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(54) Titre : REDUCTION DE L'ENTRAÎNEMENT PARTICULAIRE PAR DES FLUIDES
(54) Title: CONTROL OF PARTICULATE ENTRAINMENT BY FLUIDS

(57) **Abrégé/Abstract:**

An aqueous slurry composition for use in industries such as petroleum and pipeline industries that includes: a particulate, an aqueous carrier fluid, a chemical compound that renders the particulate surface hydrophobic, and a small amount of an oil. The slurry is produced by rendering the surface of the particulate hydrophobic during or before the making of the slurry. The addition of the oil greatly enhances the aggregation potential of the hydrophobically modified particulates once placed in the well bore.



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(54) Title: CONTROL OF PARTICULATE ENTRAINMENT BY FLUIDS

(57) Abstract: An aqueous slurry composition for use in industries such as petroleum and pipeline industries that includes: a particulate, an aqueous carrier fluid, a chemical compound that renders the particulate surface hydrophobic, and a small amount of an oil. The slurry is produced by rendering the surface of the particulate hydrophobic during or before the making of the slurry. The addition of the oil greatly enhances the aggregation potential of the hydrophobically modified particulates once placed in the well bore.

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CONTROL OF PARTICULATE ENTRAINMENT BY FLUIDS

FIELD

[0001] This invention relates to fluid compositions and their use in controlling proppant flowback after a hydraulic fracturing treatment and in reducing formation sand production along with fluids in poorly consolidated formations.

BACKGROUND

[0002] Hydraulic fracturing operations are used extensively in the petroleum industry to enhance oil and gas production. In a hydraulic fracturing operation, a fracturing fluid is injected through a wellbore into a subterranean formation at a pressure sufficient to initiate fractures to increase oil and gas production.

[0003] Frequently, particulates, called proppants, are suspended in the fracturing fluid and transported into the fractures as a slurry. Proppants include sand, ceramic particles, glass spheres, bauxite (aluminum oxide), resin coated proppants, synthetic polymeric beads, and the like. Among them, sand is by far the most commonly used proppant.

[0004] Fracturing fluids in common use include aqueous and non-aqueous ones including hydrocarbon, methanol and liquid carbon dioxide fluids. The most commonly used fracturing fluids are aqueous fluids including water, brines, water containing polymers or viscoelastic surfactants and foam fluids.

[0005] At the last stage of a fracturing treatment, fracturing fluid is flowed back to the surface and proppants are left in the fractures to prevent them from closing back after the hydraulic fracturing pressure is released. The proppant-filled fractures provide high conductive channels that allow oil and/or gas to seep through to the wellbore more efficiently. The conductivity of the proppant

packs formed after proppant settles in the fractures plays a dominant role in increasing oil and gas production.

[0006] However, it is not unusual for a significant amount of proppant to be carried out of the fractures and into the well bore along with the fluids being flowed back out the well. This process is known as proppant flowback. Proppant flowback is highly undesirable since it not only reduces the amount of proppants remaining in the fractures resulting in less conductive channels, but also causes significant operational difficulties. It has long plagued the petroleum industry because of its adverse effect on well productivity and equipment.

[0007] Numerous methods have been attempted in an effort to find a solution to the problem of proppant flowback. The commonly used method is the use of so-called "resin-coated proppants". The outer surfaces of the resin-coated proppants have an adherent resin coating so that the proppant grains are bonded to each other under suitable conditions forming a permeable barrier and reducing the proppant flowback.

[0008] The substrate materials for the resin-coated proppants include sand, glass beads and organic materials such as shells or seeds. The resins used include epoxy, urea aldehyde, phenol-aldehyde, furfural alcohol and furfural. The resin-coated proppants can be either pre-cured or can be cured by an overflush of a chemical binding agent, commonly known as activator, once the proppants are in place.

[0009] Different binding agents have been used. United States Patent Nos. 3,492,147 and 3,935,339 disclose compositions and methods of coating solid particulates with different resins. The particulates to be coated include sand, nut shells, glass beads, and aluminum pellets. The resins used include urea-aldehyde resins, phenol-aldehyde resins, epoxy resins, furfuryl alcohol resins, and polyester or alkyl resins. The resins can be in pure form or mixtures containing curing agents, coupling agents or other additives. Other examples of resins and

resin mixtures for proppants are described, for example, in United States Patent Nos. 5,643,669; 5,916,933; 6,059,034 and 6,328,105.

[00010] However, there are significant limitations to the use of resin-coated proppants. For example, resin-coated proppants are much more expensive than normal sands, especially considering that a fracturing treatment usually employs tons of proppants in a single well. Normally, when the formation temperature is below 60°C, activators are required to make the resin-coated proppants bind together. This increases the cost.

[00011] Thus, the use of resin-coated proppants is limited by their high cost to only certain types of wells, or to use in only the final stages of a fracturing treatment, also known as the "tail-in" of proppants, where the last few tons of proppants are pumped into the fracture. For less economically viable wells, application of resin-coated proppants often becomes cost prohibitive.

[00012] During hydrocarbon production, especially from poorly consolidated formations, small particulates, typically of sand, often flow into the wellbore along with produced fluids. This is because the formation sands in poorly consolidated formations, are bonded together with insufficient bond strength to withstand the forces exerted by the fluids flowing through, and are readily entrained by the produced fluids flowing out of the well.

[00013] The produced sand erodes surface and subterranean equipment, and requires a removal process before the hydrocarbon can be processed. Different methods have been tried in an effort to reduce formation sand production. One approach employed is to filter the produced fluids through a gravel pack retained by a screen in the wellbore, where the particulates are trapped by the gravel pack. This technique is known as gravel packing. However, this technique is relatively time consuming and expensive. The gravel and the screen can be plugged and eroded by the sand within a relatively short period of time.

[00014] Another method that has been employed in some instances is to inject various resins into a formation to strengthen the binding of formation sands. Such an approach, however, results in uncertainty and sometimes creates undesirable results. For example, due to the uncertainty in controlling the chemical reaction, the resin may set in the wellbore itself rather than in the poorly consolidated producing zone. Another problem encountered in the use of resin compositions is that the resins normally have short shelf lives. For example, it can lead to costly waste if the operation using the resin is postponed after the resin is mixed.

[00015] Thus, it is highly desirable to have a cost effective composition and a method that can control proppant flowback after fracturing treatment. It is also highly desirable to have a composition and a method of reducing formation sand production from the poorly consolidated formation.

SUMMARY

[00016] The present invention in one embodiment relates to an aqueous slurry composition having water, particulates, a chemical compound for rendering the surface of the particulates hydrophobic and an oil.

[00017] The present invention in another embodiment relates to a method of controlling sand in a hydrocarbon producing formation comprising the steps of mixing water, particulates and a chemical compound for rendering the surface of the particulates hydrophobic, pumping the mixture into the formation.

[00018] In a further embodiment of the present invention there is provided an aqueous slurry composition comprising water, particulates selected from the group consisting of sand, resin coated sand, synthetic polymeric beads, ceramic, glass spheres, carbonate and bauxite particulates, a chemical compound for rendering the surface of the particulates hydrophobic, and an oil.

[00019] In another aspect of the present invention there is provided method of controlling proppant flowback in a hydrocarbon producing formation comprising the steps of: mixing water, particulates, a chemical compound for rendering the surface of the particulates hydrophobic and an oil; and pumping the mixture into the formation.

[00020] In a further aspect of the present invention, there is provided a method of controlling proppant flowback in a hydrocarbon producing formation comprising the steps of: contacting particulates with a medium containing a chemical compound to render the surface of the particulates hydrophobic, separating the particulate from the medium, blending the hydrophobic particulate with water and an oil to form a mixture, and pumping the mixture into the formation.

DETAILED DESCRIPTION OF THE INVENTION

[00021] Aggregation phenomena induced by hydrophobic interaction in water are observed everywhere, in nature, industrial practice, as well as in daily life. In general, and without being bound by theory, the hydrophobic interaction refers to the attractive forces between two or more apolar particles in water. When the hydrophobic interaction becomes sufficiently strong, the hydrophobic particles come together to further reduce the surface energy, essentially bridging the particles together and resulting in the formation of particle aggregations, known as hydrophobic aggregations. It is also known that micro-bubbles attached to hydrophobic particle surfaces also tend to bridge the particles together.

