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W. W. ROBINSON ET AL

2,286,835

WELL DRILLING AND COMPLETION

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FIG. 1

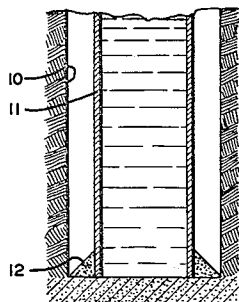


FIG. 2

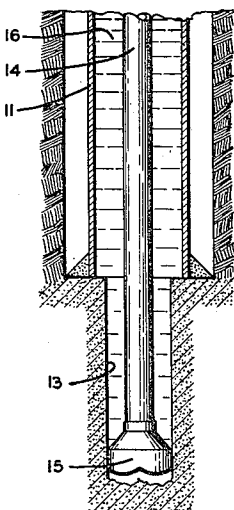


FIG. 3

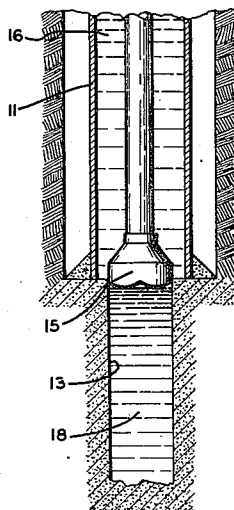


FIG. 4

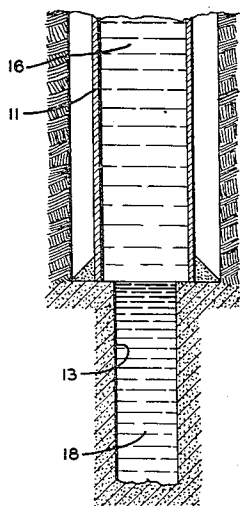


FIG. 5

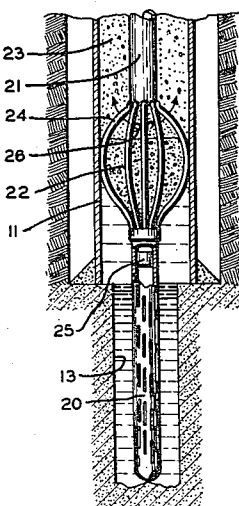
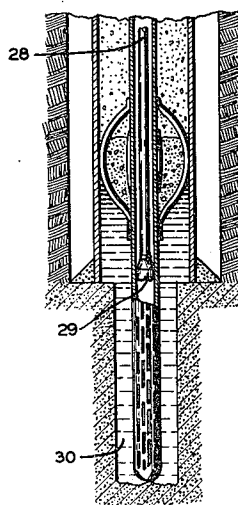


FIG. 6



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## UNITED STATES PATENT OFFICE

2,286,835

## WELL DRILLING AND COMPLETION

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Application October 7, 1939, Serial No. 298,388

13 Claims. (Cl. 255—1.8)

This invention relates to the drilling and completion of a well, such as an oil well, and is particularly applicable to the drilling and completion of deep wells or wells having high bottom temperatures.

Previous practice in the drilling of wells of this character, particularly in the rotary drilling of deep wells, has involved the sinking of a bore for reception of the casing down to the level adjacent the top of the productive formation or oil sand, or down to the top of the area into which the liner is to be run. After cementing the casing in place in this bore, a drill of somewhat smaller diameter is introduced by lowering the drill stem through the casing, and then an open-hole portion or bore of the well of smaller diameter is drilled to the required depth through the pay sand. In such rotary drilling, it is customary to employ a drilling mud by circulating the mud down the hollow drill stem to the locus of drilling, the mud being then returned in the annular channel between the drill stem and well bore or casing to the surface of the well. The drilling mud performs various functions, including lubrication of the drill stem and bit, removal of the cuttings from the well by suspending them in the circulating mud, and formation of a filter cake on the exposed wall of the bore hole to resist water infiltration into the well, lost circulation and loss of the aqueous phase of the drilling mud, disintegration or caving of the well wall and other advantages. After drilling the open-hole portion to the required depth, the liner is then run and landed in this open-hole portion, the liner generally being perforated throughout a portion of its length so that the perforations will lie opposite the producing area or zone when so located in the well.

Following the running of the liner, a charge of acid may be introduced into the open-hole portion of the formation to remove the mud cake from the wall of the bore hole opposite the productive strata and to open up or increase the porosity of the formation surrounding the perforate portion of the liner. The well is then ready to be placed on production.

