

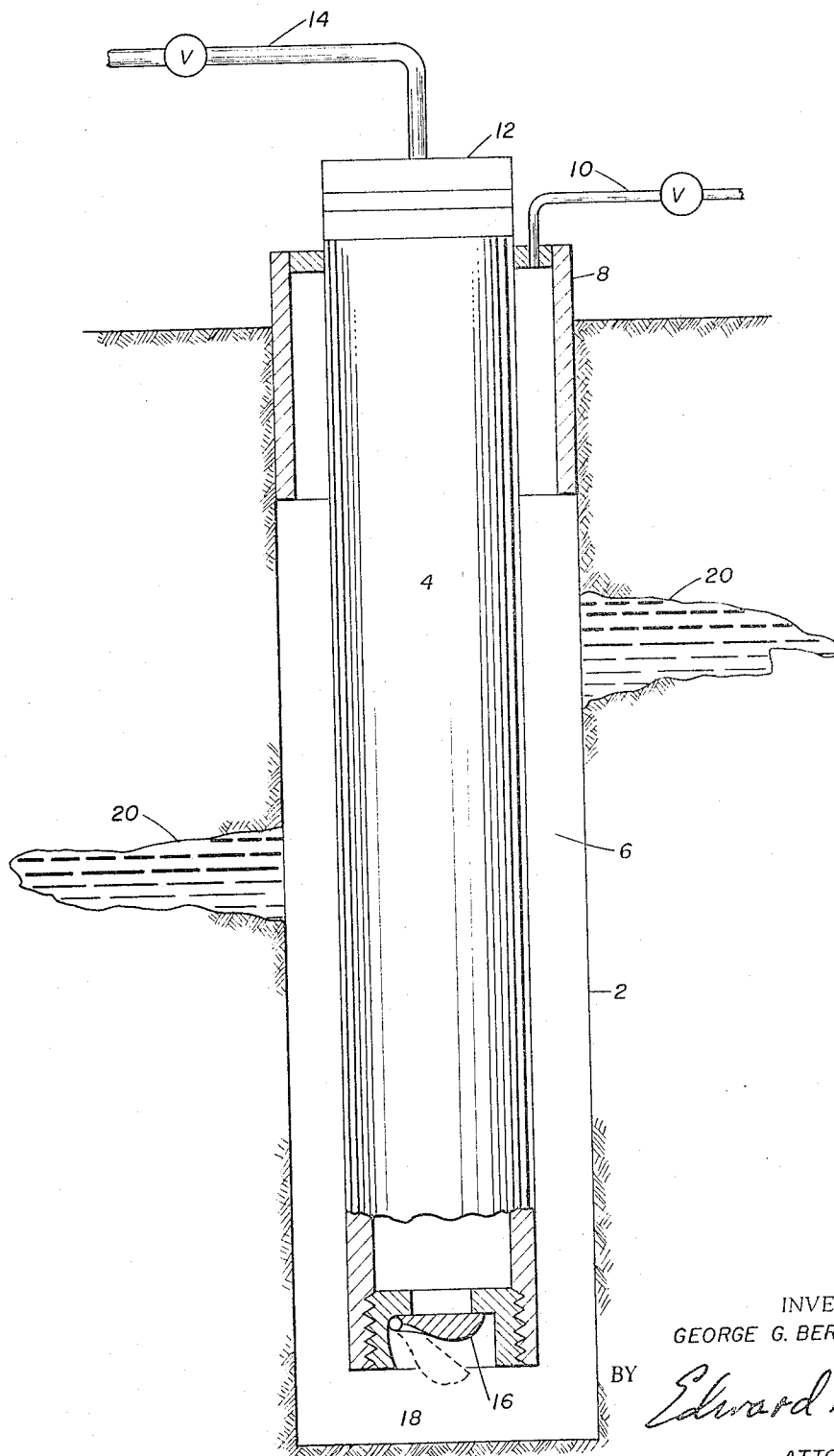
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METHOD OF USING A FOAMING AGENT IN A CEMENTING PROCESS

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METHOD OF USING A FOAMING AGENT IN A CEMENTING PROCESS

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This invention relates to improvements in cementing oil and gas wells, and, in particular, to the cementing of pipes disposed in such wells.

