(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 403 025 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **90201532.0**

(51) Int. Cl.5: **E21B 33/13, E21B 21/12**

(22) Date of filing: **13.06.90**

(30) Priority: **14.06.89 GB 8913647**

(43) Date of publication of application:
19.12.90 Bulletin 90/51

(84) Designated Contracting States:
DE GB NL

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(54) Method of drilling and lining a borehole.

(57) A method of drilling and lining a borehole comprises the steps of drilling a borehole while a drilling fluid is circulated through the bores of a multibore drill pipe string and an over-retarded cement slurry is kept substantially stationary in a pipe-formation annulus surrounding said string, whereupon after retrieval of the drilling assembly from the borehole the cement is allowed to set to an annular lining of solid cement alongside the borehole wall.

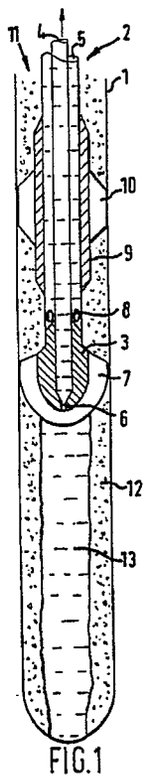

FIG.1

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METHOD OF DRILLING AND LINING A BOREHOLE

The invention relates to a method of drilling and lining a borehole.

In the art of drilling wells in subsurface earth formations it is known to stabilize at the end of a drilling run the borehole wall by a cement lining.

Applicant's co-pending patent application No. 8814004 discloses a borehole stabilization technique wherein at the end of a drilling run a stinger is lowered into the borehole whereupon slugs of a cement slurry and drilling fluid are subsequently injected into the stinger until the cement slurry fills the annular space around the stinger and the drilling fluid fills the interior of the stinger. Subsequently the stinger is retrieved from the borehole while leaving an annular body of cement slurry and a core of drilling fluid in the borehole whereupon the cement is allowed to set to form an annular lining alongside the borehole wall.

Applicant has now discovered that it is possible to inject a cement slurry into the borehole already during the drilling process so that it is possible to cover the borehole wall already at an early stage with a cement slurry which is directly placed in intimate contact with the surrounding formation in the absence of the deposition during drilling of a mud cake that has to be washed away before placement of the cement lining.

The method according to the invention thereto comprises the steps of:

- drilling a borehole section while circulating a drilling fluid down through a bore of a multibore drill pipe string carrying a drill bit and up through another bore of said drill pipe string while keeping a volume of an over-retarded cement slurry substantially stationary in an annulus between the outer circumference of the drill pipe string and the borehole wall,
- filling at least a lower portion of the bores with a liquid having substantially the same density as the cement slurry,
- retrieving the bit and drill pipe string from the borehole while the liquid flows from the bores into the wellbore, whereafter the cement slurry solidifies to an annular body of solid cement.

Preferred procedures for placing the cement slurry in the pipe-formation annulus can be derived from U.S. patent specification No. 4,718,503. This prior art reference discloses the use of two different fluids in a drilling process, wherein during drilling a first fluid is circulated through the bores of a multibore drill string whereas a second fluid is placed in the pipe formation annulus either by injecting during the drilling process this fluid at the top of the annulus or by interrupting the drilling process and circulating a slug of said second fluid down via at least one of the bores of the drill string and up through the annulus. In the method according to the invention the second fluid comprises the over-retarded cement slurry whereas the first fluid comprises the drilling fluid.

Preferably the injected cement slurry comprises an over-retarded hydraulic cement which only hardens out under the influence of a cement solidifying agent. This may be accomplished by using a cement slurry comprising a hydraulic cement which is over-retarded with a glucose compound and by using a cement solidifying agent comprising calcium chloride ($CaCl_2$) to neutralize the retarder. Alternatively the cement slurry may comprise a hydraulic cement which is over-retarded with a retarder that disintegrates at a critical temperature whilst the cement solidifying agent comprises chemicals which cause an exothermic reaction to raise the temperature above said critical value.