[00022] In this invention the concept of hydrophobic aggregation is applied to develop compositions and methods to control proppant flowback as well as to reduce formation sand production during well production. Unlike in conventional approaches, where attention is focused on making proppants or sand particles sticky through formation of chemical bonds between resins coated on the particle surfaces, in the present invention the attention is focused on

making particle aggregations by bridging the particles through strong hydrophobic force or micro-bubbles. Moreover, the hydrophobic surfaces of the particles induced by the present compositions reduce the friction between the particles and water making them harder to be entrained by fluids flowing out of the well.

[00023] In general, only a limited amount of agents is required in the present invention, and the field operational is simple.

[00024] There are different ways of carrying out the invention. For example, during a fracturing operation, a proppant, for example, sand, which is naturally hydrophilic and can be easily water wetted, is mixed with a fluid containing a chemical agent, referred as hydrophobizing agent, which makes the sand surface hydrophobic. The hydrophobizing agent can be simply added into a sand slurry comprising sand and fracturing fluid which is pumped down the well. Depending on the hydrophobizing agent used and the application conditions, different fracturing fluids (aqueous or non-aqueous fluids) can be used. Aqueous fluid is normally preferred. Of particular interest as a fracturing fluid, is water, or brine or water containing a small amount of a friction reducing agent, also known as slick-water.

[00025] The hydrophobizing agent can be applied throughout the proppant stage or during a portion of the proppant stage such as the last portion of the proppant stage, i.e., tail-in. Alternatively, sand can be hydrophobized first and dried and then used to make a slurry and pumped into fracture.

[00026] It has been discovered that when a small amount of an oil, including hydrocarbon oil and silicone oil, is mixed into the aqueous slurry containing the hydrophobized sands, the hydrophobic aggregation is enhanced significantly. The possible explanation for this is that the concentration of oil among the hydrophobic sands may further enhance the bridge between sand grains.

[00027] The present invention can be used in a number of ways. For example, in a fracture operation, proppant such as sand is mixed with a hydrophobizing agent in water based slurry and pumped into the fractures, and then followed by over flush with oil or water containing a small amount of oil to strengthen the bridge between the sand grains. Similarly, the same operation can be applied in the tail-in stage. Alternatively the slurry containing a hydrophobizing agent can be pumped into the fracture forming the proppant pack, which can be further consolidated by oil or condensate contained in the formation. Or the pre-hydrophobized sand is used as proppant and then followed by flushing with water, containing small amount of oil. Or the pre-hydrophobized sand is used as proppant which can be further consolidated by oil or condensate contained in the formation. Or the pre-hydrophobized sand is tailed in and followed by flushing with water containing small amount of oil. In all such operations, a gas such as nitrogen, carbon dioxide or air can be mixed into the fluid.

[00028] There are different ways of pre-treating the solid surface hydrophobic. For example, one may thoroughly mix the proppants, preferable sands, with a fluid containing the appropriate hydrophobizing agent for certain period of time. After the proppant grains are dried, they can be used in fracturing operations. Different fluids can be used. Different hydrophobizing agents may need different conditions to interact with the solid surface. When an aqueous fluid is used, the pH of the fluid may also play a role.

[00029] Besides controlling proppant flowback in hydraulic fracturing treatments, the present invention is also useful in reducing formation sand production during well production. In the majority of cases, sand production increases substantially when wells begin to produce water. The formation sand is normally hydrophilic, or water-wet, and therefore is easily entrained by a flowing water phase. Depending on the hydrophobizing agent used and the operational conditions, different carrying fluids, aqueous or non-aqueous, can be used. There are different methods, according to the present invention, to treat a

formation to reduce formation sand production. For example, a fluid, preferably an aqueous fluid, containing an appropriate amount of hydrophobizing agent can be injected into the poorly consolidated formation. After the sand grains become hydrophobic they tend to aggregate together. The hydrophobic surfaces also reduce the dragging force exerted by the aqueous fluid making them more difficult to be entrained by the formation fluid. If the water phase contains certain amount of oil, the hydrophobic aggregation between sand grains can be further enhanced. Alternatively, the fluid contain the hydrophobizing agent can be first injected into the poorly consolidated formation, and then followed by injecting small volume of oil or a fluid containing oil. In all these applications, a gas such as nitrogen, carbon dioxide or air can be mixed into the fluid.

[00030] Also, the compositions and methods of the present invention can be used in gravel pack operations, where the slurry containing hydrophobised sands are added in the well bore to remediate sand production.

[00031] There are various types of hydrophobizing agents for sand, which can be used in the present invention. For example, it is known that many organosilicon compounds including organosiloxane, organosilane, fluoro-organosiloxane and fluoro-organosilane compounds are commonly used to render various surfaces hydrophobic. For example, see United States Patent Nos. 4,537,595; 5,240,760; 5,798,144; 6,323,268; 6,403,163; 6,524,597 and 6,830,811.

[00032] Organosilanes are compounds containing silicon to carbon bonds. Organosiloxanes are compounds containing Si-O-Si bonds. Polysiloxanes are compounds in which the elements silicon and oxygen alternate in the molecular skeleton, i.e., Si-O-Si bonds are repeated. The simplest polysiloxanes are polydimethylsiloxanes.

[00033] Polysiloxane compounds can be modified by various organic substitutes having different numbers of carbons, which may contain N, S, or P moieties that impart desired characteristics. For example, cationic polysiloxanes

are compounds in which organic cationic groups are attached to the polysiloxane chain, either at the middle or the end. Normally the organic cationic group may contain a hydroxyl group or other functional groups containing N or O. The most common organic cationic groups are alkyl amine derivatives including secondary, tertiary and quaternary amines (for example, quaternary polysiloxanes including, quaternary polysiloxanes including mono- as well as, di-quaternary polysiloxanes, amido quaternary polysiloxanes, imidazoline quaternary polysiloxanes and carboxy quaternary polysiloxanes).

[00034] Similarly, the polysiloxane can be modified by organic amphoteric groups, where one or more organic amphoteric groups are attached to the polysiloxane chain, either at the middle or the end, and include betaine polysiloxanes and phosphobetaine polysiloxanes.

[00035] Similarly, the polysiloxane can be modified by organic anionic groups, where one or more organic anionic groups are attached to the polysiloxane chain, either at the middle or the end, including sulfate polysiloxanes, phosphate polysiloxanes, carboxylate polysiloxanes, sulfonate polysiloxanes, thiosulfate polysiloxanes. The organosiloxane compounds also include alkylsiloxanes including hexamethylcyclotrisiloxane, octamethylcyclotetrasiloxane, decamethylcyclopentasiloxane, hexamethyldisiloxane, hexaethyldisiloxane, 1,3-divinyl-1,1,3,3-tetramethyldisiloxane, octamethyltrisiloxane, decamethyltetrasiloxane.

[00036] The organosilane compounds include alkylchlorosilane, for example methyltrichlorosilane, dimethyldichlorosilane, trimethylchlorosilane, octadecyltrichlorosilane; alkyl-alkoxysilane compounds, for example methyl-, propyl-, isobutyl- and octyltrialkoxysilanes, and fluoro-organosilane compounds, for example, 2-(n-perfluoro-octyl)-ethyltriethoxysilane, and perfluoro-octyldimethyl chlorosilane.

[00037] Other types of chemical compounds, which are not organosilicon compounds, which can be used to render particulate surface hydrophobic are certain fluoro-substituted compounds, for example certain fluoro-organic compounds including cationic fluoro-organic compounds.

[00038] Further information regarding organosilicon compounds can be found in Silicone Surfactants (Randal M. Hill, 1999) and the references therein, and in United States Patent Nos. 4,046,795; 4,537,595; 4,564,456; 4,689,085; 4,960,845; 5,098,979; 5,149,765; 5,209,775; 5,240,760; 5,256,805; 5,359,104; 6,132,638 and 6,830,811 and Canadian Patent No. 2,213,168.

