Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
Field of the Invention

The present invention pertains to a well cleanout system comprising plural serially-injected fluid compositions and a method for removing contaminants from cased and open-hole wellbores using such compositions.

Background

In the drilling and workover of oil and gas wells and certain types of fluid-injection wells, it is necessary and desirable to remove contaminants such as drilling fluids, pipe sealants and lubricants and other residue from the wellbore. Failure to perform an effective cleanout operation can result in contamination and plugging of an earth formation from which fluids are desired to be produced. Moreover, wells which have already produced subterranean fluids, including wells having so-called open-hole wellbores, periodically benefit from cleaning of the wellbore to remove contaminants such as iron sulfide precipitates, injection water contaminants and filter cake of certain fluids which have been injected into the wellbore but which have not been removed as a result of producing fluids from the wellbore.

The objectives in wellbore cleanout processes are primarily focused on complete displacement of drilling fluids or other fluids occupying the wellbore and removal of drilling fluid residue and other contaminants occupying the wellbore. In this regard, a displacement fluid, sometimes called a spacer fluid, should be similar in density to the drilling or other fluid occupying the wellbore to prevent substantial commingling of these fluids during the displacement process. Still further, the displacement fluid should contain an agent which is effective in removing contaminants adhering to the wellbore walls as well as certain solids which may be loosely in residence in the wellbore.

Still further, an effective drive fluid for driving the displacement fluid through the wellbore is one which will minimize mixing with the displacement fluid and has a "piston" effect for driving the displacement fluid through the wellbore space and out of the wellbore without substantial mixing with the drive fluid. This fluid should have viscoelastic and pseudo plastic time independent properties to provide the piston-like displacement effect and gel-like suspension characteristics.

Still further, a desirable well cleanout system and method requires a buffer to prevent mixing of the viscous gel drive fluid with a final stage comprising a cleaning or wash pill to provide the final stage of cleanout.

Prior art efforts to provide effective well cleanout processes have resulted in unsatisfactory quality and speed of cleanout as well as unwanted mixing and failure of the fluid slugs or pills displaced through the wellbore to provide the cleanout process. However, the objectives and desiderata outlined above have been met with the improved system and method of the present invention.

SUMMARY OF THE INVENTION

The present invention provides an improved wellbore cleanout system comprising plural fluid compositions which are sequentially displaced through a wellbore to remove drilling fluid and other contaminants from the wellbore walls and the wellbore space.

In accordance with an important aspect of the present invention, a wellbore cleanout system is provided which utilizes plural slugs or pills of fluid which are injected into the wellbore to displace the drilling fluid, without substantial mixing, while maintaining an interface which is miscible or near miscible with the drilling fluid and while still further protecting the integrity of a displacement or spacer pill or slug from uncontrolled dilution and dispersion.

In particular, the present invention provides a fluid system for displacing drilling fluid and the like from a wellbore and for cleaning the wellbore walls of said drilling fluid and other contaminants in said wellbore, said system comprising: a first stage aqueous displacement fluid pill for displacing drilling fluid from said wellbore, a second stage drive fluid pill for driving said displacement fluid from said wellbore, a third stage buffer fluid pill; and a fourth stage wash fluid pill; and wherein said wash fluid pill includes an organic solvent.

The present invention further provides a fluid system for displacing drilling fluid and the like from a wellbore and for cleaning the wellbore walls of said drilling fluid and other contaminants in said wellbore, said system comprising: a first stage aqueous displacement fluid pill for displacing drilling fluid from said wellbore, a second stage drive fluid pill for driving said displacement fluid from said wellbore, a third stage buffer fluid pill; and a fourth stage wash fluid pill; and wherein said wash fluid pill includes an organic solvent.

The present invention further provides a fluid system for displacing wellbore fluids and the like from a wellbore and for cleaning the wellbore walls of said fluids and other contaminants in said wellbore; said system comprising: a displacement fluid pill for displacing said wellbore fluids and for cleaning the walls of said wellbore, said displacement fluid pill comprising water and surfactant; a buffer fluid pill; and a wash fluid pill; and wherein said wash fluid pill includes an organic solvent.
In accordance with yet a further aspect of the present invention, a wellbore cleanout system is provided which (a) is operable to accommodate gradual density and viscosity transition between drilling fluid or the like being displaced from the wellbore and a completion fluid which will occupy the wellbore after the displacement and cleaning process, (b) provide fast-acting and turbulent cleaning action, and (c) reduce the volume of components of the system and of completion fluid which must be discarded due to contamination.

In particular, a wellbore cleanout system is provided which includes a unique displacement or spacer fluid composition which is pumped into the wellbore to displace drilling fluid and to remove drilling fluid from the wellbore walls together with other contaminants. This displacement fluid advantageously includes an effective cleaning composition utilizing primarily a glucose based surfactant having a lipophilic portion comprising a linear alkyl chain, or a branch alkyl chain (which may contain one or more double bonds or a hydroxy group) or an alkyl phenol chain. A cosurfactant may be used such as linear or branch alkyl alcohol ethoxylates, alkyl phenol ethoxylates, amphoteric, anionic, and cationic surfactants.

Still further, the system includes a viscous fluid slug or pill which provides a piston-like driving effect for displacing the displacement fluid without significant mixing with the displacement fluid thereby protecting the displacement fluid from uncontrolled dilution and dispersion while also providing a gradual density transition.

Still further, the invention includes a buffer fluid slug or pill which serves as a buffer providing a gradual viscosity transition between the viscous drive fluid slug and a washing or cleaning pill or slug which includes a solvent and which may be displaced through the wellbore in turbulent flow to provide a final step in the cleaning process.