The invention will be described in more detail with reference to the accompanying drawing, in which:

- Figure 1 shows a section of a borehole from which a bit and multibore drill string are retrieved while leaving a cement slurry alongside the borehole wall,
- Figure 2 shows a section of the borehole of Figure 1 while a stinger is pulled there through, and
- Figure 3 shows a section of the borehole of Figure 1 while drilling a lower extension therethrough after hardening of the cement mass.

Referring to Figure 1 there is shown an underground borehole 1 from which a drilling assembly comprising a multibore drill pipe string 2 and a wing type drill bit 3 is retrieved. The drill pipe string 2 contains two co-axial bores 4 and 5, respectively, via which drilling fluid is circulated during the drilling process. The drill bit 3 comprises a central nozzle 6 via which during drilling the drilling fluid is injected from the interior of the inner bore 4 into mud channels 7 alongside the bit face. Openings 8 are provided at the lower end of the outer drill pipe of the string 2 to allow during drilling the drilling fluid carrying drill cuttings to flow up into the outer bore 5 of the string 2.

The drill string 2 is equipped with thick walled drill collars 9 to create weight on bit and a series of stabilizer fins 10 are mounted on the collars 9 for keeping the bit 3 in a centralized position in the borehole 1.

During the drilling process cement slurry is injected at the top of a pipe-formation annulus 11 between the string 2 and borehole wall to form an

annular body 12 of cement slurry that fills at least a lower portion of the annulus 11.

The stabilizer fins 10, in combination with the large diameter drill collars 9, provide a restriction against mixing of the cement slurry 12 with drilling fluid 13 during the drilling process. A further restriction against contact between the drilling fluid 13 and cement slurry 12 during drilling may be provided by a sealing skirt (not shown) around the lower end of the drill collars 9 which opens if the circulation pressure of the drilling fluid exceeds a pre-set value.

The drilling fluid 13 circulating through the bores 4 and 5 during drilling may be any suitable fluid, such as water, oil or a foam. The circulated fluid 13 may have another density than the cement slurry 14 provided that the resulting difference in hydrostatic pressure at the bottom hole is compensated by the circulating pressure of the drilling fluid.

However, at the end of a drilling run it is important that, before the fluid circulation is interrupted and the drilling assembly is retrieved from the borehole as shown in Fig. 1, the bores 4 and 5 are filled with a weighted, preferably bentonitic, liquid that has about the same density as the cement slurry column in the annulus 11. In this way it is ensured that no gravity segregation of the cement slurry will take place after retrieval of the drilling assembly.

The cement slurry contains an over-retarded hydraulic cement, such as Portland cement or an epoxy or polymeric resin, and e.g. chopped reinforcement fibres or additives such as latex polymers and epoxies to optimize the elastic properties of the cement.

The composition of the cement slurry 12 is selected such that the grooves that are pulled through the slurry column during retrieval of the drilling assembly by the stabilizer fins 10 and the wings of the bit 3 flatten out before the cement starts to set.

The cement slurry is over-retarded with a retarding additive which prevents setting of the cement during the drilling process. Before retrieval of the drilling assembly, it is filled with a bentonitic liquid containing a cement solidifying agent which induces the cement to set as soon as the drilling assembly has been retrieved from the borehole.

However, instead of filling the bores 4 and 5 of the drilling assembly with a bentonitic liquid at the end of a drilling run the bores may be filled with an over-retarded cement slurry as well. If in that case the drilling assembly is retrieved from the borehole at least a lower portion of the hole is entirely filled with the over-retarded cement slurry, whereupon a mud core can be spotted in the centre of the borehole by a stinger as illustrated in Figure 2.

As shown in Figure 2 the stinger 20 may be lowered into the borehole 1 after retrieval of the drilling assembly for creating an accurately centralized mud core 13 in the cement slurry 12 and for adding a cement solidifying agent.