It is customary in oil and gas petroleum wells that at least some of the pipes in the well be cemented over at least a part of their length in order that they will be held firmly in place in the well. It is conventional in the production of oil to seal off the producing horizon or formation from the other strata above and below in order to prevent insofar as possible ingress or intrusion of contaminating material such as water, oil and gas. According to present procedures cement is introduced into the casing at the well head and is forced by pressure of drilling mud behind the cement downwardly through the casing and upwardly into the annular space between the casing and the well bore. The height of the annular cement fill is of course first determined from the location of the formations which are to be sealed and the amount of cement is theoretically computed from a careful study of a well log and the annular space to be filled.

It has also been proposed to utilize compressed air or gas in lieu of the drilling mud so that excessive pressures will not cause failure of the well casing or break-down of the formation around the well due to the high weight or pressure of cement or mud thereon.

These methods have so far proved to be somewhat impractical in that when using a drilling mud, prior to injecting a cementitious material or slurry, so as to clear the annular space of foreign material, the drilling mud has been lost to the formation due to the presence of highly permeable streaks, strata, faults, cracks, etc. If the drilling fluid preparatory treatment is dispensed with and the cementitious material or slurry is pumped down the casing and driven up the annulus by a drilling mud, the cementitious material itself is lost to the highly permeable zones of the well bore and thusly adds greatly to the cost of cementing operations. Where air is utilized as the displacing medium, the same serious drawbacks arise because of the loss of the air to the permeable zones. One means of avoiding this loss is of course by the use of conventional packer means or the use of an extra well casing inserted adjacent the permeable strata or zone so that air or gas is not lost to these zones. However, the serious drawback with the use of air is that explosive or flammable mixtures may be formed because of the presence of natural gas, or hydrocarbon gases within the well bore.

It is an object of the present invention to overcome the problems briefly pointed out above and more specifically to provide a method for cementing wells which is efficient and economical.

A principal object of the invention is to provide methods for cementing wells and in particular oil and gas wells.

Another object of the invention is to provide such methods which are safe, economical, simple to perform and yet are dependable.

A further principal object of the invention is to provide cementing methods for oil or gas wells which provide superior cementing thereof.

Briefly the invention contemplates disposing a foam within the annulus of the well bore formed by the casing and the face of the well bore whereby the foam penetrates the well bore face thereby lowering the permeability

thereof. The foam may be injected through the casing and upward into the annulus per se or a surfactant-containing solution may be injected through the well casing and into the annulus under a sufficient pressure to penetrate the exposed well bore face followed by gas injection under sufficient pressure to contact the surfactant or foaming agent thereby generating foam within the interstices of the area of the formation adjacent the well casing thereby significantly lowering the permeability of the formation so treated. Subsequently, a cementitious material or cement slurry is pumped into the well casing and is displaced upwardly into the annulus by means of compressed air, gas or foam. After the desired amount of cement has been pumped into the annulus, air injection is discontinued and the cementitious material allowed to set.

Other objects and advantages of the invention will appear from the following description of preferred embodiments thereof; reference being made to the accompanying drawing of which:

The drawing is a vertical cross-sectional view in schematic representation showing a well adapted for employment of the invention.

Referring now to the drawing there is shown a well 2 having therein casing 4 forming annulus 6. Upper casing 8 is provided to seal annulus 6 from the atmosphere so that annulus 6 may be pressurized. Extending into casing 8 is valved conduit 10 which is provided to vent annulus 6 to the atmosphere or alternatively, through which fluids may be injected into annulus 6 via upper casing 8. Casing 4 is connected to well head member 12 provided with valved conduit 14 through which a cementitious material or slurry may be injected into casing 4. Near the lower terminus of casing 4 is check valve 16 which permits fluid flow through casing 4 only into the bottom of the well 18 or annulus 6. The check valve prohibits the entry of any fluid within annulus 6 into the interior of casing 4. It is readily apparent that any fluid pumped into annulus 6 will soon be lost due to highly permeable zones or fractures 20.

