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METHOD OF COMPLETING WELLS

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This invention relates to a method of completing wells in producing formations composed of loosely cemented sands or sandstone.

In many sections of the country the producing formations are composed of loosely cemented sands or sandstones. These formations, which are referred to generically as sand formations, are not sufficiently consolidated to permit completion of wells therein by simple methods. It is not feasible to complete wells in such formations merely by leaving an open hole, as is often possible in limestone and other well-cemented formations, since the hole will collapse due to crumbling and movement of the sand caused by the necessary pressure differential during production. The practice usually followed is to drill out the hole, then while the hole is full of drilling mud which functions to prevent crumbling of the walls of the formation, to insert a liner or screen to which a flow tubing may be attached. This practice is satisfactory, particularly if accompanied by gravel packing, but the screens are relatively expensive and when used in a formation containing unconsolidated fine sands are worn down by the abrasion caused by the sand contained in the flowing crude oil.

It is an object of the present invention to provide a method of completing wells in producing sands whereby the use of liners or screens may be made unnecessary or the sands may be conditioned so as to make the use of liners or screens more satisfactory.

Other objects of the invention in part will be obvious and in part will appear hereinafter.

I have discovered that sand bodies are relatively consolidated and resist displacement by flowing oil or gas when the sand grains are coated with a solid or semi-solid material which adheres tenaciously to the sand surface and which is insoluble in oil. This effect is even noticeable when sand is wet with a small amount of water, since the tension in the water surface film acts to bind the sand grains in place. Many oil-field sands are apparently consolidated in this manner, but such apparent consolidation is temporary, and disappears as soon as the water content increases and particularly when some water begins to flow with the oil or gas stream. A more permanent consolidation may be obtained if the water is replaced by a solid or even very highly viscous liquid which is water-insoluble, oil-insoluble and which adheres to the sand more tenaciously than either oil or water.

I have discovered in accordance with the invention that sands can be consolidated by a method comprising removing water from the sands if water is present therein, passing into the sands a solution of a relatively hard, crude oil-insoluble bitumen such as asphalt which is a solid or semi-solid at the temperature of the formation, and then passing crude oil through the sands. The removal of water may be accomplished either before or after the introduction of the asphalt. I have found that the bitumen solution permeates the sands thoroughly under these conditions and that the bitumen precipitated by the crude oil acts as a bonding agent. As a result, firmly bonded sands are produced which resemble in all essential respects a well-consolidated producing formation. Further, the binding material not only does not retard the flow of oil but improves the characteristics of the sands, apparently by a surface effect, with respect to the flow of oil.

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Accordingly, a well may be completed by treating the sands to a substantial depth about the open hole as described above and then without the use of a screen or liner, merely putting the well on production. In some cases, however, especially where the oil sands have structural weaknesses it may be desirable to run a liner and/or a screen. In this case the treatment simplifies insertion of the liner and prevents the movement of fine sand into the well.

When completing a well in accordance with the invention it is important to drill through the formation in such manner as to leave the walls of the hole in condition to receive the treating solutions and to permit their moving a substantial distance back into the formation. As phases of the present invention, I have developed various ways that this may be done. The invention will be described in connection with the use of asphalt but it will be understood that similar bitumens which are not strictly asphalts according to some definitions may be used.

In accordance with one manner of proceeding the well is drilled down to the formation by any suitable method and casing is preferably set at this point. Thereafter, if an aqueous drilling mud has been employed in the drilling operation, this fluid is replaced by an oil base fluid. Suitable oil base fluids are well-known in the art and usually contain a fluid medium which is a crude oil, fuel oil, or other relatively heavy mineral oil, a weighting material such as a spent refinery clay, ground oyster shells or other finely-divided material, and also usually a sedimentation inhibitor such as organic acids or organic sulfonates. The hole is completed into the formation by the conventional rotary method using this

fluid. This results in a hole having a filter cake on the walls thereof composed of the weighting material and cuttings bonded by constituents of the liquid medium of the fluid. An asphalt solvent such as one of those described hereinafter is then introduced into the well, as a slug in the stream of drilling fluid or by means of a dump bailer. When this solvent is in the hole drilled in the formation, pressure is applied to the column of fluid so as to force the solvent through the filter cake and any desired distance back into the formation.

The use of the solvent at this point results in the removal of crude oil from the filter cake and also in forcing crude oil and other fluids, such as any water which may be present, back from the walls of the hole. Immediately following the solvent in the system there is introduced a solution of an oil-insoluble asphalt which is a solid or semi-solid at the temperature of the formation. To avoid mixing this solution with the drilling fluid, it is preferably followed by a slug of solvent. When the asphalt solution has reached bottom, pressure is applied to the fluid to force the solution back into the formation a sufficient distance to accomplish consolidation, for example, a distance of several feet.