In order to facilitate the removal of the mud cake from the open-hole portion by acid treatment, the drilling mud employed for penetrating the productive formation may include a proportion of alkaline earth carbonate, such as calcium carbonate, with a view to increasing the percentage of acid-soluble material in the mud cake and assisting disruption thereof by chemical reaction and gas liberation. Contrary to published

literature and the normal expectation, it has been found that the addition of calcium carbonate to an ordinary drilling mud composed of a suspension of clay in water, with the calcium carbonate content consisting of about 10–30% by weight of the total solids of the mud, may fail to produce a mud cake readily disintegrable by acid treatment, with the result that the producing formation may remain partially sealed or blocked against inflow of oil, particularly in low-pressure areas.

Further, in the drilling of deep wells in certain areas, particularly where a high bottom hole temperature is encountered, considerable difficulty has been encountered in the past due to sticking of the liner as the latter is lowered into the open-hole portion. This is often due to the fact that the high bottom hole temperature dehydrates the drilling mud present in the open-hole portion so rapidly that a cake of such thickness is built up around the well wall as to jam the liner before it can be lowered into position. In order to land the liner, operators have tried extensive reaming and underreaming of the open-hole portion in addition to so-called washing down the liner, but such operations are time-consuming and expensive. Moreover, in the time interval required to raise the drilling tools out of the hole after the final drilling or reaming and to lower the liner into position, the mud in the open-hole portion often solidifies into a cake of such thickness as to prevent the liner from being properly landed.

One of the principal objects of the present invention is to provide a method for the drilling and completion of a well of this character which will obviate the above noted difficulties and enable the liner to be run and landed and the well completed and placed on production with a minimum of labor and with high effectiveness.

Another object of the present invention is to provide a method of drilling and completing the open-hole portion of such a well which will prevent the formation of a mud cake of such thickness as to interfere with the proper running and landing of the liner, and which at the same time will afford a cake that is readily disintegrable by acid after the liner has been landed so that the well can be placed on production with high efficiency.

Other objects and advantages of the invention will be apparent from the following description when taken in conjunction with the annexed drawing and appended claims.

In the drawing, which illustrates a preferred

embodiment of the method of drilling and completing a well in accordance with the present invention—

Fig. 1 is a diagrammatic vertical sectional view of the lower underground portion of a well which has been drilled to the top of the area into which the liner is to be run, showing the cementing of the casing in position therein;

Fig. 2 is a similar view of the same well, illustrating the drilling of the open-hole portion;

Fig. 3 is a similar view of the well, illustrating the replacing of the drilling mud in the open-hole portion with a special composition of thin cake-forming fluid by a spotting operation;

Fig. 4 is a similar view of the well following removal of the drill stem and bit after the spotting operation.

Fig. 5 is a similar view of the well, illustrating the running of the liner into the open-hole portion and the cementing of the same in place in the well; and

Fig. 6 is a similar view of the well, illustrating the completion thereof by acid treatment.

In accordance with the present invention, the well is drilled to the top of the area into which the liner is to be run by the use of any suitable or conventional drilling fluid, and the casing may then be run and cemented in place. The open-hole portion is drilled, preferably with the employment of a limed-bentonite drilling mud of the character disclosed and claimed in the copending application of William W. Robinson, Serial No. 146,369, now Patent No. 2,198,563, which forms a mud sheath which is readily and rapidly disintegrated by acid. After drilling and reaming are completed, the mud in the open-hole portion is replaced with a special composition of a weighted soap-containing fluid which is of such character as to form only a thin waterproof cake about the wall of the said open-hole portion and which is of such thinness as to avoid interference with the proper running and landing of the liner. The drilling tools are then removed slowly and with a minimum of agitation out of the open-hole portion and then rapidly from the well, and the liner is lowered and landed in position in the open-hole portion. Following this, acid is introduced down the well into the liner and through perforations in the wall of the liner into the open-hole portion, where it rapidly disintegrates the mud cake and any remaining composition, which is substantially completely or at least primarily acid-soluble, and the well is then ready to be placed on production.