[00039] Organosilanes can be represented by the formula

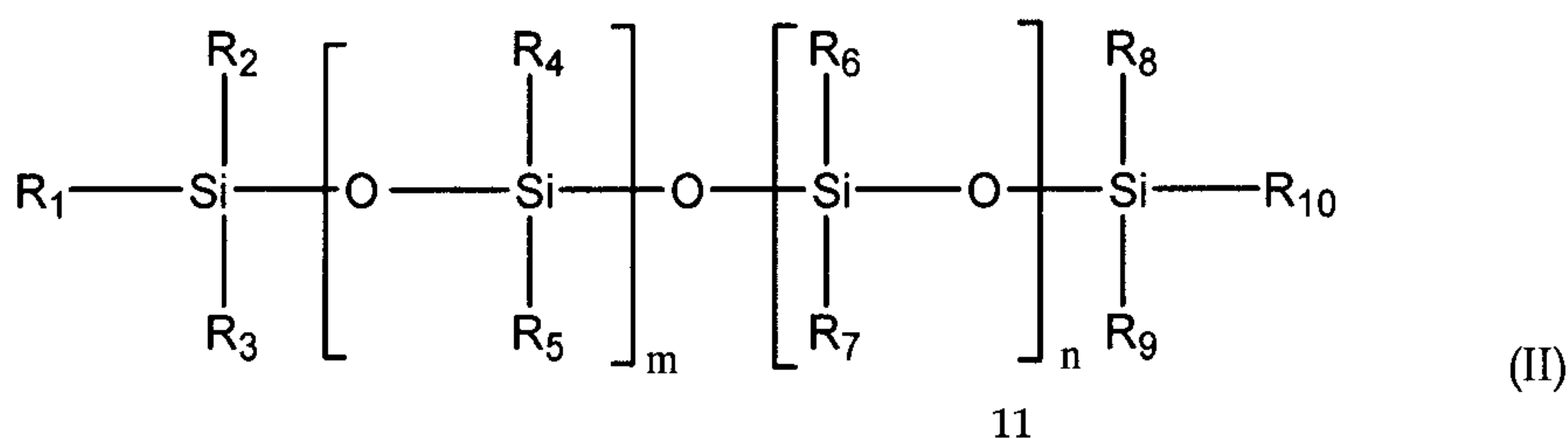


wherein R is an organic radical having 1-50 carbon atoms that may possess functionality containing N, S, or P moieties that imparts desired characteristics, X is a halogen, alkoxy, acyloxy or amine and n has a value of 0-3. Examples of organosilanes include:

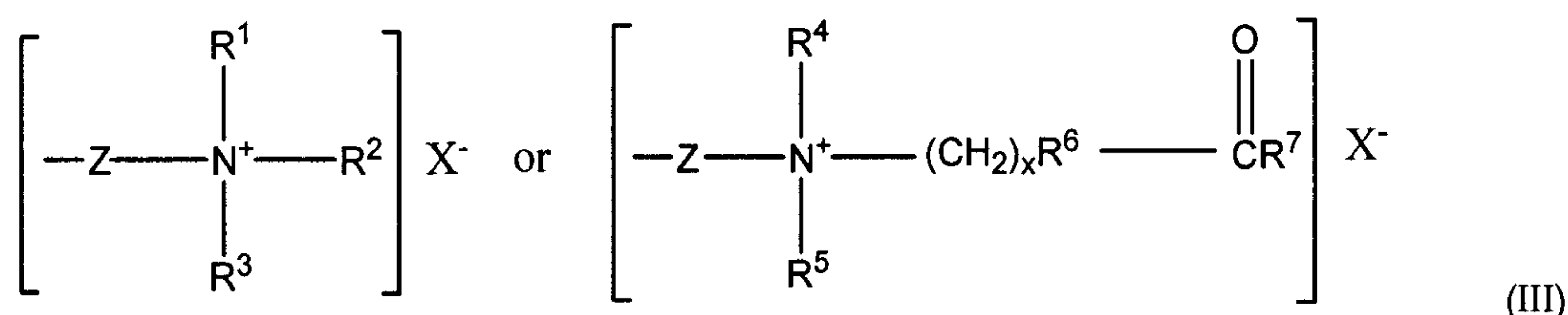
CH₃SiCl₃, CH₃CH₂SiCl₃, (CH₃)₂SiCl₂, (CH₃CH₂)₂SiCl₂, (C₆H₅)₂SiCl₂,
 (C₆H₅)SiCl₃, (CH₃)₃SiCl, CH₃HSiCl₂, (CH₃)₂HSiCl, CH₃SiBr₃,
 (C₆H₅)SiBr₃, (CH₃)₂SiBr₂, (CH₃CH₂)₂SiBr₂, (C₆H₅)₂SiBr₂, (CH₃)₃SiBr, CH₃HSiBr₂,
 (CH₃)₂HSiBr, Si(OCH₃)₄, CH₃Si(OCH₃)₃, CH₃Si(OCH₂CH₃)₃,
 CH₃Si(OCH₂CH₂CH₃)₃, CH₃Si[O(CH₂)₃CH₃]₃, CH₃CH₂Si(OCH₂CH₃)₃,
 C₆H₅Si(OCH₃)₃, C₆H₅CH₂Si(OCH₃)₃, C₆H₅Si(OCH₂CH₃)₃, CH₂=CHCH₂Si(OCH₃)₃,
 (CH₃)₂Si(OCH₃)₂, (CH₂=CH)Si(CH₃)₂Cl, (CH₃)₂Si(OCH₂CH₃)₂,
 (CH₃)₂Si(OCH₂CH₂CH₃)₂, (CH₃)₂Si[O(CH₂)₃CH₃]₂, (CH₃CH₂)₂Si(OCH₂CH₃)₂,
 (C₆H₅)₂Si(OCH₃)₂, (C₆H₅CH₂)₂Si(OCH₃)₂, (C₆H₅)₂Si(OCH₂CH₃)₂,
 (CH₂=CH)₂Si(OCH₃)₂, (CH₂=CHCH₂)₂Si(OCH₃)₂, (CH₃)₃SiOCH₃,
 CH₃HSi(OCH₃)₂, (CH₃)₂HSi(OCH₃), CH₃Si(OCH₂CH₂CH₃)₃,
 (CH₂=CHCH₂)Si(OCH₂CH₂OCH₃)₂, (C₆H₅)₂Si(OCH₂CH₂OCH₃)₂,

$(\text{CH}_3)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$, $(\text{CH}_2=\text{CH})_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$,
 $(\text{CH}_2=\text{CHCH}_2)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$, $(\text{C}_6\text{H}_5)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$,
 $\text{CH}_3\text{Si}(\text{CH}_3\text{COO})_3$, 3-aminotriethoxysilane, methyldiethylchlorosilane,
 butyltrichlorosilane, diphenyldichlorosilane, vinyltrichlorosilane,
 methyltrimethoxysilane, vinyltriethoxysilane, vinyltris(methoxyethoxy)silane,
 methacryloxypropyltrimethoxysilane, glycidoxypropyltrimethoxysilane,
 aminopropyltriethoxysilane, divinyl-di-2-methoxysilane, ethyltributoxysilane,
 isobutyltrimethoxysilane, hexyltrimethoxysilane, n-octyltriethoxysilane,
 dihexyldimethoxysilane, octadecyltrichlorosilane, octadecyltrimethoxysilane,
 octadecyldimethylchlorosilane, octadecyldimethylmethoxysilane and quaternary
 ammonium silanes including 3-(trimethoxysilyl)propyldimethyloctadecyl
 ammonium chloride, 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium
 bromide, 3-(trimethylethoxysilylpropyl)didecylmethyl ammonium chloride,
 triethoxysilyl soyapropyl dimonium chloride, 3-
 (trimethylethoxysilylpropyl)didecylmethyl ammonium bromide, 3-
 (trimethylethoxysilylpropyl)didecylmethyl ammonium bromide, triethoxysilyl
 soyapropyl dimonium bromide, $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{P}^+(\text{C}_6\text{H}_5)_3\text{Cl}^-$,
 $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{P}^+(\text{C}_6\text{H}_5)_3\text{Br}^-$, $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{P}^+(\text{CH}_3)_3\text{Cl}^-$,
 $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{P}^+(\text{C}_6\text{H}_{13})_3\text{Cl}^-$, $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2\text{C}_4\text{H}_9\text{Cl}^-$,
 $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2\text{CH}_2\text{C}_6\text{H}_5\text{Cl}^-$, $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2\text{CH}_2\text{CH}_2\text{OHCl}^-$,
 $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{C}_2\text{H}_5)_3\text{Cl}^-$, $(\text{C}_2\text{H}_5\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2\text{C}_{18}\text{H}_{37}\text{Cl}^-$.

