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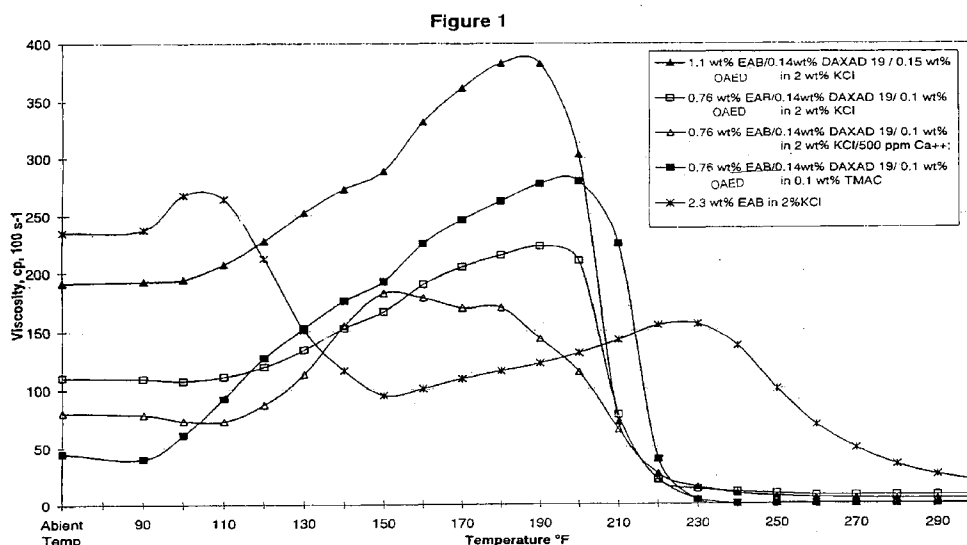
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(54) Title: MULTICOMPONENT VISCOELASTIC SURFACTANT FLUID AND METHOD OF USING AS A FRACTURING FLUID



(57) Abstract: There is a viscoelastic fluid. The fluid has one or more cationic surfactants selected from the group consisting of certain quaternary salts, certain amines, and combinations thereof; one or more anionic polymers/anionic surfactants; one or more of certain zwitterionic/amphoteric surfactants; and water. There is also a method of fracturing a subterranean formation. The viscoelastic fluid is pumped through a wellbore and into a subterranean formation at a pressure sufficient to fracture the formation. There is also a method for gravel packing a subterranean formation.

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MULTICOMPONENT VISCOELASTIC SURFACTANT FLUID
AND METHOD OF USING AS A FRACTURING FLUID

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a viscoelastic fluid.

10 The present invention further relates to a method of
fracturing a subterranean formation with a viscoelastic fluid.

2. Description of the Related Art

15 Viscoelastic surfactant (VES) fluids have continued to
grow in use in oilfield applications because of their
advantages over conventional polymer systems. Such advantages
include higher permeability in the oil bearing zone, lower
formation or subterranean damage, higher viscosifier recovery
20 after fracturing, elimination of need for enzymes or oxidizers
to break down viscosity, and easier hydration and faster
build-up to optimum viscosity.

Growth in the use of VES fluids has been inhibited by the
25 high cost of surfactants required to formulate such fluids.
Another problem with use of VES fluids is their low tolerance
of organic/inorganic salts and clay stabilizers, such as
potassium chloride and tetramethyl ammonium chloride (TMAC),
in subterranean formations. Another problem with use of VES
30 fluids is the high temperatures encountered in deep well
oilfield applications, i.e. up to 250° C. High temperatures
can break down the viscosity of VES fluids and render them

ineffective in fracturing operations when viscoelastic surfactants are present at low concentrations or require use of high viscoelastic surfactant concentrations to avoid such viscosity breakdown. Use of viscoelastic surfactants at low concentrations also can result in unacceptably long shear recovery time after high shear operation.

In the prior art, attempts have been made to remedy breakdown in viscosity performance by adding polymers and/or cosurfactants, such as low molecular weight anionic polymers. However, shear recovery can be unacceptably long and/or organic/inorganic salt tolerance may be inadequate.

Accordingly, it would be desirable to have a VES fluid that could be formulated on a cost-effective basis, i.e., with relatively low levels of viscoelastic surfactant. It would further be desirable to have a VES fluid that exhibits high tolerance with respect to organic/inorganic salts and clay stabilizers. It would still further be desirable to have a VES fluid with relatively low levels of viscoelastic surfactant that maintains a high level of viscosity performance at high temperatures and shear recovery comparable to fluids with a relatively high concentration of viscoelastic surfactants.

SUMMARY OF THE INVENTION

It is an object of the present invention to have a viscoelastic fluid.

It is another object of the present invention to have a viscoelastic fluid useful in oilfield applications.

It is still another object of the present invention to have a viscoelastic surfactant fluid that can be formulated with a relatively low level of surfactant for cost-effective performance.

5

It is a further object of the present invention to have a viscoelastic fluid with high tolerance to organic/inorganic salts, such as KCl and TMAC and Ca^{++} and Mg^{++} ions.

10

It is yet a further object of the present invention to have a viscoelastic fluid that maintains a high level of viscosity performance at high temperatures.

15

It is a further objective of the present invention to have a viscoelastic surfactant fluid that exhibits good shear recovery after high shear operation.

20

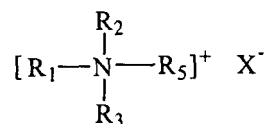
According to this and other objects and advantages of the present invention, there is provided a viscoelastic fluid. The fluid has one or more selected cationic surfactants, one or more selected anionic polymers and/or anionic surfactants, one or more selected zwitterionic and/or amphoteric surfactants, and water.

25

The cationic surfactant is selected from i) certain quaternary salts and ii) certain amines, iii) certain amine oxides, iv) and combinations thereof.

30

The quaternary salts have the structural formula:

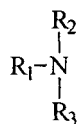


wherein R_1 is a hydrophobic moiety of alkyl, alkylarylalkyl, alkoxyalkyl, alkylaminoalkyl or
 5 alkylamidoalkyl, and wherein R_1 has from about 12 to about 25 carbon atoms and may be branched or straight-chained and saturated or unsaturated.

R_2 , R_3 , and R_5 are, independently, an aliphatic moiety
 10 having from 1 to about 30 atoms or an aromatic moiety having from 7 to about 15 atoms. The aliphatic moiety can be branched or straight-chained and saturated or unsaturated.

X is suitable counter-anion, such as Cl^- , Br^- , and
 15 $\text{CH}_3\text{CH}_2\text{SO}_4^-$.

The amines have the following structural formula:

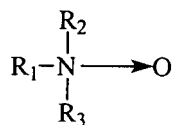


20

wherein R_1 , R_2 and R_3 are as defined above.

The amine oxides have the following structural
 formula:

25

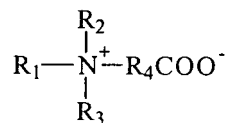


wherein R_1 , R_2 and R_3 are as defined above.