It will be noted that due to the action of the solvent on the filter cake and in forcing the crude oil away from the hole this solution is permitted to pass into the formation for a substantial distance without precipitation of asphalt. A quantity of crude oil is then forced back into the formation, this being accomplished from a manipulative standpoint in the same manner as the introduction of the other liquids. The effect of the crude oil is to precipitate the asphalt from solution in the solvent and the asphalt, therefore, acts as a bonding material to consolidate the sands. The well may then be completed by simply permitting production through the casing or by running a flow tubing to the formation, packing off the annular space between the tubing and casing and permitting the well to flow.

In my United States Patent No. 2,241,255 an oil base drilling fluid is disclosed which is particularly desirable for operating the above treatment, since an oil-insoluble asphalt is incorporated in the drilling fluid to enhance its wall-building character. When using such a fluid to drill into the oil-producing sand, a filter cake is formed on the face of the sand which obstructs the flow of fluid into the sand by having all of its interstices sealed with the oil-insoluble asphalt. If a solvent for the asphalt is placed in the well and the solvent forced through the filter cake into the sand, it will carry the oil-insoluble asphalt into the sand. The objects of this invention are then attained if the sand is subsequently dried so that the asphalt has an opportunity to adhere to the sand grains and seal their contact points. In cases where sufficient asphalt is not provided by the drilling fluid, this procedure may be supplemented by introducing additional asphalt solution.

Similar results may be obtained in accordance with another manner of proceeding by drilling down to the formation as above described, setting casing, and then replacing the drilling fluid with a special fluid in which the fluid medium is a solvent for the asphalt, although not necessarily the same solvent as that used in making up the asphalt solution later to be introduced. This special drilling fluid in the usual case will also contain a colloidal material such as a resin or colloidal clay to impart sufficient viscosity and gel-forming characteristics to the fluid. During the drilling-in operation the pressure exerted by the drilling fluid at the formation is preferably about that necessary to counter-balance the formation pressure. Normally, this pressure will be due simply to the hydrostatic head of the drilling fluid in the well, the specific gravity of the fluid being adjusted to accomplish this object.

When the hole has been completed using this special fluid, which results in the laying down on the walls of the hole a filter cake impervious to the liquid medium of the drilling fluid at the existing pressure, the drilling fluid is replaced in the hole opposite the formation by a solution of asphalt. The pressure on the column of fluid in the well is then increased by means of a pump, for example, to a sufficiently high point to force the asphalt solution through the filter cake and out into the formation the desired distance. The asphalt solution is followed by crude oil as described above, resulting in the precipitation of the asphalt in the formation and consolidation of the oil sands.

In cases where it is difficult to utilize sufficient pressure to force the asphalt solution through the filter cake and into the formation the introduction of the asphalt solution may be preceded by a step involving scraping the face of the hole opposite the formation so as to remove a portion of the filter cake. This operation should be accomplished while maintaining the fluid at a pressure in excess of the formation pressure. Also, where it is desirable to secure an especially good penetration of the asphalt solution an asphalt solvent may be forced back into the formation at a pressure considerably in excess of the formation pressure prior to the introduction of the asphalt solution.

The method of the invention may also be carried out by drilling the hole into the formation in the ordinary way using an aqueous drilling fluid. In this case it is particularly important to dehydrate the sand prior to introducing the asphalt solution. The sand may be dehydrated by chemical treatment or by lowering a heated body into the hole in the formation while the hole is filled with oil, to heat this oil above the boiling point of the water, and then forcing the highly heated oil through the sand.

In accordance with another embodiment of the invention, a chemical dehydrating agent such as acetone may be included in an oil base fluid which is used for drilling-in the hole in the formation. When using a fluid of this type, the dehydrating agent enters the formation during drilling acts to dehydrate the sands and prepare the sands for the introduction of the asphalt solution. Of course, additional dehydration may be accomplished prior to or after the introduction of the asphalt solution. For example, in practicing the invention using the oil base fluid disclosed in my Patent No. 2,241,255 there may be added to the fluid 5 to 10 per cent by weight of a chemical dehydrating agent such as acetone but not enough to render the asphalt soluble. A drilling fluid of this class is one containing a crude oil or similar oil, about 10 per cent by weight of acid treated clay which has become spent in the treatment of lubricating oil in the hot contacting process, about 2 per cent by weight of lamp black, about 6 per cent by weight of sulphurized asphalt, and about 5 to 10 percent by weight of acetone. After the hole has been completed the sands may be con-

solidated by passing through the filter cake, successively, an asphalt solvent, a solution of asphalt, and a crude oil, followed if necessary by additional dehydration.

