OPIC
Office de la propriété intellectuelle du Canada

CIPO
Canadian Intellectual Property Office

(12) (19) (CA) **Brevet-Patent**

(11) (21) (C) **2,136,632**

(86) 1993/05/24
(87) 1993/12/09
(45) 2001/04/17

(72) Jenkins, Richard Duane, US
(72) Bassett, David Robinson, US
(72) Lightfoot, Richard Hall, US
(72) Boluk, Mehmet Yaman, CA
(73) UNION CARBIDE CHEMICALS AND PLASTICS TECHNOLOGY CORPORATION, US

(51) Int.Cl.^{5} C09K 3/18
(30) 1992/05/29 (887,643) US

(54) **LIQUIDES ANTI-GIVRAGE POUR AERONEFS**
(54) **AIRCRAFT ANTI-ICING FLUIDS THICKENED BY ASSOCIATIVE POLYMERS**

(57) An anti-icing fluid suitable for ground treatment of aircraft, being a glycol-based, aqueous solution containing a hydrophobe-bearing, macromonomer-containing polymer thickener in an amount of less than about 5 weight %. Thickening occurs predominantly by association among hydrophobe groups. Thickening may be enhanced by addition of a surfactant or other materials which act as co-thickeners. Use of this thickened fluid does not adversely affect airfoil lift characteristics during takeoff, because the fluid exhibits shear thinning and readily flows off the aircraft surfaces when exposed to wind shear during the air-craft's takeoff run.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : C08F 246/00, 220/28, 220/04 C09K 3/18	A1	(11) International Publication Number: WO 93/24543 (43) International Publication Date: 9 December 1993 (09.12.93)

(21) International Application Number: PCT/US93/04865

(22) International Filing Date: 24 May 1993 (24.05.93)

(30) Priority data:
887,643 29 May 1992 (29.05.92) US

(71) Applicant: UNION CARBIDE CHEMICALS & PLASTICS TECHNOLOGY CORPORATION [US/US]; 39 Old Ridgebury Road, Danbury, CT 06817-0001 (US).

(72) Inventors: JENKINS, Richard, Dean; 309 Fletcher Lane, Hurrican, WV 25526 (US).BASSETT, David, Robinson; 2018 Huber Road, Charleston, WV 25314 (US). LIGHTFOOT, Richard, Hall; 301 E. 75 Street - Apt. 9G, New York, NY 10021 (US). BOLUK, Mehmut, Yaman; 2275 Belgrave Avenue, Montreal, Quebec H4A 2L9 (CA).

(74) Agent: JOHNSON, Karen, L.; Union Carbide Chemicals & Plastics, Technology Corporation, 39 Old Ridgebury Road, Danbury, CT 06817-0001 (US).

(81) Designated States: AU, BB, BG, BR, CA, FI, HU, JP, KP, KR, LK, MG, MN, MW, NO, NZ, PL, RO, RU, SD, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

2136632

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: AIRCRAFT ANTI-ICING FLUIDS THICKENED BY ASSOCIATIVE POLYMERS

(57) Abstract

An anti-icing fluid suitable for ground treatment of aircraft, being a glycol-based, aqueous solution containing a hydrophobe-bearing, macromonomer-containing polymer thickener in an amount of less than about 5 weight %. Thickening occurs predominantly by association among hydrophobe groups. Thickening may be enhanced by addition of a surfactant or other materials which act as co-thickeners. Use of this thickened fluid does not adversely affect airfoil lift characteristics during takeoff, because the fluid exhibits shear thinning and readily flows off the aircraft surfaces when exposed to wind shear during the aircraft's takeoff run.

AIRCRAFT ANTI-ICING FLUIDS THICKENED BY ASSOCIATIVE POLYMERS

Brief Summary of the Invention

Technical Field

This invention relates to glycol-based aircraft anti-icing fluids (AAFs) which are thickened with certain polymers containing hydrophobe-bearing macromonomers which thicken the AAF via an associative mechanism.

Background of the Invention

Aircraft that are either parked on the ground or are on the ground between flights can accumulate snow, ice, freezing rain or frost on the aircraft surfaces in cold winter weather. The presence of such deposits, particularly on airfoil surfaces, is a generally unsafe airfoil condition in that it hampers and can thwart liftoff, or at least is highly undesirable during takeoff and early flight periods since even small accumulations can result in severe deterioration of the airfoil aero-dynamic performance characteristics, occasionally causing crashes on takeoff/liftoff resulting in loss of life.

Glycols have long been used in aqueous solutions of various strengths that are sprayed onto the aircraft, as a deicing agent, to remove snow, ice, freezing rain and frost deposits from aircraft surfaces. After this treatment, the glycol fluid desirably remains as a film coating on the aircraft surfaces, to serve as an anti-icing agent that provides continued antifreeze protection and delays the further formation or accretion of snow, ice, freezing rain or frost deposits on the aircraft surfaces. The same glycol-based fluid, in various concentrations, may be used for both deicing and anti-icing functions.

Glycol-based fluids for anti-icing, however, typically contain a thickening agent and desirably possess the following attributes (none of which preclude its use as a deicer):

(i) formation of an essentially continuous film coating, after its application by conventional spraying devices, even on non-horizontal aircraft surfaces critical to the aircraft's aero-dynamic performance during takeoff/liftoff such as the vertical tail fin and the smoothness of the fuselage surfaces;

(ii) extended, long-term protective anti-icing action; and

(iii) viscosity and rheology characteristics that promote formation of an effective tenacious protective film coating, yet enable the fluid coating to flow off the aircraft airfoil surfaces during takeoff, prior to aircraft rotation.

AAFs of the prior art are thickened typically with very large molecules (e.g., xanthan gum or various organic polymers) which thicken by molecular entanglement and intermolecular friction. Such thickeners are deficient in that they do not provide optimal non-Newtonian behavior (i.e., their viscosity may not decrease sufficiently rapidly and/or extensively under wind-shear forces) for use under all weather conditions and on relatively slow-moving turboprop aircraft. Moreover, such thickeners are subject to undue degradation of viscosity as a result of severe shear forces imposed by the spraying nozzles used to apply the AAF to the aircraft.

This invention is based on the unexpected discovery that certain macromonomer-containing polymeric thickeners which thicken by association among hydrophobes possess particular efficacy as thickeners for glycol-based aircraft anti-icing fluids.

Disclosure of the Invention

In accordance with this invention, an anti-icing fluid suitable for ground treatment of aircraft is provided which is a glycol-based solution thickened essentially with a hydrophobe-bearing, macromonomer-containing polymer in an amount of less than about 5 weight %. The macromonomer-containing polymer is present in the anti-icing fluid in an amount sufficient to thicken the fluid to promote its adherence to aircraft surfaces when applied to a stationary aircraft but also allow for its wind shear-induced removal during the takeoff run prior to rotation.

Accordingly, the present invention provides an aircraft anti-icing fluid comprising, in admixture, a glycol, water, and a hydrophobe-bearing, alkali-swellable, polymeric thickener which thickens principally by an inter-molecular associative mechanism among hydrophobe groups, said fluid being sufficiently viscous to adhere to the airfoil surfaces of an aircraft at rest, but becoming sufficiently fluid under the influence of wind shear forces to flow off the airfoil surfaces when they are at or near take-off speed. Preferably, the thickener comprises a carboxylic backbone to which the hydrophobes are attached by flexible, pendant chains, particularly wherein the flexible, pendant chains comprise one or more hydrophilic polymers. It is also desirable that the flexible, pendant chains are sufficiently long to place the hydrophobes beyond the carboxyl environment of the backbone. While the thickeners of this invention are capable of considerable variation in molecular weight, depending upon their molecular constituency (and indeed that is one of their advantages), it is preferred that each repeating unit have a molecular weight of no more than about 6,000, preferably no more than about 3,000.

The properties of the present AAF may also be advantageously expressed in accordance with airline standard tests for performance: Water spray encurance time, and boundary layer displacement thickness. Accordingly, the present invention provides an AAF wherein the water spray endurance time is at least about 30 minutes, preferably at least about 40 minutes, but wherein the boundary layer displacement thickness is less than about 8 mm, preferably less than about 6 mm, at -20 C.

The invention further provides a method for thickening a glycol/water anti-icing fluid comprising admixing with said fluid a thickener of this invention. In addition, the invention includes a method for providing anti-icing protection to aircraft comprising applying to the airfoil surfaces of the aircraft an AAF containing a thickener of this invention.

The thickeners of this invention are preferably derived from polymerizable carboxylic acids with which have been co-polymerized hydrophobe-bearing macromonomers. Thus, the preferred macromonomer-containing polymers useful in this invention comprise:

(A) about 1-99.9, preferably about 10-70, weight percent of one or more alpha, beta-mono- ethylenically unsaturated carboxylic acids, typically methacrylic acid;

(B) about 0-98.9, preferably about 30-85, weight percent of one or more monoethylenically unsaturated monomers, typically ethyl acrylate;

(C) about 0.1-99, preferably about 5-60, weight percent of one or more monoethylenically unsaturated macromonomers; and

(D) about 0-20, preferably about 0-10, weight percent or greater of one or more polyethylenically unsaturated monomers, typically trimethylol propane triacrylate.

The macromonomer portion preferably comprises at least about 5% weight percent of the polymer.

The anti-icing fluid is preferably an Association of European Airlines AEA-Type II de/anti-icing fluid, thickened with a macromonomer- containing polymer in an amount of less than about 5 weight %. The macromonomer-containing polymer thickener is desirably present in an amount of from about 0.05 to 3 weight %, more preferably from about 0.1 to 1 weight %.

The glycol component of the glycol-based fluid is preferably ethylene glycol, either alone or in combination with other glycols like diethylene glycol or propylene glycol. The glycol component of the aqueous anti-icing fluid is desirably present in an amount of at least about 40 weight %, preferably from about 50-95 weight %.

Detailed Description

Aircraft Anti-Icing Fluids (AAFs) prevent ice, snow, freezing rain and the like forms of frozen precipitations/accumulations from adhering to clean planes after de-icing. A typical aircraft anti-icing fluid is composed of an alkaline ethylene glycol and water solvent mixtures (roughly equal parts on a weight basis; the pH is about 8.5) that contains ionic corrosion inhibitors, rheology modifiers, and surfactants that promote wetting of the fluid on the aircraft during spray application. Common rheology modifiers used in aircraft anti-icing fluids include cross-linked polyacrylates, carboxypolymethy-lene, and polysaccharides (xanthan gum and Carrageenan). Airlines that operate in Europe and Canada, where hoary-frost hinders wintertime airline operations, use these fluids.

The ideal thickener gels the AAF at rest to prevent the accumulation of rain water and ice on the bare airfoil after de-icing, and to promote the adhesion of the fluid to vertical surfaces. To minimize lift loss, the AAF dramatically thins under shear so that it flows readily off the aircraft wing during the takeoff run prior to rotation -- rotation is the point at which the airfoil lift is sufficient for the pilot to take-off -- which corresponds to a shear stress of on the order of about 10 Pa. AAF viscosity should not vary significantly with temperature change or water dilution: a viscosity that doesn't change, or that increases slightly, with water dilution correlates with hold-over time -- the length that the plane can last in bad weather needing another de-icing treatment.

The glycol-based anti-icing fluid of this invention, along with its desirable performance characteristics, may be obtained with most conventional glycol-based fluids via use of the macromonomer-containing polymer as a fluid thickener. The macromonomer-containing polymer is intended for use as the primary thickener in conventional glycol-based anti-icing fluids for aircraft usage. Aircraft anti-icing fluids referred to as Association of European Airlines (AEA) Type II fluids contain a thickener, and the macromonomer-containing polymers described herein are especially well suited for use as thickeners in these fluids.