5 The anionic polymer has about 8 to about 100 monomeric units and at least one negatively charged moiety. Sulfonated polymers are preferred. Anionic surfactants will have alkyl chains of about 6 to about 18 carbon atoms with at least one negatively charged moiety.

10

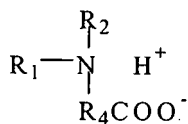
The zwitterionic surfactant has the following structural formula:



15

wherein R_1 , R_2 , and R_3 are as described above. R_4 is a hydrocarbyl radical with a chain length of 1 to 4 carbon atoms.

20 The amphoteric surfactant has the following structural formula:



wherein R_1 , R_2 , and R_4 are as described above.

25

Further according to the present invention, there is provided a method of fracturing a subterranean formation, comprising the step of pumping the viscoelastic fluid through a wellbore and into a subterranean formation at a pressure
5 sufficient to fracture the formation.

Still further according to the present invention, there is provided a method of gravel packing a subterranean formation, comprising the step of pumping the viscoelastic
10 fluid and gravel into a wellbore.

DESCRIPTION OF THE FIGURES

15 Figure 1 is a plot diagram of the viscosity profile as a function of temperature for fluids of the present invention versus a comparison fluid.

Figure 2 is a plot diagram of the viscosity profile as a
20 function of temperature for a fluid of the present invention versus comparison fluids.

DETAILED DESCRIPTION OF THE INVENTION

The property of viscoelasticity in general is well known, and reference is made to S. Gravsholt, Journal of Coll. And Interface Sci., 57(3), 575 (1976); Hoffmann et al., "Influence of Ionic Surfactants on the Viscoelastic Properties of Zwitterionic Surfactant Solutions", Langmuir, 8, 2140-2146 (1992); and Hoffmann et al., "The Rheological Behaviour of Different Viscoelastic Surfactant Solutions," Tenside Surf. Det., 31, 389-400, 1994. Several test methods have been specified in these references to determine whether a liquid possesses viscoelastic properties. One test that has been found useful in determining the viscoelasticity of an aqueous solution is swirling the solution and visually observing whether the bubbles created by the swirling recoil after the swirling is stopped. Any recoil of the bubbles indicates viscoelasticity. Another useful test is to measure the storage modulus (G') and the loss modulus (G'') at a given temperature. If $G' > G''$ is at some point or over some range of points below about 10 rad/sec, typically between about 0.001 to about 10 rad/sec, more typically between about 0.1 and about 10 rad/sec, at a given temperature and if $G' > 10^{-2}$ Pascals, preferably 10^{-1} Pascals, the fluid is typically considered viscoelastic at that temperature. Rheological measurements, such as G' and G'' , are discussed more fully in "Rheological Measurements", Encyclopedia of Chemical Technology, vol. 21, pp. 347-372, (John Wiley & Sons, Inc., N.Y., N.Y., 1997, 4th ed.).

Viscoelasticity is caused by a different type of micelle formation than the usual spherical micelles formed by most surfactants. Viscoelastic surfactant fluids form worm-like,

rod-like or cylindrical micelles in solution. The formation of long, cylindrical micelles creates useful rheological properties. The viscoelastic surfactant solution exhibits shear thinning behavior, and remains stable despite repeated
5 high shear applications.

The viscoelastic surfactants useful in the fluids of the present invention are selected zwitterionic surfactants and/or amphoteric surfactants and cationic surfactants. A
10 zwitterionic surfactant has a permanently positively charged moiety in the molecule regardless of pH and a negatively charged moiety at alkaline pH. A cationic surfactant has a positively charged moiety regardless of pH. An amphoteric surfactant has both a positively charged moiety and a
15 negatively charged moiety over a certain pH range (e.g., typically slightly acidic), only a negatively charged moiety over a certain pH range (e.g., typically slightly alkaline) and only a positively charged moiety at a different pH range (e.g., typically moderately acidic).

20

The selected viscoelastic surfactants and polymers to form a viscoelastic fluid that exhibits enhanced performance compared to conventional viscoelastic fluids. The viscoelastic fluid of the present invention can exhibit high
25 viscosity levels at high temperatures and low viscoelastic surfactant levels and high tolerance for with respect to Ca^{++} ions and clay stabilizers compared to conventional viscoelastic fluids. The viscoelastic fluid of the present invention exhibits enhanced performance compared to
30 viscoelastic fluids having only the combination of the selected zwitterionic/amphoteric surfactants and cationic surfactants the combination of the zwitterionic/amphoteric

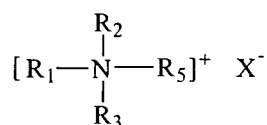
surfactants and the selected anionic polymer/anionic surfactant, or the combination of the selected cationic surfactants and the selected anionic polymer/anionic surfactant.

5

The cationic surfactant is selected from i) certain quaternary salts and ii) certain amines, iii) amine oxide, iv) and combinations thereof.

10

The quaternary salts have the structural formula:



wherein R₁ is a hydrophobic moiety of alkyl, alkylarylalkyl, alkoxyalkyl, alkylaminoalkyl or alkylamidoalkyl. R₁ has from about 18 to about 30 carbon atoms and may be branched or straight-chained and saturated or unsaturated. Representative long chain alkyl groups include octadecentyl (oleyl), octadecyl (stearyl), docosenoic (erucyl) and the derivatives of tallow, coco, soya and rapeseed oils. The preferred alkyl and alkenyl groups are alkyl and alkenyl groups having from about 18 to about 22 carbon atoms.

R₂, R₃, and R₅ are, independently, an aliphatic group having from 1 to about 30 carbon atoms or an aromatic group having from 7 to about 15 carbon atoms. The aliphatic group preferably has from 1 to about 20 carbon atoms, more preferably from 1 to about 10 carbon atoms, and most preferably from 1 to about 6 carbon atoms. Representative aliphatic groups include alkyl, alkenyl, hydroxyalkyl,

carboxyalkyl, and hydroxyalkyl-polyoxyalkylene. The aliphatic group can be branched or straight-chained and saturated or unsaturated. Preferred alkyl chains are methyl and ethyl. Preferred hydroxyalkyls are hydroxyethyl and hydroxypropyl.

- 5 Preferred carboxyalkyls are acetate and propionate. Preferred hydroxyalkyl-polyoxyalkylenes are hydroxyethyl-polyoxyethylene and hydroxypropyl-polyoxypropylene. Examples of aromatic moieties include cyclic groups, aryl groups, and alkylaryl groups. A preferred alkylaryl is benzyl.

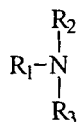
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X is suitable anion, such as Cl^- , Br^- , and $(\text{CH}_3)_2\text{SO}_4^-$.