Whatever the nature of the original drilling fluid, the sands may be dried in various ways. For example, a noncorrosive chemical dehydrating liquid which is oil soluble or miscible when dried, but has preferential solubility for water, may be used. As examples of such liquids aliphatic ketones such as acetone, methyl ethyl ketone, methyl isobutyl ketone and the like may be mentioned. The organic anhydrides, particularly the fatty acid anhydrides such as acetic anhydride, propionic anhydride, butyric anhydride and mixed anhydrides, such as acetyl formyl oxide are other examples of dehydrating liquids. These liquids are preferably employed in the form of oil solution, such as a crude oil or mineral oil distillate solution. The reaction may be facilitated when an organic acid anhydride is used by the addition of a small amount of a catalyst such as sulfuric acid, sodium acetate, zinc chloride and the like, which hastens the conversion of the anhydrides in the presence of water to the corresponding acid.

In drying sands it is preferred to flush the sands first with a non-aqueous liquid such as a crude oil or asphalt solvent. Thereafter a solution of acetone and crude oil may be pumped out into the sands and this may be followed by a crude oil solution of acetic anhydride containing a small amount of catalyst such as sulfuric acid. Following the drying of the sands, the sands are preferably flushed with an asphalt solvent so as to leave the sands about the hole substantially free from crude oil. Thereafter the asphalt solution is forced through the sands under pressure and a quantity of crude oil is also introduced to cause precipitation of the asphalt as described above. After placing flow tubing and removing the fluids from the well the well is ready for production.

It will be understood that the invention is not limited to the details of any of the foregoing ways of operating and that the steps of the methods may be combined. For example, any suitable drying procedure, such as those disclosed, may be employed in the operation of any of the methods, and this procedure may follow placing of the asphalt. Also, when using a non-aqueous fluid as the drilling-in fluid to complete a well in a formation containing an inconsequential amount of water the drying procedure may be omitted.

Various types of bitumens may be employed in accordance with the invention provided that they are insoluble in crude oil and solid or semi-solid at the temperature of the formation. A suitable asphalt for use may be selected from the classes of natural and petroleum asphalts. Sulfurized asphalts, which are obtained by heating residual oils or residual asphalts with sulfur at high temperatures, are of especial interest. To prepare an asphalt for use in the present invention the asphalt may be leached with a solvent for the oily constituents thereof so as to leave a harder oil-insoluble residue. Because of the varying temperatures encountered in underground formations, the changing characteristics of crude oils, and the different solvents which may be used, it is impossible to define an asphalt which will be the most desirable to use in any given case. However, in general it may be stated that the asphalt or other bitumen employed should have a high affinity for dry sand, and be solid, or at least highly viscous at the reservoir temperatures which are usually between 125° F. and 230° F. Such bitumens may be considered as being substantially solid at the temperature of the formation.

The solvents employed in accordance with the invention are selected principally in view of two considerations. First, they should have sufficient solvent power for the asphalt employed, and secondly they should be the most economical materials having the required solvent powers. Chlorinated aliphatic solvents such as carbon tetrachloride may be used and also strong solvents such as carbon disulfide. Other solvents which are of interest are aromatic solvents such as benzol, toluol, xylol, light coal, tar oil and the like; chlorinated aromatic solvents such as chlorbenzene; nitrated aromatic solvents such as nitrobenzene; and nitroparaffins.

In order that the invention may be understood more fully, the following examples are given.

Example 1

An oil-bearing sand approximately 6500 feet below ground level and 30 feet thick is brought into production as follows: The well is drilled to the top of the sand body with a water-base drilling fluid. Casing is set and cemented at this depth, and the drilling fluid changed to an oil-base fluid with which the sand is penetrated to a depth of about 29 feet. The oil-base drilling fluid containing oil-wettable solids forms a filter cake on the walls of the sand through which oil is slowly flowing back into the oil-bearing sand. When the well is drilled, the drill stem and bit are removed and a dump bailer is run to bottom on a wire line carrying a 5% solution of acetone in oil. At least 5 drums (50 gal. each) of the acetone-in-oil solution are thus placed on the bottom of the hole and in contact with the sand body. Pump pressure is applied to the well head until the 5 drums of solution are forced into the sand followed by at least ten to fifteen barrels of oil from the oil-base drilling fluid. A solution of 10% oil-insoluble bitumen in carbon tetrachloride is then placed on bottom preferably preceded by about 2.5 drums of carbon tetrachloride. The dump bailer is used to place these fluids on the bottom of the hole, and pump pressure is applied at the surface to force the fluids out through the filter cake into the sand. At least ten to fifteen barrels of oil are forced out into the sand following the bitumen injection. Drilling tools are then returned to the hole and the face of the sand under-reamed to a distance of several inches to remove the bitumen-contaminated filter-cake. The well is then brought into production in the usual manner. If sand is well consolidated, no screen is set; if some sand remains unconsolidated, a slotted liner or screen may be set in the usual manner.