Glycol-based deicing and anti-icing fluids are well known having been used for aircraft deicing and anti-icing applications for decades. The primary component of the fluid, which provides its deicing and anti-icing properties, is a water-soluble glycol compound. The glycol-based fluids typically contain one or more glycols selected from ethylene glycol, propylene glycol, and diethylene glycol, including mixtures thereof. Other glycols or polyols with freezing point depressant properties may also be used, along with the above-noted glycols or in lieu of them.

A preferred fluid formulation contains ethylene glycol as the major glycol component, desirably at least about 80 weight % ethylene glycol. Propylene glycol and/or diethylene glycol may also be present in the glycol-based fluid. Diethylene glycol, in combination with propylene glycol, is another glycol formulation that is suitable for use in this invention. The choice and relative amounts of specific glycols present in the glycol-based fluid will depend on the particular anti-icing, antifreeze properties desired for the fluid, e.g., freezing point characteristics, pour point, etc.

The anti-icing fluid is an aqueous solution, i.e., ethylene glycol or other suitable glycol that is diluted with water. The glycol should be present in the aqueous solution in an amount of at least about 40 weight %, and preferably is present in an amount of at least about 50 weight %, up to about 95 weight %. The combined glycol and water components of the fluid preferably constitute at least about 90 weight % of the total composition and more preferably at least about 95 weight % of the total composition.

The amount of glycol is desirably sufficient to yield a freezing point for the fluid that is less than about -10°C, more preferably, less than about -30°C.

Illustrative macromonomer-containing polymers useful in this invention and processes for preparation thereof are disclosed in U.S. Patent No. 5,292,843.

A large proportion of one or more alpha, beta-monoethylenically unsaturated carboxylic acid monomers can be present in the polymers useful in this invention. Various carboxylic acid monomers can be used, such as acrylic acid, methacrylic acid, ethacrylic acid, alpha-chloroacrylic acid, crotonic acid, fumaric acid, citraconic acid, mesaconic acid, itaconic acid, maleic acid and the like, including mixtures thereof. Methacrylic acid is preferred, particularly in concentrations of at least about 40% by weight of the polymer. A large proportion of carboxylic acid monomer is desirable to provide a polymeric structure which will swell or dissolve and provide a thickener when reacted with an alkali, e.g., sodium hydroxide.

The polymers useful in this invention can also contain a significant proportion of one or more monoethylenically unsaturated monomers. The preferred monomers provide water-insoluble polymers when homopolymerized and are illustrated by acrylate and methacrylate esters, such as ethyl acrylate, butyl acrylate or the corresponding methacrylate. Other monomers which can be used are styrene, alkyl styrenes, vinyl toluene, vinyl acetate, vinyl alcohol, acrylonitrile, vinylidene chloride, vinyl ketones and the like. Nonreactive monomers are preferred, those being monomers in which the single ethylenic group is the only group reactive under the conditions of polymerization. However, monomers which include groups reactive under baking conditions or with divalent metal ions such as zinc oxide may be used in some situations, like hydroxyethyl acrylate.

Other illustrative monoethylenically unsaturated monomers useful in this invention include, for example, propyl methacrylate, isopropyl methacrylate, butyl methacrylate, n-amyl methacrylate, sec-amyl methacrylate, hexyl methacrylate, lauryl methacrylate, stearyl methacrylate, ethyl hexyl methacrylate, crotyl methacrylate, cinnamyl methacrylate, oleyl methacrylate, ricinoleyl methacrylate, hydroxy ethyl methacrylate, hydroxy propyl methacrylate, vinyl propionate, vinyl butyrate, vinyl tert-butyrate, vinyl caprate, vinyl stearate, vinyl laurate, vinyl oleate, vinyl methyl ether, vinyl ethyl ether, vinyl n-propyl ether, vinyl iso-propyl ether, vinyl n-butyl ether, vinyl iso-butyl ether, vinyl iso-octyl ether, vinyl phenyl ether, α–chlorovinyl phenyl ether, vinyl β-naphthyl ether, methacryonitrile, acrylamide, methacrylamide, N-alkyl acrylamides, N-aryl acrylamides, N-vinyl pyrrolidone, N-vinyl-3-morpholinones, N-vinyl-oxazolidone, N-vinyl-imidazole and the like including mixtures thereof.

The macromonomers useful in this invention can be represented by the formula:

$$R^1\text{-}(OR^2)_z\text{-}R^3\text{-}\overset{\displaystyle R^4}{\overset{|}{C}}\text{=}CR^5R^6 \qquad \text{(I)}$$

wherein:

R^1 is a monovalent residue of a substituted or unsubstituted complex hydrophobe compound;

each R^2 is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue;

R^3 is a substituted or unsubstituted divalent hydrocarbon residue;

R^4, R^5 and R^6 are the same or different and are hydrogen or a substituted or unsubstituted monovalent hydrocarbon residue; and

z is a value of 0 or greater.

The macromonomer compounds useful in this invention can be prepared by a number of conventional processes, except for inclusion of the complex hydrophobe compounds described herein. Illustrative processes are described, for example, in U.S. Patent Nos. 4,514,552, 4,600,761, 4,569,965, 4,384,096, 4,268,641, 4,138,381, 3,894,980, 3,896,161, 3,652,497, 4,509,949, 4,226,754, 3,915,921, 3,940,351, 3,035,004, 4,429,097, 4,421,902, 4,167,502, 4,764,554, 4,616,074, 4,464,524, 3,657,175, 4,008,202, 3,190,925, 3,794,608, 4,338,239, 4,939,283 and 3,499,876. Other macromonomer compounds which may be useful in this invention include complex hydrophobe-bearing oligomers disclosed in U.S. Patent No. 5,739,378.

Illustrative substituted and unsubstituted divalent hydrocarbon residues represented by R^2 in formula I above include those described for the same type of substituents in formulae (i) and (ii) below. Illustrative substituted and unsubstituted monovalent hydrocarbon residues represented by R^4, R^5 and R^6 in formula I above include those described for the same type of substituents in formulae (i) and (ii) below.

Illustrative R^3 substituents include, for example, the organic residue of ethers, esters, urethanes, amides, ureas, urethanes, anhydrides and the like including mixtures thereof. The R^3 substituent can be generally described as a "linkage" between the complex hydrophobe-bearing surfactant or alcohol, and the unsaturation portion of the macromonomer compound. Preferred linkages include the following: urethane linkages from the reaction of an isocyanate with a hydroxyl-bearing surfactant; urea linkages from the reaction of an isocyanate with an amine-bearing surfactant; unsaturated esters of surfactants such as the esterification product of a surfactant with an unsaturated carboxylic acid or an unsaturated anhydride; unsaturated esters of alcohols; esters of ethyl acrylate oligomers, acrylic acid oligomers, and allyl-containing oligomers; half-esters of surfactants such as those made by the reaction of a surfactant with maleic anhydride; unsaturated ethers prepared by reacting vinyl benzyl chloride and a surfactant or by reacting an allyl glycidyl ether with a surfactant, alcohol, or carboxylic acid.

The oxyalkylene moieties included in the macromonomer compounds (I) may be homopolymers or block or random copolymers of straight or branched alkylene oxides. Mixtures of alkylene oxides such as ethylene oxide and propylene oxide may be employed. It is understood that each R^2 group in a particular substituent for all positive values of z can be the same or different. While ethylene oxide is preferred, it has been observed that large amounts of ethylene oxide may have a detrimental effect on the thermal and/or dilution stability of the thickened AAF.

The complex hydrophobe compounds having at least one active hydrogen useful in preparing the macromonomer compounds useful in this invention can be represented by the formula:

$$\begin{array}{l} R_1\text{-}(O\text{-}CH_2)_a \\ \qquad\qquad\qquad \diagdown \\ \qquad\qquad\qquad\quad R_3\text{-}(OR_4)_x\text{-}(OR_5)_y\text{-}OR_6 \\ \qquad\qquad\qquad \diagup \\ R_2\text{-}(O\text{-}CH_2)_b \end{array} \qquad (i)$$

wherein R_1 and R_2 are the same or different and are hydrogen or a substituted or unsubstituted monovalent hydrocarbon residue, R_3 is a substituted or unsubstituted divalent or trivalent hydrocarbon residue, each R_4 is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, each R_5 is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, R_6 is hydrogen, a substituted or unsubstituted monovalent hydrocarbon residue or an ionic substituent, a and b are the same or different and are a value of 0 or 1, and x and y are the same or different and are a value of 0 or greater; provided at least two of R_1,

R_2, R_3, R_4, R_5 and R_6 are a hydrocarbon residue having greater than 2 carbon atoms in the case of R_1, R_2 and R6 or having greater than 2 pendant carbon atoms in the case of R_3, R_4 and R_5.

Other complex hydrophobe compounds having at least one active hydrogen useful in preparing the macromonomer compounds useful in this invention can be represented by the formula:

$$\begin{array}{c} R_7\text{-}(OCH_2)_d\text{-}R_9\text{-}(OR_{10})_f\text{-}OR_{11} \\ | \\ R_{15} \\ | \\ R_8\text{-}(OCH_2)_e\text{-}R_{12}\text{-}(OR_{13})_g\text{-}OR_{14} \end{array} \qquad \text{(ii)}$$

wherein R_7 and R_8 are the same or different and are hydrogen or a substituted or unsubstituted monovalent hydrocarbon residue, R_{11} and R_{14} are the same or different and are hydrogen, a substituted or unsubstituted monovalent hydrocarbon residue or an ionic substituent, R_9 and R_{12} are the same or different and are a substituted or unsubstituted divalent or trivalent hydrocarbon residue, each R_{10} is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, each R_{13} is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, R_{15} is a substituted or unsubstituted divalent hydrocarbon residue, d and e are the same or different and are a value of 0 or 1, and f and g are the same or different and are a value of 0 or greater; provided at least two of R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14} and R_{15} are a hydrocarbon residue having greater than 2 carbon atoms in the case of R_7, R_8, R_{11} and R_{14} or having greater than 2 pendant carbon atoms in the case of R_9, R_{10}, R_{12}, R_{13} and R_{15}.

Illustrative substituted and unsubstituted monovalent hydrocarbon residues contain from 1 to about 50 carbon atoms or

2136632

greater and are selected from alkyl radicals including linear or branched primary, secondary or tertiary alkyl radicals, such as methyl, ethyl, n-propyl, isopropyl, amyl, sec-amyl, t-amyl, 2-ethylhexyl and the like; aryl radicals such as phenyl, naphthyl and the like; arylalkyl radicals such as benzyl, phenylethyl, tri-phenylmethylethane and the like; alkylaryl radicals such as octylphenyl, nonylphenyl, dodecylphenyl, tolyl, xylyl and the like; and cycloalkyl radicals such as cyclopentyl, cyclohexyl, cyclohexylethyl and the like. The permissible hydrocarbon residues may contain fluorine, silicon, or other non-carbon atoms.

Preferably, the substituted and unsubstituted hydrocarbon residues are selected from alkyl and aryl radicals which contain from about 1 to 30 carbon atoms or greater. More preferably, the alkyl radicals contain from 1 to 18 carbon atoms, while the aryl, arylalkyl, alkylaryl and cycloalkyl radicals preferably contain from 6 to 18 carbon atoms or greater.

