

1

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GAS LIFT SYSTEM

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The present invention relates to the use of gas to lift liquids from boreholes in the earth and is particularly concerned with an improved gas lift system for use in oil wells and similar boreholes.

Gas lift systems have been widely used to produce crude oil from wells penetrating low pressure subterranean formations. Most of the systems currently employed require the injection of gas into the annulus between the production tubing and casing at the surface under sufficient pressure to force it through one or more gas lift valves located in the tubing string below the oil level. The gas which thus flows into the tubing carries slugs of oil upwardly to the surface. By controlling the gas injection rate, pressure and other variables, significant improvements in production can often be obtained at relatively low cost. Experience has shown, however, that the efficiency of such systems is generally poor because of the tendency of the injected gas to by-pass the oil. Efforts to avoid or minimize this problem and related difficulties through the use of mechanical pistons, balls and similar devices in the past have been only partially successful.

The present invention provides a new and improved gas lift system that alleviates many of the problems which have characterized systems available in the past. In accordance with the invention, it has now been found that improved gas lift efficiency can be obtained by the intermittent injection of slugs of a liquid which is substantially immiscible with the liquid being lifted from the well, which does not adhere to the walls of the tubing and casing, and which has sufficient viscosity to resist the forces acting on it during flow. Tests have shown that such a system minimizes by-passing of the gas and slippage of the oil or water being lifted, that it permits the use of lower gas injection rates than might otherwise be required for a given oil production rate, and that it avoids many of the problems which are inherently encountered in using mechanical pistons and similar devices. These and other advantages make the system attractive under a variety of operating conditions.

The exact nature and objects of the invention can best be understood by referring to the following detailed description of the apparatus and materials employed in its practice and to the accompanying drawing which schematically illustrates the system.

The apparatus shown in the drawing comprises a borehole 11 drilled downwardly through nonproductive upper strata 12 and 13 into a low pressure oil-bearing zone 14. The wellbore contains a string of casing 15 which has been cemented in place with cement 16 to provide a fluid-tight seal and thus prevent the escape of connate fluids from one zone to another. The lower end of the casing and surrounding cement has been perforated as indicated by reference numeral 17 to provide communication between the wellbore and the oil-bearing formation. The invention is not limited to this type of completion, however, and is equally applicable to open hole completions where the casing terminates above or a short distance below the upper boundary of the producing zone. A string of production tubing 18 has been installed in the wellbore and extends from a tubing hanger in the well head 19 to a point within the producing zone. The lower end of the tubing is provided with a conventional check valve 20 to permit the flow of oil from the surrounding oil-bearing formation into the lower end of the tubing and prevent

2

flow in the opposite direction. A packer 21, shown schematically, is mounted near the lower end of the tubing to close off the annular space between the tubing and casing at a point above the perforations. The annular space above the packer serves as a compressed gas reservoir; while that below the packer is used as an oil accumulation zone. One or more gas-lift valves 22 are mounted on the tubing near the upper surface of the packer to permit the entry of gas into the tubing string under pressure. Any of a variety of conventional valves may be used.

The surface equipment shown in the drawing includes a "Christmas tree" 23 which is connected to wellhead 19 and includes the usual pressure gauges, flow meters and other equipment. These are not shown. Line 24 communicating with the production tubing extends from the Christmas tree to a separator 25 which may be of conventional design. A treating unit, not shown in the drawing, may be provided if the produced fluids include appreciable quantities of water and emulsion problems are encountered. The overhead gas line from the separator normally extends to a gas storage facility not shown. Line 26 from the storage facility is connected to a compressor 27 used for gas injection purposes. Makeup gas may be added to the system through line 28 if necessary. Gas line 29 extends from the discharge side of the compressor through a check valve 30 into the annulus between the casing and production tubing at the wellhead. The check valve permits the injection of gas into the annulus from the compressor but prevents flow in the opposite direction. Oil line 31 extends from the separator to an oil storage facility not shown. Liquid line 32 from the lower end of the separator is connected to pump 33. Makeup liquid may be added through line 34. The pump discharge line 35 extends through check valve 36 into the annulus between the casing and production tubing to permit injection of the lifting liquid.