Referring to Fig. 1 of the drawing, 10 illustrates the bore hole of the well which is drilled with any suitable or conventional drilling mud down adjacent to the top of the producing formation or oil sand, or down to the top of the area into which the liner is to be run. 11 illustrates the casing which is lowered in place in this bore and then cemented as indicated at 12. In a typical example, a 10% hole may be drilled and a 7" casing cemented in place therein.

Fig. 2 illustrates the drilling of the open-hole portion 13 of the well which passes into the productive formation. This is accomplished by lowering the hollow drill stem 14 carrying the drill or bit 15 through the casing 11, the drilling being accomplished by rotating the drill stem and bit in the customary manner of rotary drilling with circulation of a drilling mud down the hollow drill stem 14 to the locus of drilling and thence back up through the annular channel between the drill stem and the open-hole portion

or casing. The circulating drilling mud in this annular channel is indicated at 16. Preferably, the drilling mud employed for this operation is a limed bentonite mud of the character of that disclosed and claimed in the copending application of William W. Robinson mentioned above. As set forth therein, such a drilling mud is prepared by dispersing about 3-6% by weight of bentonite in water and adding about 8-30% or more by weight on the weight of the total drilling mud of alkaline earth carbonate, such as calcium carbonate; or by adding bentonite to a drilling mud containing both clay and alkaline earth carbonate and in which the alkaline earth carbonate is present in a large proportion which at least approximates the weight of the other suspended solids of the drilling mud. For purposes of easy description, such a mud is herein termed a "limed-bentonite drilling mud." The mud sheath formed about the bore hole by the use of such a mud is found to be readily and rapidly disintegratable by acid. The straight bentonite mud containing alkaline earth carbonate can be used where the density of this fluid is sufficient to control any gas or oil under pressure, such as in low pressure formations; otherwise heavier weighted or clay muds limed with carbonate of the character specified above are employed. While such a special drilling mud is preferably employed for the drilling of the open-hole portion to further facilitate the proper completion of the well, it is pointed out that the method of the present invention obviates the necessity of employing such a special mud and any suitable conventional drilling fluid or mud can be used for this operation.

In place of running and cementing the casing 11 prior to drilling the open-hole portion 13, the bore 10 can be drilled with a larger diameter bit and the open-hole portion 13 drilled with a smaller diameter bit, the casing 11 then run, landed and cemented on the shoulder formed at the junction of the two bore holes of different diameters, and the open-hole portion 13 then carefully reamed and rereamed, preferably using a limed-bentonite mud as the drilling fluid for this reaming operation.

After the last reaming, the tools are left slowly rotating on the bottom, as illustrated in Fig. 2. Then a calculated volume of the special composition of the present invention is introduced down the hollow drill stem 14 so as to replace the drilling mud 16 and fill the open-hole portion 13 with this special composition indicated at 18 in Fig. 3. This special composition is a soap-containing aqueous fluid preferably weighted with barytes, iron oxide, calcium carbonate or other suitable weighting material, to approximate or exceed the weight of the drilling mud 16, so that this special composition will remain in position in the open-hole portion 13 beneath the column of drilling mud 16 confined within the casing 11.

A very satisfactory composition for this purpose is prepared by emulsifying rosin in an aqueous alkaline solution to which is added barytes or other suitable weighting material to give the desired weight per cubic foot. By way of example, in the preparation of an emulsified rosin fluid weighing about 64 pounds per cubic foot, crude wood rosin having a melting point of 115° F. was added in the proportion of 55 pounds of the melted rosin to 7 gallons of a caustic-soda ash mix containing 11.25 pounds of sodium carbonate and 1 pound of caustic soda to 7 gallons of water, the mix having been heated to boiling

prior to the addition of the melted rosin. After the addition of the rosin, 10 gallons of hot water were added, followed by stirring until a smooth emulsion was obtained. Cold water was then added to a final volume of 50 gallons. To this sodium resinate fluid, barytes was then added in a proportion to increase the weight to approximately 77 pounds per cubic foot in the case where the drilling mud 16 weighed about 76 pounds per cubic foot.

In a sodium resinate drilling fluid of this character, it has been found possible to weight the same with barytes as much as 15 pounds or more per cubic foot above its normal weight and still provide a pumpable fluid which can be properly handled and circulated.