However, in the practice of this invention to overcome cementitious material or slurry loss, a foam is disposed within annulus 6 under sufficient pressure to penetrate the well bore face and hence highly permeable zones 20. The foam may be generated on the surface (by apparatus which is well known in the art and will not be described herein) and injected per se via conduit 14 into casing 4 through check valve 16 into annulus 6 in sufficient amount and under sufficient pressure so that it will penetrate the well bore face and substantially plug or block the highly permeable zones 20. It may also be introduced into annulus 6 by means of conduit 10 which communicates directly through upper casing 8 to annulus 6. In many instances it will be preferable to inject a surfactant-containing solution into annulus 6 and then thereafter generate foam in situ. This may be accomplished by injecting air or gas through conduit 10. In any event, no matter which expedient is used it is only important that foam be generated within the annulus or within the interstices of the formation adjacent the well bore. The placement of foam in these interstices substantially reduces the permeability of the treated formation.

After the well bore has been substantially saturated with foam, cementitious material or cement slurry is injected through casing 4 via conduit 14 where it passes through check valve 16 to the bottom of the well 18. After the measured volume of cementitious material has been injected, valved conduit 10 is opened to the atmosphere and compressed air or additional foam injected via conduit 14 into casing 4 to displace the cement up-

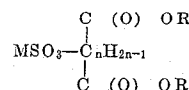
wardly around the casing completely filling annulus 6 to the desired height. While the cement is being moved upwards, the accumulated foam, gas, air, etc. is dispelled from annulus 6 via conduit 10 thereby reducing the amount of pressure necessary to displace the cement within the annulus. It is of course understood that once the cementitious material reaches the desired height within annulus 6, valved conduit 10 is thereafter shut off from the atmosphere. Because of the presence of the foam within the highly permeable zones 20 and within the interstices of the formation along the entire well bore face, the cement is not carried into the formation 2 and consequently much less cement is needed to seal formation 2 from the well. After the cement has been held in the well or annulus 6 for a sufficient time to set, the gas or foam pressure of the displacement fluid may be relieved. While other displacement fluids such as drilling mud may be utilized it is preferred to use air to displace the cementitious material within annulus 6. Because of check valve 16 the cementitious material will not flow from annulus 6 into casing 4. However, it is also to be pointed out that check valve 16 is not necessary to the benefits of this invention and its use may be obviated by maintaining a sufficient pressure within casing 4 to retain cementitious material within the annulus 6.

It will generally be preferred to inject a surfactant-containing solution into the annulus so that same will penetrate the well bore face a radial distance of at least about one foot followed by a sufficient amount of gas to generate foam in situ within the interstices of the well bore face treated with the surfactant-containing solution. The amount of surfactant-containing solution to be injected will normally depend on the type of formation involved and the magnitude of the well bore to be treated. Ordinarily 1 to 10 barrels per foot of formation, to be treated, will be sufficient to produce the desired effect. Generally the surfactant or foaming agent will comprise about 0.01 to 10 weight percent of the solution. The solution will generally act as a carrier for the surfactant or foaming agent and may be either water-base or oil-base in which event the surfactant to be incorporated therein will also be either oil- or water-soluble so as to be compatible with the carrier fluid.

The term "surfactant" or "foaming agent" as used in this specification and appended claims denotes a surfactant or foaming agent which will have a tendency to generate foam in a subterranean formation or stratum in the presence of a liquid and a gas. Additionally the foam generated should have the ability to retard the passage of fluid therethrough. Because of a variance in the foaming characteristics of any one particular foaming agent, type of strata to be plugged, and the distance through the formation in which a foam is to be generated, it will sometimes be necessary to conduct a few simple laboratory core experiments to determine the amount of surfactant or foaming agent necessary to effectively plug the interstices of the strata to be treated. These are tests which are well known in the art and simply involve taking a core sample from the well bore or from the formation in the general vicinity of the well bore, determining its permeability and porosity, and then calculating the amount of surfactant necessary to effectively plug the pores or interstices of the formation.