The liquids employed for purposes of the invention are solutions which are substantially immiscible with the liquids produced from the wellbore, which do not adhere to the casing, tubing and other equipment with which they come in contact, and which have sufficient viscosity to resist shear or rupture during flow. In wells where the produced liquid consists primarily of crude oil, an aqueous solution containing a water soluble or water-dispersible polysaccharide, polyacrylamide, sulfonated polyvinyl aromatic, or a similar water thickener in a concentration sufficient to produce a viscosity substantially higher than that of the oil may be employed. The walls of the casing, tubing and other equipment used in gas lift wells are normally oil wet and hence adherence of the aqueous fluid to the walls is not a problem. In wells where the produced liquid consists primarily of water, a high viscosity petroleum fraction or an intermediate fraction thickened with polyisobutylene, polystyrene or a similar oil-soluble polymer may be used. In wells of this latter type, the tubing and casing may be treated to render them water wet and thus prevent adherence of the oleaginous liquid. In either case, the liquid employed will preferably have a viscosity within the range between about 100 centipoises and about 100,000 centipoises.

The preferred liquids for purposes of the invention, are viscoelastic liquids characterized by extremely high internal cohesion or tensile strength and the ability to mend or reform rapidly after being divided. Aqueous liquids having highly viscoelastic properties which permit their use for purposes of the invention can be readily prepared by treating a variety of water-soluble polymers in aqueous solution to produce cross-linking of the polymer molecules or by reacting two or more materials in solution to produce an equivalent structure. Typical of the liquids which may have such properties are aqueous solutions of guar gum and similar glycans having ad-

adjacent cis hydroxyl groups cross-linked with borax, calcium chloride, or a similar polyvalent metal compound; modified guar gum solutions cross-linked by changing the solution pH or adding an oxidizing agent; aqueous solutions of polyacrylamides and acrylamide copolymers cross-linked with chromic chloride or an equivalent cross-linking agent; and similar solutions containing polymers in which the polymer molecules are cross-linked with one another, either directly or through intermediate compounds. Studies have shown that the high viscoelasticity of such solutions is due primarily to the degree of cross-linking rather than to the chemical composition of the liquids per se and that any of a variety of different liquids having the requisite viscoelasticity can be employed for purposes of the invention.

A particularly effective class of viscoelastic liquids useful for purposes of the invention are those prepared by cross-linking glycans having adjacent cis hydroxyl groups attached to one or more of the monosaccharide units with polyvalent cross-linking agents. Glycans containing such groups, unlike those in which the adjacent hydroxyl groups occupy the trans position, readily undergo cross-linking reactions with a variety of polyvalent cross-linking agents. These reactions permit the rapid formation of highly viscoelastic liquids suitable for purposes of the invention. Monosaccharide units having adjacent cis hydroxyl groups include d-mannose, d-mannuronic acid and d-mannopyranose. Glycans containing such units may be homoglycans or heteroglycans. Typical homoglycans include 1,4'-d-mannose linear polysaccharides such as ivory nut mannan, wood mannan and salep mannan; 1,4'-d-mannuronic acid linear polysaccharides such as alginic acid; 1,2',1,3' and 1,6'-d-mannose branched chain polysaccharides such as yeast mannan; 1,4'-d-mannose branched chain polysaccharides such as the mannan of *Porophyra umbilicalis*; and other d-mannose polysaccharides such as mannocarolose. Heteroglycans containing adjacent cis hydroxyl groups include glucomannans such as those obtained from *Amorphophallus* and *Aloe vera*; galactomannans such as those obtained from the endosperm of the honey locust, flame tree, guar plant, Kentucky coffee bean, palo verde, locust bean, tara, lucerne, huizache and *Sophora japonica*; d-arabinose and d-mannose polysaccharides; d-glucose, d-mannose and d-galactose polysaccharides; and d-galactose, d-mannose and N-acetyl-d-glucoseamine polysaccharides. It will be understood that all of the above named materials are not equally effective for the purposes of the invention and that certain materials are therefore preferred over others.