The invention contemplates the use of a series of four slugs or pills of fluids to provide the optimum displacement and cleanout process which is particularly useful in cleaning out oil-based or water-based muds, although not limited thereto, minimize the dilution and dispersion of each of the pills or slugs of fluid, provide a gradual density and viscosity transition between the fluid being displaced from the wellbore and each of the pills or slugs as well as the final completion fluid which is to occupy the wellbore, provide fast-acting, turbulent cleaning action in the wellbore and minimize the volume of completion fluid, in particular, which must be discarded due to contamination. The above-noted objectives, advantages and superior features of the present invention will be further appreciated by those skilled in the art upon reading the detailed description which follows in conjunction with the drawing.

**BRIEF DESCRIPTION OF THE DRAWING**

Figure 1 is a diagram of the molecular structure of a preferred surfactant; Figure 2 is a schematic diagram of a wellbore showing one general arrangement of the various fluid slugs or pills which are pumped through the wellbore in accordance with the present invention; and Figure 3 is a diagram showing certain characteristics of a preferred drive fluid in accordance with the present invention.

**DESCRIPTION OF PREFERRED EMBODIMENTS**

In the description which follows, like parts are marked throughout the specification and drawing with the same reference numerals, respectively. The drawing figures are not to scale and certain elements are shown in generalized or somewhat schematic form in the interest of clarity and conciseness.

The above-described problems and desiderata in cleanout of subterranean wellbores have been resolved with two primary factors which are central to the success of the cleanout system and method of the present invention. Gradual density transition between the slugs or pills of the fluids is advantageous in that minimal commingling of fluids occurs. Secondly, an advantageous composition is provided for the drive fluid which displaces the displacement fluid resulting in better viscosity control than prior art compositions. Still further, fluid turbulence in the wash slugs or pills is provided with improved cleaning effect. Lastly, improved cleaning slugs or pills are provided which use alkyl polyglycoside cleaning agents and non-aromatic solvents, both of which significantly enhance the quality of the wellbore cleaning and the efficiency of displacement of wellbore fluids and other contaminants.

In accordance with the teaching of U.S. Patent Application Serial No. 07/863,529, assigned to the assignee of the present invention, it has been discovered that certain alkyl polyglycoside surfactants, which are non-ionic in nature, and which utilize the many hydroxyl groups in the polysaccharide chain to achieve hydrophilicity, in combination with caustic materials such as sodium hydroxide and potassium hydroxide, may be particularly effective in a cleanout fluid for removing from wellbores oil-based drilling mud residue, pipe thread sealants and lubricants, hydrocarbon substances such as diesel oil, mineral oil and crude oil and other naturally-occurring formation fluids. The oil-soluble portion of the alkyl polyglycoside surfactant may be controlled by the alkyl chain length which can be varied from C4 to C18. Each saccharide group is typically equivalent to 5-7 ethylene oxide groups, and therefore is very effective in
rendering water-soluble properties to alkyl polyglycoside surfactants even at high tempera-
tures, high salinity and hardness conditions such as in seawater.

[0021] Figure 1(a) shows the structure of the alkyl polyglycoside molecule that contains a hydrophilic group which is
derived from starch and is comprised of one or more anhydroglucose units. There are two ether oxygens and three
hydroxyl groups per glucose unit, plus a terminal hydroxyl group. The lipophilic portion of the molecule resides in the
alkyl chain wherein R can be a linear alkyl chain, as indicated in Figure 1(b), and wherein n preferably ranges from 4
to 18. Alternatively, R can be a branch alkyl chain, as indicated in Figure 1(c), wherein m and k are odd numbers and
m is equal to k + 2, or an alkyl phenol chain as indicated in Figure 1(d). The polymerization reaction can provide
oligomer distributions from x = 0 up to x = 10.

[0022] The concentration of the alkyl polyglycoside surfactant for use in the first or displacement fluid stage may be
in the range of about 1.0% to 10.0% by weight of the total composition for use in displacing both oil-based drilling muds
and water-based drilling muds. The water solubility and oil solubility requirements can be optimized by choosing the
appropriate alkyl chain length or a mixture of alkyl chain length and/or the polysaccharide in the molecule. Preferably the surfactant includes a hydrophilic group comprised of one or more anhydrous glucose units and a lipophilic
portion selected from a group consisting of a linear alkyl chain, a branch alkyl chain which may contain one or more
double bonds or a hydroxy group and an alkyl phenol chain. Preferably the surfactant comprises an alkyl polyglycoside
having an alkyl chain length in the range C4 to C18. A cosurfactant such as a linear alkyl ethoxylate or an alkyl phenol
ethoxylation may be included in the total concentration of surfactant. The cosurfactant may also be selected from am-
photeric, anionic and cationic type surfactants. The weight concentration of the cosurfactant in the total should be in
the range of 0.0% and 3.0%. In other words, if the total concentration of surfactant is 5.0% and the concentration of the
cosurfactant is .25%, the concentration of the alkyl polyglycoside surfactant would be 4.75% by weight of the total composition.

[0023] The displacement fluid which is to include the alkyl polyglycoside surfactant, and a cosurfactant, if any, may
be one of those described in U.S. Patent 5,030,366, issued July 9, 1991 to Wilson, et al, and assigned to the assignee
of the present invention. In particular, a suitable displacement or "spacer" fluid should comprise fresh water mixed with a
composition which may include the following substances provided in the quantities described as part of a dry mixture:
sulfonated styrene maleic anhydride copolymer in the amount of about 10% to 50% by weight, about 40% to 90% by
weight of a gell agent such as bentonite and about 1% to about 20% by weight of a viscosifier selected from a group
consisting of Welan gum, hydroxymethylcellulose, carboxymethyl hydroxymethylcellulose, attapulgite, partially hydrosylized
polyacrylamide, sepiolite, bentonite, acrylamide polymers, acrylic acid polymers, 2-acrylamido-2-methylpropane sul-
phonic acid copolymers, polyvinyl pyrrolidinone and silicate extenders.