Representative quaternary salts of the above structure include methylpolyoxyethylene(12-18)octadecan ammonium
 15 chloride, methylpolyoxyethylene(2-12)cocoalkyl ammonium chloride, and isotridecyloxypropyl polyoxyethylene (2-12) methyl ammonium chloride.

The amines have the following structural formula:

20



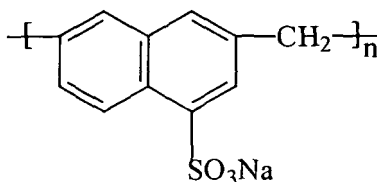
wherein R_1 , R_2 , and R_3 are as defined above.

- Representative amines of the above structure include
 25 polyoxyethylene(2-15)cocoalkylamines, polyoxyethylene(12-18)tallowalkylamines, and polyoxyethylene(2-15)oleylamines.

- The fluid also has an anionic polymer. The polymer has about 8 to about 100 monomeric units and at least one
 30 negatively charged moiety. Sulfonated polymers are preferred.

Representative anionic polymers include, but are not limited to, polynaphthalene sulfonate, sulfonated polystyrenes, and sulfonated styrene/maleic anhydride copolymers. A most preferred anionic polymer is polynaphthalene sulfonate and has

5 the following structural formula:

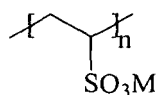


wherein n is an integer from about 8 to about 100.

10 Preferred polynaphthalene sulfonates have a weight average molecular weight of from about 2,000 to about 20,000.

Another preferred anionic polymer are polyalkylene sulfonates having the following structural formula:

15



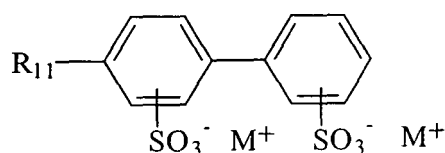
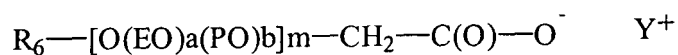
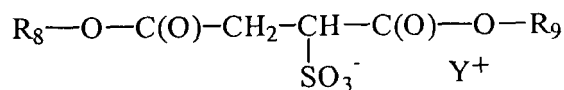
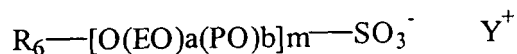
wherein n is an integer from about 8 to about 100. M is an inorganic or organic cation, such as alkaline metal or

20 ammonium ions, e.g. K^+ , Na^+ , and NH_4^+ .

Selected anionic surfactants useful in the viscoelastic surfactant fluid of the present invention include those having alkyl chains of about 6 to about 18 carbon atoms with at least

25 one negatively charged moiety.

Representative anionic surfactants include those of the following structural formulas:



5

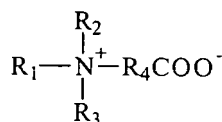
and combinations thereof.

R_6 is selected from a group consisting of alkyl, aryl, alkaryl, alkylarylalkyl, arylalkyl, alkylamidoalkyl, alkylaminoalkyl; wherein the alkyl group has from about 6 to about 18 carbon atoms; wherein the aryl group represents a phenyl, diphenyl, diphenylether, or naphthalene moiety; and wherein the total carbon atom content of R_6 is no more than about 18 carbon atoms. R_6 is preferably C_{10} to C_{18} alkyl or alkylamidoalkyl. R_6 can be represented by octyl, nonyl, decyl, dodecyl and the like. Substitutes from natural sources having mixed carbon chain lengths can be used or purified to reduce the number of carbon chain lengths in the alkyl groups. Preferred alkylamidoalkyls are coco/lauryl amidopropyl, oleyl/stearyl amidopropyl, octylamidopropyl, and decylamidopropyl.

M represents hydrogen, an alkali metal such as sodium or potassium, or $-[R_7-(EO)_a(PO)_b(BO)_c]_m-O-]_q-P(O)(OM)_2$.

Y represents a counter-ion, which is preferably an alkali metal such as sodium or potassium, more preferably sodium; EO represents ethyleneoxy radicals, PO represents propyleneoxy radicals. BO represents butoxy radicals. The letters a, b, and c are, independently, integers from 0 to 50, wherein "a" is preferably an integer from 0 to 15 and "b" is preferably an integer from 0 to 10, and "c" is preferably an integer from 0 to 10, wherein EO, PO and BO, radicals can be randomly mixed or in the discrete blocks. "m" is 0 or 1. "R₇" is C₈ to C₁₈ alkylene. R₈ is C₈ - C₁₈ alkyl or C₈ - C₁₈ alkylamido. "R₉" is C₁ - C₄ alkyl or Y (counter-ion). R₁₀ is C₁₀ - C₁₄ alkyl. "q" is an integer from 1 to about 10.

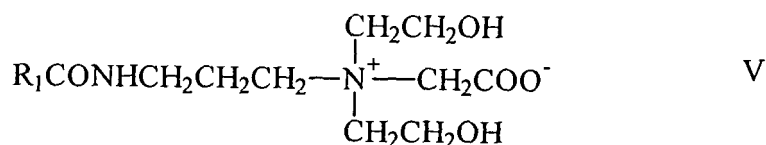
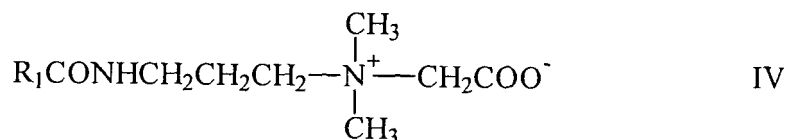
Selected zwitterionic surfactants useful in the viscoelastic surfactant fluid of the present invention are represented by the following structural formula:



wherein R₁ is as described above. R₂ and R₃ are, independently, an aliphatic moiety having from 1 to about 30 carbon atoms or an aromatic moiety having from 7 to about 15 carbon atoms. The aliphatic moiety preferably has from 1 to about 20 carbon atoms, more preferably from 1 to about 10 carbon atoms, and most preferably from 1 to about 6 carbon atoms. The aliphatic group can be branched or straight chained and saturated or unsaturated. Representative

aliphatic groups include alkyl, alkenyl, hydroxyalkyl, carboxyalkyl, and hydroxyalkyl-polyoxyalkylene. Preferred alkyl chains are methyl and ethyl. Preferred hydroxyalkyls are hydroxyethyl and hydroxypropyl. Preferred carboxyalkyls are acetate and propionate. Preferred hydroxyalkyl-polyoxyalkylenes are hydroxyethyl-polyoxyethylene or hydroxypropyl-polyoxypropylene). R_4 is a hydrocarbyl radical (e.g. alkylene) with chain length 1 to 4 carbon atoms. Preferred are methylene or ethylene groups. Examples of aromatic moieties include cyclic groups, aryl groups, and alkylaryl groups. A preferred arylalkyl is benzyl.

Specific examples of selected zwitterionic surfactants include the following structures:



wherein R_1 is as described above.