The use of various commercial foaming surfactants or foaming agents is contemplated, the characteristics of which may be determined from available published tables. An example of a satisfactory oil-soluble foaming agent is a 1:1 mixture of dicocodimethylammonium chloride and decyltrimethylammonium chloride. This mixture can be used in the amount of about 2% by weight with excellent results. An example of a suitable water-soluble surfactant or foaming agent is polyoxyethylated octylphenol, known commercially under the trade name "Triton X-100." Other examples of suitable foam-producing

agents are dimethyldidodecylammonium chloride; methyltrioctenylammonium iodide; trimethyldecylammonium chloride; dibutyldihexadecylammonium chloride; water-soluble salts of esters of C₃-C₆ sulfo dicarboxylic acids having the general formula



where M is a substituent forming a water-soluble salt, such as alkali metals, ammonium, and substituted ammonium, R is a C₃-C₁₆ alkyl substituent, and n is an integer from 1-4, e.g., monosodium dioctyl sulfosuccinate, ammonium dilaurylsulfosuccinate, monosodium dibutyl sebacate, monosodium diamyl sulfoadipate, and others; and water-soluble perfluoroalkanoic acids and salts having 3-24 carbon atoms per molecule, e.g., perfluorooctanoic acid, perfluoropropanoic acid, perfluorononanoic acid. Other surfactive agents which may be used in the practice of this invention are:

Trade Name	Chemical Name
25 Aerosol C-61.....	Ethanolatedalkylguanidine-amine complex.
Aerosol OS.....	Sodium isopropynaphthalene sulfonate.
Arquad 2 C.....	Dicocodimethylammonium chloride.
Arquad T.....	Tallow trimethylammonium chloride.
Duponol EP.....	Fatty alcohol alkylolamine sulfate.
Duponol RA.....	Modified ether alcohol sulfate sodium salt.
Duponol WAQ.....	Sodium lauryl alcohol sulfate.
30 Ethomid HT-60.....	Condensation of hydrogenated tallow amide and ethylene oxide.
Hyonic FA-75.....	Modified fatty alkylolamide.
Miranol HM ¹	Ethylene cyclomido 1-lauryl, 2-hydroxy ethylene Na alcoholate methylene Na carboxylate.
Miranol MM ¹	Same as Miranol HM except myristyl group is substituted for lauryl group.
35 Nacconal NR.....	Alkylarylsulfonate.
Ninol AA62.....	Lauric diethanolamide.
Ninol 1001.....	Fatty acid alkanolamide.
Petrowet R.....	Sodium alkylsulfonate.
Pluronic L44.....	Condensation product of ethylene oxide with propylene glycol.
Product BCO.....	C-cetyl betaine.
Renex 650.....	Polyoxyethylenealkyl aryl ether.
40 Sorbit AC.....	Sodium alkylnaphthalenesulfonate.
Sulfanole FAF.....	Sodium salt of fatty alcohols, sulfated.
Triton AS-30.....	Sodium lauryl sulfate.
Triton X-100.....	Alkylarylpolylethanol.
Span 20.....	Sorbitan Monolaurate.
Span 40.....	Sorbitan Monopalmitate.
Span 85.....	Sorbitan Trioleate.
Tween 65.....	Polyoxyethylene Sorbitan Tristearate.
Tween 81.....	Polyoxyethylene Sorbitan Mono-oleate.
45 OPE 1.....	Octylphenoxyethanols.
OPE-2.....	Do.
OPE-3.....	Do.
Triton GR-7.....	Dioctyl sodium sulfosuccinate.
Triton B-1950.....	Modified phthalic glycerol alkyl resin.
Triton X-45.....	Iso-octylphenoxy polyethoxyethanol (about 5 ethoxy groups per molecule).

¹ Concentrate.

The types of cementitious materials contemplated to be utilized in the practice of this invention are the common pumpable cement slurries such as a mixture of Portland or Portland type cement with a requisite amount of water to form a pumpable neat slurry. Other materials may also include polymers, resins, etc., and need not be described in detail herein in that such matters are outside the scope of this invention and are well within the knowledge of those familiar with the cementing art.

While the primary advantage of this invention lies in the use of low cementing pressures and reduction of fluid loss to the formation, other additional advantages are also present. For instance, where foam is used as the displacing fluid for the cementitious material any leaks in the above-ground pumping equipment will be readily detected which is not the case when air is the displacing fluid. The formation of foam in the formation and the generation of foam in the formation adjacent to the well casing will reduce the flow of extraneous water and other fluids into the well and thereby prevent dilution of the cement. In addition the use of foam will decrease the explosion or fire hazard when air and

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gas are vented to the atmosphere since foam is a fire retardant material.

