferentially oil-wet. The liquid hydrocarbon then becomes able to channel through and around the filter cake. This channeling lessens the force of the differential pressure acting on the drill string and lowers the frictional force causing sticking of the drill pipe. Thus, the mechanical force required thereafter to loosen the drill string is lessened. The body of liquid, after being passed to the desired location or locations, accordingly, is permitted to remain until sufficient oil-wetting and sufficient channeling occurs to lessen substantially the mechanical force necessary to loosen the drill pipe. Preferably, the body of liquid is permitted to remain for a period of at least two minutes. More preferably, the body of liquid is permitted to remain for a period of at least five minutes. Longer times are, of course, suitable.

Following the waiting period, mechanical force is applied to the drill pipe to loosen the drill pipe. The mechanical force may be torque or may be tension. If desired, both torque and tension may be employed simultaneously or separately to the drill pipe.

The following examples will be further illustrative of the invention.

In the examples, an apparatus was employed which simulated pressure differential sticking of drill pipe. The apparatus comprises an enclosed cylindrical chamber having suitable openings for introducing and removing of liquid and for imposing within the chamber a measured gas pressure. At a slight distance above the bottom surface of the chamber, and extending across the entire cross-sectional area of the chamber, is a perforated brass plate which can be covered with a filter paper. Below the perforated plate is an outlet port from the chamber leading to the atmosphere. Suspended above the perforated plate by means of a spring having a known tension per unit length of elongation is a bob having a known surface area. The spring is attached to a rod which is movable vertically through a measurable distance by means of a handle connected exteriorly of the chamber.

EXAMPLES 1 AND 2

In the first example, the perforated plate was covered by filter paper. The bob, suspended at the end of the spring, was positioned at a level 1/32 of an inch above the filter paper. A known amount of drilling fluid was then passed into the chamber. Nitrogen was next passed into the chamber until the pressure therein was 250 pounds per square inch absolute. Filtrate from the drilling fluid passed through the filter paper and the perforated brass plate and out of the chamber through the outlet port under the differential over the filter paper and the plate between the nitrogen pressure in the chamber and the pressure of the atmosphere. The nitrogen pressure was then released and the level of the drilling fluid within the chamber was adjusted by means of a suction tube to a fixed point. The nitrogen pressure was again restored and a filter cake thicker than 1/32 of an inch was formed upon the filter paper. The bob was embedded in the filter cake and differential pressure sticking of the bob upon the filter cake occurred under the pressure differential existing between the chamber and the atmosphere. With the nitrogen pressure being maintained, the handle was thereafter operated to apply tension to the spring attached

to the bob. This tension was continually increased until the bob was released from the filter cake. The tension of the spring on the bob at the time of release was measured. Knowing the tension of the spring and the contact surface area of the bob with the filter cake, the force necessary to overcome the differential pressure sticking, i.e., to release the bob, was calculated.

In the second example, the same procedure was followed. However, following differential pressure sticking of the bob, the nitrogen pressure within the chamber was released and a given volume of diesel oil was passed into the chamber. The nitrogen pressure was again restored and the diesel oil was permitted to remain in contact with the bob and the filter cake for a period of five minutes. Thereafter the handle was operated to apply force to the bob to overcome the differential pressure sticking. The force on the bob upon release was calculated from the elongation of the spring.

The table following gives the example number and the force upon the bob in pounds per square inch required to overcome the differential pressure sticking.

Table I

Example number:	Force
1	53
2	52

EXAMPLES 3 to 6

In Examples 3 to 6, the same procedure was followed as in Example 2. However, following differential pressure sticking of the bob, in place of the diesel oil a body of liquid comprising a mixture of diesel oil and, in an amount of 4 percent by volume of the diesel oil, of various alkyl aryl polyethylene oxides was passed into the chamber and contacted with the filter cake and the bob. The volume of each of the bodies of liquid was the same as the volume of the diesel oil employed in Example 2. Following contact of the bob and the filter cake with the body of liquid for a period of five minutes, the handle was operated to apply tension to the spring to release the bob from the filter cake. The force on the bob upon release was then calculated from the elongation of the spring. The table following gives the example number, the particular alkyl aryl polyethylene oxide, the number of ethylene oxide groups on the average in the polyethylene oxide chain, and the force required to overcome differential pressure sticking in pounds per square inch.