The galactomannans derived from vegetable sources are particularly effective for purposes of the invention. Upon hydrolysis, these materials yield the two simple sugars, mannose and galactose. Analyses have shown them to be long chain polymers of d-mannopyranose units linked at the beta-1,4 position and having d-galactopyranose units located as side chain on the molecule. The d-galactopyranose units are connected to the C₆ atoms of the d-mannose units which make up the main structural framework. The ratio of d-galactose to d-mannose in these galactomannans generally ranges from about 1:1.2 to about 1:2, depending upon the particular vegetable source from which the material is obtained. In all cases, however, the mannose residues have cis hydroxyl groups at the C₂ and C₃ positions, accounting for the cross-linking reactions obtained and making them useful for purposes of the invention. Guar gum is an outstanding example of these materials.

Certain of the glycans made up of monosaccharide units containing adjacent cis hydroxyl groups, 1,4'-mannuronic acid polysaccharides such as alginic acid for example, are not readily soluble in water and are therefore generally employed in the form of a water-soluble salt. Sodium alginate is marketed commercially in the form of a crude material derived from kelps and as a refined product for use in the food, pharmaceutical and textile

industries. Ammonium alginate and other water-soluble salts are also available from commercial sources and may be utilized. In lieu of employing a water soluble salt, alginic acid and sodium hydroxide or a similar base can be reacted in the presence of water to form the water-soluble material.

The glycans containing monosaccharide units having adjacent cis hydroxyl groups form viscous colloidal solutions when hydrated in water. The viscosity obtained depends upon the hydration time, the temperature of the solution, the concentration of the glycan in solution, the pH, the ionic strength of the solution, and the type of agitation employed. Colloidal solutions having high viscosity are generally preferred in preparing the viscoelastic solution used for purposes of the invention. Solution viscosity increases until complete hydration has occurred at the end of about twenty-four hours. A hydration period of from about 5 minutes to about 2 hours is usually preferred in preparing the colloidal solution. The rate of hydration depends upon the particular glycan used and increases with increasing temperature. Galactomannans and similar glycans are compatible with sodium chloride and related salts over a wide range of concentrations and hence naturally-occurring brines can be employed in preparing the colloidal solutions.

The colloidal solutions utilized to prepare the viscoelastic liquid are normally prepared by simply adding the powdered glycan to a tank of water or brine and agitating the resultant mixture. Agitation should be continued until the solution becomes viscous. Thereafter the solution may be permitted to hydrate and thickened for a period of from about 5 minutes to about 2 hours. A small amount of sodium hydroxide may be added to increase pH and stabilize the mixture. About 0.05 pound of caustic per barrel of water is generally satisfactory. Other basic materials in correspondingly larger or smaller amounts may also be used. After about 24 hours, colloidal solutions of certain of the glycans begin to lose their viscosity due to fermentation and enzymatic hydrolysis. A bactericidal or bacteriostatic preservative may be added to prevent this degradation. A variety of organic materials may be employed for this purpose. Suitable materials include formaldehyde, chlorinated phenolic compounds, benzoic acid and the like. The amount of preservative used will depend upon the particular agent selected.

Glycans of the type discussed above are normally employed in concentrations ranging from about 0.5 to about 12.0 pounds per barrel of water in preparing the aqueous colloidal solutions. Guar gum concentrations between about 1.0 and about 3.0 pounds per barrel of water have generally been found most effective; while sodium alginate concentrations between about 8 and about 12 pounds per barrel of water are preferred. Other glycans may be used in intermediate concentrations. The concentrations given are expressed in terms of 42 gallon barrels.