[0024] Preferably the displacement fluid includes a dispersant selected from a group consisting of sulfonated styrene
maleic anhydride, sulfonated vinyl toluene maleic anhydride and sulfonated iso-butylene maleic anhydride.

[0025] Preferably the displacement fluid includes a dispersant, water, a viscosifier and a surfactant.

[0026] The quantity of the displacement fluid which is pumped into a typical wellbore should occupy at least about
400 feet to 1200 feet of wellbore space during the displacement and cleanout procedure. The displacement fluid should
have a density not significantly less than, and preferably the same or slightly less than, the density of the drilling fluid
or other fluid in the wellbore that is to be displaced during the displacement and cleanout procedure. It has been
determined that, if the density of the displacement fluid pill is within about 2.0 lbs. per gallon less than the density of the
drilling or other fluid in the wellbore, an insignificant mixing or commingling of fluids will take place in a normal
cleanout procedure in accordance with the invention.

[0027] The second slug or pill of fluid displaced through the wellbore functions primarily as a piston-like or driving
element for the slug or pill of displacement fluid. The second fluid pill is preferably a viscous gel solution which has a
relatively steep slope of viscosity versus shear rate and also a very high viscosity at low or near-zero shear rate, such as
0.1 reciprocal seconds or less. Preferably, the viscous gel comprises water and xanthan gum. In accordance with the
present invention, the use of a biopolymer gel solution such as clarified xanthan gum has been discovered to have
superior performance characteristics. The xanthan gum has improved rheological properties over synthetic polymers
such as HEC (hydroxyethyl cellulose) and polyacrylamides. Figure 3 illustrates the characteristic shear rate in re-
ciprocal seconds (Sec⁻1) versus viscosity in centipoises (cp) at 160°F for gels made up of 2.5 lbs. of clarified xanthan
gum per barrel of water (42 U.S. gallons per barrel), in particular a brand known as Xanvis, and 2.8 lbs. of HEC per
barrel of water. The rheological behaviors would be similar in potassium chloride or sodium chloride brine.

[0028] It will be noted from Figure 3 that the viscosities at relatively high shear rates (100 to 1000 reciprocal seconds)
of the Xanvis gel are lower (in a range of about 20 cp to 150 cp) than that attainable with HEC while the viscosities at
low shear rates (.1 or lower reciprocal seconds) are significantly higher (in a range of about 27,000 cp to 35,000 cp).
This shear rate versus viscosity characteristic enables the drive fluid pill or slug to proceed through the wellbore with
minimal turbulence while also maintaining a fairly uniform "piston-like" characteristic to displace the displacement fluid
without substantial mixing therewith. In fact, the density of the drive fluid pill may be significantly less than that of the
displacement fluid. For example, if the displacement fluid has a density of about 15.0 to 16.0 lbs. per gallon, the drive
The present invention also provides a method for displacing fluid from and cleaning a wellbore space of a subterranean well having a tubing string extending therewithin, said method comprising circulating the fluid system of polymer gel in completion brine returns can plug off the brine filtration system, thereby incurring additional expense of the substantial mixing zone created by fingering of the completion brine into the viscous drive fluid. The presence of polymer gel in completion brine returns can plug off the brine filtration system, thereby incurring additional expense. In a preferred embodiment, the displacement fluid comprises a dispersant, water, a viscosifier and a surfactant comprising an alkyl polyglycoside in the range of about 0.5% to 10.0% by weight of said displacement fluid; and said drive fluid comprises xanthan gum.

The well cleanout system and method contemplates the use of a third stage fluid pill which is preferably comprises a quantity of brine, preferably chloroform brine or seawater which can be provided in densities up to about 10.0 lbs. per gallon using sodium chloride so as to mitigate any large density differential between the second stage pill and the third stage pill as well as between the third stage pill and a fourth stage pill. Because of a fairly critical temperature characteristic, bromide brines are not suitable for use as the third stage or buffer pill adjacent to a drive fluid pill which includes a xanthan gum polymer. Bromide ions will tend to reduce the rheological stability of the xanthan gum significantly and destroy its viscosity qualities at elevated temperatures, typically above 60°C. The selection of the third stage fluid described immediately above is based on the assumption that some mixing of this buffer fluid with the second stage drive fluid will occur. Accordingly, the placement of a third stage fluid pill between the drive fluid pill and a fourth stage fluid pill, which will complete the cleanout procedure, is desirable.

A major advantage of the four-stage fluid system with the four separate fluid slugs or pills described herein-above is that when a completion in brine is pumped into and through a well behind the fourth stage slug or pill, only a minimal volume of such brine has to be discarded due to polymer contamination. In a conventional three-stage fluid slug cleanout system, for example, (displacement fluid, followed by wash fluid, followed by viscous drive fluid) there is always a large disposal volume of brine as well as a substantial delay in taking the brine surface returns because of the substantial mixing zone created by fingering of the completion brine into the viscous drive fluid. The presence of polymer gel in completion brine returns can plug off the brine filtration system, thereby incurring additional expense and delaying well operations.

The present invention also provides a method for displacing fluid from and cleaning a wellbore space of a subterranean well having a tubing string extending therewithin, said method comprising circulating the fluid system of the present invention into said well and optionally thereafter circulating a completion fluid into said well to displace the...
fluids of the fluid system through said well.  