Table II

Example Number	Alkyl Aryl Polyethylene Oxide	No. of Ethylene Oxide Groups	Force
3	Polyethylene Oxide of Octyl Phenol	7.5	4
4	do	9.5	2
5	Polyethylene Oxide of Nonyl Phenol	9.0	4
6	do	9.5	4

EXAMPLES 7 AND 8

In Example 7, the same procedure was followed as in Example 1, and, in Example 8, the same procedure was followed as in Examples 3 to 6. However, in each of Examples 7 and 8, the nitrogen pressure employed was 350 pounds per square inch absolute, and, in Example 8, the alkyl aryl polyethylene oxide employed was polyethylene oxide of octyl phenol having on the average 7.5 ethylene oxide groups and was employed in the amount of 6 percent by volume of the diesel oil. The table gives the example number and the force upon the bob in pounds per square inch required to overcome the differential pressure sticking.

Table III

Example number:	Force
7	65
8	5

EXAMPLES 9 AND 10

In each of Examples 9 and 10, the same procedure was followed as in Examples 7 and 8 with the exception that the nitrogen pressure employed was 500 pounds per square inch absolute. The table gives the example number and the force upon the bob in pounds per square inch required to overcome the differential pressure sticking.

Table IV

Example number:	Force
9	88
10	9

Having thus described my invention, it will be understood that such description has been given by way of illustration and example and not by way of limitation, reference for the latter purpose being had to the appended claims.

I claim:

1. In the process of drilling a well borehole in the earth wherein a drill bit is rotated within said well by a drill string equipped with drill collars, a drilling fluid containing solid materials is circulated within said well, a drilling fluid filter cake forms along the wall of said well borehole and, upon cessation of rotation of said drill string said drill string becomes immobilized in said filter cake along said wall of said well borehole by differential pressure sticking, the steps for releasing said immobilized drill string comprising passing into said well borehole and into contact with said drill string and said filter cake at the point where said drill string is immobilized a unitary body of liquid comprising a mixture of a liquid hydrocarbon and an alkyl aryl polyethylene oxide having not less than 6 and not more than 10 carbon atoms in the alkyl group and on the average not less than 6 and not more than 11 ethylene oxide groups, maintaining contact of said unitary body of liquid with said drill string and said filter cake, and thereafter applying mechanical force to said drill string to move said drill string.

2. The process of claim 1 wherein said liquid hydrocarbon is petroleum crude oil.

3. The process of claim 1 wherein said unitary body of liquid contains said alkyl aryl polyethylene oxide in an amount of at least 2 percent by volume of said liquid hydrocarbon.

4. The process of claim 1 wherein said unitary body of liquid contains said alkyl aryl polyethylene oxide in an amount between 2 and 10 percent by volume of said liquid hydrocarbon.

5. The process of claim 1 wherein said liquid hydrocarbon has a boiling point between 300° F. and 850° F.

6. The process of claim 1 wherein said alkyl aryl polyethylene oxide is polyethylene oxide of octyl phenol having 7 to 8 ethylene oxide groups on the average.

7. The process of claim 1 wherein said alkyl aryl polyethylene oxide is polyethylene oxide of octyl phenol having 9 ethylene oxide groups on the average.

8. The process of claim 1 wherein said alkyl aryl polyethylene oxide is polyethylene oxide of octyl phenol having 10 ethylene oxide groups on the average.

9. The process of claim 1 wherein said alkyl aryl polyethylene oxide is polyethylene oxide of nonyl phenol having 9½ ethylene oxide groups on the average.

10. The process of claim 1 wherein said unitary body of liquid is immiscible with fluid in said well borehole at the leading edge and the trailing edge of said unitary body of liquid upon passage into said well borehole and into contact with said drill pipe and said filter cake.

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