The galactomannans and other glycans having adjacent cis hydroxyl groups can be cross-linked in aqueous solution to form highly viscoelastic liquids by means of a variety of polyvalent cross-linking agents. Suitable materials include calcium chloride, calcium citrate, lead acetate, basic lead acetate, aluminum sulfate, borax and compounds which in solution yield borate ions. Some of these cross-linking agents are highly sensitive to the pH of the solution, however, and if the pH is too high or too low may result in the formation of a precipitate or gel unsuitable for purposes of the invention. For this reason, lead acetate, basic lead acetate and the borate cross-linking agents which are less sensitive to pH are preferred. Suitable borate compounds which may be utilized include boric acid, calcium metaborate, sodium metaborate, potassium metaborate, potassium tetraborate, sodium tetraborate, sodium metaborate tetrahydrate, sodium tetraborate and sodium tetraborate decahydrate. The latter com-

pound, marketed commercially as borax, is preferred because of its low cost and ready availability.

The concentration in which the cross-linking agent is employed will normally range between about 0.01 and about 12.0 pounds per barrel of colloidal solution, again depending upon the particular glycan used. The most effective concentration also varies with the different cross-linking agents. Cross-linking agent concentrations between about 0.05 and about 0.4 pounds per barrel have generally been found most effective with guar gum solutions for example; while concentrations at the upper end of the 0.01 to 12.0 pounds range are more suitable for sodium alginate and certain other glycans. The cross-linking agent may be predissolved in a small amount of water before it is added to the colloidal glycan solution or may instead be added as a slurry in water or oil. The temperature may be increased to reduce the water required if a solution is employed. The use of from about 0.1 to about 0.2 pounds of a ten molar borax solution as a cross-linking agent for guar gum has been found to give excellent results.

The viscoelastic solutions containing the glycans are formed by mixing the cross-linking agent into the glycan solution. Cross-linking takes place rapidly. The reaction may be carried out in any of a number of different ways. One procedure is to inject the cross-linking agent into the glycan solution as it is pumped from a tank in which it was initially prepared. Another is to add boric acid to the glycan solution and then effect cross-linking by raising the pH of caustic or basic buffer. Regardless of the particular method utilized, cross-linking of the glycan molecules must be effected before the solution acquires the viscoelastic properties preferred for purposes of the invention.

A typical cross-linked guar gum solution useful for purposes of the invention may contain from about 1 to about 3 pounds of dry guar gum per barrel of water and from about 0.05 to about 0.4 pound of boric acid per barrel of water. The colloidal guar gum solution prior to addition of the boric acid will generally have a viscosity between about 150 and about 300 centipoises when tested at 75° F. with a Brookfield L.V.T. viscometer, using the number 1 spindle at 12 revolutions per minute. The cross-linked solution will have a viscosity of several thousand centipoises. The final pH of the solution after the boric acid has been added to effect cross-linking will depend somewhat upon the temperature conditions under which the material is to be used but will generally range between about 9.0 and about 10.0. A buffer such as a mixture of sodium carbonate and sodium bicarbonate, triethylenamine, mixtures of phenol with caustic or lime, tetrasodiumpyrophosphate or mixtures of phosphate, a mixture of magnesium hydroxide and magnesium chloride or the like can be added to the solution to maintain the pH if desired.

In lieu of cross-linking a glycan of the type described above with borax or a similar material, glycans which have been chemically modified to provide new sites susceptible of cross-linking with a change in the pH or upon the addition of an oxidizing agent may be employed. One such glycan is a modified guar gum manufactured and distributed commercially under the trade name "Guartec 185" by General Mills, Inc. of Minneapolis, Minnesota. Tests have shown that this material can be readily cross-linked in aqueous solution to produce highly viscoelastic liquids by adding sodium hydroxide or a similar alkaline material to the solution in a concentration sufficient to render the solution basic or by adding an oxidizing agent such as sodium peroxide, sodium dichromate, potassium permanganate or the like. By employing such modified glycans, preparation of the viscoelastic liquids is simplified.