In a preferred embodiment of this invention, R_1, R_2, R_7 and R_8 can individually be a hydrocarbon radical represented by the formula:

$$\begin{array}{l} R_{16}\text{-}(OCH_2)_h \diagdown \\ \qquad\qquad\qquad\quad R_{18}\text{-} \\ R_{17}\text{-}(OCH_2)_i \diagup \end{array} \qquad \text{(iii)}$$

wherein R_{16} and R_{17} are as defined for R_1, R_2, R_7 and R_8 above, h and i are the same or different and are a value of 0 or 1, and R_{18} is as defined for R_3 above. For compounds represented by formulae (i) and (ii), it is understood that each formula (iii) radical in a given compound may be the same or different and the R_{16} and/or R_{17} groups may themselves be a formula (iii) radical to provide complex hydrophobes of a dendritic or of a cascading nature as described below. Further, R_4, R_5, R_{10} and R_{13} can individually be a hydrocarbon radical represented by the formula:

$$-CH[(OR_{19})_jOR_{20}]- \qquad (iv)$$

wherein R_{19} is as defined for R_4, R_5, R_{10} and R_{13} above, R_{20} is as defined for R_6, R_{11} and R_{14} above, and j is a value of 0 or greater.

Illustrative ionic substituents for R_6, R_{11}, R_{14} and R_{20} include cationic and anionic substituents such as sulfates, sulfonates, phosphates and the like. R_6, R_{11}, R_{14} and R_{20} may preferably be an organic residue containing 1 or more hydroxyls or nitrogen derivatives or epoxides or other reactive groups which may or may not contain unsaturation.

Other illustrative terminal groups which are described by R_6, R_{11}, R_{14} and R_{20} include, for example, hydrocarbon residues which may contain allylic or vinylic unsaturation, acrylic or methacrylic functionality, styryl or alpha-methylstyryl functionality, and the like, such as the reaction product between the terminal alcohol (R_6, R_{11}, R_{14} and R_{20} = H) and glycidyl methacrylate, isocyanatoethyl methacrylate, alpha, alpha-dimethyl-m-isopropenyl benzyl isocyanate (m-TMI), and the like. Other examples of terminal groups may include hydrocarbon residues of alkyl, aryl, aralkyl, alkaryl, and cycloalkyl radicals which may or may not be substituted with one or more of the following: hydroxyl, carboxyl, isocyanato, amino, mono- or disubstituted amino, quaternary ammonium, sulfate, sulfonate, phosphate, epoxy, and the like and may or may not contain other non-carbon atoms including silicon or fluorine. Also included can be divalent siloxy radicals. Other nonhydrocarbon terminal groups may include sulfates, phosphates, and the like.

Illustrative divalent hydrocarbon residues represented by R_3, R_4, R_5, R_9, R_{10}, R_{12}, R_{13}, R_{15}, R_{18} and R_{19} in the above formulae include substituted and unsubstituted radicals selected from alkylene, -alkylene-oxy-alkylene-, -arylene-oxy-arylene-, arylene, alicyclic radicals, phenylene, naphthylene, -phenylene-$(CH_2)_m(Q)_n(CH_2)_m$-phenylene- and -naphthylene-$(CH_2)_m(Q)_n(CH_2)_m$-naphthylene- radicals, wherein Q individually represents a substituted or unsubstituted divalent bridging group selected from -$CR_{21}R_{22}$-, -O-, -S-, -NR_{23}-, -$SiR_{24}R_{25}$- and -CO-, wherein R_{21} and R_{22} individually represent a radical selected from hydrogen, alkyl of 1 to 12 carbon atoms, phenyl, tolyl and anisyl; R_{23}, R_{24} and R_{25} individually represent a radical selected from hydrogen and methyl, and each m and n individually have a value of 0 or 1. More specific illustrative divalent radicals represented by R_3, R_4, R_5, R_9, R_{10}, R_{12}, R_{13}, R15, R18 and R_{19} include, e.g., 1,1-methylene, 1,2-ethylene, 1,3-propylene, 1,6-hexylene, 1,8-octylene, 1,12-dodecylene, 1,4-phenylene, 1,8-napthylene, 1,1'-biphenyl-2,2'-diyl, 1,1'-binaphthyl-2,2'-diyl, 2,2'-binaphthyl-1,1'-diyl and the like. The alkylene radicals may contain from 2 to 12 carbon atoms or greater, while the arylene radicals may contain from 6 to 18 carbon atoms or greater. Preferably, R_3, R_4, R_5, R_9, R_{10}, R_{12}, R_{13}, R_{15}, R_{18} and R_{19} are an alkylene or arylene radical. The permissible divalent hydrocarbon residues may contain fluorine, silicon, or other non-carbon atoms.

Illustrative trivalent hydrocarbon residues represented by R_3, R_9, R_{12} and R_{18} in the above formulae include substituted and unsubstituted radicals selected from

```
\      \        \
 CH-, C(R26)-, CR27-
/      /        /
```

and the like, wherein R_{26} is a substituted or unsubstituted monovalent hydrocarbon residue as described herein and R_{27} is a substituted or unsubstituted divalent hydrocarbon residue as described herein.

2136632

Of course, it is to be further understood that the hydrocarbon residues in the above formulae may also be substituted with any permissible substituent. Illustrative substituents include radicals containing from 1 to 18 carbon atoms such as alkyl, aryl, aralkyl, alkaryl and cycloalkyl radicals; alkoxy radicals; silyl radicals such as $-Si(R_{28})_3$ and $-Si(OR_{28})_3$, amino radicals such as $-N(R_{28})_2$; acyl radicals such as $-C(O)R_{28}$; acyloxy radicals such as $-OC(O)R_{28}$; carbonyloxy radicals such as $-COOR_{28}$; amido radicals such as $-C(O)N(R_{28})_2$ and $-N(R_{28})COR_{28}$; sulfonyl radicals such as $-SO_2R_{28}$; sulfinyl radicals such as $-SO(R_{28})_2$; thionyl radicals such as $-SR_{28}$; phosphonyl radicals such as $-P(O)(R_{28})_2$; as well as halogen, nitro, cyano, trifluoromethyl and hydroxy radicals and the like, wherein each R_{28} can be a monovalent hydrocarbon radical such as alkyl, aryl, alkaryl, aralkyl and cycloalkyl radicals, with the provisos that in amino substituents such as $-N(R_{28})_2$, each R_{28} taken together can also compromise a divalent bridging group that forms a heterocyclic radical with the nitrogen atom, in amido substituents such as $-C(O)N(R_{28})_2$ and $-N(R_{28})COR_{28}$, each R_{28} bonded to N can also be hydrogen, and in phosphonyl substituents such as $-P(O)(R_{28})_2$, one R_{28} can by hydrogen. It is to be understood that each R_{28} group in a particular substituent may be the same or different. Such hydrocarbon substituent radicals could possibly in turn be substituted with a permissible substituent such as already herein outlined above.

Preferred alkylene oxides which can provide random or block oxyalkylene units in the complex hydrophobe compounds represented by formulae (i) and (ii) include alkylene oxides such as ethylene oxide, propylene oxide, 1,2-butylene oxide, 2,3-butylene oxide, 1,2- and 2,3-pentylene oxide, cyclohexylene oxide, 1,2-hexylene oxide, 1,2-octylene oxide, 1,2-decylene oxide, and higher alpha-olefin epoxides; epoxidized fatty alcohols such as epoxidized soybean fatty alcohols and epoxidized linseed fatty alcohols; aromatic epoxides such as styrene oxide and 2-methyl styrene oxide; and hydroxy- and halogen-substituted alkylene oxides such as glycidol, epichlorohydrin and epibromohydrin. The preferred alkylene oxides are ethylene oxide and propylene oxide. Also included can be hydrocarbon residues from substituted and unsubstituted cyclic esters or ethers such as oxetane and tetrahydrofuran. It is understood that the compounds represented by formulae (i) and (ii) herein can contain random and/or block oxyalkylene units as well as mixtures of oxyalkylene units. It is further understood that each R_4, R_5, R_{10}, R_{13} and R_{19} group in a particular substituent for all positive values of x, y, z, f, g and j respectively can be the same or different.

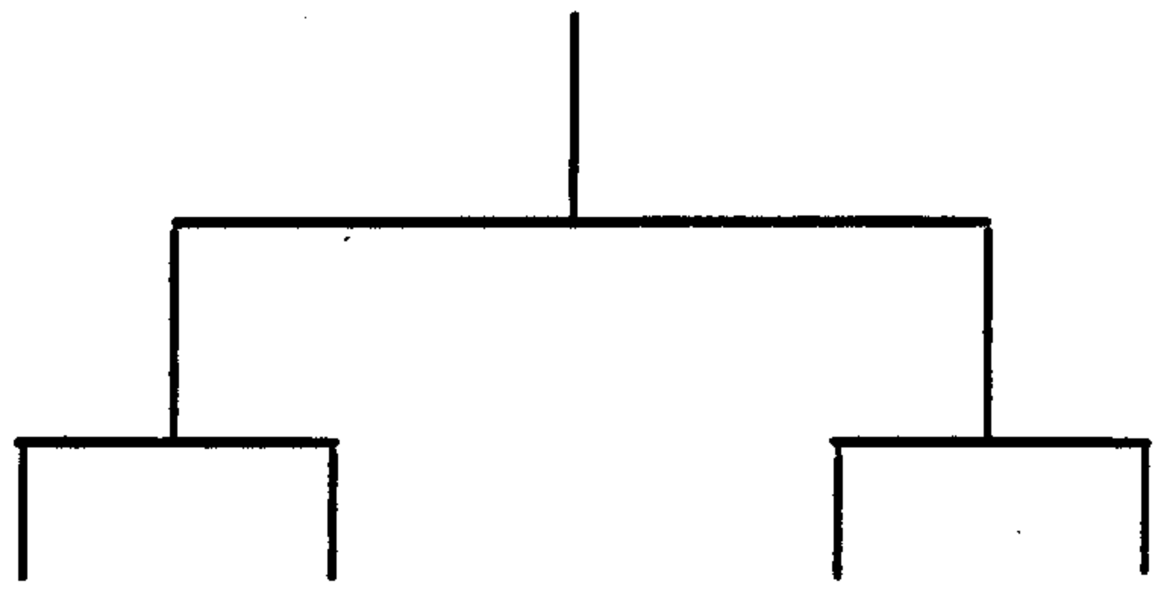
The values of x, y, z, f, g and j are not narrowly critical and can vary over a wide range. For example, the values of x, y, z, f, g and j can range from 0 to about 200 or greater, preferably from about 0 to about-100 or greater, and more preferably from about 0 to about 50 or greater. Any desired amount of alkylene oxide can be employed, for example, from 0 to about 90 weight percent or greater based on the weight of the complex hydrophobe compound.

Referring to the general formulae (i) and (ii) above, it is appreciated that when R^1, R^2, R^7 and/or R^8 are a hydrocarbon residue of formulae (iii) above, the resulting compound may include any permissible number and combination of hydrophobic groups of the dendritic or cascading type. Such compounds included in the above general formulae should be easily ascertainable by one skilled in the art. Illustrative complex hydrophobe compounds having at least one active hydrogen useful in this invention and processes for preparation thereof are disclosed in U.S. Patent No. 5,292,843.