[00040] Among different organosiloxane compounds which are useful for
 the present invention, polysiloxanes modified with organic amphoteric or
 cationic groups including organic betaine polysiloxanes and organic quaternary
 polysiloxanes are examples. One type of betaine polysiloxane or quaternary
 polysiloxane is represented by the formula

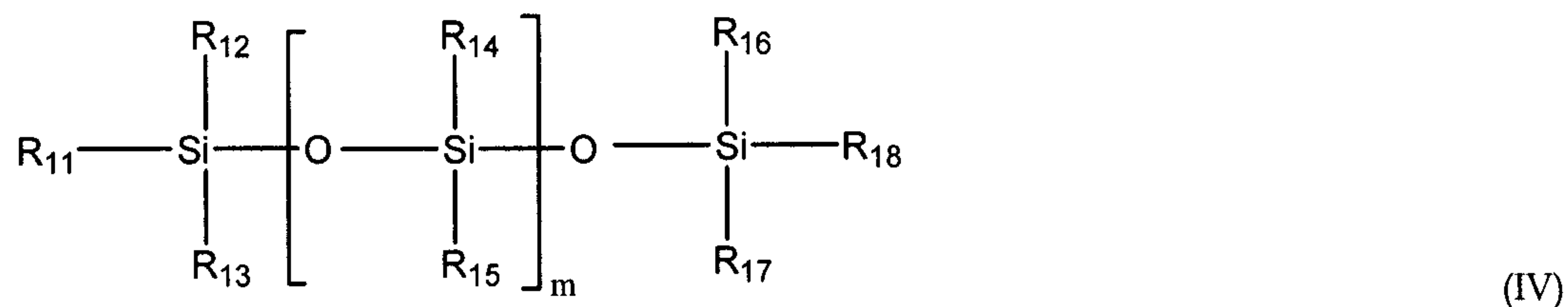


wherein each of the groups R_1 to R_6 , and R_8 to R_{10} represents an alkyl containing 1-6 carbon atoms, typically a methyl group, R_7 represents an organic betaine group for betaine polysiloxane, or an organic quaternary group for quaternary polysiloxane, and have different numbers of carbon atoms, and may contain a hydroxyl group or other functional groups containing N, P or S, and m and n are from 1 to 200. For example, one type of quaternary polysiloxanes is when R_7 is represented by the group

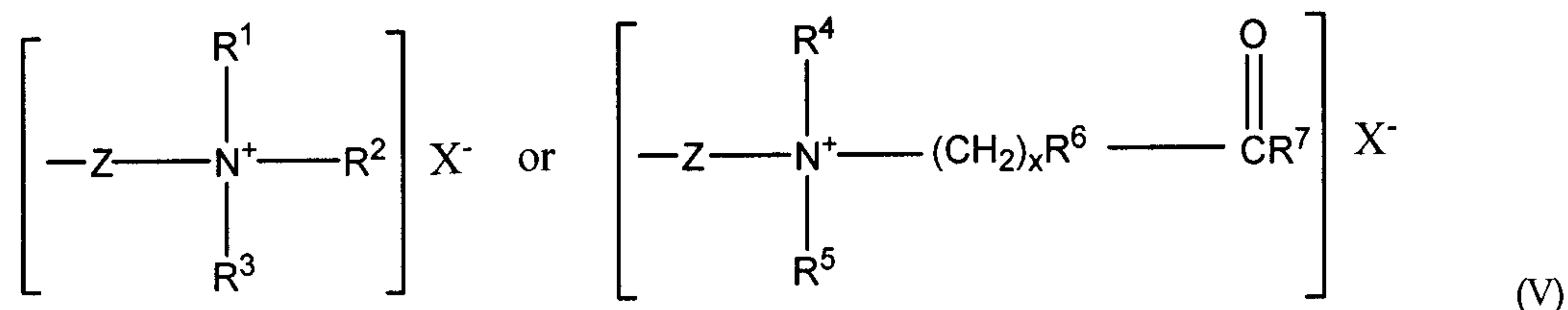


wherein R^1 , R^2 , R^3 are alkyl groups with 1 to 22 carbon atoms or alkenyl groups with 2 to 22 carbon atoms. R^4 , R^5 , R^7 are alkyl groups with 1 to 22 carbon atoms or alkenyl groups with 2 to 22 carbon atoms; R^6 is $-O-$ or the NR^8 group, R^8 being an alkyl or hydroxyalkyl group with 1 to 4 carbon atoms or a hydrogen group; Z is a bivalent hydrocarbon group with at least 4 carbon atoms, which may have a hydroxyl group and may be interrupted by an oxygen atom, an amino group or an amide group; x is 2 to 4; The R^1 , R^2 , R^3 , R^4 , R^5 , R^7 may be the same or the different, and X^- is an inorganic or organic anion including Cl^- and CH_3COO^- . Examples of organic quaternary groups include $[R-N^+(CH_3)_2-CH_2CH(OH)CH_2-O-(CH_2)_3-] (CH_3COO^-)$, wherein R is an alkyl group containing from 1-22 carbons or an benzyl radical and CH_3COO^- an anion. Examples of organic betaine include $-(CH_2)_3-O-CH_2CH(OH)(CH_2)-N^+(CH_3)_2CH_2COO^-$. Such compounds are commercial available. Betaine polysiloxane copolyol is one of examples. It should be understood that cationic polysiloxanes include compounds represented by formula (II), wherein R_7 represents other organic amine derivatives including organic primary, secondary and tertiary amines.

[00041] Other examples of organo-modified polysiloxanes include di-betaine polysiloxanes and di-quaternary polysiloxanes, where two betaine or quaternary groups are attached to the siloxane chain. One type of the di-betaine polysiloxane and di-quaternary polysiloxane can be represented by the formula



wherein the groups R₁₂ to R₁₇ each represents an alkyl containing 1-6 carbon atoms, typically a methyl group, both R₁₁ and R₁₈ group represent an organic betaine group for di-betaine polysiloxanes or an organic quaternary group for di-quaternary, and have different numbers of carbon atoms and may contain a hydroxyl group or other functional groups containing N, P or S, and m is from 1 to 200. For example, one type of di-quaternary polysiloxanes is when R₁₁ and R₁₈ are represented by the group



wherein R¹, R², R³, R⁴, R⁵, R⁶, R⁷, Z, X⁻ and x are the same as defined above. Such compounds are commercially available. Quaternium 80 (INCI) is one of the commercial examples.

[00042] It will be appreciated by those skilled in the art that cationic polysiloxanes include compounds represented by formula (III), wherein R₁₁ and R₁₈ represents other organic amine derivatives including organic primary, secondary and tertiary amines. It will be apparent to those skilled in the art that there are different mono- and di-quaternary polysiloxanes, mono- and di-betaine

polysiloxanes and other organo-modified polysiloxane compounds which can be used to render the solid surfaces hydrophobic and are useful in the present invention. These compounds are widely used in personal care and other products, for example as discussed in United States Patent Nos. 4,054,161; 4,654,161; 4,891,166; 4,898,957; 4,933,327; 5,166,297; 5,235,082; 5,306,434; 5,474,835; 5,616,758; 5,798,144; 6,277,361; 6,482,969; 6,323,268 and 6,696,052.