A characteristic of the weighted soap composition of the present invention is its ability to form an extremely thin filter cake on the wall of the bore hole, even when subjected to high bottom hole temperatures of the order of 200-250° F. and above, the thin filter cake being highly waterproof. The ability of a drilling fluid to form a satisfactory thin waterproofing cake of this character is conveniently determined by a filter press test in which the drilling fluid is confined or held under a high pressure for a predetermined length of time against a porous filter surface or cloth. In such a test the weighted sodium resinate drilling fluid described above formed a filter cake  $\frac{3}{4}$  of an inch thick after the mixture had been held under a pressure of 3000 pounds per square inch for one hour, with only 8.6 ccs. of water passing through the filter press. In comparison therewith, a conventional clay drilling mud under the same test conditions gave a filter cake  $\frac{17}{64}$  of an inch thick with 35.3 ccs. of water passing through the filter press.

While a mixture of sodium carbonate and sodium hydroxide has been described above by way of example in the formation of the sodium resinate fluid, it is to be understood that any suitable or equivalent alkaline materials, such as borax, ammonia, alkali metal bicarbonates, alkali metal silicates, etc., may be used for this purpose. Moreover, while a resinate soap has been found to give very satisfactory results, other water-soluble alkaline soaps which react with acid to give a liquid reaction product that can be removed from the well in the subsequent acid treatment, can be used for purposes of our invention. Thus, alkaline soaps of such fatty acids as lauric, palmitic, stearic, oleic, etc., and soaps formed from fatty materials as well as various artificial resins and gums are included. Whenever the expression "soap-containing fluid" is used throughout the description and claims, it is to be understood that this includes any of the materials enumerated above. Further, while a concentrated soap-containing fluid which is weighted with a suitable weighting material of high specific gravity of the character enumerated above is preferably employed for this purpose, it is to be understood that a proportion of clay, bentonite or other similar solid material can be in suspension in the fluid so long as the soap is in sufficient proportion to provide the thin waterproof filter cake of the character described above, and so long as the soap and other acid-soluble material such as alkaline earth carbonate are in sufficient proportion to render the filter cake substantially completely disintegrable in the subsequent acid treatment.

It is therefore to be understood that the expression "soap-containing fluid" includes the

concentrated material which may be free, or substantially free, from clay solids as well as mixtures of aqueous clay suspensions with high concentrations of soap.

In certain cases, the soap-containing fluid can be weighted to the required extent with clay without the use of barytes or other equivalent weighting material.

After the required volume of soap-containing fluid has been pumped down the drill stem 14, this is followed by a carefully measured amount of regular drilling mud or other fluid which will completely displace the soap-containing fluid from the drill pipe and leave the open-hole portion 13 filled with the soap-containing fluid when the drilling tools are slowly pulled up so that the bit 15 is about the level of the lower end of the casing 11, as shown in Fig. 3. The drilling tools are then pulled out of the well at the customary speed, leaving the open-hole portion 13 filled with the spotted soap-containing fluid 18 and the casing 11 thereabove filled with drilling mud 16, as shown in Fig. 4. With the soap-containing fluid generally filling the area to be occupied by the liner and having displaced most of the drilling mud from that zone, any mud remaining therein will be permeated by the soap-containing fluid so as to assume properties which effectively resist the high underground temperature, with the result that only a very thin and highly waterproof cake will be formed about the wall of the open-hole portion by the time the liner arrives.

After the drilling tools have been removed from the hole, the liner is lowered into the well and landed within the open-hole portion, as illustrated in Fig. 5. As shown therein, the liner comprises a lower perforated section 20 located within the open-hole portion and an upper unperforated stem or sustaining portion 21 positioned above the open-hole 13 and within the casing 11. Fig. 5 illustrates a suitable construction to cement the liner in place after it is landed by means including a conventional cement basket 22 carried by the liner between the portions 20 and 21 thereof. Any suitable construction of cement basket or other device for confining the cement 23 to the space above the open-hole 13 can be employed, such for example as the type of basket described and illustrated on pages 209 and 223 of the 1938 edition of the Composite Catalog of Oilfield and Pipeline Equipment, published by the Gulf Publishing Company of Houston, Texas. As shown, the basket is constructed of a series of mild flexible sheet brass fingers or petals 24 mounted on reinforcing steel ribs which overlap each other in either closed or expanded position with a sufficient margin to prevent the fluid above the basket from passing to the formation below. When running in the hole, the upward force of the mud or drilling fluid tends to compress the petals and thus provides free passage between the basket and the wall of the casing. As soon as the liner assembly comes to rest, the upward pressure on the petals is relieved and they expand to contact the wall of the casing and form a seal which prevents fluid above the basket from passing to the space below the basket.