[0038] A typical well displacement and cleanout procedure will now be described utilizing the system and method of the invention. Figure 2 illustrates the well cleanout system being displaced through a well 10 extending in an earth formation 11 and having a cased portion 12, an open-hole portion 14 and a tubing string 16 extending within the well from a wellhead 18. The decision on whether or not to pump the four-stage displacement and cleanout system fluids down through a tubing string and up through the well annulus, as shown in Figure 2, or vice versa, may be based on several factors. Generally, if the density of the final completion fluid (i.e. the fifth stage) is relatively high, it would be desirable to pump the fluid slugs, and the completion fluid thereafter, down through the tubing string and up through the annulus to minimize commingling of the completion fluid with the cleanout system fluid pills, particularly the fourth stage. Another reason for pumping the well cleanout system down through the tubing string would be to minimize the chance of plugging any small-diameter orifices or ports such as might be found in a drill bit if the system was pumped through a drillstring. Also, removal of bottom-of-the-well solids contaminants may also be easier accomplished by pumping the treatment system down through the tubing string and up through the annulus.  

[0039] On the other hand, if the density of the completion fluid is relatively low, this would favor pumping the cleanout fluid pills serially down through the well annulus and up through the tubing string.  

[0040] The first stage of the cleanout system comprising the drilling fluid displacement slug or pill is preferably composed of the aforementioned compositions of sulfonated styrene maleic anhydride, a water, a weighting agent, a vis-cosifier, an alkyl polyglycoside surfactant and a cosurfactant to provide displacement of the drilling fluid, particularly oil-based or water-based drilling muds, provide some miscibility at the interface of the drilling fluid and the first stage slug or pill to avoid the formation of any emulsion of adverse viscosities and to provide cleaning of the wellbore surfaces comprising the inner and outer surfaces of the tubing string, the open hole wall surface of a wellbore and/or the inner wall surfaces of the well casing. The displacement fluid also functions to entrain and remove solids particles loosely residing in the wellbore or adhered to the drilling fluid or oil coatings on the wellbore wall surfaces. The first stage fluid may be made up in densities ranging from 9.0 to 19.0 lbs. per gallon and should be approximately the same or slightly less dense than the drilling fluid that is being displaced, as previously mentioned.  

[0041] If the cleanout system is being pumped down through a so-called workstring or a drillstring, such a tubing string may be reciprocated and/or rotated during the injection and displacement process to enhance the cleaning action of the first stage pill. All blending and storage tanks and flowlines leading to the well should be cleaned in advance. A sufficient quantity of the first stage pill should be made up to occupy about 400 feet to 1200 feet of wellbore annulus. Typically, the displacement fluid pill should be in the amount of 20 barrels to 60 barrels volume (42 U.S. gallons per barrel). The surfactant formulation used in the displacement fluid pill preferably includes an alkyl polyglycoside surfactant known as APG 600 or Glucopon 600 available from Henkel Corporation of Amber, Pennsylvania, and a small amount of a non-ionic surfactant sold under the trade name Neodol 91-2.5 available from Shell Chemical Company of Houston, Texas. Typically, the displacement fluid composition comprises 1.0% to 5.0% by weight of total active surfactants. Moreover, the ratio of the alkyl polyglycoside surfactant to the nonionic cosurfactant should be in the range of 5:1 to 2:1 by weight. Example compositions are shown in Table I.

<table>
<thead>
<tr>
<th>TABLE I</th>
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<tbody>
<tr>
<td>APG® 600</td>
</tr>
<tr>
<td>3.8 %v</td>
</tr>
<tr>
<td>4.8 %v</td>
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</tbody>
</table>

50% active material

[0042] By way of example, the displacement fluid pill in the amount of 33 barrels may be made up using 22.5 barrels of fresh water and 350 lbs. of a dry spacer mix in accordance with the compositions described hereinabove or in U.S. Patent 5,030,366 and available from Halliburton Energy Services as their Alpha spacer mix. Preferably the spacer mix is added to the water slowly at an interval of ten minutes for each 50 lb. bag while shearing the mixture with maximum pumping rate for fifteen to twenty minutes. A weighting agent in the amount of 13,000 lbs. is then injected into the pill solution in a blending and storage tank while blending and circulating with a pump for about 15 minutes.  

[0043] Subsequently, 8.0 gallons of Neodol 91-2.5 are added together with 41.0 gallons of Glucopon 600 alkyl polyglycoside surfactant. Preferably, the alkyl polyglycoside surfactant is added last, about one-half hour before pumping into the wellbore, to avoid foaming.  

[0044] The drive fluid pill (second stage) is thereafter made up in a blending tank in the amount of 33 barrels, at a density of 10.0 lbs. per gallon, by adding citric acid to 29.5 bbl of water to lower the pH to about 4.0. Seventy-five pounds of Xanvis brand xanthan gum polymer are then added slowly at the rate of 12.5 lbs. per minute while mixing to disperse the polymer. At this point, a diluted caustic soda solution may be added slowly to raise the pH of the drive
fluid to the range of about 9.0 to 10.0 until it becomes thickened. In order to bring the density of the drive fluid pill up to 10.0 lbs. per gallon, 3600 lbs. of sodium chloride are then added to the pill solution. This solution is sheared at maximum pumping rate for about fifteen to thirty minutes to help it yield its full viscosity. The quantity of drive fluid pill made up should also occupy from 400 feet to 1200 feet of wellbore space.

A sufficient quantity of completion fluid (brine) is made up for use as the third or buffer stage, preferably having a density of 8.5 lbs. per gallon and of a total volume equivalent to about 600 feet to 1200 feet of wellbore annular space. The fourth or wash stage fluid may also be made by adding about 6.3 barrels of organic solvent, i.e. Super Pickle or CE101, to 14.0 barrels of completion brine. A sufficient quantity of the buffer fluid slug or pill must be used to assure that any residual polymer gel resulting from mixing of the drive fluid pill with the buffer pill does not contaminate the wash pill.