Other representative zwitterionic surfactants include dihydroxyethyl tallow glycinate, oleamidopropyl betaine, and erucyl amidopropyl betaine.

5 Selected amphoteric surfactants useful in the viscoelastic surfactant fluid of the present invention are represented by the following structural formula:

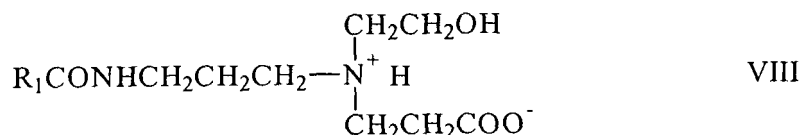


10

wherein R_1 , R_2 , and R_4 are as described above.

Specific examples of amphoteric surfactants include those of the following structural formulas:

15



wherein R_1 is as described above. X^+ is an inorganic cation such as Na^+ , K^+ , NH_4^+ associated with a carboxylate group or hydrogen atom in an acidic medium.

20

The selected zwitterionic and amphoteric surfactants are functionally interchangeable and may be used separately or alone (alternatively) or in combination with each other.

Additional teachings to the selected zwitterionic and amphoteric surfactants are disclosed in U.S. Patent No. 6,258,859 B1, which is incorporated herein in its entirety.

5 The surfactants are used in an amount, which, in combination with the other ingredients, such as the anionic polymer, is sufficient to form a viscoelastic fluid, which amount will typically be a minor amount by weight of the fluid (e.g., less than about 50% by weight). The total
10 concentration of the selected zwitterionic/amphoteric and cationic surfactants typically ranges from about 0.1 to about 10 wt%, more typically from about 0.1 to about 5 wt%, and even more typically from about 0.25 to about 2 wt% based on the weight of the fluid. The weight percentage of the cationic
15 surfactant in the total active surfactant (exclusive of solvents) typically ranges from about 1 to about 40 wt%, more typically from about 3 to about 20 wt%, and even more typically from about 5 to about 20 wt% (based on total required cationic surfactant and zwitterionic/amphoteric
20 surfactant of the present invention). Because of the cost of the surfactants, it is desirable, if possible, to minimize surfactant concentration. Most preferably, the concentration of the selected zwitterionic/amphoteric and cationic surfactants will be less than 3 wt% based on fluid weight.
25 The selected anionic polymer is typically used at about 0.01 to about 5 wt%, more typically about 0.05 to about 3 wt%, and most typically about 0.1 to 0.5 wt% based on weight of the fluid. Optimum concentrations for the selected surfactants and anionic polymers can be determined experimentally for a
30 particular fluid system.

The viscoelastic fluid is aqueous. Water is preferably

present in an amount by weight about 50 percent or more by weight of the fluid. Most preferred fluids have about 70 weight percent or more of water by weight of the fluid. The water can be from any source so long as the source has no
5 contaminants incompatible with the other components of the viscoelastic fluid (e.g., such as to cause undesirable precipitation). Thus, the water need not be potable and may be brackish or contain other materials typical of sources of water found in or near oil fields.

10

The fluid optionally has one or more members from the following group: organic acids, organic acid salts, inorganic salts, and combinations thereof. This member will typically be present in a minor amount (e.g., about 20 wt% or less by
15 weight of the fluid).

The organic acid is typically a sulfonic acid or a carboxylic acid and the anionic counter-ion of the organic acid salts are typically sulfonates or carboxylates.

20 Representative of such organic molecules include various aromatic sulfonates and carboxylates such as p-toluene sulfonate, naphthalene sulfonate, chlorobenzoic acid, salicylic acid, phthalic acid and the like, where such counter-ions are water-soluble. Most preferred are salicylate,
25 phthalate, p-toluene sulfonate, sodium xylene sulfonates, hydroxynaphthalene carboxylates, e.g. 5-hydroxy-1-naphthoic acid, 6-hydroxy-1-naphthoic acid, 7-hydroxy-1-naphthoic acid, 1-hydroxy-2-naphthoic acid, preferably 3-hydroxy-2-naphthoic acid, 5-hydroxy-2-naphthoic acid, 7-hydroxy-2-naphthoic acid,
30 and 1,3-dihydroxy-2-naphthoic acid and 3,4-dichlorobenzoate. The organic acid or salt thereof typically aids the development of increased viscosity which is characteristic of

preferred fluids. Although no bound by any theory, the association of the organic acid or salt thereof with the micelle might decrease the aggregation curvature of the micelle, and, thus, promote the formation of a worm-like or rod-like micelle. The organic acid or salt thereof will typically be present in the viscoelastic fluid at a weight concentration of from about 0.1 wt% to about 10 wt%, more typically from about 0.1 wt% to about 7 wt%, and even more typically from about 0.1 wt% to about 6 wt% based on fluid weight.

The inorganic salts that are particularly suitable for use in the viscoelastic fluid include water-soluble potassium, sodium, or ammonium salts, such as potassium chloride or ammonium chloride. Potassium chloride is most preferred. Additionally, calcium chloride, calcium bromide and zinc halide salts may also be used. The inorganic salts may aid in the development of increased viscosity, which is characteristic of preferred fluids. Further, the inorganic salt may assist in maintaining the stability of a geologic or subterranean formation to which the fluid is exposed. Formation stability, in particular clay stability (by inhibiting hydration of the clay), can be achieved at a concentration levels of a few percent by weight or less. Thus, density of fluid is usually not significantly altered by the presence of the inorganic salt. If fluid density is an important consideration, heavier inorganic salts may be used. The inorganic salt will typically be present in the viscoelastic fluid at a weight concentration of from about 0.1% to about 30%, more typically from about 0.1% to about 10%, and even more typically from about 0.1% to about 8%. Organic salts, e.g. trimethylammonium hydrochloride and

tetramethylammonium chloride, may also be useful in addition to, or as a replacement for, the inorganic salts.

As an alternative to the organic salts and inorganic salts, or as a partial substitute therefor, one can use a medium to long chain alcohol (preferably an alkanol), preferably having five to ten carbon atoms, or an alcohol ethoxylate (preferably an alkanol ethoxylate) preferably of a 12 to 16 carbon alcohol and having 1 to 6, preferably 1-4, oxyethylene units.

The viscoelastic surfactant solution is useful as a fracturing fluid or water-based hydraulic fluid. The viscoelastic fluid used as a fracturing fluid may optionally contain a gas such as air, nitrogen or carbon dioxide to provide an energized fluid or a foam.

When used as a hydraulic fracturing fluid, the viscoelastic fluid may contain other conventional constituents that perform specific desired functions, e.g., corrosion inhibition, fluid-loss prevention and the like. A proppant can be suspended in the fracturing fluid. The pH of the fluid will typically range from strongly acidic (e.g., less than a pH of about 3) to slightly alkaline (e.g., from a pH just greater than 7.0 to about 8.5, more typically to about 8.0) or moderately alkaline (e.g., a pH of about 8.5 to about 9.5).