The lower portion of the basket is screwed to the top of the perforate section 20 of the liner, and the bottom of the basket carries a plug 25 which seals against the passage of fluid down through the hollow sustaining portion 21 into the perforate section 20. The sustaining portion 21 is provided with ports or perforations 26 opposite the fingers or petals of the basket so that when

cement is introduced down the hollow stem 21 it will pass out the ports 26 and be deflected upwardly, as indicated by the arrows in Fig. 5, to fill the annular space between the stem 21 and the casing 11 above the basket. In this manner, the sustaining portion of the liner is cemented within the casing itself. While the above illustrates a preferred method of landing and cementing the liner in place, it should be understood that there are many different forms of perforated liners and many different conventional methods of placing them in a well, any of which can be used in conjunction with the method of our invention.

After the cement has set, the bottom plug 25 in the cementing basket 22 is drilled out by lowering a drill stem 28 carrying a bit 29 through the hollow sustaining portion 21 of the liner, as illustrated in Fig. 6. After this is done the bit exposes the soap-containing fluid remaining in the open-hole 13 and within the perforated section 20 of the liner. With the tools still in the hole, a suitable acid such as inhibited hydrochloric or muriatic acid is pumped down, as indicated at 30, to react with the residual resinate or other soap, open up the perforations in the liner, and remove the mud cake about the wall of the open-hole portion. The acid is allowed to stand within this portion for a suitable period of time, such as about 12-24 hours or more, following which the well is placed on production.

As a specific example of the application of our invention, an oil well was drilled in the North Belridge extension field of California with 7 $\frac{1}{4}$ " casing run to 7861 feet in depth, and with a 6 $\frac{5}{8}$ " open-hole portion drilled to a bottom depth of 8446 feet, thereby leaving 585 feet of open-hole to be occupied by the perforated pipe or liner. The drilling of the open-hole portion was done with the circulation of a bentonite drilling fluid containing ground oyster shell, the lining of the mud serving to increase the specific gravity about 3-5 pounds per cubic foot, reducing the filter cake thickness and rendering the mud reactable with acid. The use of limed mud in this operation also affords an additional advantage in the event of stuck drill pipe during the drilling operation, in that acid can be pumped down to assist in freeing the stuck pipe by reaction with the carbonate content of the mud.

After the last reaming of this open-hole portion, 146 cubic feet of sodium resinate drilling fluid of the character described above weighted to approximately 78 pounds per cubic foot with barytes were pumped down and spotted in the open-hole portion, the bottom hole temperature of which was determined to be 243° F. This was followed by a 75-pound per cubic foot mud chaser to displace the resinate fluid from the drill pipe and the drilling tools were then removed. Over an interval of approximately eight hours, the drilling tools were removed from the hole and the liner made up, run and successfully landed without any difficulty. This was a 5' liner perforated for a distance of 286 feet from a depth of 8,160 feet to 8,446 feet. In less than two hours after the landing of the liner, the cementing of the same had been completed. Several days later, 31.2 cubic feet of 30% commercial inhibited muriatic acid were pumped down a 2 $\frac{1}{2}$ " tubing hung at a depth of 8,222 feet, and the acid allowed to react for approximately 48 hours. The well was then brought in with excellent results.

Obviously many modifications and variations

of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof and therefore only such limitations should be imposed as are indicated in the appended claims.

We claim:

1. In the drilling and completion of a well wherein the cased bore is drilled to the top of the area into which the liner is to be run and an open-hole portion drilled with circulation of drilling mud below the cased bore into the producing formation for reception of the liner, the method of preventing the liner from sticking during the running thereof into said open-hole portion, which comprises replacing the drilling mud in the open-hole portion prior to the removal of the drilling tools therefrom with a spotted fluid composition having a high concentration of acid soluble and waterproofing material and not more than a small proportion of clay solids such that the composition has high waterproofing and thin filter cake-forming character and the resulting filter cake is substantially completely disintegrable by hydrochloric acid, and maintaining the said open-hole portion substantially filled with said spotted fluid composition during the removal of the drilling tools, the running of the liner and landing of the same within said open-hole portion.