Accurate centralization of the stinger 20 may be accomplished by centralizing the lower end of the stinger 20 with a series of bow spring centralizer blades 21. The stinger may be equipped with a mixing sub (not shown) known from Applicants' co-pending patent application No. 8814004 via which the cement solidifying agent is mixed with the cement slurry. Instead of mixing the cement solidifying agent with the cement slurry at a downhole location it may also be mixed with the cement slurry at the surface by circulating the slurry up to the surface where the solidifying agent, and possibly other substances, are added and then circulating the slurry down into the annulus around the stinger whereupon the interior of the stinger is filled with mud and the mud core is spotted in the cement slurry by retrieving the stinger from the borehole as shown in Figure 2.

The cement solidifying agent may consist of calcium chloride ($CaCl_2$) if the cement slurry is over-retarded with a glucose compound. After injecting the calcium chloride into the borehole via the stinger it will neutralize the glucose compound and the cement starts to set.

Alternatively the cement slurry 12 may be over-retarded with a retarder which disintegrates at a critical temperature, in which case the cement solidifying agent may comprise chemicals which cause an exothermic reaction to raise the temperature of the cement slurry 12 above said critical value. Instead of using chemicals also an electric or other heat source may be mounted on the lower end of the stinger to raise the temperature of the slurry 12 to said critical value.

It will be understood that the use of the stinger 20 is optional. The use of the stinger is useful if a drill bit 3 has to be used without a central nozzle.

Figure 3 shows how after setting of the cement slurry to a solid annular lining 30 alongside the borehole wall the borehole 1 may be deepened by a drilling assembly comprising a multibore drill pipe string 32 and a small diameter bit 33. The bit 33 is also used for milling the mud core 13 spotted by the stinger shown in Figure 2 to a desired minimum diameter. During the milling operations the mud core 13 guides the bit 33 such that it is centralized in the hole 1. The drilling assembly of Figure 3 is equipped with a smaller diameter bit 33, stabilizer fins 34 and drill collars 35 than the assembly of Figure 1, whereas the drill string may consist of the same multibore drill string as shown in Figure 1.

During drilling with the assembly of Figure 3

again a drilling fluid is circulated down via an internal bore 36 of the drill pipe string 32 to a central nozzle 37 of the bit 33, from where the fluid is circulated up via openings 38 in the drill pipe string 32 into the outer bore 39 of said string 32 as indicated by the arrows I and II. During drilling the drill string 32 may be rotated as illustrated by arrow III or the string 32 may be kept stationary if the drill bit is driven by a downhole drilling motor (not shown).

During drilling the annular space 40 between the drill string 32 and the inner surface of the cement lining 30 may be completely filled with a fresh cement slurry, but if desired only the annular space 40B between the drill string and the wall 41 of the borehole extension protruding below the cement lining 30 may be filled with cement slurry.

The annular body of the cement slurry may be allowed to set and may be subsequently milled out again to a proper diameter in the same manner as described with reference to Figures 1-3, namely by using an over-retarded hydraulic cement for the slurry and by filling at the end of a drilling run the bores 36 and 39 of the multibore drill string 32 either with a bentonitic liquid having about the same density as the cement slurry or with the cement slurry itself. In the latter case a mud core is spotted by a stinger in the manner described with reference to Figure 2, whereupon the annular body of cement is allowed to set.

It will be understood that instead of drilling the lower extension with the bit that is used for milling out the hardened lining of the upper part of the borehole different bits may be used for the milling and drilling operations as well. In the latter case the bit for drilling the lower extension may be equipped with side reamers which allows to drill the lower extension to the same diameter as the lined upper part of the borehole.

While the foregoing description with reference to the accompanying drawings is directed to preferred embodiments of the method according to the invention, many modifications and variations may be made without departing from the concept of the present invention.

Accordingly, it should be clearly understood that the method referred to in the foregoing description with reference to the drawing are illustrative only and is not intended as a limitation on the scope of the invention.