The viscoelastic fluid may optionally have one or more additional thickeners and fluid-loss control additives known in the industry, such as water-soluble or water-dispersible polymers (guar and guar derivatives, xanthan, polyacrylamide, starch and starch derivatives, cellulosic derivatives,

polyacrylates, polyDADMAC [poly(diallyl dimethyl ammonium chloride] and combinations thereof), and clay (Bentonite and attapulgite).

5 The viscoelastic fluid may optionally have conventional surfactants/cosurfactants other than the viscoelastic surfactants described above. Such surfactants/cosurfactants can include anionic, cationic, nonionic, zwitterionic, and amphoteric species. The fluid may also have any solvent or
10 vehicles known in the art (in addition to water), such as lower monohydric alcohols, polyhydric alcohols, and the like.

 The viscoelastic fluid is useful in conventional hydraulic fracturing methods. Useful methods are disclosed in
15 U.S. Pat. No. 5,551,516, which is incorporated by reference. Oil-field applications and methods are also described in "Oil-field Applications", Encyclopedia of Polymer Science and Engineering, vol. 10, pp. 328-366 (John Wiley & Sons, Inc., New York, N.Y., 1987), which is also incorporated herein by
20 reference.

 Hydraulic fracturing refers to methods used to stimulate the production of fluids, such as oil and natural gas, from subterranean formations. In hydraulic fracturing, a
25 fracturing fluid is injected through a wellbore and against the face of the formation at a pressure and flow rate at least sufficient to overcome the overburden pressure and to initiate and/or extend a fracture(s) into the formation. The
fracturing fluid usually carries a proppant such as 20-40 mesh
30 sand, bauxite, glass beads, and the like, suspended in the fracturing fluid and transported into a fracture. The proppant keeps the formation from closing back down upon

itself when pressure is released. The proppant filled fractures provide permeable channels through which the formation fluids can flow to the wellbore and thereafter be withdrawn. Viscoelastic fluids have also been extensively
5 used in gravel pack treatment.

U.S. Serial No. 11/141,853, filed June 1, 2005 and U.S. Provisional Application 60/576,124, filed June 2, 2004, are hereby incorporated herein in their entirety.

10

The following are examples of the present invention. They are illustrative of the invention and are not to be construed as limiting. Unless otherwise indicated, all percentages or parts are by weight.

15

EXAMPLES

Fluids of the present invention were prepared and tested for viscosity performance as a function of temperature.
20 Viscosity performance related to suitability for use in fracturing applications.

The zwitterionic surfactant employed was erucyl amidopropyl betaine (EAB). The anionic polymer employed was
25 polynapthalene sulfonate (DAXAD 19 polymer manufactured by Hampshire Chemical Corp.). The cationic surfactants employed were methylpolyoxyethylene octadecan ammonium chloride (OAED) and polyoxyethylene cocoalkylamines (CAEO). All ingredients were formulated by mixing.

30

Two fluids of the following formulations were tested:

27 wt% EAB/ 3.8wt% DAXAD 19/ 3.9wt% CAEO (balance is solvents); and 27 wt% EAB/ 3.8 wt% DAXAD 19/ 3.9wt% OAED (balance is solvents).

5 The fluids showed very good viscosity performance at the 2.1 wt% surfactant use level (0.9 wt% active) up to 215° F with very good shear recovery (less than 15 seconds). The systems were compatible with 2 wt% KCl (potassium chloride), 2 wt% KCl with 500 ppm Ca⁺⁺, 0.1 wt% TMAC (trimethyl ammonium
10 chloride) and 0.1 wt% TMAC with 300ppm Ca⁺⁺. The three components were formulated together with IPA and water with very good stability and flowability in the temperature range from 20° F to 150° F.

15 Additional fluids were formulated as set forth in Figure 1. Four fluids of the present invention were formulated as follows: I) 1.1 wt% EAB/0.14 wt% DAXAD 19 / 0.15 wt% OAED in 2 wt% KCl (balance is solvents); II) 0.76 wt% EAB/0.14wt% DAXAD 19/ 0.1 wt% OAED in 2 wt% KCl (rest are solvents); III) 0.76
20 wt% EAB/0.14wt% DAXAD 19/ 0.1 wt% OAED in 2 wt% KCl/500 ppm Ca⁺⁺ (balance is solvents); and IV) 0.76 wt% EAB/0.14 wt% DAXAD 19/ 0.1 wt% OAED in 0.1 wt% TMAC (balance is solvents). A comparative fluid was formulated as follows with only 2.3 wt% EAB in 2 wt% KCl (balance is solvents). The viscosity
25 performance versus temperature is set forth in Figure 1.

 An additional fluid of the present invention and three comparative fluids were formulated and their viscosity performance versus temperature tested. A fluid of the present
30 invention was formulated as follows: 1.1 wt% EAB/0.14wt% DAXAD 19 / 0.15 wt% OAED in 2 wt% KCl (balance is solvents). Three comparative fluids were formulated as follows: I) 1.1 wt% EAB

/ 0.15 wt% OAED in 2 wt% KCl (balance is solvents); II) 1.1wt% EAB / 0.14 wt% DAXAD 19 in 2 wt% KCl (balance is solvents); and III) 1.1 wt% EAB / 0.14 wt% of DAXAD 19 / 0.15 wt% Alkaquat DMB-451 (benzyl triammonium chloride made by Rhodia Inc.) in 2
5 wt% KCl (balance is solvents). The viscosity performance versus temperature is set forth in Figure 2.

It should be understood that the foregoing description is only illustrative of the present invention. Various
10 alternatives and modifications can be devised by those skilled in the art without departing from the invention. Accordingly, the present invention is intended to embrace all such alternatives, modifications and variances that fall within the scope of the appended claims.

15

WHAT IS CLAIMED IS

1. A viscoelastic fluid, comprising:

5 one or more cationic surfactants;

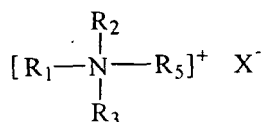
one or more anionic polymers;

one or more zwitterionic and/or amphoteric surfactants;

10 and

water; wherein the one or more cationic surfactants is selected from the group consisting of

15 i) quaternary salts having the following structural formula:

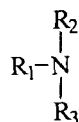


20 wherein R₁ is a hydrophobic moiety of alkyl, alkylarylalkyl, alkoxyalkyl, alkylaminoalkyl or alkylamidoalkyl, wherein R₁ has from about 18 to about 30 carbon atoms and may be branched or straight-chained and saturated or unsaturated; R₂, R₃, and R₅ are, independently,
25 selected from the group consisting of an aliphatic moiety having from 1 to about 30 carbon atoms and an aromatic moiety having from 7 to about 30 carbon atoms; the aliphatic moiety being branched or straight-chained and saturated or unsaturated;

30

wherein X is a counter-anion;

ii) amines having the following structural formula:

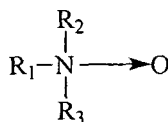


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wherein R_1 , R_2 and R_3 are the same as defined above;

iii) amine oxides having the following structural
formula:

10



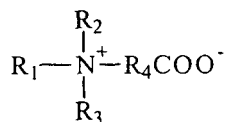
wherein R_1 , R_2 and R_3 are as defined above; and

15

iv) combinations thereof;

wherein the zwitterionic surfactant has the following
structural formula:

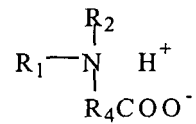
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wherein R_1 , R_2 , and R_3 are as described above; R_4 is a
hydrocarbyl radical with a chain length 1 to 4;

25

and wherein the amphoteric surfactant has the following structural formula:



5

wherein R_1 , R_2 , and R_4 are as described above.