[00043] Another example of organosilicon compounds which can be used in the composition of the present invention are fluoro-organosilane or fluoro-organosiloxane compounds in which at least part of the organic radicals in the silane or siloxane compounds are fluorinated. Suitable examples are fluorinated chlorosilanes or fluorinated alkoxysilanes including 2(n-perfluoro-octyl)ethyltriethoxysilane, perfluoro-octyldimethylchlorosilane, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_3)_2$, $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_3)_3$, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$ and $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_3$ and $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2(\text{CH}_2)_3\text{NHC}(\text{O})(\text{CF}_2)_6\text{CF}_3\text{Cl}^-$. Other compounds which can be used, but less preferable, are fluoro-substituted compounds, which are not organic silicon compounds, for example, certain fluoro-organic compounds.

[00044] The following provides several non-limiting examples of compositions and methods according to the present invention.

Example 1

[00045] 300 g of 20/40 US mesh frac sand was added into 1000 ml of water containing 2 ml of a solution containing 20 vol % Tegopren™ 6924, a di-quaternary polydimethylsiloxane from Degussa Corp., and 80 vol % of ethylene glycol mono-butyl ether, and 1 ml of TEGO™ Betaine 810, capryl/capramidopropyl betaine, an amphoteric hydrocarbon surfactant from Degussa Corp.. The slurry was shaken up and then let stand to allow sands settle down. When tilted slowly, the settled sand tended to move as cohesive masses. After 10 ml of silicon oil, where its viscosity is 200 cp, was mixed into the slurry

and shaken up sand grains were visually observed to clump together forming strong bridge among each other.

[00046] The solution was decanted, and the sand was dried overnight at the room temperature for further tests.

Example 2

[00047] 200 g of pre-treated sand according to Example 1 was placed in a fluid loss chamber to form a sand pack and wetted with water. Afterward, 300 ml of water was allowed to filter from the top through the sand pack. The time was stopped when water drops slowed to less than one every five seconds. Same test using untreated sand was carried out as the reference. The average filter time over 6 runs for the pre-treated sand was 2 minutes and 5 seconds, while it was 5 minutes for the untreated sand.

Example 3

[00048] 200 g of pre-treated sand according to Example 1 was placed in a fluid loss chamber to form a sand pack and wetted with kerosene. Afterward, 300 ml of kerosene was allowed to filter from the top through the sand pack. The time was stopped when kerosene drops slowed to less than one every five seconds. Same test using untreated sand was carried out as the reference. The average filter time over 5 runs for the pre-treated sand was 3 minutes and 2 seconds, while it was 3 minutes and 28 seconds for the untreated sand.

Example 4

[00049] 100 ml of water and 25 grams of 30/50 US mesh fracturing sands were added into each of two glass bottles (200ml). The first sample was used as the reference. In the second sample, 2 ml of a solution containing 20% Tegopren 6924 and 80% of ethylene glycol mono-butyl ether, and 0.5 ml of kerosene were added. The slurry was shaken up and then let stand to allow sands settle down. When tilted slowly, the settled sand tended to move as cohesive masses. Sand

grains were visually observed to clump together forming strong bridge among each others.

Example 5

[00050] 100 ml of water and 25 grams of 30/50 US mesh fracturing sands were added into each of two glass bottles (200ml). The first sample was used as the reference. In the second sample, 2 ml of a solution containing 20% Tegopren 6924 and 80% of ethylene glycol mono-butyl ether, and 0.5 ml of frac oil were added. The slurry was shaken up and then let stand to allow sands settle down. When tilted slowly, the settled sand tended to move as cohesive masses. Sand grains were visually observed to clump together forming strong bridge among each others.

CLAIMS:

1. An aqueous slurry composition comprising:

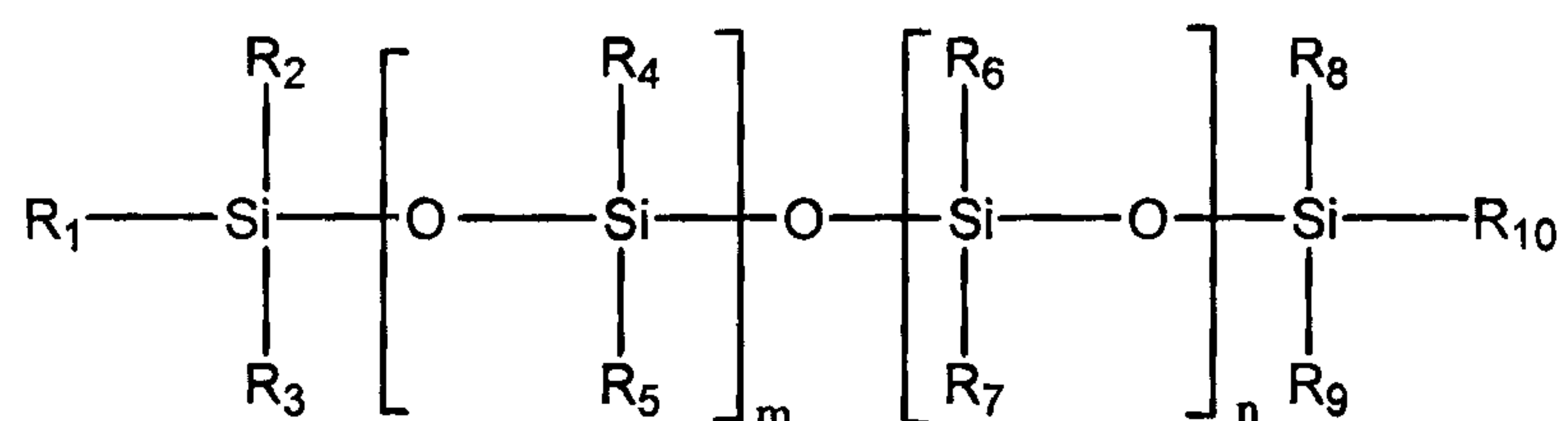
water;

particulates selected from the group consisting of sand, resin coated sand, synthetic polymeric beads, ceramic, glass spheres, carbonate and bauxite particulates;

a chemical compound for rendering the surface of the particulates hydrophobic; and

an oil.

2. The composition of claim 1, wherein the chemical compound is an organo-siloxane having the formula



wherein each of R_1 to R_6 and R_8 to R_{10} , represents an organic radical containing 1-6 carbon atoms, R_7 represents an organic amphoteric group for an organic amphoteric polysiloxane or an organic cationic group for an organic cationic polysiloxane, and m and n are from 1 to 200.

3. The composition of claim 2, wherein the chemical compound is an organic amphoteric polysiloxane.

4. The composition of claim 3, wherein the chemical compound is an organic amphoteric polysiloxane, and the values of m and n are from 1 to 100.