Displacement into the well is started by pumping the displacement fluid pill, followed by pumping the drive fluid pill, followed by pumping the buffer fluid pill and finally pumping the wash fluid pill. A 4.0 barrel per minute pumping rate is preferably maintained until all four stages are pumped into the wellbore. Pumping should continue until total displacement of oil-based drilling fluid or other drilling fluid is completed. The drilling fluid or "mud" is routed to a disposal tank upon its return from the wellbore and the displacement fluid pill, the drive fluid pill and the buffer and wash fluid pills are also routed to a disposal tank for proper disposal upon their return from the wellbore.

With the foregoing procedure, contamination of the completion brine (fifth stage) is expected to be no more than 10 to 20 barrels. Once the brine returns look clear, they may be taken to a conventional filtration unit while circulation is continued at a relatively high rate to displace additional one or two wellbore volumes, or until the brine clarity reads 30 NTU's or less.

It should be mentioned that the drilling fluid, for example, an oil-based drilling mud composition, may be modified during the drilling process to facilitate the cleanout procedure. For example, when nearing total hole depth, preparation for the cleanout and completion operation may be carried out by increasing the oil-water volumetric ratio to 80/20 or higher, if possible, while reducing the excess lime content to a minimum of 0.0 to 1.0 lbs. per barrel. The rheology of oil-based mud, that is the plastic viscosity, yield point and gel strength should also be modified so that the yield point is less than the displacement fluid pill. Secondly, a casing or tubing scraper may be run such as the Hedge Hog brand casing brush similar to that described in U.S. Patent 4,896,720. The drilling fluid should be maintained in circulation during the scraper run and the workstring or drillstring may be rotated and reciprocated also during displacement.

Those skilled in the art will appreciate from the foregoing that an improved wellbore cleanout system and method have been provided by the present invention. The first stage comprising the displacement fluid pill provides a density balanced displacement of drilling fluids with substantial cleaning of the tubing and casing surfaces or the wellbore surface of an open-hole wellbore. Each of the fluid stages or pills are prevented from undergoing uncontrolled dilution and dispersion with a gradual density and viscosity transition and a fast-acting and turbulent cleaning action is provided by the fourth stage pill. Preferably the densities of each of said fluids comprising said second, third and fourth stages do not vary from the densities of the fluid of the adjacent stage by more than about 2.4g/cc (2.0 lbs. per gallon). The entire system not only provides improved cleaning action but minimizes the volume of completion fluid which must be discarded due to contamination.

Although a preferred embodiment of a system and method for cleaning wellbores has been described hereabove, those skilled in the art will recognize that various substitutions and modifications may be made to the system and method without departing from the scope and spirit of the invention as recited in the appended claims.

Claims

1. A fluid system for displacing drilling fluid and the like from a wellbore and for cleaning the wellbore walls of said drilling fluid and other contaminants in said wellbore, said system comprising:

   a first stage aqueous displacement fluid pill for displacing drilling fluid from said wellbore,
   a second stage drive fluid pill for driving said displacement fluid from said wellbore,
   a third stage buffer fluid pill; and
   a fourth stage wash fluid pill;

   and wherein said wash fluid pill includes an organic solvent.

2. A fluid system as claimed in any one of the preceding claims characterised in that the densities of each of said fluids comprising said second, third and fourth stages do not vary from the densities of the fluid of the adjacent stage by more than about 2.4g/cc (2.0 lbs. per gallon).
3. A fluid system for displacing drilling fluid and the like from a wellbore and for cleaning the wellbore walls of said drilling fluid and other contaminants in said wellbore, said system comprising:

   a first stage aqueous displacement fluid pill for displacing drilling fluid from said wellbore,
   a second stage drive fluid pill for driving said displacement fluid from said wellbore, and
   a wash fluid pill,

   and wherein said wash fluid pill includes an organic solvent.

4. A fluid system as claimed in claim 1, claim 2 or claim 3 characterised in that said drive fluid comprises a viscous gel.

5. A fluid system as claimed in claim 4 characterised in that said viscous gel comprises water and xantham gum.

6. A fluid system as claimed in claim 5 characterised in that said drive fluid comprises a chloride brine and xantham gum.

7. A fluid system as claimed in claim 5 or claim 6 characterised in that said displacement fluid comprises a dispersant, water, a viscosifier and a surfactant comprising an alkyl polyglycoside in the range of about 0.5% to 10.0% by weight of said displacement fluid; and

   said drive fluid comprises water and xantham gum.

8. A fluid system for displacing wellbore fluids and the like from a wellbore and for cleaning the wellbore walls of said fluids and other contaminants in said wellbore; said system comprising:

   a displacement fluid pill for displacing said wellbore fluids and for cleaning the walls of said wellbore, said
   displacement fluid pill comprising water and a surfactant;
   a buffer fluid pill; and
   a wash fluid pill;

   and wherein said wash fluid pill includes an organic solvent.

9. A fluid system as claimed in claim 1, claim 2 or claim 8 characterised in that said buffer fluid comprises a quantity of brine.

10. A fluid system as claimed in claim 8 or claim 9 characterised in that said surfactant includes a hydrophilic group comprised of one or more anhydrous glucose units and a lipophilic portion selected from a group consisting of a linear alkyl chain, a branch alkyl chain which may contain one or more double bonds or a hydroxy group and an alkyl phenol chain.

11. A fluid system as claimed in claim 10 characterised in that said surfactant comprises an alkyl polyglycoside having an alkyl chain length in the range C4 to C18.