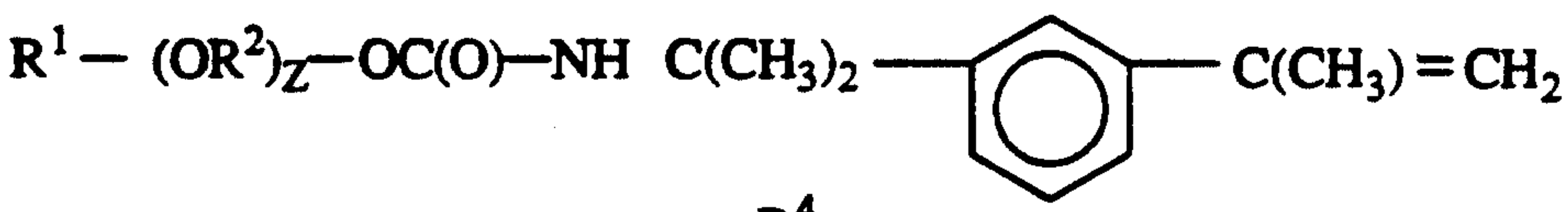
In a preferred embodiment of this invention, the structure shown in formula (iii) can be a residue of the reaction product between epichlorohydrin and an alcohol, including those

2136632

alcohols whose residues can be described by formula (iii), or a phenolic, or a mixture thereof. The structures which result can be described as complex hydrophobes of a dendritic or of a cascading nature. Pictorially, they can be described as shown below:



Preferred macromonomer compounds useful in this invention include those represented by the formulae:



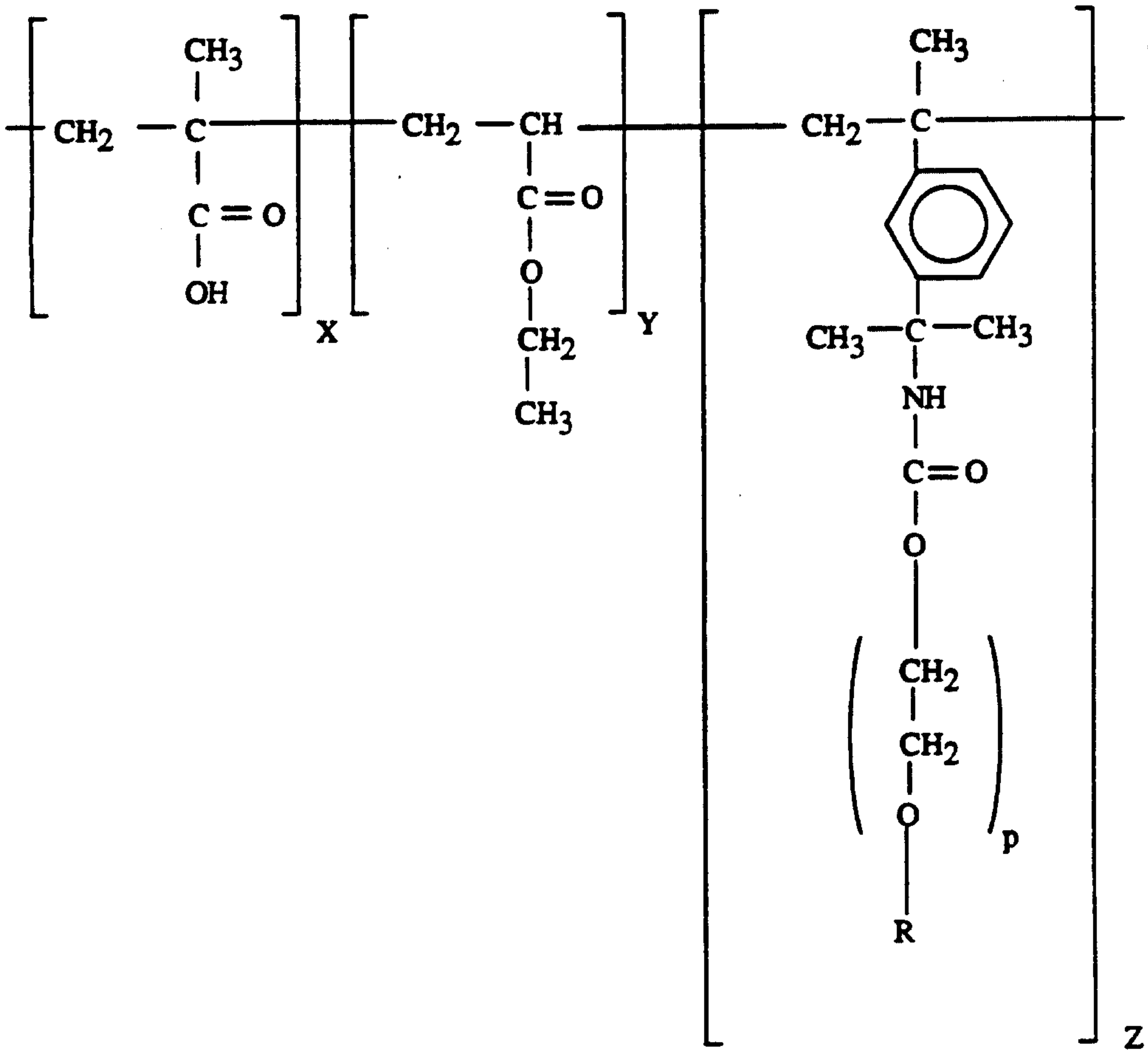
(XII)

$$R^1-(OR^2)_z-CH_2\underset{\displaystyle (OR_{19})_jOH}{\underset{|}{C}}HCH_2OCH_2\overset{\displaystyle R^4}{\overset{|}{C}}=CH_2 \qquad \text{(XIII)}$$

$$R^1-(OR^2)_Z-OC(O)-\overset{\displaystyle R^4}{\overset{|}{C}}=CH_2 \qquad \text{(XIV)}$$

wherein R^1, R^2, R^4, R^{19}, z and j are as defined herein.

A preferred polymeric thickener of this invention conforms to the formula


(XV)

The preferred ranges are as follows: acid monomer X is 10-40%, co-polymerizable non-associative monomer Y is 10-50%, associative monomer Z is 5-30% with p equal to 20-80 moles of ethoxylation (or propoxylation). The hydrophobe R can be an alkaryl, such as nonylphenol or dinonylphenol or may have the following structure:

2136632

$$
\begin{array}{l}
R_1 - O - CH_2 \\
\qquad\qquad\quad | \\
\qquad\qquad\quad CH - \\
\qquad\qquad\quad | \\
R_2 - O - CH_2
\end{array}
$$

where R_1 and R_2 are as previously defined.

The macromonomer compounds useful in this invention can undergo further reaction(s) to afford desired derivatives thereof. Such permissible derivatization reactions can be carried out in accordance with conventional procedures known in the art. Illustrative derivatization reactions include, for example, esterification, etherification, alkoxylation, amination, alkylation, hydrogenation, dehydrogenation, reduction, acylation, condensation, carboxylation, oxidation, silylation and the like, including permissible combinations thereof. This invention is not intended to be limited in any manner by the permissible derivatization reactions or permissible derivatives of macromonomer compounds.

More particularly, the hydroxyl-terminated macromonomer compounds of this invention can undergo any of the known reactions of hydroxyl groups illustrative of which are reactions with acyl halides to form esters; with ammonia, a nitrile, or hydrogen cyanide to form amines; with alkyl acid sulfates to form disulfates; with carboxylic acids and acid anhydrides to form esters and polyesters; with alkali metals to form salts; with ketenes to form esters; with acid anhydrides to form carboxylic acids; with oxygen to form aldehydes and carboxylic acids; ring-opening reactions with lactones, tetrahydrofuran; dehydrogenation to form aldehydes, isocyanates to form urethanes, and the like.

The monoethylenically unsaturated macromonomer component is subject to considerable variation within the formula presented previously. The essence of the maromonomer is a complex hydrophobe carrying a polyethoxylate chain (which may include some polypropoxylate groups) and which is terminated with at least one hydroxy group. When the hydroxy-terminated polyethoxylate complex hydrophobe used herein is reacted with a monoethylenically unsaturated monoisocyanate, for example, the result is a monoethylenically unsaturated urethane in which a complex hydrophobe polyethoxylate structure is associated with a copolymerizable monoethylenic group via a urethane linkage.

The monoethylenically unsaturated compound used to provide the monoethylenically unsaturated macromonomer is subject to wide variation. Any copolymerizable unsaturation may be employed, such as acrylate and methacrylate unsaturation. One may also use allylic unsaturation, as provided by allyl alcohol. These, preferably in the form of a hydroxy-functional derivative, as is obtained by reacting a C^2-C^4 monoepoxide, like ethylene oxide, propylene oxide or butylene oxide, with acrylic or methacrylic acid to form an hydroxy ester, are reacted in equimolar proportions with an organic compound, such as toluene diisocyanate or isophorone diisocyanate. The preferred monoethylenic monoisocyanate is styryl, as in alpha, alpha-dimethyl-m-isopropenyl benzyl isocyanate. Other suitable organic compounds include, for example, monoethylenically unsaturated esters, ethers, amides, ureas, anhydrides, other urethanes and the like.

The polymers useful in this invention can be prepared via a variety of polymerization techniques known to those skilled in the art. The technique of polymerization influences the microstructure, monomer sequence distribution in the polymer backbone and its molecular weight to influence the performance of the polymer. Illustrative polymerization techniques include, for example, conventional and staged emulsion polymerization via batch, semi-continuous, or continuous processes, micellar polymerization, inverse emulsion polymerization, solution polymerization, non-aqueous dispersion polymerization, interfacial polymerization, emulsion polymerization, suspension polymerization, precipitation polymerization, addition polymerizations such as free radical, anionic, cationic or metal coordination methods, and the like.

The thickeners useful in this invention possess structural attributes of two entirely different types of thickeners (those which thicken by alkali swelling or solubilization of a polymeric entity, and those which thicken due to association), and this may account for the superior thickening properties which are obtained herein. It is believed, however, that for purposes of providing the non-Newtonian rheology which is critical to the performance of these thickeners in AAFs, it is the association among hydrophobe groups (and the wind shear-induced disassociation) which is the predominant mechanism.

The aqueous emulsion copolymerization is entirely conventional. To obtain an estimate of thickening efficiency, the product can be diluted with water to about 1% solids content and then neutralized with alkali. The usual alkali is ammonium hydroxide, but sodium and potassium hydroxide, and even amines, like triethylamine, may be used for neutralization. The neutralized product dissolves in the water to provide an increase in the viscosity. In the normal mode of addition, the unneutralized thickener is added to a fluid and then neutralized. This facilitates handling the thickener because it has a lower viscosity before neutralization. This procedure also makes more water available for formulation.

The polymers useful in this invention are typically produced by conventional aqueous emulsion polymerization techniques, using appropriate emulsifiers for emulsifying the monomers and for maintaining the polymer obtained in a suitable, dispersed condition. Commonly used anionic surfactants such as sodium lauryl sulfate, dodecylbenzene sulfonate and ethoxylated fatty alcohol sulfate can be used as emulsifiers. The emulsifier may be used in a proportion of 0.5 to 6% of the weight monomers.

Preferably, water-soluble initiators such as alkali metal or ammonium persulfate are used in amounts from 0.01 to 1.0% on the weight of monomers. A gradual addition thermal process employed at temperatures between 60°C to 100°C is preferred over redox systems.

The polymerization system may contain small amounts (0.01 to 5% by weight, based on monomer weight) of the chain transfer agent mercaptans such as hydroxyethyl mercaptan, ß-mercaptopropionic acid and alkyl mercaptans containing from about 4 to 22 carbon atoms, and the like. The use of mercaptan modifier reduces the molecular weight of the polymer and therefore its thickening efficiency.