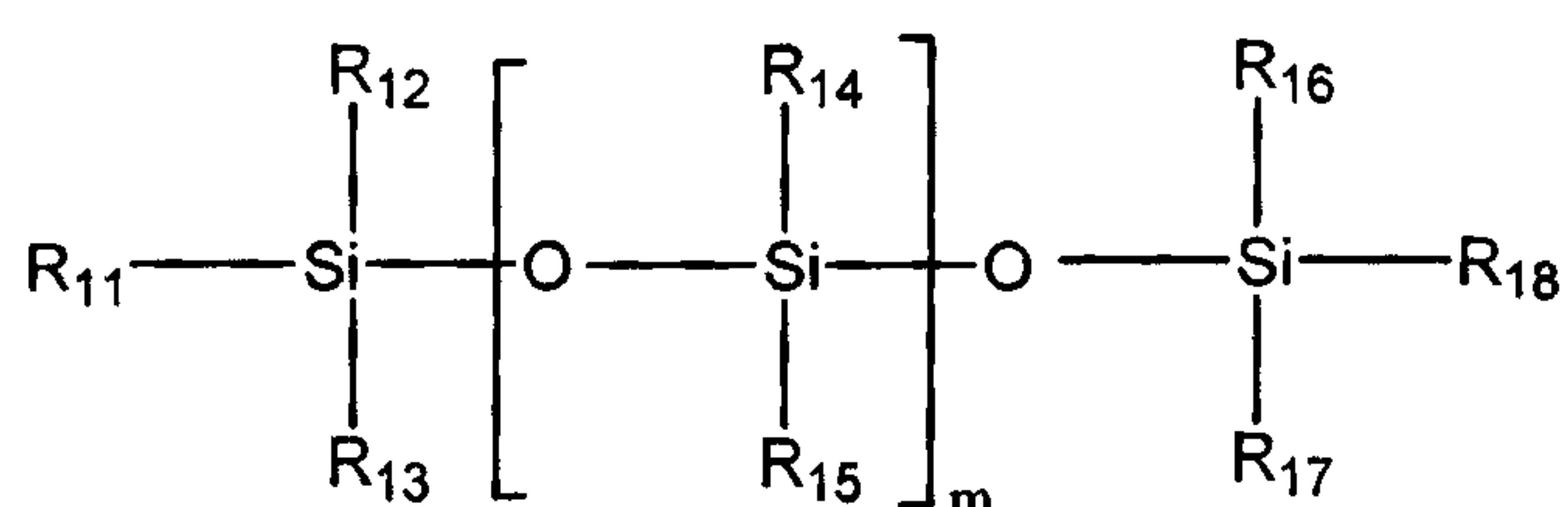
5. The composition of claim 4, wherein the chemical compound is an organic amphoteric polysiloxane, wherein each of R_1 to R_6 and R_8 to R_{10} is a methyl group and the values of m and n are from 1 to 100.

6. The composition of claim 2, wherein the chemical compound is an organic cationic polysiloxane.

7. The composition of claim 6, wherein the chemical compound is an organic cationic polysiloxane, and the values of m and n are from 1 to 100.

8. The composition of claim 7, wherein the chemical compound is an organic cationic polysiloxane, and each of R_1 to R_6 and R_8 to R_{10} is a methyl group and the values of m and n are from 1 to 100.

9. The composition of claim 1, wherein the chemical compound is an organo-siloxane having the formula



where R_{12} to R_{17} each represents an organic radical containing 1-6 carbon atoms, one of R_{11} and R_{18} represents an organic amphoteric group and the other of R_{11} and R_{18} represents an organic amphoteric group or an organic radical for a di-amphoteric polysiloxane or one of R_{11} and R_{18} represents an organic cationic group and the other of R_{11} and R_{18} represents an organic cationic group or an organic radical for a di-cationic polysiloxane, and m is 1 to 200.

10. The composition of claim 9, wherein the chemical compound is a di-amphoteric polysiloxane.

11. The composition of claim 10, wherein the chemical compound is a di-amphoteric polysiloxane and the values of m are from 1 to 100.

12. The composition of claim 11, wherein each of R_{12} to R_{17} represents a methyl group and the m is from 1 to 100.

13. The composition of claim 8, wherein the chemical compound is a di-cationic polysiloxane.

14. The composition of claim 13, wherein the chemical compound is a di-cationic polysiloxane, and the values of m are from 1 to 100.

15. The composition of claim 14, wherein each of R_{12} to R_{17} represents a methyl group and the m is from 10 to 100.

16. The composition of claim 1, wherein the chemical compound is an organosilane having the formula



wherein R is an organic radical having 1-50 carbon atoms, X is a halogen, alkoxy, acyloxy or amine and n has a value of 1-3.

17. The composition of claim 16, wherein the organosilane is selected from the group consisting of: CH_3SiCl_3 , $CH_3CH_2SiCl_3$, $(CH_3)_2SiCl_2$, $(CH_3CH_2)_2SiCl_2$, $(C_6H_5)_2SiCl_2$, $(C_6H_5)SiCl_3$, $(CH_3)_3SiCl$, CH_3HSiCl_2 , $(CH_3)_2HSiCl$, CH_3SiBr_3 , $(C_6H_5)SiBr_3$, $(CH_3)_2SiBr_2$, $(CH_3CH_2)_2SiBr_2$, $(C_6H_5)_2SiBr_2$, $(CH_3)_3SiBr$, CH_3HSiBr_2 , $(CH_3)_2HSiBr$, $Si(OCH_3)_4$, $CH_3Si(OCH_3)_3$, $CH_3Si(OCH_2CH_3)_3$, $CH_3Si(OCH_2CH_2CH_3)_3$, $CH_3Si[O(CH_2)_3CH_3]_3$, $CH_3CH_2Si(OCH_2CH_3)_3$, $C_6H_5Si(OCH_3)_3$, $C_6H_5CH_2Si(OCH_3)_3$, $C_6H_5Si(OCH_2CH_3)_3$, $CH_2=CHCH_2Si(OCH_3)_3$, $(CH_3)_2Si(OCH_3)_2$, $(CH_3)_2Si(OCH_2CH_3)_2$, $(CH_3)_2Si(OCH_2CH_2CH_3)_2$, $(CH_3)_2Si[O(CH_2)_3CH_3]_2$, $(CH_3CH_2)_2Si(OCH_2CH_3)_2$, $(C_6H_5)_2Si(OCH_3)_2$, $(C_6H_5CH_2)_2Si(OCH_3)_2$, $(C_6H_5)_2Si(OCH_2CH_3)_2$, $(CH_2=CH)_2Si(OCH_3)_2$, $(CH_2=CHCH_2)_2Si(OCH_3)_2$, $(CH_3)_3SiOCH_3$, $CH_3HSi(OCH_3)_2$, $(CH_3)_2HSi(OCH_3)$, $CH_3Si(OCH_2CH_2CH_3)_3$, $(CH_2=CHCH_2)_2Si(OCH_2CH_2OCH_3)_2$, $(C_6H_5)_2Si(OCH_2CH_2OCH_3)_2$, $(CH_3)_2Si(OCH_2CH_2OCH_3)_2$, $(CH_2=CH)_2Si(OCH_2CH_2OCH_3)_2$, $(CH_2=CHCH_2)_2Si(OCH_2CH_2OCH_3)_2$, $(C_6H_5)_2Si(OCH_2CH_2OCH_3)_2$, $CH_3Si(CH_3COO)_3$, methyl-diethylchlorosilane, butyl-trichlorosilane, diphenyl-dichlorosilane, vinyl-trichlorosilane, methyl-trimethoxysilane, vinyl-triethoxysilane,

vinyltris(methoxyethoxy)silane, methacryloxypropyltrimethoxysilane, glycidoxypropyltrimethoxysilane, aminopropyltriethoxysilane, divinyl-di-2-methoxysilane, ethyltributoxysilane, isobutyltrimethoxysilane, hexyltrimethoxysilane, n-octyltriethoxysilane, dihexyldimethoxysilane; trichloro-octadecylsilane, 3-(trimethoxysilyl)propyldimethyloctadecyl ammonium chloride, 3-(trimethylethoxysilylpropyl)didecylmethyl ammonium chloride and triethoxysilyl soyapropyl dimonium chloride.

18. The composition of claim 1 further comprising a gas.

19. The composition of claim 18, wherein the gas is selected from the group consisting of air, nitrogen, carbon dioxide, methane and mixtures thereof.

20. The composition of claim 1, wherein the oil is selected from the group consisting of a hydrocarbon oil, a silicon oil, kerosene oil, a frac oil and combinations thereof.

21. The composition of claim 1, wherein the particulates are sand or resin coated sand.

22. The composition of claim 1, wherein the chemical compound is selected from the group consisting of an organosilane, an organosiloxane, a fluoro-organosilane, a fluoro-organosiloxane, a fluoro-organic compound and combinations thereof.

23. The composition of claim 1, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic cationic groups, polysiloxanes modified with one or more organic amphoteric groups, polysiloxanes modified with one or more organic anionic groups, amine silanes and combinations thereof.

24. The composition of claim 1, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic cationic groups.

25. The composition of claim 1, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic amphoteric groups.

26. The composition of claim 1, wherein the chemical compound is a fluoro-organic

compound.