Liquids which are highly viscoelastic and suitable for purposes of the invention can also be prepared by cross-linking water soluble acrylamide polymers. Suitable

polymers include polyacrylamides and copolymers of acrylamides with other polymerizable vinyl compounds such as acrylic acid, methacrylic acid, alkyl esters of acrylic and methacrylic acids, methacrylamide, styrene, vinyl acetate, acrylonitrile, methacrylonitrile, vinyl alkyl ethers, vinyl chloride, vinylidene chloride and the like. Such polymers are generally produced from the corresponding unsaturated monomers in the presence of benzoyl peroxide or a similar polymerization catalyst and consist of long chain polymer molecules having a minimum of cross linkages. Molecular weights are generally 25,000 or higher. The polymers are then usually treated with sodium hydroxide or a similar base to hydrolyze up to about 10% of the amide groups and convert them to carboxyl groups. The resulting polymers are thus made up of long chain hydrocarbon molecules having amide groups or carboxyl groups attached to different carbon atoms in the chain. A variety of such acrylamide polymers and copolymers are available commercially. One such commercial material is manufactured by the Dow Chemical Company of Midland, Michigan under the trade name "Separan." Similar materials are marketed under the trade name "Cyanamer P-26" and "Cyanamer P-250" by American Cyanamide Company of New York, New York.

The polyacrylamides and similar water soluble polymers can readily be cross-linked in aqueous solution by treating them with chromium chloride, aluminum sulfate, and similar polyvalent cross-linking agents. The amount of cross-linking agent required to produce a liquid having highly viscoelastic properties will depend to a large extent upon the number of active sites available for cross-linking on the polymer molecule, upon the polymer molecular weight, upon the cross-linking agent selected and upon similar factors. In general, the optimum concentrations of a particular polymer and cross-linking agent can be readily determined by means of known rheological tests familiar to those skilled in the art.

Non-aqueous viscoelastic liquids suitable for purposes of the invention can be prepared by suspending hydroxy aluminum soaps in gasoline, kerosene, or a similar hydrocarbon; by adding viscous nitrocellulose or a similar material to butylacetate or a related solvent; or by dissolving natural rubber in toluene or a comparable hydrocarbon solvent. Liquids prepared by the solution of hydroxy aluminum soap of organic acid in naphtha, gasoline, kerosene, gas oil, crude oil or the like are preferred. Such liquids are generally produced with hydroxy aluminum soaps of fatty and naphthenic acids. Fatty acid soaps which may be employed include mono- and dihydroxy aluminum soaps of fatty acids containing from about 12 to about 24 carbon atoms per molecule. Typical of such soaps are those derived from lauric acid, myristic acid, palmitic acid, oleic acid, linoleic acid, stearic acid, arachidic acid, behenic acid and mixed acids derived from naturally-occurring materials such as coconut oil, tallow fat, cottonseed oil, soy bean oil and the like. Naphthenic acid soaps which may be utilized include aluminum hydroxy and dihydroxy soaps of hexahydrobenzoic acid and substituted hexahydrobenzoic acid. The use of mixed soaps containing both a fatty acid derivative and a naphthenic acid derivative generally results in more stable liquids and hence such soaps are preferred for purposes of the invention. The use of aluminum naphthenate and aluminum coconut oil acid soaps are particularly effective. In lieu of employing a mixed aluminum soap, it is sometimes advantageous to utilize aluminum naphthenate or a similar soap and a free fatty acid.