12. A fluid system as claimed in any one of claims 1 to 11 characterised in that said organic solvent comprises a d-Limonene based solvent.

13. A fluid system as claimed in any one of claims 1 to 12 characterised in that the concentration of said solvent in said wash fluid is in the range of 20% to 50% by volume.

14. A fluid system as claimed in any one of claims 1 to 13 characterised in that said wash fluid further includes at least one of an alkyl polyglycoside surfactant, a cosurfactant and a caustic agent.

15. A fluid system as claimed in claim 14 characterised in that said caustic agent is selected from sodium hydroxide and potassium hydroxide.

16. A fluid system as claimed in claim 14 or claim 15 characterised in that the concentration of said surfactant in said wash fluid is in the range of 0.5% to 10.0% by weight.

17. A fluid system as claimed in any one of the preceding claims in which the displacement fluid includes a dispersant,
water, a viscosifier and a surfactant.

18. A fluid system as claimed in claim 17 characterised in that said displacement fluid includes a surfactant in the amount of about 1.0% to 10.0% by weight of said displacement fluid.

19. A fluid system as claimed in claim 17 or claim 18 characterised in that said surfactant is as specified in Claim 10 or Claim 11.

20. A fluid system as claimed in any one of claims 17 to 19 characterised in that said displacement fluid includes a cosurfactant selected from a group consisting of linear or branch alkyl alcohol ethoxylate, alkyl phenol ethoxylate, amphoteric, anionic, and cationic surfactants.

21. A fluid system as claimed in any one of claims 17 to 20 characterised in that said displacement fluid includes a dispersant selected from a group consisting of sulfonated styrene maleic anhydride, sulfonated vinyl toluene maleic anhydride and sulfonated isobutylene maleic anhydride.

22. A fluid system as claimed in any one of claims 17 to 21 characterised in that said displacement fluid includes one or more viscosifiers selected from a group consisting of Welan gum, hydroxyethylcellulose, carboxymethyl hydroxyethylcellulose, attapulgite, partially hydrolized polyacrylamide, sepiolite, bentonite, acrylamide polymers, acrylic acid polymers, 2-acrylamido-2-methylpropane sulfonic acid copolymers, polyvinyl pyrrolidone and silicate extenders.

23. A fluid system as claimed in any one of the preceding claims characterised in that said displacement fluid pill has a density which is the same as or slightly less than the density of said drilling fluid.

24. A method for displacing fluid from and cleaning a wellbore space of a subterranean well having a tubing string extending therewithin, said method comprising circulating a fluid system as claimed in any one of claims 1 to 23 into said well and optionally thereafter circulating a completion fluid into said well to displace the fluids of the fluid system through said well.

**Patentansprüche**

1. Flüssigkeitssystem zum Verdrängen von Bohrspülung und ähnlichem aus einem Bohrloch und zum Reinigen der Bohrochwände von der Bohrspülung und anderen Verunreinigungen in dem Bohrloch, welches System umfaßt:

   einen Block wäßrige Verdrängungsflüssigkeit als erste Stufe zum Verdrängen der Bohrspülung aus dem Bohrloch,
   einen Block Treibflüssigkeit als zweite Stufe zum Austreiben der Verdrängungsflüssigkeit aus dem Bohrloch,
   einen Block Pufferflüssigkeit als dritte Stufe; und
   einen Block Waschflüssigkeit als vierte Stufe;

   und worin der Block Waschflüssigkeit ein organisches Lösungsmittel enthält.

2. Flüssigkeitssystem nach irgendeinem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Dichte jeder dieser die zweite, dritte und vierte Stufe ausmachenden Flüssigkeiten nicht mehr als ungefähr 2,4 g/cc (2,0 lbs pro Gallone) von der Dichte der Flüssigkeit der angrenzenden Stufe abweicht.

3. Flüssigkeitssystem zum Verdrängen von Bohrspülung und ähnlichem aus einem Bohrloch und zur Reinigung der Bohrochwände von der Bohrspülung und anderen Verunreinigungen in dem Bohrloch, welches System umfaßt:

   einen Block wäßrige Verdrängungsflüssigkeit als erste Stufe zum Verdrängen der Bohrspülung aus dem Bohrloch,
   einen Block Treibflüssigkeit als zweite Stufe zum Austreiben der Verdrängungsflüssigkeit aus dem Bohrloch,
und

eine Block Waschflüssigkeit,

und worin der Block Waschflüssigkeit ein organisches Lösungsmittel enthält.

4. Flüssigkeitssystem nach Anspruch 1, Anspruch 2 oder Anspruch 3, dadurch gekennzeichnet, daß die Treibflüssigkeit ein viskoses Gel umfaßt.

5. Flüssigkeitssystem nach Anspruch 4, dadurch gekennzeichnet, daß das viskose Gel Wasser und Xanthan umfaßt.

6. Flüssigkeitssystem nach Anspruch 5, dadurch gekennzeichnet, daß die Treibflüssigkeit Chloridsalzlösung und Xanthan umfaßt.

7. Flüssigkeitssystem nach Anspruch 5 oder Anspruch 6, dadurch gekennzeichnet, daß die Verdrängungslöslichkeit ein Dispersionsmittel, Wasser, ein Viskosiliziermittel und ein Surfactant mit einem Alkylpolyglykosid in einer Menge zwischen ungefähr 0,5 bis 10,0 Gew.-% der Verdrängungslöslichkeit umfaßt; und die Treibflüssigkeit Wasser und Xanthan umfaßt.