27. The composition of claim 1, wherein the chemical compound is a fluoro-organosilane.

28. The composition of claim 1, wherein the chemical compound is selected from the group consisting of 2-(n-perfluoro-octyl)ethyltriethoxysilane, perfluoro-octyldimethylchlorosilane, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_3)_2$, $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_3)_3$, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$ and $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_3$ and $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2(\text{CH}_2)_3\text{NHC}(\text{O})(\text{CF}_2)_6\text{CF}_3\text{Cl}^-$.

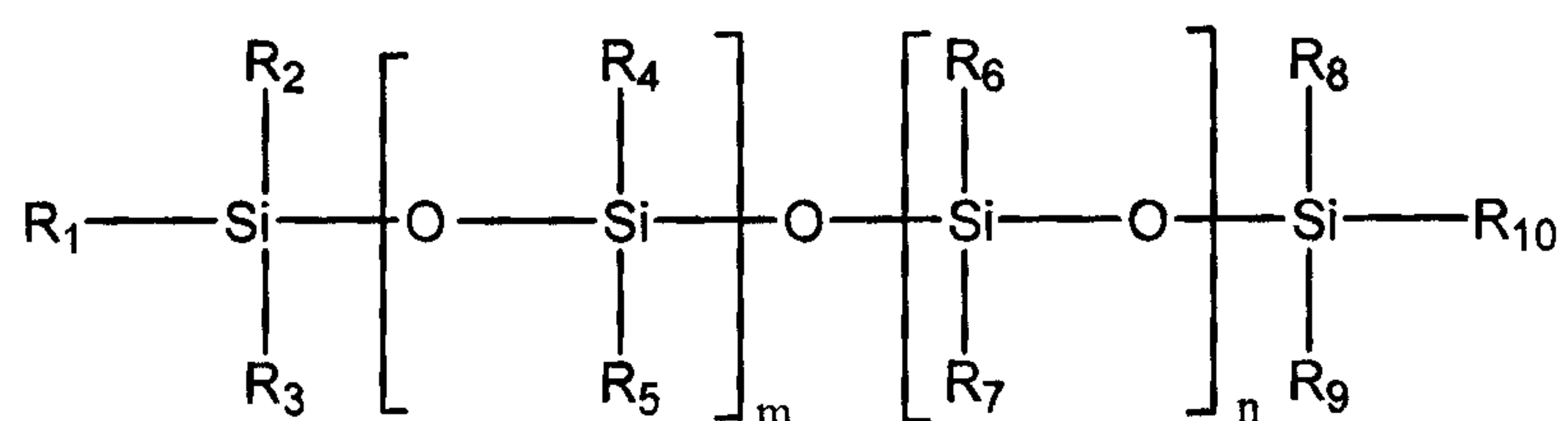
29. The composition of claim 1, wherein the chemical compound is a cationic fluoro-organic compound.

30. The composition of claim 1, wherein the chemical compound is a fluoro-organosiloxane.

31. A method of controlling proppant flowback in a hydrocarbon producing formation comprising the steps of: mixing water, particulates, a chemical compound for rendering the surface of the particulates hydrophobic and an oil; and pumping the mixture into the formation.

32. The method of claim 31, wherein the chemical compound is selected from the group consisting of an organosilane, an organosiloxane, a fluoro-organosilane, a fluoro-organosiloxane and a fluoro-organic compound.

33. The method of claim 32, wherein the chemical compound is an organo-polysiloxane having the formula



wherein each of R_1 to R_6 and R_8 to R_{10} , represents an organic radical containing 1-6 carbon atoms, R_7 represents an organic-amphoteric group for an organic amphoteric polysiloxane or an organic cationic group for an organic cationic polysiloxane, and m and n are from 1 to 200.

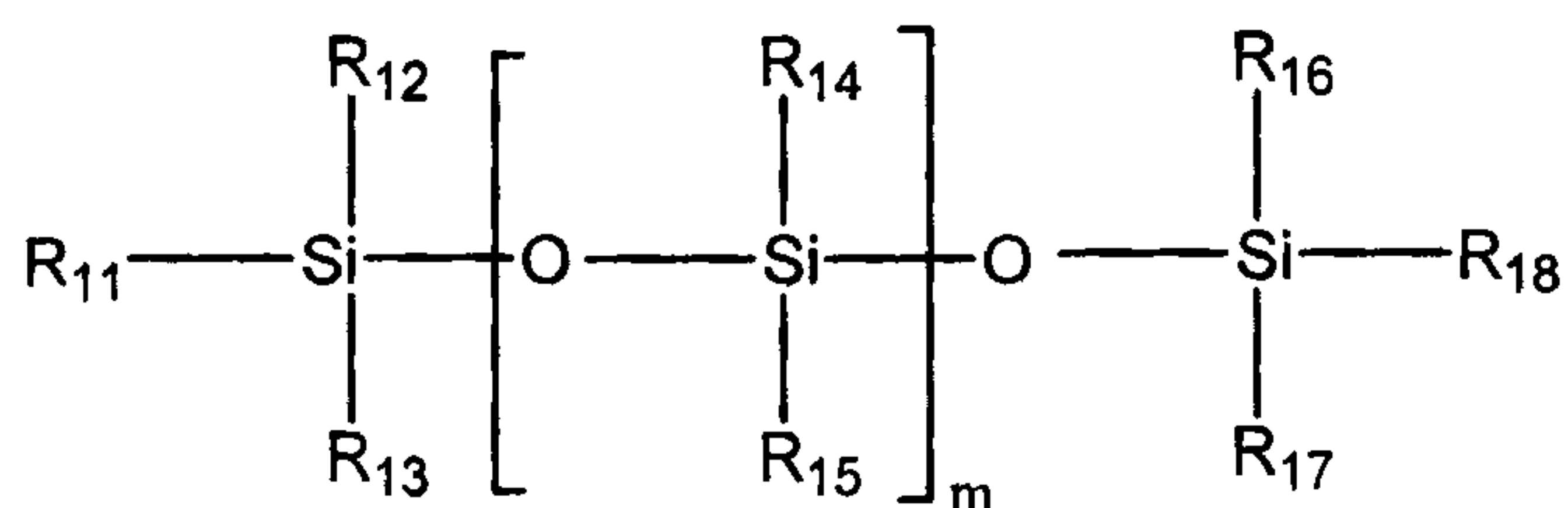
34. The method of claim 33, wherein the particulates are sands.

35. The method of claim 32, wherein the chemical compound is an organosilane having the formula



wherein R is an organic radical having 1-50 carbon atoms, X is a halogen, alkoxy, acyloxy or amine and n has a value of 1-3.

36. The method of claim 32, wherein the chemical compound is an organo-siloxane having the formula



where R_{12} to R_{17} each represents an organic radical containing 1-6 carbon atoms, one of R_{11} , and R_{18} represents an organic amphoteric group and the other of R_{11} and R_{18} represents an organic amphoteric group or an organic radical for a di-betaine polysiloxane or an organic cationic group for a di-cationic polysiloxane, and m is 1 to 200.

37. The method of claim 31, including the step of subjecting the mixture to shear in the presence of a gas.

38. The method of claim 37, wherein the gas is selected from the group consisting of air, nitrogen, carbon dioxide, methane and mixtures thereof.