2. The fluid of claim 1, wherein the one or more cationic surfactants is one or more quaternary salts.

10

3. The fluid of claim 2, wherein the quaternary salt is methylpolyoxyethylene octadecan ammonium chloride.

4. The fluid of claim 1, wherein the one or more cationic surfactants is one or more amines.

15

5. The fluid of claim 1, wherein the one or more cationic surfactants is selected from the group consisting of methylpolyoxyethylene octadecan ammonium chloride, methylpolyoxyethylene cocoalkyl ammonium chloride and isotridecyloxypropyl polyoxyethylene methyl ammonium chloride, polyoxyethylene cocoalkyl amines, polyoxyethylene tallowalkyl amines, and polyoxyethylene oleyl amines.

20

6. The fluid of claim 4, wherein the amine is polyoxyethylene cocoalkyl amines.

25

7. The fluid of claim 1, wherein the one or more cationic surfactants is present at from about 1 to about 40 wt% based on weight of active surfactant.

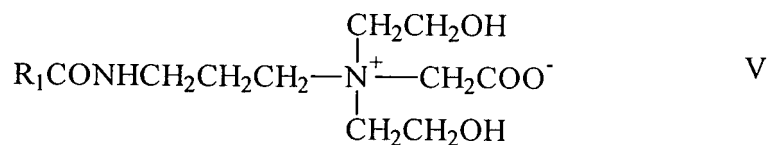
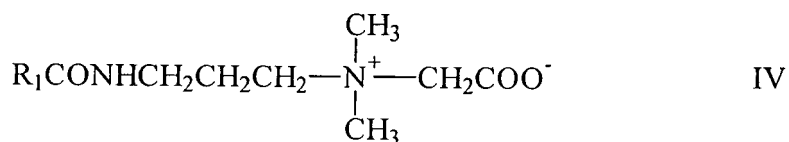
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8. The fluid of claim 1, wherein the one or more cationic surfactants is present at from about 5 to about 20 wt% based on weight of active surfactant.

5

9. The fluid of claim 1, wherein the one or more anionic polymers is present at from about 0.01 to about 5 wt%.

10. The fluid of claim 1, wherein the one or more zwitterionic surfactants is selected from the group consisting of the following structural formulas:



15

and combinations thereof.

11. The fluid of claim 1, wherein the one or more zwitterionic surfactants is erucyl amidopropyl betaine.

12. The fluid of claim 1, wherein the water is present at about 50 wt% or more based on fluid weight.

5 13. The fluid of claim 1, wherein the water is present at about 70 wt% or more based on fluid weight.

10 14. The fluid of claim 1, wherein the one or more cationic surfactants and the one or more zwitterionic and/or amphoteric surfactants are present at about 0.1 to about 10 wt% based on fluid weight.

15 15. The fluid of claim 1, wherein the one or more cationic surfactants and the one or more zwitterionic and or amphoteric surfactants are present at about 0.25 to about 2 wt% based on fluid weight.

20 16. The fluid of claim 1, wherein the one or more cationic surfactants and the one or more zwitterionic and/or amphoteric surfactants are present at less than 2 wt% based on fluid weight.

25 17. The fluid of claim 1, further comprising a component selected from the group consisting of organic acids, organic acid salts, inorganic salts, and combinations thereof.

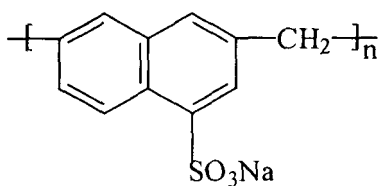
30 18. The fluid of claim 17, wherein the component is selected from the group consisting of potassium chloride and trimethylammonium chloride.

19. The fluid of claim 17, wherein the component is present at about 0.1 wt% to about 10 wt%.

20. The fluid of claim 1, further comprising a proppant.

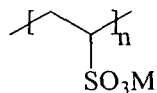
21. The fluid of claim 17, further comprising a
5 proppant.

22. The fluid of claim 1, wherein the one or more
anionic polymers has the following structural formula:



wherein n is an integer from about 8 to about 100.

23. The fluid of claim 1, wherein the one or more
15 anionic polymers has the following structural formula:



wherein n is an integer from about 8 to about 100.

24. The fluid of claim 1, wherein the one or more
anionic polymers is present at from about 0.1 wt% to about 5
wt%.

25. The fluid of claim 22, wherein the one or more
anionic polymers is present at from about 0.1 wt% to about 5
wt%.

26. The fluid of claim 23, wherein the one or more anionic polymers is present at from about 0.1 wt% to about 5 wt%.

5

27. The fluid of claim 1, wherein the one or more cationic surfactants is present at from about 1 to about 40 wt% based on weight of active surfactant, wherein the anionic polymer is present at from about 0.1 wt% to about 5 wt% based
10 on fluid weight, wherein the water is present at about 50 wt% or more based on fluid weight, wherein the one or more cationic surfactants and the one or more zwitterionic and/or amphoteric surfactants are present at about 0.1 to about 10 wt% based on fluid weight, the fluid further comprising a
15 component selected from the group consisting of organic acids, organic acid salts, inorganic salts, and combinations thereof, wherein the component is present at about 0.1 wt% to about 10 wt% based on fluid weight.

20

28. The fluid of claim 1, wherein R_1 is an alkyl or alkenyl group having about 18 to about 22 carbon atoms, and wherein R_2 , R_3 and R_5 , independently, each have about 1 to about 6 carbon atoms.

25

29. The fluid of claim 24, wherein R_1 is an alkyl or alkenyl group having about 18 to about 22 carbon atoms, and wherein R_2 , R_3 and R_5 , independently, each have about 1 to about 6 carbon atoms.