Example 2

An oil-bearing sand similar to that described in Example 1 is brought into production by a procedure exactly like that described in Example 1 except that the drilling-in process is conducted with an oil base drilling fluid containing oil, an oil-wettable solid, lamp black and a small amount of an oil-insoluble bitumen. The filter cake thus formed on the sand is almost impermeable to the flow of oil. This cake is made permeable by the introduction into the hole by dump bailer of at least 3 drums of bitumen solvent such as carbon tetrachloride, which also contains additional oil-

insoluble bitumen in solution. This solution dissolves the bitumen in the filter cake and is thus permitted to flow under pump pressure into the sand. An electrical heating element is then lowered into the well to the bottom, the oil in the hole heated well above the boiling point of water at the pressure of the fluids in the sand, and this hot oil forced out into the sand by application of pump pressure at the well head. At least 10 to 15 barrels of the heated oil are thus forced into the sand. The well is then brought into production as described in Example 1.

As noted above, in some cases it may not be possible to accomplish sufficient consolidation of the sands to permit production of the well without a liner or screen. In these cases the present method has the advantage of holding the formation in place during placing of the liner or screen and preventing excessive flow of sand into the well. Also, in locations where the use of a screen or screened liner would normally be required, by treating the sands as described the well may be completed by simply using perforated casing opposite the formation.

Although the invention is particularly concerned with completing oil wells, it will be obvious to those skilled in the art that the method of the invention may be applied to the completion of gas wells and condensate or distillate wells.

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.

I claim:

1. In the art of completing an oil well in poorly-consolidated oil sands, the method which comprises drilling-in the hole in the formation while circulating an oil base drilling fluid containing in suspension a crude oil-insoluble bitumen which is substantially solid at the temperature of the formation, whereby there is laid down on the face of the formation a filter cake containing said bitumen, placing opposite the formation a solvent for said bitumen and forcing said solvent through the filter cake and into the formation, thereafter placing a solution of bitumen opposite the formation and forcing the solution into the formation, then forcing crude oil into the formation permeated by the solution of bitumen to precipitate the bitumen and consolidate the oil sands, removing fluids from the well, and flowing crude oil from the formation through the well.

2. A method in accordance with claim 1 wherein the oil base drilling fluid also contains a liquid chemical dehydrating agent.

3. In the art of completing an oil well in poorly-consolidated oil sands, the method which comprises drilling-in the hole in the formation while circulating an oil base drilling fluid containing in suspension a crude oil-insoluble asphalt which is substantially solid at the temperature of the formation, whereby there is laid down on the face of the formation a filter cake containing said asphalt, forming a fluid stream comprising a slug of an asphalt solvent, a slug of a solution of crude oil-insoluble asphalt which is substantially solid at temperature of the formation and a slug of crude oil, circulating said stream in said oil well until the slug of asphalt solvent is opposite the formation, subjecting the column of fluid in the well to pressure to force the asphalt solvent a substantial distance into the formation, circulating the stream of fluid until the solution of asphalt is opposite the formation, increasing the pressure on the column of fluid in the well to force the solution of asphalt a substantial distance into the formation, circulating the stream of fluid in the well until the slug of crude oil is opposite the formation, increasing the pressure on the column of fluid in the well to force the crude oil into the formation permeated by the solution of asphalt to precipitate the asphalt and consolidate the oil sands, removing fluids from the well, and thereafter flowing crude oil from the formation through the well.

4. A method in accordance with claim 3 wherein the oil base drilling fluid also contains a chemical dehydrating agent.

5. In the art of completing an oil well in poorly consolidated oil sands, the method which comprises drilling-in the hole in the formation while circulating a drilling fluid containing a solid weighting material in suspension from a location of drilling to the surface and return, whereby a filter cake of the solid material is formed on the well bore, rendering a portion of the well bore opposite the loosely consolidated oil bearing formation permeable while maintaining a column of drilling fluid in the well, placing opposite the said formation while maintaining the column of fluid in the well a solution of crude oil-soluble bitumen which is substantially solid at the temperature of the formation and forcing said solution into the formation, then forcing crude oil into the formation permeated by the solution of bitumen to precipitate the bitumen and consolidate the oil sands, removing fluids from the well, and flowing crude oil from the formation through the well.

6. A method in accordance with claim 5, wherein the said loosely consolidated oil bearing formation is chemically dehydrated prior to precipitation of the said bitumen in the formation.

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The following references are of record in the file of this patent:

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