Claims

1. A method of drilling and lining a borehole in an earth formation, the method comprising the steps of:
- drilling a borehole section while circulating a drilling fluid down through a bore of a multibore drill pipe string carrying a drill bit and up through another bore of said drill pipe string while keeping a volume of an over-retarded cement slurry substantially stationary in an annulus between the outer circumference of the drill pipe string and the borehole wall,
- filling at least a lower portion of the bores with a liquid having substantially the same density as the cement slurry,
- retrieving the bit and drill pipe string from the borehole while the liquid flows from the bores into the wellbore, whereafter the cement slurry solidifies to an annular body of solid cement.

2. The method of claim 1 wherein before retrieval of the bit and drill pipe string from the borehole at least a lower portion of the bores is filled with the over-retarded cement slurry and after retrieval of the bit and drill pipe from the borehole a stinger is lowered to the bottom of the borehole whereupon the stinger is entirely filled with the liquid having about the same density as the cement slurry and the stinger is subsequently raised through the borehole while its lower end is centralized in the borehole thereby spotting a liquid core co-axially inside the annular body of cement slurry.

3. The method of claim 1 wherein at the end of a drilling run a liquid containing a cement solidifying agent is circulated through at least one of the bores of the drill pipe string whereupon the bit and drill pipe string are retrieved from the borehole, thereby leaving a core of liquid surrounded by an annular column of cement in the borehole at the end of a drilling run.

4. The method of any preceding claim wherein the liquid is a weighted bentonitic liquid.

5. The method of any one of claims 1-4 wherein at least part of the volume of the cement slurry is placed in the annulus by injecting a slug of the cement slurry down through at least one of the bores of the drill pipe string and up through the annulus.

6. The method of any one of claims 1-4 wherein at least part of the volume of the cement slurry is placed in the annulus by injecting the slurry into the upper end of the annulus and circulating the injected slurry down through the annulus to completely fill at least a lower portion of the annulus with the slurry.

7. The method of claims 5 and 6 wherein part of the volume of the cement slurry is placed in the annulus by injecting during an interruption of the drilling process a slug of the slurry down through at least one of the bores of the drill pipe string and up through the annulus whereas another part of the slurry is placed by injecting during the drilling process slurry into the upper end of the annulus.

8. The method of any preceding claim wherein

the injected cement slurry comprises an over-retarded hydraulic cement which only hardens out under influence of a cement solidifying agent.

9. The method of claim 8 wherein the injected cement slurry comprises a hydraulic cement which is over-retarded with a glucose compound and the cement solidifying agent comprises calcium chloride to neutralize the retarder.

10. The method of claim 8 wherein the cement slurry comprises a hydraulic cement which is over-retarded with a retarder which disintegrates at a critical temperature and the cement solidifying agent comprises chemicals which cause an exothermic reaction to raise the temperature above said critical value.

11. The method of any one of claims 5-7 wherein the cement solidifying agent is added to the cement slurry by circulating the slurry up to the surface where the agent is injected into the slurry, whereupon the slurry containing the agent is circulated again into the borehole and allowed to set to a solid lining alongside the borehole wall.