The polymers useful in this invention may further be modified by introducing an amount of component (D), namely, one or more polyethylenically unsaturated copolymerizable monomers effective for crosslinking, such as diallylphthalate, divinylbenzene, allyl methacrylate, trimethylol propane triacrylate, ethyleneglycol diacrylate or dimethacrylate, 1,6-hexanediol diacrylate or dimethylacrylate, diallyl benzene, and the like. Thus, from about 0.05 or less to about 20% or greater of such polyethylenically unsaturated compound based on total weight of monomer may be included in the composition forming the polymer. The resulting polymers are either highly branched or in the form of three-dimensional networks. In the neutralized salt form, those networks swell in an aqueous system to act as a highly efficient thickener.

Other illustrative polyethylenically unsaturated monomers useful in this invention include, for example, any copolymerizable compound which contains two or more nonconjugated points of ethylenic unsaturation or two or more nonconjugated vinylidene groups of the structure, $CH_2=C=$, such as divinyltoluene, trivinylbenzene, divinylnaphthalene, trimethylene glycol diacrylate or dimethacrylate, 2-ethylhexane-1,3-dimethyacrylate, divinylxylene, divinylethylbenzene, divinyl ether, divinyl sulfone, allyl ethers of polyhdric compounds such as of glycerol, pentaerythritol, sorbitol, sucrose and resorcinol, divinylketone, divinylsulfide, allyl acrylate, diallyl maleate, diallyl fumarate, diallyl phthalate, diallyl succinate, diallyl carbonate, diallyl malonate, diallyl oxalate, diallyl adipate, diallyl sebacate, diallyl tartrate, diallyl silicate, triallyl tricarballylate, triallyl aconitate, triallyl citrate, triallyl phosphate, N,N-methylenediacrylamide, N,N'-methylenedimethacrylamide, N,N'-ethylidenediacrylamide and 1,2-di-(a-methyl-methylenesulfonamide)-ethylene.

Other polymers which may be useful in this invention include those polymers disclosed in U.S. Patent Nos. 5,426,182, 5,461,100, 5,292,828 and 5,739,378. Polymers having a backbone containing urethane units are within the scope of the invention.

The polymer may be utilized in a variety of ways to provide the thickener or thickened compositions of this invention. For example, the polymer, while in aqueous dispersion or dry form, may be blended into an aqueous system to be thickened followed by addition of a neutralizing agent. Alternatively, the polymer may first be neutralized in aqueous dispersion form and then blended with the aqueous system. Preferably, if co-thickening by a surfactant (as discussed below) is desired, the components are separately blended (as dry components or as dispersions or slurries) into an aqueous dispersion to be thickened, followed by the neutralization step.

Although aqueous concentrates of the polymer in acid form and the surfactant may be formed and added to an aqueous dispersion to be thickened as needed, followed by neutralization, such concentrates tend to be too viscous for easy handling. It is nevertheless possible to prepare either a dry blend or an aqueous, high solids composition which is sufficiently low in viscosity as to be pumpable or pourable, and then to further thicken the admixture by addition of an alkaline material.

The polymer thickener may be provided in a dry state in number of ways. For example, the unneutralized polymer may be spray or drum dried and, if desired, blended with a surfactant co-thickener. However, it is also possible to spray dry or otherwise dehydrate the neutralized polymer thickener, and then reconstitute the aqueous thickener dispersion at a future time and place by agitation in a aqueous medium, provided the pH of the dispersion is maintained at pH 7 or higher.

The more usual method of application of the dispersion of this invention for aqueous thickening is to add the aqueous dispersion of the polymer to the medium to be thickened and, after mixing, to introduce an alkaline material to neutralize the acid. The major portion of the thickening effect is obtained in a few minutes upon neutralization. In the presence of high concentrations of electrolytes, the viscosity development may take much longer. This method of applying a polymer to an aqueous system before neutralization enables one to handle a high solids thickener in a non-viscous state, to obtain a uniform blend, and then to convert to a highly viscous condition by the simple addition of an alkaline material to bring the pH of the system to 7 or above.

The aqueous solutions thickened with the neutralized polymers of this invention exhibit good viscosity stability even at a pH as high as 13.

The polymer may be used to thicken compositions under acidic conditions in the presence of a relatively large amount of surfactants wherein the thickened composition, for example, an aqueous system, has a pH below 7, even as low as 1.

An enhancement of thickening (herein termed "co-thickening") can result upon the addition of a surfactant to an aqueous system containing the polymer of this invention, when the polymer is neutralized. In some cases the thickening can be enhanced up to about 40 times the viscosity afforded by the neutralized polymer alone. A wide range of surfactants may be used. Although trace amounts of surfactant may be residually present from the polymerization of the monomers comprising the polymer (for example, whatever may remain of the about 1.5 weight percent surfactant on monomers), such amounts of surfactant are not alone believed to result in any significant co-thickening.

On the basis of an aqueous system containing about 0.1 to 5% by weight of polymer solids, a useful amount of surfactant for optimum co-thickening is about 0.1 to 1.0% by weight of the total system. As indicated, the amounts of polymer and surfactant cothickener may vary widely, even outside these ranges, depending on polymer and surfactant type and other components of the aqueous system to be thickened. However, the co-thickening can reach a maximum as surfactant is added and then decreases as more surfactant is added. Hence, it may be uneconomical to employ surfactant in amounts outside the stated concentrations and polymer/surfactant ratios, but this can be determined in a routine manner in each case.

The preferred method of application of the polymer and the surfactant for aqueous thickening is to add in any sequence the polymer and the surfactant to the medium to be thickened and, after mixing, to introduce an alkaline material to neutralize the acid. This method of applying polymer and surfactant to an aqueous system before neutralization enables one to handle a high solids thickener in a non-viscous state, to obtain a uniform blend, and then to convert to a highly viscous condition by the simple addition of an alkaline material to bring the pH of the system to 7 or above. However, the polymer in the aqueous system may also be neutralized before addition of the surfactant.

The surfactants which may be used preferably include nonionics and anionics, singly or in combination, the selection necessarily depending upon compatibility with other ingredients of the thickened or thickenable dispersions of this invention. Cationic and amphoteric surfactants may also be used provided they are compatible with the polymer and other ingredients of the aqueous system, or are used in such small amounts as not to cause incompatibility.

Suitable anionic surfactants that may be used include the higher fatty alcohol sulfates such as the sodium or potassium salt of the sulfates of alcohols having from 8 to 18 carbon atoms, alkali metal salts or amine salts of high fatty acid having 8 to 18 carbon atoms, and sulfonated alkyl aryl compounds such as sodium dodecyl benzene sulfonate.

Examples of nonionic surfactants include alkylphenoxypolyethoxyethanols having alkyl groups of about 7 to 18 carbon atoms and about 9 to 40 or more oxyethylene units such as octylphenoxy- polyethoxyethanols, dodecylphenoxypolyethoxy-ethanols; ethylene oxide derivatives of long-chain carboxylic acids, such as lauric, myristic, palmitic, oleic; ethylene oxide condensates of long-chain alcohols such as lauryl or cetyl alcohol, and the like.

Examples of cationic surfactants include lauryl pyridinium chloride, octylbenzyltrimethyl- ammonium chloride, dodecyltrimethylammonium chloride condensates of primary fatty amines and ethylene oxide, and the like.

The foregoing and numerous other useful nonionic, anionic, cationic, and amphoteric surfactants are described in the literature, such as McCutcheon's Detergents & Emulsifiers 1981 Annual, North America Edition, MC Publishing Company, Glen Rock, NJ 07452, U.S.A.

In general, solvents (or mixtures of solvents, other organics and volatiles) can be used to manipulate the viscosity of polymer-containing systems. In the examples herein, it is interesting to note how mineral spirits act like co-thickener, and how the water solubility of the other solvent influences how much mineral spirits can be added before the solution separates into a two phase system.

The amount of the polymer that may be dissolved in any given aqueous composition may fall within a wide range depending on the particular viscosity desired.

Thus, although any effective amount of the polymer may be employed for dissolution, typically from about 0.05 to about 20%, preferably from about 0.1 to about 5%, and most preferably from about 0.1 to about 3% by weight, based on the weight of the final aqueous composition including polymer is used.

In addition to the macromonomer-containing polymer that functions as a thickener for the fluid, the glycol-based fluid may also contain small amounts of other functional ingredients, such as corrosion inhibitors, surfactants, anti-oxidants, stabilizers and the like. These components are ordinarily present in individual amounts of less than about 2 weight %, typically in the range of about 0.01-1 weight % for each component.

The macromonomer-containing polymer used as a thickener in the glycol-based fluids of this invention is responsible for their advantageous properties as aircraft anti-icing fluids. The macromonomer-containing polymer is employed in amounts that effect a significant modification in the rheological properties of the glycol-based fluids. The anti-icing glycol-based fluids of this invention do not exhibit rheological properties associated with conventional Newtonian fluids.

The anti-icing fluids of this invention, furthermore, should be distinguished from conventionally thickened anti-icing fluids because they operate by an associative mechanism. The glycol-based deicing/anti-icing fluid of U.S. Pat. No. 4,358,389, thickened with a crosslinked polyacrylate and optionally xanthan gum, is exemplary of such prior art fluids.

When applied to exposed aircraft surfaces, the fluid is sufficiently viscous and/or tacky and has sufficient structure, i.e., gel-like structure, that it tends to cling or adhere to the surfaces, even non-horizontal surfaces. A coating of sufficient thickness is formed to prevent the adherence or accretion of ice, snow, sleet, freezing rain, frost or the like on such surfaces while the aircraft is stationary or taxiing on the ground. Once the aircraft begins its takeoff run, however, the fluid readily flows off the aircraft surfaces under the influence of wind shear, before lift-off occurs. Consequently, there are no appreciable amounts of fluid present on the aircraft surfaces prior to the pilot's rotation of the aircraft to initiate liftoff from the runway and subsequently when the aircraft has become airborne. This result is highly desirable since a residual layer of anti-icing fluid on the airfoil surfaces, like traces of snow, ice, freezing rain or frost, can adversely affect the lift performance characteristics of the airfoil.

It should be noted that without the presence of the macromonomer-containing polymer thickener employed in this invention, the aqueous glycol fluid would exhibit relatively low viscosity and would tend to drain off any non-horizontal surfaces under the influence of gravity, leaving an insufficient film behind to function effectively as an anti-icing agent over an extended period of time.

The macromonomer-containing polymer thickener is employed in this invention in an amount that increases the viscosity and/or tackiness of the glycol-based fluid and, moreover, gives it a gel-like physical structure under zero shear or very low shear conditions.

The amount of macromonomer-containing polymer thickener in the aqueous glycol-based fluid should be less than about 5 weight %, based on the weight of the fluid. The amount of thickener is preferably within the range of about 0.05-3 weight %, and more preferably within the range of from about 0.1-1 weight %.

When the glycol-based fluid containing these amounts of macromonomer-containing polymer thickener is applied to the exposed surfaces of a stationary aircraft, the gravity-induced flow of the fluid coating from non-horizontal surfaces (i.e., inclined, vertical, or the like) is greatly retarded or stopped for appreciable periods of time.

The thickened anti-icing fluid produces a coating, when applied to aircraft surfaces by conventional methods, that imparts anti-icing or antifreeze characteristics to the treated aircraft surface and minimizes the adherence or accretion of ice, snow, sleet, etc., on or to the exposed aircraft surfaces.