The aluminum soaps and related compounds can be used with naphtha, gasoline, kerosene, gas oil and similar liquid hydrocarbons by first adding an aluminum naphthenate, oleate or similar soap to the hydrocarbon and agitating it until all of the soap has been dissolved. The soap will normally be added in a concentration of

from about 1 to about 10% by weight, the exact amount utilized depending upon the particular liquid and soap employed. From about 1 to about 10% by weight of an aluminum coconut acid soap or a mixture of free fatty acid can then be added with agitation in order to effect formation of the viscoelastic liquid. The concentration required will again depend upon the particular material selected. It is generally necessary to age the liquid containing the soap for a period ranging from a few minutes up to about 24 hours or longer in order to produce high viscoelasticity. In lieu of this procedure the soap can be dissolved with separate portions of kerosene or a similar hydrocarbon liquid and these portions can then be later combined to effect the formation of a viscoelastic liquid. Still another procedure is to mill the soaps together to produce a mixture which can be incorporated into hydrocarbons to produce viscoelasticity. Regardless of the procedure utilized, it is generally necessary to age the materials for a considerable period in order to produce a liquid having the desired properties.

A variety of materials containing aluminum and similar metallic soaps are marketed commercially for use in thickening liquid hydrocarbons for the manufacture of greases and lubricants and are suitable for the preparation of viscoelastic liquids to be used for purposes of the invention. One such material is an aluminum stearate manufactured by the Witco Chemical Company of New York and marketed under the trade name "Witco 171-S". Similar products are listed in the sales literature of other manufacturers and will therefore be familiar to those skilled in the art. The use of such commercial materials generally facilitates the preparation of highly viscoelastic liquids and is therefore preferred.

In utilizing a viscous or a highly viscoelastic liquid of the type described in the preceding paragraphs in the apparatus shown in the drawing, a slug of the liquid selected is periodically introduced into the annulus of the well between casing 15 and production tubing 18 at well head 19. The rate at which the slugs are introduced will depend upon the time required for fluids from the producing formation to fill the tubing to the equilibrium level. In general, sufficient time should elapse following the introduction of each slug to permit the produced fluids to rise within the tubing a substantial distance above gas lift valve 22. It is not essential, however, that the maximum amount of fluid from the formation be allowed to accumulate before each slug is introduced. The volume of each slug of the liquid will depend primarily upon the viscosity or viscoelasticity of the liquid and the depth of the producing formation. Where a very viscous or highly viscoelastic liquid is utilized, a smaller slug can be used than might be required if a less viscous or viscoelastic liquid were employed. In similar manner, smaller slugs can generally be employed in shallow wells than in relatively deep wells. The volume utilized should be sufficient in any case to effectively segregate the liquid being lifted in the tubing from the gas used as a lifting agent until the liquids reach the surface. Slugs of from about 1 to about 20 barrels will generally be sufficient but greater volumes may be employed if necessary.

Each slug of liquid introduced into the well bore as described in the preceding paragraph moves downwardly in the annulus as indicated by reference numeral 40 in the drawing. When the slug reaches the bottom of the annulus adjacent gas lift valve 22 and the fluids produced from the formation have risen in the tubing a substantial distance above the valve, the annulus pressure is increased by pumping in gas at the well head through line 29 containing check valve 30. This forces the slug of viscous or viscoelastic liquid through the gas lift valve into the production tubing beneath a column of formation liquids contained therein. The injection of gas is continued until sufficient gas to lift the column of liquid and the viscous or viscoelastic liquid slug beneath it to the surface has flowed into the tubing. At this point,

the injection of gas is discontinued. A second slug of viscous or highly viscoelastic liquid will then have reached the bottom of the annulus adjacent the gas lift valve. The injected gas forces the liquids in the tubing upwardly toward the well head. This results in a reduction in the pressure in the lower part of the tubing and causes additional oil to flow in through check valve 20.

The fluids reaching the well head are circulated through line 24 to separator 25. The gas is taken overhead from the separator to a gas storage facility not shown in the drawing and may later be passed through line 26 to compressor 27 for reinjection. The oil which is produced is discharged from a separator through line 31 to a suitable storage tank. The viscous or viscoelastic liquid is withdrawn from the separator through line 32 and may be accumulated in an intermediate vessel not shown in the drawing until it is later reinjected by means of pump 33 through line 35.