30

30. A viscoelastic fluid, comprising:

one or more cationic surfactants;

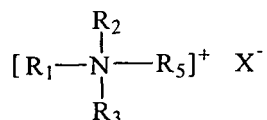
one or more anionic surfactants having alkyl chains of about 6 to about 18 carbon atoms with at least one negatively charged moiety;

5

one or more zwitterionic and/or amphoteric surfactants;
and

water; wherein the one or more cationic surfactants is
10 selected from the group consisting of

i) quaternary salts having the following structural
formula:

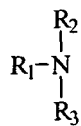


15

wherein R₁ is a hydrophobic moiety of alkyl, alkylarylalkyl, alkoxyalkyl, alkylaminoalkyl or alkylamidoalkyl, wherein R₁ has from about 18 to about 30
20 carbon atoms and may be branched or straight-chained and saturated or unsaturated; R₂, R₃, and R₅ are, independently, selected from the group consisting of an aliphatic moiety having from 1 to about 30 carbon atoms and an aromatic moiety having from 7 to about 30 carbon atoms; the aliphatic moiety
25 being branched or straight-chained and saturated or unsaturated;

wherein X is a counter-anion;

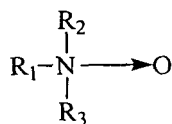
30 ii) amines having the following structural formula:



wherein R_1 , R_2 and R_3 are the same as defined above;

5

iii) amine oxides having the following structural formula:



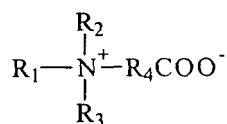
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wherein R_1 , R_2 and R_3 are as defined above; and

iv) combinations thereof;

15

wherein the zwitterionic surfactant has the following structural formula:

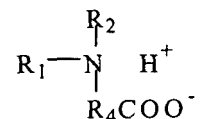


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wherein R_1 , R_2 , and R_3 are as described above; R_4 is a hydrocarbyl radical with a chain length 1 to 4;

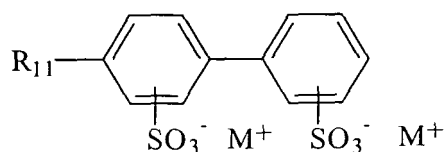
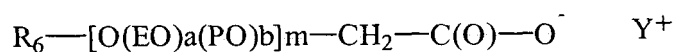
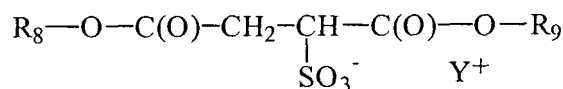
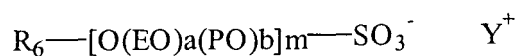
and wherein the amphoteric surfactant has the following structural formula:

25



wherein R_1 , R_2 , and R_4 are as described above.

- 5 31. The method of claim 30, wherein the anionic surfactant has the following structural formula selected from the group consisting of:



10

and combinations thereof;

- wherein R_6 is selected from a group consisting of alkyl, aryl, alkaryl, alkylarylalkyl, arylalkyl, alkylamidoalkyl, alkylaminoalkyl; wherein the alkyl group has from about 6 to about 18 carbon atoms; wherein the aryl group represents a phenyl, diphenyl, diphenylether, or naphthalene moiety; wherein the total carbon atom content of R_6 is no more than about 18 carbon atoms; wherein M is selected from the group consisting of hydrogen, an alkali metal, and $-[R_7-$
- 15
- 20

(EO)_a(PO)_b(BO)_c]_m-O-]_q-P(O)(OM)₂; wherein Y is a counter-ion; wherein EO is an ethyleneoxy radical; wherein PO is an propyleneoxy radical; wherein BO is a butoxy radical; wherein each of the EO, PO, and BO radicals can be randomly mixed or in discrete blocks; wherein a, b, and c are, independently, integers from 0 to 50; wherein "m" is 0 or 1; wherein "R₇" is C₈ to C₁₈ alkylene; wherein R₈ is C₈ - C₁₈ alkyl or C₈ - C₁₈ alkylamido; wherein "R₉" is C₁ to C₄ alkyl or Y; wherein R₁₀ is C₄ - C₈ alkyl; and wherein "q" is an integer from 1 to about 10.

32. The fluid of claim 30, further comprising a component selected from the group consisting of organic acids, organic acid salts, inorganic salts, and combinations thereof.

33. The fluid of claim 32, further comprising a proppant.

34. A method of fracturing a subterranean formation, comprising the step of pumping a viscoelastic fluid through a wellbore and into a subterranean formation at a pressure sufficient to fracture the formation, wherein the viscoelastic fluid is the viscoelastic fluid according to claim 1.

35. A method of fracturing a subterranean formation, comprising the step of pumping a viscoelastic fluid through a wellbore and into a subterranean formation at a pressure sufficient to fracture the formation, wherein the viscoelastic fluid is the viscoelastic fluid according to claim 30.

36. The method of claim 35 wherein the viscoelastic fluid further comprises a gas selected from air, nitrogen or carbon dioxide to provide an energized fluid or a foam.

37. The method of claim 36 wherein the viscoelastic fluid further comprises a gas selected from air, nitrogen or carbon dioxide to provide an energized fluid or a foam.

5

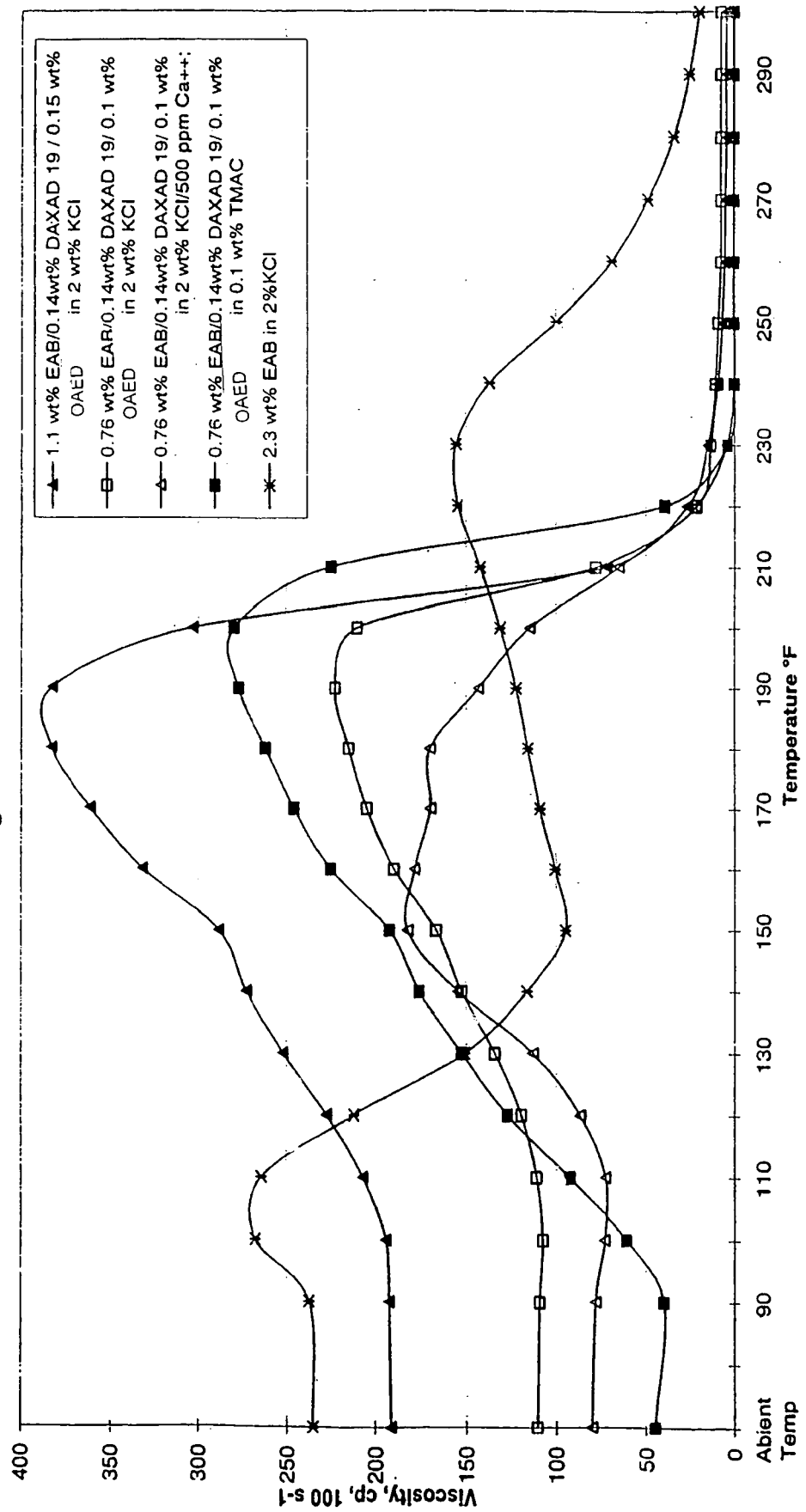
38. A method of gravel packing a subterranean formation, comprising the step of pumping a viscoelastic fluid and gravel into a wellbore, wherein the viscoelastic fluid is the viscoelastic fluid according to claim 1.