The apparent viscosity produced by the macromonomer-containing polymer thickener in the glycol-based fluids of this invention is desirably in the range of about 1,000-20,000 mPa.s, preferably 2,000-8,000 mPa.s, as measured with a Brookfield LVT viscometer at 0.3 rpm and 0°± 1°C using a #31 spindle.

Once the aircraft begins its takeoff run, but prior to rotation and lift-off, the impact of the relative wind on the airfoils and other exposed surfaces treated with anti-icing fluid and also mechanical vibration in the wings and other aircraft surfaces causes sufficient shear force on the anti-icing fluid to thin it so that it behaves like a relatively non-viscous material. It then readily drains off the airfoils and other treated aircraft surfaces.

During the aircraft's takeoff run and prior to rotation (the point at which airfoil lift is sufficient for the pilot to effect lift-off and fly the aircraft off the ground), the wind shear from the relative wind changes the rheological behavior of the fluid of this invention, causing substantial shear thinning and an appreciable decrease in its apparent viscosity that allows it to flow freely off the airfoil surfaces. The airfoil surfaces are thus not only kept free of any adhering i.e., snow or the like, but also free of thickened fluid, both of which could have a deleterious effect on the airfoil lift performance.

The macromonomer-containing polymer is used as the primary thickener in the anti-icing fluid of this invention. As noted above, however, minor amounts of other ingredients, including other thickeners, may also be present to provide additional thickening or gelling functionality or modify rheological behavior. The macromonomer-containing polymer used as the essential thickening component desirably represents at least about 80 weight % of the thickening components present; preferably, it represents in excess of about 90 weight % of the thickener employed.

The gel-forming macromonomer-containing polymers employed as thickeners in this invention exhibit the desired shear thinning characteristics described above, yet are resistant to pump and nozzle shear-induced degradation. This particular characteristic is important since anti-icing fluids are typically applied using conventional ground-based deicing equipment which incorporates a pump driven spraying system. The macromonomer-containing polymer thickened aqueous glycol-based anti-icing fluids of this invention exhibit sufficient shear thinning to be readily pumpable in conventional aircraft ground deicing equipment.

The aqueous glycol-based fluids of this invention are primarily intended for use as anti-icing fluids for treating stationary aircraft but may be used for aircraft and general deicing purposes as well, e.g., treating automobile or vehicle windshields and other exposed surfaces.

The following are rheology modifier design variables:

(i) the structure and concentration of the associative macromonomer, including: a) the size and structure of the hydrophobe; b) the moles of alkoxylation between hydrophobe and the double bond; c) the chemical nature of the bond between the alkoxylated portion and the reactive double bond (e.g., ester, ether, or urethane linkages); and d) the structure of the double bond itself (acrylic, methacrylic, crotonic, styrenic, etc.);

(ii) the structure and concentration of acid monomer in the polymer (e.g., acrylic, methacrylic, crotonic, itaconic, etc.);

(iii) the structure and concentration of the non-associative monomer, including monomers that cross-link the polymer during polymerization (e.g., trimethylol propane triacrylate), and those that leave cross-linkable functionality in the associative polymer without crosslinking during polymerization (e.g., 2-hydroxyethylacrylate); and

(iv) the molecular weight of the polymer, as controlled by mercaptans during polymerization.

All of these parameters influence the fluid's steady shear viscosity profile, viscoelastic and extensional properties, and thickening efficiency. Parameters (ia) and (ib) control rheology by regulating the morphology, thermodynamics, and kinetics of the association junctions. Parameter (ic) controls the hydrolytic stability of the bond that connects the surfactants to the polymer backbone, as well as the ease (and cost) of the synthesis of the associative macromonomer. Parameter (id) controls the sequence of incorporation into polymer for the macromonomer, and controls the amount of reactor coagulum produced during polymerization, which determines the production viability of the polymer. Parameters (ii) and (iii) control the transition temperature (i.e., chain stiffness), hydrophobicity, and water solubility of the polymer backbone.

Because the viscosity of the fluid should not decrease significantly as water dilutes it (for improved hold-over time and water spray endurance), the association activity of the polymer should balance the loss in viscosity due to polymer dilution. Because the viscosity of the fluid should not increase significantly with drop in temperature, the hydrodynamic size of the polymer should decrease enough to compensate for the increase in viscosity of the ethylene glycol and water solvent mixture. (Hydrogen bonding among water molecules and ethylene glycol molecules doubles the viscosity of a 50/50 mixture of ethylene glycol and water as the temperature decreases from 20°C to 0°C.)

The influence of water dilution and temperature change on the viscosity of model AAF's composed of 0.5% polymer solutions in equal weight mixtures ethylene glycol and water was tested. The results are given in Table Q below.

The water dilution experiment is essentially a titration of the polymer containing glycol solution with water that is constructed such that concentration of polymer is 0.5% when the glycol concentration reaches 50%. Compositions that contain less than 50% water by weight correspond to the "dry-out experiment," that simulates the evaporation of water; compositions that contain more than 50% water correspond to the water spray endurance test that simulates the effect of freezing rain impinging on a treated aircraft waiting on the runway. The viscosity of the solution was measured as water was added to it. Whether or not the fluid viscosity is invariant to dilution depends on the moles of ethylene oxide in the macromonomer, the concentrations of associative macromonomer, and methacrylic acid in the polymer.

The degree to which the viscosity of the model AAF depends on temperature depends also on the structure of the associative polymer. The dependence of solution viscosity on polymer coil size and concentration are often expressed in terms of empirical master correlations of the form $\eta/\mu = f(c[\eta])$, such as the Huggins equation:

$$\frac{\eta}{\mu} = 1 + c[\eta] + K' c^2[\eta]^2 + \ldots \qquad (1)$$

where η is the viscosity of the polymer solution, μ is the viscosity of the solvent, $c[\eta]$ is a dimensionless coil volume, and the constant K' characterizes the first effects of polymer interaction on the viscosity. The Huggins parameter K' is usually independent of polymer molecular weight for long polymer chains, and has a value of about 0.4 for polymers in good solvents without interaction effects, and a value of about 0.8 for polymers in theta solvents. Equations like Equation (1) often unify viscosity data over a broad range of molecular weights and concentration for a given dilute polymer-solvent system.

Because the solvent mixture of ethylene glycol and water increases in viscosity as temperature decreases, the contribution of the solvent to the overall viscosity of the solution can be excluded, and only the increment that the polymer contributes through its specific viscosity need be examined:

$$\frac{\left[\frac{\eta}{\mu} - 1\right]_T}{\left[\frac{\eta}{\mu} - 1\right]_{T_{ref}}} = \frac{[\eta]_T}{[\eta]_{T_{ref}}} \quad (2)$$

The instrinsic viscosity [η] depends on the hydrodynamic size of the polymer coil, which depends on polymer molecular weight, solvent quality, and temperature. Taking a ratio of intrinsic viscosity relative to that obtained at an arbitrary reference temperature T_{ref} allows one to isolate the influence of temperature for a given molecular weight of polymer.

Temperature correlations for viscosity usually take the form of an Arrehnius type equation:

$$\frac{\left[\frac{\eta}{\mu} - 1\right]_T}{\left[\frac{\eta}{\mu} - 1\right]_{T_{ref}}} = \exp\left[\frac{\Lambda H}{R} \left(\frac{1}{T} - \frac{1}{T_{ref}}\right)\right] \quad (3)$$

where R is the ordinary gas constant and ΛH the activation energy for a change in viscosity with respect to temperature. The activation energy for change provides a quantitative number to compare the influence of temperature to change the viscosity of an anti-icing fluid: if ΛH is zero, the viscosity of the solution changes exactly in the same way as the solvent does; if ΛH is greater than zero, then the polymer coil expands, and the solution viscosity increases as temperature increases; if ΛH is less than zero, then the polymer coil

2136632

contracts, and the solution viscosity decreases as temperature decreases. ΔH is determined by fitting the temperature dependence of the specific viscosity for 0.5% polymer solutions in a 50/50 ethylene glycol/water solvent mixture to equation (3) by a standard least squares method.

Whether or not the fluid viscosity is invariant to temperature depends on the concentration of associative macromonomer in the polymer, the moles of ethylene oxide in the macromonomer, and the concentration of carboxylic moieties in the polymer. If a particular macromonomer-containing polymer structure is found to be unacceptably sensitive to dilution and/or thermal effects (which tend to be inversely related to each other), compensation may be attempted by altering the water solubility and glass transition temperature of the polymer backbone. Thus, for instance, ethyl acrylate may be partially replaced with methyl acrylate.

The co-thickening interaction of polymer thickener with nonionic surfactant can provide shear-thinning, yet nearly temperature invariant viscosity profile. In the past, this effect was achieved through formulation with anionic surfactants. Nonionic surfactant systems have the advantage of being able to use carbon steel tanks for storage purposes.

As used herein, the term "complex hydrophobe" is contemplated to include all permissible hydrocarbon compounds having 2 or more hydrophobe groups, e.g., bis-dodecylphenyl, bis-nonylphenyl, bis-octylphenyl and the like.

For purposes of this invention, the term "hydrocarbon" is contemplated to include all permissible compounds having at least one hydrogen and one carbon atom. In a broad aspect, the permissible hydrocarbons include acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, aromatic and

2136632

nonaromatic organic compounds, which can be substituted or unsubstituted.

As used herein, the term "substituted" is contemplated to include all permissible substituents of organic compounds unless otherwise indicated. In a broad aspect, the permissible substituents include acyclic and cyclic, branched and unbranched, carbocyclic and heterocyclic, aromatic and nonaromatic substituents of organic compounds. Illustrative substituents include, for example, alkyl, alkyloxy, aryl, aryloxy, hydroxy, hydroxyalkyl, amino, aminoalkyl, halogen and the like in which the number of carbons can range from 1 to about 20 or more, preferably from 1 to about 12. The permissible substituents can be one or more and the same or different for appropriate organic compounds. This invention is not intended to be limited in any manner by the permissible substituents of organic compounds.

The invention is illustrated by certain of the following examples.

Example 1

Preparation of 1,3-Bis(nonylphenoxy)-2-propanol

To a five neck, two liter, round bottom flask equipped with an addition funnel, thermometer, nitrogen dispersant tube, mechanical stirrer, and a decanting head with a water-cooled condenser were added 220 grams (1.00 mole) of nonylphenol and 250 milliliters of cyclohexane. The solution was then heated to reflux and 2.8 grams (1.3 weight % based on nonylphenol) of potassium hydroxide in 10 milliliters of water was slowly added to the flask. After essentially all the water was recovered in the decanting head (10 milliliters + 1 milliliter formed), 250.7 grams (0.91 mole) of nonylphenyl glycidyl ether was added dropwise. During the addition of the glycidyl ether, the reaction temperature was maintained between 60 and 80°C. After the addition was complete, the solution was refluxed for four hours. The contents of the flask were then washed with a five percent aqueous solution of phosphoric acid, and the organic layer was separated from the water layer and washed twice with deionized water. The reaction mixture was then placed in a one liter round bottom flask, and the remaining cyclohexane and unreacted nonylphenol were recovered by distillation, first at atmospheric pressure, then under vacuum at 0.2 mm Hg. The kettle temperature was not allowed to exceed 180°C during the distillation to prevent discoloration of the product. The concentrated solution was then refiltered to give 425 grams of a pale-yellow liquid. End-group MW analysis gave a molecular weight of 506.8 (theoretical MW = 496.8). Ir and nmr spectra were identical to previously recorded spectra for the compound.