8. Flüssigkeitssystem zum Verdrängen von Bohrlochflüssigkeiten und ähnlichem aus einem Bohrloch und zum Reinigen der Bohrlochwände von diesen Flüssigkeiten und anderen Verunreinigungen in dem Bohrloch; welches System umfaßt:

- einen Block Verdrängungslöslichkeit zum Verdrängen der Bohrlochflüssigkeiten und zum Reinigen der Wände dieses Bohrlochs, wobei der Block Verdrängungslöslichkeit Wasser und ein Surfactant umfaßt;
- einen Block Pufferflüssigkeit; und
- einen Block Waschflüssigkeit;

und worin der Block Waschflüssigkeit ein organisches Lösungsmittel enthält.

9. Flüssigkeitssystem nach Anspruch 1, Anspruch 2 oder Anspruch 8, dadurch gekennzeichnet, daß die Pufferflüssigkeit eine Menge Salzlösung umfaßt.

10. Flüssigkeitssystem nach Anspruch 8 oder Anspruch 9, dadurch gekennzeichnet, daß das Surfactant eine hydrophile Gruppe aus einer oder mehreren Anhydroglucoseeinheiten und einen lipophilen Teil, ausgewählt aus einer Gruppe bestehend aus einer linearen Alkylkette, einer verzweigten Alkylkette, die ein oder mehrere Doppelbindungen oder eine Hydroxygruppe enthalten können, und einer Alkylphenolkette, umfaßt.


12. Flüssigkeitssystem nach irgendeinem der Ansprüche 1 bis 11, dadurch gekennzeichnet, daß das organische Lösungsmittel ein Lösungsmittel auf Basis von d-Limonen umfaßt.

13. Flüssigkeitssystem nach irgendeinem der Ansprüche 1 bis 12, dadurch gekennzeichnet, daß die Konzentration des Lösungsmittels in der Waschflüssigkeit im Bereich von 20 bis 50 Vol.-% liegt.

14. Flüssigkeitssystem nach irgendeinem der Ansprüche 1 bis 13, dadurch gekennzeichnet, daß die Waschflüssigkeit ferner wenigstens einer der folgenden Zusätze, nämlich ein Alkylpolyglykosid-Surfactant, ein Cosurfactant oder ein Ätzmittel, umfaßt.

15. Flüssigkeitssystem nach Anspruch 14, dadurch gekennzeichnet, daß das Ätzmittel ausgewählt ist aus Natriumhydroxid und Kaliumhydroxid.

16. Flüssigkeitssystem nach Anspruch 14 oder Anspruch 15, dadurch gekennzeichnet, daß die Konzentration des Surfactants in der Waschflüssigkeit im Bereich von 0,5 bis 10,0 Gew.-% liegt.

18. Flüssigkeitssystem nach Anspruch 17, dadurch gekennzeichnet, daß die Verdrängungsflüssigkeit ein Surfactant in einer Menge von ungefähr 1,0 bis 10,0 Gew.-% der Verdrängungsflüssigkeit umfaßt.

19. Flüssigkeitssystem nach Anspruch 17 oder Anspruch 18, dadurch gekennzeichnet, daß das Surfactant wie in Anspruch 10 oder Anspruch 11 definiert ist.


23. Flüssigkeitssystem nach irgendeinem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der Block Verdrängungsflüssigkeit eine Dichte hat, die gleich der oder etwas geringer als die Dichte der Bohrspülung ist.

24. Verfahren zum Verdrängen von Flüssigkeit aus und zum Reinigen von einem Bohrlochraum eines unterirdischen Bohrlochs mit einem darin verlaufenden Rohrstrang, wobei das Verfahren das Zirkulierenlassen eines Flüssigkeitssystems nach irgendeinem der Ansprüche 1 bis 23 in das Bohrloch und gegebenenfalls danach das Zirkulierenlassen einer Abschlußflüssigkeit in das Bohrloch zum Verdrängen der Flüssigkeiten des Flüssigkeitssystems durch das Bohrloch umfaßt.

Revendications

1. Système de fluides pour déplacer un fluide de forage et analogue à partir d'un puits de forage et pour débarrasser les parois de puits de forage dudit fluide de forage et d'autres agents de contamination dans ledit puits de forage, ledit système comprenant :

   un galet de fluide de déplacement aqueux constituant un premier étage pour déplacer le fluide de forage depuis ledit puits de forage ;
   un galet de fluide d'entraînement constituant un deuxième étage pour entraîner ledit fluide de déplacement depuis ledit puits de forage ;
   un galet de fluide tampon constituant un troisième étage ; et
   un galet de fluide de lavage constituant un quatrième étage ; et dans lequel ledit galet de fluide de lavage comprend un solvant organique.

2. Système de fluides selon la revendication précédente, caractérisé en ce que les densités de chacun desdits fluides constituant lesdits deuxième, troisième et quatrième étages ne varient pas par rapport aux densités du fluide de l'étage adjacent de plus de 2,4 g/cc (2,0 litres par gallon).

3. Système de fluides pour déplacer un fluide de forage et analogue à partir d'un puits de forage et pour débarrasser les parois de puits de forage dudit fluide de forage et d'autres agents de contamination dans ledit puits de forage, ledit système comprenant :

   un galet de fluide de déplacement aqueux constituant un premier étage pour déplacer le fluide de forage depuis ledit puits de forage,
   un galet de fluide d'entraînement constituant un deuxième étage pour entraîner ledit fluide de déplacement
4. Système de fluides selon la revendication 1, la revendication 2 ou la revendication 3, caractérisé en ce que ledit fluide d'entraînement comprend un gel visqueux.

5. Système de fluides selon la revendication 4, caractérisé en ce que ledit gel visqueux comprend de l'eau et de la gomme de xanthane.