2. The method as defined in claim 1, in which the open-hole portion is drilled with a limed bentonite drilling mud, and the spotted fluid composition which replaces this mud is a weighted soap-containing drilling fluid of sufficient soap concentration to provide the thin waterproof cake-forming property specified, and in which the well is completed following landing of the liner by acid treatment.

3. The method according to claim 1, in which the spotted fluid composition is a weighted emulsified rosin of sufficient rosin concentration to provide the thin waterproof cake-forming property specified.

4. The method in the drilling and completion of a well, which comprises drilling the cased bore to the top of the area into which the liner is to be run, drilling an open-hole portion with the circulation of drilling mud below the cased bore into the producing formation, replacing the drilling mud in the open-hole portion with a spotted weighted soap-containing fluid of sufficient soap concentration to have high waterproofing and thin cake-forming properties, running and landing the liner in the said open-hole portion, cementing the liner between the cased bore and an imperforate section of the liner extending above the open-hole portion while preventing the ingress of cement into the open-hole portion, and then introducing acid into the said open-hole portion.

5. The method in the drilling and completion of a well, which comprises drilling the well to the top of the area into which the liner is to be run, running the casing and fastening the same in place, drilling an open-hole portion of the well below the casing into the producing formation with the circulation of a drilling fluid, then spotting in the open-hole portion a special weighted fluid composition to displace the drilling fluid therein, said composition having a high concentration of acid soluble and waterproofing material and not more than a small proportion of clay solids such that it has the property of forming a thin highly waterproof filter cake on the

wall of the open-hole portion even when exposed to high bottom-hole temperatures of the order of 200-250° F. and above, whereby difficulty due to sticking in the subsequent running of a liner is avoided, said filter cake being substantially completely disintegrable by hydrochloric acid, said fluid composition having a weight per unit of volume which at least approximates the weight of the drilling fluid which it displaces, removing the drilling tools from the well and running a liner into the said open-hole portion while maintaining the said spotted fluid composition therein, landing the liner in place in said open-hole portion, and then removing the filter cake from the wall of said open-hole portion and placing the well on production.

6. The method in the drilling and completion of a well, which comprises drilling the well to the top of the area into which the liner is to be run, drilling an open-hole portion into the producing formation with the circulation of a drilling mud, replacing the drilling mud in the open-hole portion with a spotted fluid composition of high waterproofing and thin cake-forming character even when exposed to high bottom-hole temperatures of the order of 200-250° F. and above, and which cake is readily disintegrable by acid, running the liner and landing the same in the open-hole portion while maintaining the said spotted fluid composition therein, and then acid-treating the well.

7. The method as defined in claim 6, in which the spotted fluid composition is a weighted soap-containing fluid of sufficient soap concentration to provide the thin waterproof cake-forming property specified.

8. The method as defined in claim 6, in which the spotted fluid composition comprises an alkali metal resinate in sufficient concentration to provide the thin waterproof cake-forming property specified.

9. The method as defined in claim 6, in which the spotted fluid composition consists primarily

of water, a weighting material and sodium resinate in sufficient concentration to provide the thin waterproof cake-forming property specified.

10. The method as defined in claim 6, in which the spotted fluid composition consists primarily of water, an alkaline earth carbonate and sodium resinate in sufficient concentration to provide the thin waterproof cake-forming property specified.

11. The method as defined in claim 6, in which the drilling mud circulated during the drilling of the open-hole portion is a limed-bentonite drilling mud.

12. The method in the running of a liner into the open-hole portion of a well which has been drilled with the circulation of a drilling fluid, which comprises introducing into the well a sufficient amount of a special weighted fluid composition of acid soluble and waterproofing material substantially free from clay solids to displace the drilling fluid from the said open-hole portion of the well, the said fluid composition having a weight per unit of volume which at least approximates the weight of the drilling fluid which it displaces, and further having the property of forming a thin highly waterproof filter cake on the wall of the open-hole portion even when exposed to high bottom-hole temperatures of the order of 200-250° F. and above, such that sticking during the subsequent running of a liner is avoided, thereafter removing the drilling tools from the well and running a liner into the said open-hole portion while maintaining the said spotted fluid composition therein, and landing the liner in place in said open-hole portion.

13. The method according to claim 12, in which the spotted fluid composition has the property of forming a filter cake which is readily disintegrable by acid, and in which the well is completed following the running and landing of the liner by acid treatment.

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