While the invention has been described wherein the entire length of well casing is cemented it is self-evident that by the use of packers to isolate a highly permeable zone, that only this zone may be subjected to the practice of the described invention. In this instance, packers are merely placed within the annulus to seal off the permeable section from the remainder of the well bore and then the well casing is perforated and foam disposed and forced into the highly permeable section before the introduction of cement. It will also be readily apparent that where the bottom of the well bore is very highly permeable, it will be preferred to inject a generated foam into the well casing so that the permeable well bottom will be effectively plugged or sealed which will then permit the introduction of a surfactant-containing solution or additional foam to completely pressure up the annulus with foam prior to the introduction of the cementitious material.

The following example will satisfactorily serve to illustrate the invention. A well bore 5 inches in diameter is drilled to a depth of 4,216 feet. During the drilling operations a 4½ inch casing is periodically inserted within the well bore forming an annular space between the well bore face and the well casing. It is found that highly permeable strata exist substantially co-extensively with the well casing. A foam solution utilizing "Triton X-100" is generated on the surface and injected into the annulus until a pressure of 585 p.s.i. is obtained. A check valve at the casing bottom restricts foam to the annulus. Thereafter, 31.5 cubic feet of Portland cement admixed with a sufficient amount of water to provide a pumpable slurry is injected through the well casing and is displaced upwardly through the annulus by means of compressed air. The surface annulus pressure is 650 p.s.i. after the cement is positioned. After the cement has been allowed to set up the displacing fluid or compressed air is then vented to the atmosphere and conventional well working processes initiated such as perforating to open up the pay zone of the formation previously cemented off.

While a preferred embodiment of the invention has been shown and described, many modifications thereof may be made by persons skilled in the art without departing from the spirit of the invention and it is intended to protect all forms of the invention falling within the scope of the herein set forth description and the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In the cementing of wells wherein an annulus is formed by the well bore and the well casing the improvement which comprises disposing a foam in the annulus of the well zone to be cemented prior to circulating a volume of cementitious material into the well to the well zone to be cemented.

2. A method of cementing in wells comprising placing a casing within the well bore thereby forming an annulus; disposing a foam in said annulus at the zone to be cemented under sufficient pressure to penetrate the well bore face at said zone whereby the permeability of said well bore face is substantially reduced; and thereafter introducing a cementitious material into the well casing and displacing it with a fluid into said zone to be cemented and permitting the cementitious material to set in the well.

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3. The method in accordance with claim 2 wherein said fluid is air.

4. The method in accordance with claim 2 wherein said fluid is foam.

5. The method in accordance with claim 3 wherein said casing has a check valve at the terminus thereof permitting fluid flow only into said annulus.

6. A method of cementing in wells wherein a casing is placed within a well bore, thereby forming an annulus, comprising disposing an agent, capable of producing a stable foam under formation conditions upon intimate contact with a fluid and a liquid, in said annulus; generating foam in said annulus under a sufficient pressure to cause penetration of the well bore face by said foam whereby the permeability of said well bore face is substantially reduced; and thereafter circulating a cementitious material into said annulus and permitting the cementitious material to set in the annulus.

7. The method in accordance with claim 6 wherein the foam producing agent is introduced into said annulus by means of a carrier liquid in the amount of about 1 to 10 barrels per foot of formation, said agent comprising about 0.01 to 10% by weight of said carrier; and air is subsequently injected.

8. The method in accordance with claim 7 wherein said agent is water soluble and said carrier liquid is water.

9. The method in accordance with claim 7 wherein said agent is oil soluble and said carrier liquid is a hydrocarbon.

10. The method in accordance with claim 9 wherein said casing has a check valve at the terminus thereof permitting fluid flow only into said annulus and said cementitious material is injected into said casing and displaced into said annulus by means of a fluid.

11. The method in accordance with claim 10 wherein said fluid is air.

12. The method in accordance with claim 10 wherein said fluid is foam.

13. The method of cementing in wells comprising the steps:

- (a) placing a casing in the well bore thereby forming an annulus between said well bore and said casing, said casing having a check valve located near the terminus thereof permitting fluid flow only into said annulus;
- (b) injecting a foam into said casing in sufficient quantity and under sufficient pressure to substantially penetrate said well bore face thereby substantially reducing the permeability thereof;
- (c) injecting a volume of cement slurry into said casing;
- (d) driving said cement slurry through said casing and into the annulus, said cement slurry being substantially coextensive with said casing;
- (e) permitting said cement to set in said annulus.

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