It will be seen from the foregoing that the system described herein has pronounced advantages over earlier systems in that it does not require that production be interrupted at frequent intervals to permit mechanical pistons or similar devices to fall back through the tubing and does not necessitate the installation of two separate tubing strings to permit the circulation of balls or the like. The use of slugs of viscous or highly viscoelastic liquids which can readily deform and flow through valves and constrictions makes possible the adoption of the system to existing wells with only minor modifications of the well equipment.

Although the method has been described above in terms of an intermittent gas lift system wherein both the gas and viscous or viscoelastic liquid are introduced into the tubing intermittently, it is equally applicable to systems wherein the gas is introduced continuously and slugs of the liquid are injected at intervals. The gas utilized for lifting purposes may be injected from the surface as shown in the drawing or in some cases may be admitted into the tubing from the surrounding formation. A variety of different gas lift valves and auxiliary equipment for introducing the gas and viscous or viscoelastic liquid may be utilized. These and other modifications of the invention will be readily apparent to those skilled in the art.

What is claimed is:

1. A method for lifting a liquid in a conduit within a borehole which comprises introducing a slug of a first liquid into said conduit near the lower end of said borehole, said slug being introduced beneath a column of a second liquid present in said conduit, said first liquid being substantially immiscible with said second liquid, said first liquid having a substantially higher viscosity than said second liquid, and said first liquid being substantially nonwetting with respect to the walls of said conduit, and thereafter introducing sufficient gas into said conduit beneath said slug to lift said liquids upwardly within said conduit.

2. A method as defined by claim 1 wherein said first liquid is an aqueous liquid containing a water-soluble polymer and said second liquid is an oleaginous liquid.

3. A method as defined by claim 1 wherein said first liquid is an oleaginous liquid and said second liquid is water.

4. A method for lifting oil in a wellbore which comprises injecting a slug of an aqueous liquid into a conduit containing a column of oil extending upwardly in said wellbore, said aqueous liquid being injected near the lower end of said conduit beneath oil contained therein, said aqueous liquid being substantially immiscible with said oil, said aqueous liquid having a substantially higher viscosity than said oil, and said aqueous liquid being substantially nonwetting with respect to the walls of said conduit, and thereafter introducing sufficient gas into said conduit beneath said aqueous liquid to lift said liquid and oil upwardly in said conduit.

9

5. A method as defined by claim 4 wherein said aqueous liquid in an aqueous solution containing a cross-linked glycan having adjacent cis hydroxyl groups.

6. A method as defined by claim 4 wherein said aqueous liquid is an aqueous solution containing a high molecular weight acrylic polymer.

7. A gas lift method for the recovery of oil from a wellbore which comprises introducing crude oil from a subterranean formation surrounding said wellbore into a tubing string extending upwardly in said wellbore to the earth's surface; introducing a slug of an aqueous viscoelastic liquid into said tubing beneath said crude oil, said viscoelastic liquid being substantially immiscible with said crude oil, having a substantially higher viscosity than said crude oil, and being substantially nonwetting with respect to the walls of said conduit; and thereafter introducing sufficient gas into said conduit beneath said viscoelastic liquid to lift said liquid and crude oil upwardly in said conduit to the earth's surface.

10

8. A method as defined by claim 7 wherein said viscoelastic liquid contains a cross-linked guar gum.

9. A method as defined by claim 7 wherein said viscoelastic liquid contains a cross-linked alginate.

10. A method as defined by claim 7 wherein said gas is introduced into said conduit from the earth's surface.

11. A method as defined by claim 7 wherein said gas is introduced into said conduit from the surrounding formation.

12. A method as defined by claim 7 wherein said viscoelastic liquid contains a cross-linked polyacrylamide.

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LAURENCE V. EFNER, *Primary Examiner*.