12. The method of claim 1 substantially as described with reference to the accompanying drawing.

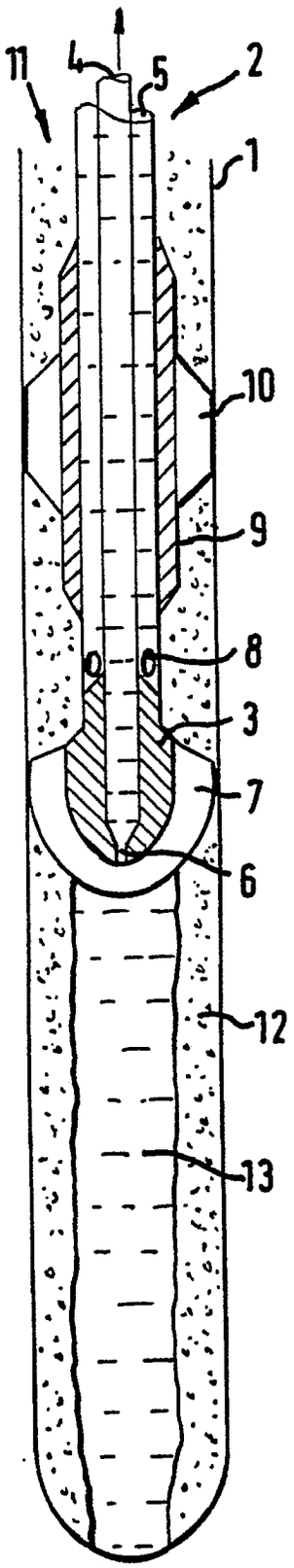

FIG.1

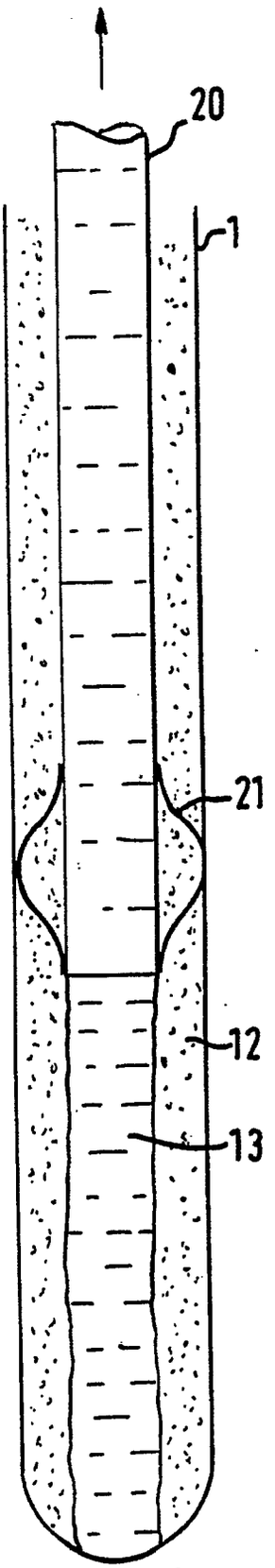

FIG.2

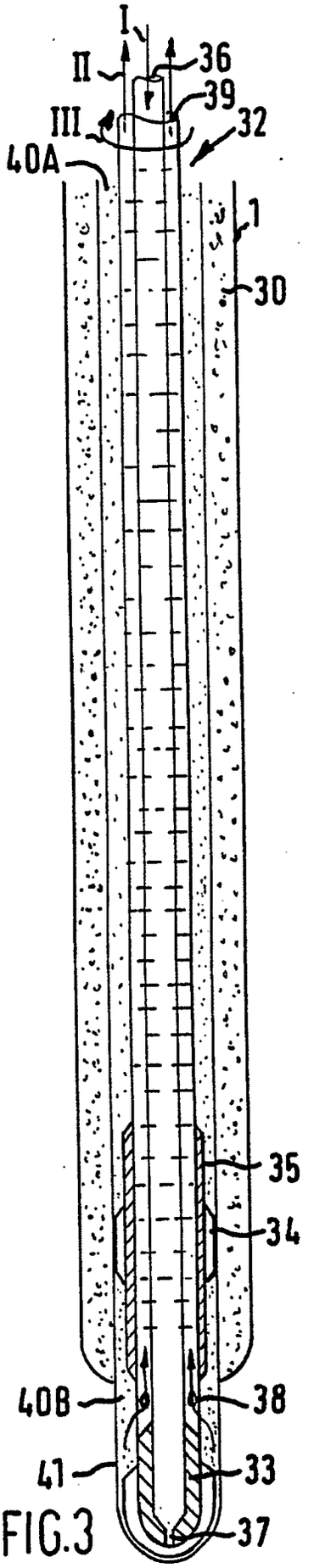

FIG.3