Example 2

Preparation of 1,3-Bis(nonylphenoxy)-2-propanol

To a five neck, two liter round bottom flask, equipped with an addition funnel, thermometer, nitrogen dispersant tube, mechanical stirrer, and a decanting head with a water-cooled condenser, were added 300 milliliters of cyclohexane and 451.7 grams (2.05 mole) of nonylphenol. The solution was then heated to reflux and 58.9 grams (1.05 mole) of potassium hydroxide in 60 milliliters of water was slowly added via the addition funnel. After essentially all the water was recovered in the decanting head (60 milliliter + 19 milliliters formed), the reaction was cooled to 40°C, and 92.5 grams (1.00 mole) of epichlorohydrin was slowly added. During the addition, the reaction temperature was maintained below 60°C by controlling the rate of epichlorohydrin addition. After all the epichlorohydrin was added, the solution was allowed to stir for one hour, and then brought to reflux for an additional three hours. The reaction mixture was then filtered under vacuum through a steam-jacketed Buchner funnel to remove the potassium chloride formed as a by-product. The filtration process was performed a total of three times to remove the majority of the salts. The reaction mixture was then placed in a one liter, round bottom flask, and the remaining cyclohexane and unreacted nonylphenol were recovered by distillation, first at atmospheric pressure, then under vacuum at 0.2 mm Hg. The kettle temperature was not allowed to exceed 180°C during the distillation to prevent discoloration of the product. The concentrated solution was then refiltered to give 275 grams of a pale-yellow liquid. End-group MW analysis gave a molecular weight of 459.7 (theoretical MW = 496.8). Ir and nmr spectra were identical to previously recorded spectra for the compound.

Example 3
Preparation of 5 Mole Ethoxylate of 1,3-Bis(nonylphenoxy)-2-propanol

To a 500 milliliter, stainless steel, high pressure autoclave was charged 200 grams (0.40 mole) of 1,3-bis(nonylphenoxy)-2-propanol, which contained a catalytic amount of the potassium salt of the alcohol as described in Example 1. After purging the reactor with nitrogen, the alcohol was heated to 130°C with stirring, and 86.9 grams (2.0 moles of ethylene oxide was added over a two hour period. The reaction temperature and pressure were maintained from 130°C to 140°C and 60 psig during the course of the reaction. After the addition of ethylene oxide was complete, the reaction mixture was held at 140°C for an additional hour to allow all the ethylene oxide to cook out. The reaction mixture was dumped while hot, under nitrogen, and neutralized with acetic acid to yield 285 grams of a pale-yellow liquid.

Example 4
Preparation of Adduct of Nonylphenyl Glycidyl Ether and 5 Mole Ethoxylate of 1,3-Bis(nonylphenoxy)-2-propanol

To a five neck, one liter, round bottom flask equipped as in Example 1 was added 119.8 grams (0.17 mole) of the 5 mole ethoxylate of 1,3-bis(nonylphenoxy)-2-propanol and 100 milliliters of cyclohexane. The mixture was refluxed (100°C) for one hour to remove residual water, and then cooled to 50°C under nitrogen to add 0.5 grams of BF_3/Et_2O. Nonylphenyl glycidyl ether (46.0 grams, 0.17 mole) was then added to the flask over a one hour period, and the reaction was heated to reflux. After three hours at reflux, the reaction mixture was transferred to a separatory funnel, while hot, and washed with a saturated aqueous solution of sodium bicarbonate. The organic layer was separated from the water layer, and washed twice with hot, deionized water. The washes were performed at 50°C to facilitate the separation of the two layers. The water and cyclohexane were then evaporated from the organic layer, under vacuum, to yield 145 grams of a pale-yellow, viscous liquid. End-group molecular weight analysis gave a molecular weight of 880 (theoretical molecular weight = 993).

Example 5
Preparation of Poly(nonylphenol glycidyl ether)

To a 500 milliliter round bottom equipped with an overhead stirrer, nitrogen inlet, reflux condenser, additional funnel, and temperature controller was charged 1.9 grams of ethanol (22 mmoles) and 200 grams of cyclohexane. The solution was brought to 50°C. Once heated, 0.5 milliliters (4 mmoles) of BF_3/Et_2O was added using a 2 milliliter syringe. Once the acid was added, 100.0 grams of nonylphenol glycidyl ether (362 mmoles) was added dropwise so as to maintain a reaction temperature of 45°C to 55°C. Once the glycidyl ether was added, the solution is refluxed for 3 hours, then cooled to about 50°C.

While hot (<60°C) the organic was transferred to a separatory funnel and was washed once with 100 milliliters of 5% sodium bicarbonate solution. The aqueous layer was drained and the organic was washed two more times with 100 milliliter portions of deionized water. The aqueous layers were decanted and the organic was dried for at least 1 hour over magnesium sulfate. Once dry, the magnesium sulfate was filtered from the organic layer, which was stripped of solvent using a rotary evaporator. The final yield of viscous polymer was 100 grams. The GPC molecular weight was Mw = 2600 and the Mn = 1700 based on monodisperse polystyrene standards.

Example 6

Ethoxylation of Poly(nonylphenol glycidyl ether)

To a 500 milliliter stainless steel Zipperclave was added 60.0 grams (0.035 moles based on an approximate molecular weight of 1700 gram/mole) of the resin prepared in Example 5 along with 0.5 gram of potassium hydroxide. The vessel was attached to an automated ethoxylation unit and was heated to 50°C. The vessel was continuously purged with nitrogen for 15 minutes and was then heated to 100°C where it was again continuously purged with nitrogen for another 15 minutes. The vessel was then heated to 140°C and was given a series of 6 purges by pressuring the vessel up to 80 psi, and then venting. Once the venting process was complete, the vessel was pressured to 20 psi with nitrogen.

The ethylene oxide lines were opened to a pair of motor-controlled valves along with the main feed line on the Zipperclave. The feed was continued and the vessel pressure was regulated at 55 psi and a temperature of 140°C. The automation was designed to hold the temperature and the pressure within safe operating limits while addition of ethylene oxide proceeded through the motor-controlled valves. The feed was allowed to continue until 60.0 grams of ethylene oxide (1.362 moles) was added based on a difference weight of the feed cylinder. After the feed was complete, the reaction was allowed to continue for 1 hour, after which the vessel was cooled to 60°C, purged 4 times with nitrogen to 80 psi and was dumped to a container. The final product yield was 115 grams with a theoretical yield of 120 grams. The GPC molecular weight of the product was Mw = 3550 and the MN = 2930 based on monodisperse polystyrene standards.

Example 7

Preparation of Poly(phenyl glycidyl ether)

To a 500 milliliter, round bottom flask equipped with an overhead stirrer, nitrogen inlet, reflux condenser, addition funnel, and temperature controller was charged 47.06 grams of phenol (500 mmoles) and 100 grams of toluene. The solution was brought to 50°C. Once heated, 1.0 milliliter (8 mmoles) of BF_3/Et_2O was added using a 2 milliliter syringe. Once the acid was added, 68.18 grams of phenyl glycidyl ether (454 mmoles) was added dropwise so as to maintain a reaction temperature of 45°C to 55°C. Once the glycidyl ether was added, the solution was refluxed for 3 hours, then cooled to about 50°C.

While hot (<60°C) the organic was transferred to a separatory funnel and was washed once with 100 milliliters of 5% sodium bicarbonate solution. The aqueous layer was drained and the organic was washed two more times with 100 milliliter portions of deionized water. The aqueous layers were decanted and the organic was dried for at least 1 hour over magnesium sulfate. Once dry, the magnesium sulfate was filtered from the organic layer which was stripped of solvent using a rotary evaporator. The final yield of viscous polymer was 90.3 grams (with 11% unreacted phenol). The GPC molecular weight was Mw = 470 and the Mn = 310 (on average a trimer) based on monodisperse polystyrene standards.

Example 8
Preparation of 1,3-Bis(phenoxy)-2-propanol using the Cascading Polyol Technique

To a 1 liter, round bottom flask equipped with an overhead stirrer, nitrogen inlet, reflux condenser, addition funnel, and temperature controller was charged 94.11 grams of phenol (1 mole), 12.86 grams of tetraethylammonium iodide (0.05 moles), 3.00 grams of water (0.17 moles), 42.08 grams of potassium hydroxide (0.75 moles), and 250 grams of toluene. To a 100 milliliter additional funnel was charged 23.13 grams of epichlorohydrin (0.25 moles) and 50 grams of toluene. The solution was brought to 65°C, at which time the epichlorohydrin solution was added over a period of 15 minutes while maintaining a reaction temperature of 65°C ± 5°C. The reaction was allowed to proceed for 48 hours.

After 48 hours, the solution was cooled down to room temperature. The toluene solution was washed with two 250 milliliters portions of deionized water. The aqueous layers were drained off, and the toluene was removed along with unreacted phenol using a rotary evaporator. The final yield of product was 64.5 grams which was 106% of theory (residual is phenol). Final product purity was about 95% as shown by GPC.

Example 9
Dimerization of 1,3-Bis(phenoxy)-2-propanol using the Cascading Polyol Technique

To a 250 milliliter round bottom flask equipped with an overhead stirrer, nitrogen inlet, reflux condenser, additional funnel, and temperature controller was charged 20.03 grams of 1,3-bis-(phenoxy)-2-propanol prepared in Example 8 (82 mmoles), 2.06

grams of tetraethylammonium iodide (8 mmoles), 0.49 grams of water (27 mmoles), 6.51 grams of potassium hydroxide (116 mmoles), and 125 grams of toluene. To a 100 milliliter addition funnel was charged 3.61 grams of epichlorohydrin (39 mmoles) and 25 grams of toluene. The solution was brought to 65°C, at which time the epichlorohydrin solution was added over a period of 15 minutes while maintaining a reaction temperature of 65°C ± 5°C. The reaction was allowed to proceed for 48 hours.

After 48 hours, the solution was cooled down to room temperature. The toluene solution was washed with two 250 milliliter portions of deionized water. The aqueous layers were drained off, and the toluene was removed using a rotary evaporator. The final yield of product was 21.6 grams which was 101% of theory. GPC showed two major components of the product. The first was the starting material at about 41% (Mn = 220) and the second was the coupled product at about 59% (Mn = 520).

Example 10
Preparation of 1,3-Bis(hexadecyloxy)-2-propanol
using the Cascading Polyol Technique

To a 500 milliliter, round bottom flask equipped with an overhead stirrer, nitrogen inlet, reflux condenser, additional funnel, and temperature controller was charged 60.61 grams of hexadecanol (0.25 moles), 6.18 grams of tetraethylammonium iodide (0.024 moles), 1.44 grams of water (0.082 moles), 20.20 grams of potassium hydroxide (0.36 moles), and 125 grams of toluene. To a 100 milliliter addition funnel was charged 11.10 grams of epichlorohydrin (0.12 moles) and 25 grams of toluene. The solution was brought to 65°C at which time the epichlorohydrin solution was added over a period of 15 minutes while maintaining a reaction temperature of 65°C ± 5°C. The reaction was allowed to proceed for 48 hours.

After 48 hours, the solution was cooled down to room temperature. The toluene solution was washed with two 250 milliliter portions of deionized water. The aqueous layers were drained off, and the toluene was removed using a rotary evaporator. The final yield of product was 70.9 grams which is 109% of theory (residual is hexadecanol).