6. Système de fluides selon la revendication 5, caractérisé en ce que ledit fluide d'entraînement comprend une saumure de chlorure et de la gomme de xanthane.

7. Système de fluides selon la revendication 5 ou la revendication 6, caractérisé en ce que ledit fluide de déplacement comprend un agent de dispersion, de l'eau, un agent augmentant la viscosité et un agent de surface comprenant un polyglycoside d'alkyle dans la plage d'environ 0,5 % à 10,0 % en poids dudit fluide de déplacement ; et ledit fluide d'entraînement comprend de l'eau et de la gomme de xanthane.

8. Système de fluides pour déplacer des fluides de puits de forage et analogue à partir d'un puits de forage et pour débarrasser les parois de puits de forage desdits fluides et d'autres agents de contamination dans ledit puits de forage ; ledit système comprenant :
   - un galet de fluide de déplacement pour déplacer lesdits fluides de puits de forage et pour nettoyer les parois dudit puits de forage, ledit galet de fluide de déplacement comprenant de l'eau et un agent de surface ;
   - un galet de fluide tampon ; et
   - un galet de fluide de lavage ;
   et dans lequel ledit galet de fluide de lavage comprend un solvant organique.

9. Système de fluides selon la revendication 1, la revendication 2 ou la revendication 8, caractérisé en ce que ledit fluide tampon comprend une certaine quantité de saumure.

10. Système de fluides selon la revendication 8 ou la revendication 9, caractérisé en ce que ledit agent de surface comprend un groupe hydrophile constitué d'une ou plusieurs unités de glucose anhydre et une partie lipophile sélectionnée à partir d'un groupe constitué par une chaîne alkyle linéaire, une chaîne alkyle ramifiée qui peut contenir une ou plusieurs liaisons doubles ou un groupe hydroxyle et une chaîne alkylphénol.

11. Système de fluides selon la revendication 10, caractérisé en ce que ledit agent de surface comprend un polyglycoside d'alkyle ayant une longueur de chaîne alkyle dans la plage de C4 à C18.

12. Système de fluides selon l'une quelconque des revendications 1 à 11, caractérisé en ce que ledit solvant organique comprend un solvant à base de d-citrène.

13. Système de fluides selon l'une quelconque des revendications 1 à 12, caractérisé en ce que la concentration dudit solvant dans ledit fluide de lavage est dans la plage de 20 % à 50 % en volume.

14. Système de fluides selon l'une quelconque des revendications 1 à 13, caractérisé en ce que ledit fluide de lavage comprend de plus au moins l'un d'un agent de surface de polyglycoside d'alkyle, d'un co-agent de surface et d'un agent caustique.

15. Système de fluides selon la revendication 14, caractérisé en ce que ledit agent caustique est sélectionné entre l'hydroxyde de sodium et l'hydroxyde de potassium.

16. Système de fluides selon la revendication 14 ou la revendication 15, caractérisé en ce que la concentration dudit agent de surface dans ledit fluide de lavage est dans la plage de 0,5 % à 10,0 % en poids.

17. Système de fluides selon l'une quelconque des revendications précédentes, dans lequel le fluide de déplacement comprend un agent de dispersion, de l'eau, un agent augmentant la viscosité et un agent de surface.
18. Système de fluides selon la revendication 17, caractérisé en ce que ledit fluide de déplacement comprend un agent de surface en une quantité d'environ 1,0 % à 10,0 % en poids dudit fluide de déplacement.

19. Système de fluides selon la revendication 17 ou la revendication 18, caractérisé en ce que ledit agent de surface est comme le spécifie la revendication 10 ou la revendication 11.

20. Système de fluides selon l'une quelconque des revendications 17 à 19, caractérisé en ce que ledit fluide de déplacement comprend un co-agent de surface sélectionné dans un groupe constitué d'un éthoxylate d'alcool d'alkyle linéaire ou ramifié, d'un éthoxylate d'alkylphénol, d'agents de surface amphothères, anioniques et cationiques.

21. Système de fluides selon l'une quelconque des revendications 17 à 20, caractérisé en ce que ledit fluide de déplacement comprend un agent de dispersion sélectionné à partir d'un groupe constitué de l'anhydride de l'acide maléique styrène sulfoné, l'anhydride de l'acide maléique vinyltoluène sulfoné et l'anhydride de l'acide maléique isobutylène sulfoné.

22. Système de fluides selon l'une quelconque des revendications 17 à 21, caractérisé en ce que ledit fluide de déplacement comprend un ou plusieurs agents augmentant la viscosité sélectionnés à partir d'un groupe constitué de la gomme de Welan, l'hydroxyéthylcellulose, l'hydroxyéthylcellulose carboxyméthylique, l'attapulgite, le polyacrylamide partiellement hydrolisé, la sépiolite, la bentonite, les polymères d'acrylamide, les polymères d'acide acrylique, les copolymères d'acide sulfonique 2-acylamido-2-méthylpropane, les agents d'allongement en silicate et polyvinylpyrrolidone.

23. Système de fluides selon l'une quelconque des revendications précédentes, caractérisé en ce que ledit galet de fluide de déplacement a une densité qui est la même ou légèrement inférieure à celle de la densité dudit fluide de forage.

24. Procédé de déplacement et de nettoyage de fluide à partir d'un espace de puits de forage d'un puits souterrain ayant une rame de colonne de production s'étendant à l'intérieur de ce dernier, ledit procédé comprenant la mise en circulation d'un système de fluides selon l'une quelconque des revendications 1 à 23 dans ledit puits et, de manière facultative après cela, la mise en circulation d'un fluide de complétion dans ledit puits pour déplacer les fluides du système de fluides à travers ledit puits.