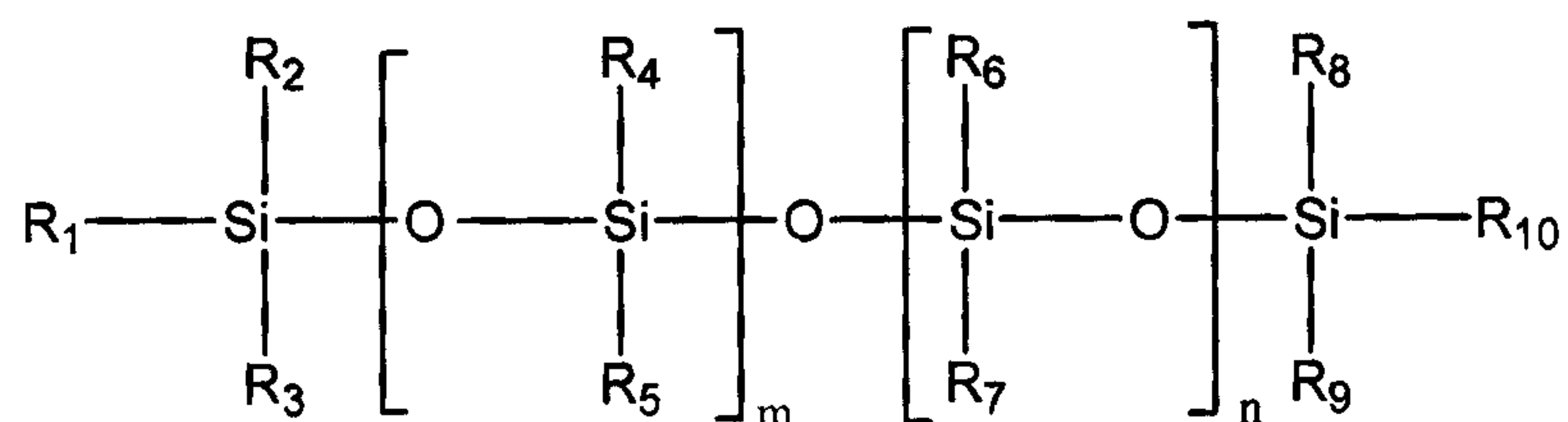
39. The method of claim 31, wherein the particulates are selected from the group consisting of sand, resin coated sand, ceramic, synthetic polymeric beads and bauxite particulates.

40. The method of claim 31, wherein the particulates are sands.

41. The method of claim 31, wherein the oil is selected from the group consisting of a hydrocarbon oil, a silicone oil, kerosene oil, a frac oil and combinations thereof.

42. The method of claim 31, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic cationic groups.
43. The method of claim 31, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic amphoteric groups.
44. The method of claim 31, wherein the chemical compound is a fluoro-organic compound.
45. The method of claim 31, wherein the chemical compound is a fluoro-organosilane.
46. The method of claim 31, wherein the chemical compound is selected from the group consisting of 2-(n-perfluoro-octyl)ethyltriethoxysilane, perfluoro-octyldimethylchlorosilane, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_3)_2$, $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_3)_3$, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$ and $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_3$ and $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2(\text{CH}_2)_3\text{NHC}(\text{O})(\text{CF}_2)_6\text{CF}_3\text{Cl}^-$.
47. The method of claim 31, wherein the chemical compound is a cationic fluoro-organic compound.
48. The method of claim 31, wherein the chemical compound is a fluoro-organosiloxane.
49. The method of claim 31, wherein the chemical compound is an amine silane.
50. A method of controlling proppant flowback in a hydrocarbon producing formation comprising the steps of: contacting particulates with a medium containing a chemical compound to render the surface of the particulates hydrophobic; separating the particulate from the medium; blending the hydrophobic particulate with water and an oil to form a mixture; and pumping the mixture into the formation.

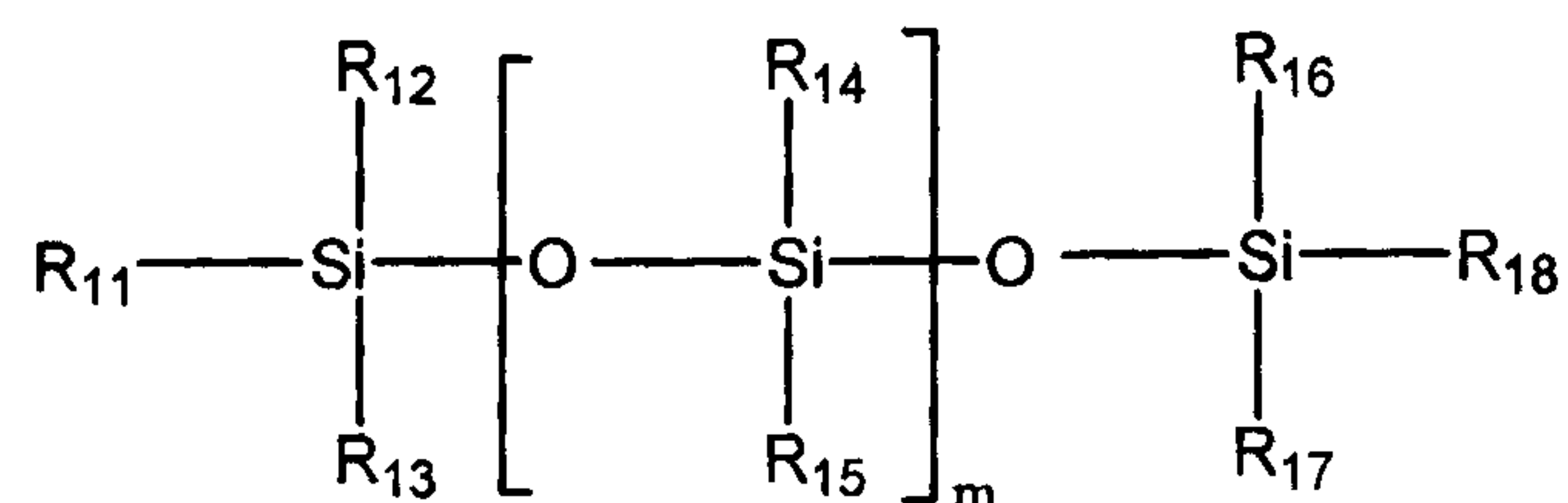
51. The method of claim 50, wherein the chemical compound is an organo-polysiloxane having the formula



wherein each of R₁ to R₆ and R₈ to R₁₀, represents an organic radical containing 1-6 carbon atoms, R₇ represents an organic amphoteric group for an organic amphoteric polysiloxane or an organic cationic group for an organic cationic polysiloxane, and m and n are from 1 to 200.

52. The method of claim 51, wherein the particulates are sands.

53. The method of claim 50, wherein the chemical compound is an organo-siloxane having the formula



where R₁₂ to R₁₇ each represents an organic radical containing 1-6 carbon atoms, one of R₁₁ and R₁₈ represents an organic amphoteric group and the other of R₁₁ and R₁₈ represents an organic amphoteric group or an organic radical for a di-betaine polysiloxane or one of R₁₁ and R₁₈ represents an organic cationic group and the other of R₁₁ and R₁₈ represents an organic cationic group or an organic radical for a di-cationic polysiloxane, and m is 1 to 200.

54. The method of claim 50, including the step of subjecting the mixture to shear in the presence of a gas.

55. The method of claim 50, wherein the gas is selected from the group consisting of air, nitrogen, carbon dioxide, methane and mixtures thereof.

56. The method of claim 50, wherein the particulates are sands.
57. The method according to claim 50, wherein the oil is selected from the group consisting of a hydrocarbon oil, a silicone oil, kerosene oil, a frac oil and combinations thereof.
58. The method of claim 50, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic cationic groups.
59. The method of claim 50, wherein the chemical compound is selected from the group consisting of polysiloxanes modified with one or more organic amphoteric groups.
60. The method of claim 50, wherein the chemical compound is a fluoro-organic compound.
61. The method of claim 50, wherein the chemical compound is a fluoro-organosilane.
62. The method of claim 50, wherein the chemical compound is a fluoro-organosiloxane.
63. The method of claim 50, wherein the chemical compound is selected from the group consisting of 2-(n-perfluoro-octyl)ethyltriethoxysilane, perfluoro-octyldimethylchlorosilane, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_3)_2$, $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_3)_3$, $(\text{CF}_3\text{CH}_2\text{CH}_2)_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_2$ and $\text{CF}_3\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_2\text{CH}_2\text{OCH}_3)_3$ and $(\text{CH}_3\text{O})_3\text{Si}(\text{CH}_2)_3\text{N}^+(\text{CH}_3)_2(\text{CH}_2)_3\text{NHC}(\text{O})(\text{CF}_2)_6\text{CF}_3\text{Cl}^-$.
64. The method of claim 50, wherein the chemical compound is a cationic fluoro-organic compound.
65. The method of claim 50, wherein the chemical compound is an amine silane.