10

39. A method of gravel packing a subterranean formation, comprising the step of pumping a viscoelastic fluid and gravel into a wellbore, wherein the viscoelastic fluid is the viscoelastic fluid according to claim 30.

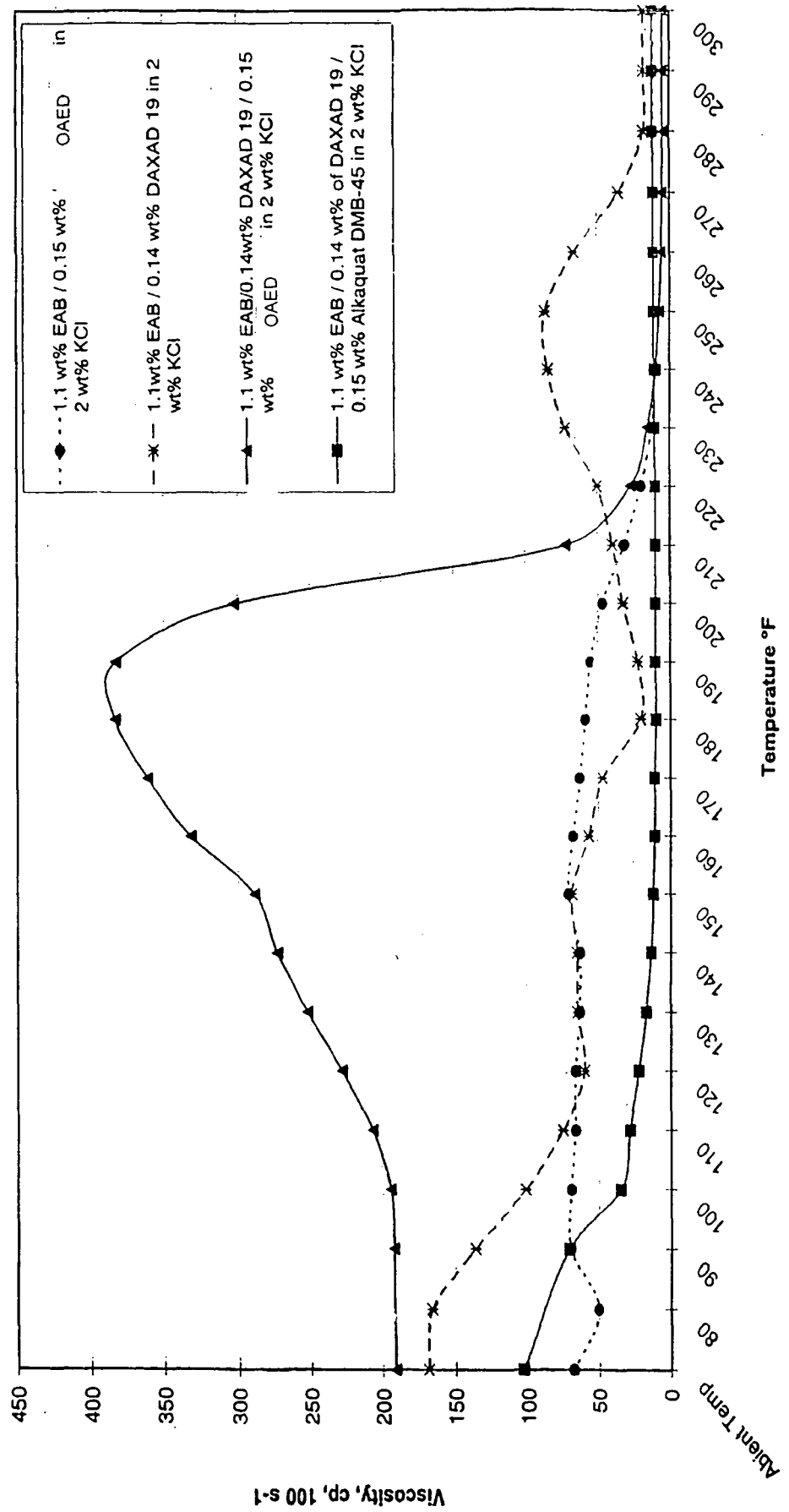
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Figure 1



2/2

Figure 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/01723

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 43/00; C09K 8/60

USPC - 507/240

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC - 507/240

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 507/\$

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Searched US Pre-grant Publications, US Patent Full-Text, EPO Abstract, JPO Abstract, Google Internet Databases for viscoelastic, fluid, air, nitrogen amphoteric, zwitterionic, surfactant

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/0019836 A1 (Li et al.) 26 January 2006 (26.01.2006); entire document, especially claims 1-35	1-39
A	US 2006/0105919 A1 (Colaco et al.) 18 May 2006 (18.05.2006); entire document	1-39

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 July 2008 (18.07.2008)

Date of mailing of the international search report

25 JUL 2008

Name and mailing address of the ISA/US

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