Example 11
Sulfation of 1,3-Bis(nonylphenoxy)-2-propanol-block-(propylene oxide)$_{10}$-block-(ethylene oxide)$_{10}$

To a 250 milliliter, round bottom flask equipped with an overhead stirrer, a temperature controller, and a vacuum adapter was added 75.0 grams of the material from Example 13 (49 mmoles). The kettle was then evacuated to <20 mmHg and heated to 100°C to remove any water. After 1 hour, the kettle was cooled to 60°C while under vacuum. When reaching 60°C, vacuum was broken with nitrogen and 5.3 grams of sulfamic acid (54 mmoles) was added. After charging the sulfamic acid, the kettle was heated to 110°C and evacuated to <20 mmHg. The reaction was allowed to proceed for 3 hours.

At the end of the hold period, the kettle was cooled to 85°C and vacuum was broken with nitrogen. 1.2 grams of diethanolamine (11 mmoles) was slowly added under a blanket of nitrogen. This solution was stirred for 30 minutes. 10 grams of ethanol was added to the kettle and the temperature was regulated to 55°C. This solution was stirred for 30 minutes. The heat was removed from the kettle and 30 grams of water along with 20 grams of ethanol were added while maintaining good agitation. The solution was stirred for 15 minutes or until cooled to room temperature (<35°C).

The pH was checked by dissolving 2 grams of the product solution in 18 grams of deionized water. If the pH was below

2136632

6.5, 0.2 gram increments of diethanolamine was added until the pH is between 6.5 and 7.5.

Example 12
Preparation of 1,3-Bis(nonylphenoxy)-2-propanol-block-(propylene oxide)$_{10}$

To a 500 milliliter stainless steel Zipperclave was added 100.0 grams (0.202 mole) of 1,3-bis(nonylphenoxy)-2-propanol prepared in Example 1 along with 0.7 grams of potassium hydroxide. The vessel was attached to an automated unit and was heated to 50°C. The vessel was continuously purged with nitrogen for 15 minutes and was then heated to 100°C where it was again continuously purged with nitrogen for another 15 minutes. The vessel was then heated to 140°C and is given a series of 6 purges by pressuring the vessel up to 80 psi, and then venting. Once the venting process was completed, the vessel was pressured to 20 psi with nitrogen.

Lines connected to a cylinder, which had been precharged with 117.0 grams of propylene oxide (2.02 moles), were opened to the motor valves along with the main feed line on the Zipperclave. The feed was continued and the vessel pressure was regulated at 55 psi and a temperature of 140°C. The automation was designed to hold the temperature and the pressure within safe operating limits while addition of ethylene oxide proceeded through a pair of motor-controlled valves. The feed was allowed to continue until all of the propylene oxide had been fed. After the feed was complete, the reaction was allowed to continue for 1 hour after which the vessel was cooled to 60°C, purged 4 times with nitrogen to 80 psi and was dumped to a container. The final product yield was 211 grams with a theoretical yield of 277 grams. The GPC molecular weight of the product was Mw = 650 and the Mn = 490 based on monodisperse polystyrene standards.

Example 13

Preparation of 1,3-Bis(nonylphenoxy)-2-propanol-block-(propylene oxide)$_{10}$-block-(ethylene oxide)$_{10}$

To a 500 milliliter stainless steel Zipperclave was added 75.0 grams of the propoxylate prepared in Example 12 (0.070 mole) along with 0.3 gram of potassium hydroxide. The vessel was attached to an automated ethoxylation unit and was heated to 50°C. The vessel was continuously purged with nitrogen for 15 minutes and was then heated to 100°C where it was again continuously purged with nitrogen for another 15 minutes. The vessel was then heated to 140°C and was given a series of 6 purges by pressuring the vessel up to 80 psi, and then venting. Once the venting process was completed, the vessel was pressured to 20 psi with nitrogen.

The ethylene oxide lines were opened to the motor valves along with the main feed line on the Zipperclave. The feed was continued and the vessel pressure was regulated at 55 psi and a temperature of 140°C. The automation was designed to hold the temperature and the pressure within safe operating limits while addition of ethylene oxide proceeded through a pair of motor control valves. The feed was allowed to continue until 30.7 grams ethylene oxide (0.696 mole) was added based on a difference weight of the feed cylinder. After the feed was complete, the reaction is allowed to continue for 1 hour, after which the vessel was cooled to 60°C, purged 4 times with nitrogen to 80 psi and was dumped to a container. The final product yield was 99 grams with a theoretical yield of 106 grams.

Example 14
Preparation of Bis(nonylphenoxy) Adduct of
1,4-Butanediol Diglycidyl Ether

To a five neck, two liter, round bottom flask equipped with an addition funnel, thermometer, nitrogen dispersant tube, mechanical stirrer, and a decanting head with a water-cooled condenser were added 506.8 grams (2.30 moles) of nonylphenol and 350 milliliters of cyclohexane. The solution was heated to reflux, and 6.5 grams (1.3 weight percent based on nonylphenol) of potassium hydroxide in 15 milliliters of water was slowly added to the round bottom flask. After all the water was recovered in the decanting head (15 milliliters + 2 milliliters formed), 220 grams (1.09 moles) of 1,4-butanediol diglycidyl ether was added dropwise between 60 and 80°C. After the addition was complete, the solution was refluxed for four hours. The contents of the flask were then washed with a five percent aqueous solution of phosphoric acid, and the organic layer was separated from the water layer and washed twice with deionized water. The reaction mixture was then placed in a one liter, round bottom flask, and the remaining cyclohexane and unreacted nonylphenol were recovered by distillation, first at atmospheric pressure, then under vacuum at 0.2 mm Hg. The kettle temperature was not allowed to exceed 180°C during the distillation to prevent discoloration of the product. The concentrated solution was then refiltered to give 710 grams of a pale-yellow liquid. Molecular weight by end-group MW analysis was 689.9 (theoretical MW = 643.0). Ir and nmr spectra were consistent with the expected structure of the product.

Example 15
Preparation of 3-Mole Ethoxylate of
1,3-Bis(nonylphenoxy)-2-propanol

To a five hundred milliliter, Zipperclave reactor were charged, under nitrogen, 200.1 grams (0.43 mole) of 1,3-

bis(nonylphenoxy)-2-propanol prepared in Example 2 and 0.20 gram (0.1 weight percent) of $BF_3 \cdot Et_2O$. The reaction mixture was heated to 80°C, and 55.1 grams (1.25 mole) of ethylene oxide was fed to the reactor over a two hour period. After all the ethylene oxide was fed, the reaction mixture was allowed to cook out for one hour and then dumped hot, under nitrogen, into a jar containing 160 milliliters of a one percent aqueous solution of sodium hydroxide. The organic layer was separated from the water layer and washed twice with deionized water. The washes were performed at 90°C to facilitate the separation of the two layers. The product was then dried by azeotropic removal of the water, using cyclohexane (300 milliliters) as the entrainer. The cyclohexane was stripped off under vacuum to give a pale-yellow liquid with a molecular weight by end-group MW analysis of 601.7 (theoretical MW = 629). Ir and nmr spectra were consistent with the expected structure of the product.

Example 16
Preparation of 8-Mole Ethoxylate of Bis(nonylphenoxy) Adduct of 1,4-Butanediol Diglycidyl Ether

To a five hundred milliliter Zipperclave reactor were charged, under nitrogen, 150.2 grams (0.22 mole) of bis(nonylphenoxy) adduct of 1,4-butanediol diglycidyl ether prepared in Example 14 and 0.30 grams (0.2 weight percent) of $BF_3 \cdot Et_2O$. The reaction mixture was heated to 80°C, and 77.5 grams (1.76 mole) of ethylene oxide was fed to the reactor over a two hour period. After all the ethylene oxide was fed, the reaction mixture was allowed to cook out for one hour and then dumped hot, under nitrogen, into a jar containing 160 milliliters of a one percent aqueous solution of sodium hydroxide. The organic layer was separated from the water layer and washed twice with deionized water. The washes were performed at 90°C to facilitate the separation of the two layers. The product was then dried by azeotropic removal of the water, using cyclohexane (300 milliliters) as the entrainer. The cyclohexane was stripped off under vacuum to give a pale-yellow liquid with a molecular weight by end-group MW analysis of 1047 (theoretical MW = 995). Ir and nmr spectra were consistent with the expected structure of the product.

Example 17

Preparation of Macromonomer Compound

Into a 1 liter, round bottom reaction flask equipped with a heating mantle, dean stark trap, condenser, thermometer, nitrogen bubbler, nitrogen purge line and stirrer was charged 300 grams of toluene and 63 grams of a surfactant identified as S-1 in Table A below. With nitrogen purge, the resulting solution was heated to reflux at approximately 110°C and azeotroped to remove trace water to dryness. The solution was subsequently cooled to 90°C, and 1.5 grams of bismuth hex chem 28% bismuth octoate catalyst (Mooney Chemical, Inc., Cleveland, Ohio) was charged and allowed to mix well, after which a stoichiometric amount of 95% m-TMI aliphatic isocyanate (American Cyanamid, Stamford, Connecticut) was charged. After the reaction proceeded at 90°C for 1.3 hours, the resulting product was cooled to 70°C and 0.03 gram of 2,6-di-tert-4-butyl phenol (BHT) preservative was added. The mixture was poured into a stainless steel pan with large surface area to facilitate drying. The final product was a waxy material, and is designated herein as macromonomer M-1.

Table A

$$
\begin{array}{l}
R_1\text{-O-CH}_2 \\
\quad | \\
\quad \text{CH-(OCH}_2\text{CH}_2)_x\text{OCH}_2\text{CH}_2\text{OH} \\
\quad | \\
\quad R_2
\end{array}
$$

R_2 = hydrogen or a R_3-O-CH_2- residue.

Surfactant	R_1	R_2/R_3	Moles of Ethoxylation
S-1	Nonylphenol	Hydrogen (R_2)	40
S-2	Nonylphenol	Nonylphenol (R_3)	40
S-3	Nonylphenol	Nonylphenol (R_3)	20
S-4	Nonylphenol	Octylphenol (R_3)	20
S-5	Nonylphenol	Octylphenol (R_3)	40
S-6	Nonylphenol	Nonylphenol (R_3)	80
S-7	Nonylphenol	Nonylphenol (R_3)	120

Examples 18-34

Preparation of Macromonomer Compounds

In a manner similar to that described in Example 17, other macromonomers were prepared using stoichiometric amounts of the surfactants and unsaturated compounds identified in Table B below.

2136632

Table B

Example No.	Surfactant	Unsaturated Compound	Macromonomer Designation
18	S-2	m-TMI	M-2
19	S-3	m-TMI	M-3
20	S-4	m-TMI	M-4
21	S-5	m-TMI	M-5
22	S-6	m-TMI	M-6
23	S-7	m-TMI	M-7
24	S-2	Isocyanato Ethyl Methacrylate	M-8
25	S-5	Isocyanato Ethyl Methacrylate	M-9
26	S-1	Methacrylic Anhydride	M-10
27	S-2	Methacrylic Anhydride	M-11
28	S-5	Methacrylic Anhydride	M-12
29	S-6	Methacrylic Anhydride	M-13
30	S-2	Acrylic Anhydride	M-14
31	S-5	Acrylic Anhydride	M-15
32	S-6	Acrylic Anhydride	M-16
33	S-2	Crotonic Anhydride	M-17
34	S-5	Maleic Anhydride	M-18

Example 35

Preparation of Alkali-Soluble Thickener

A monomer mixture (300 grams) was prepared by charging ethyl acrylate (Aldrich), methacrylic acid (Aldrich), macromonomer M-1, 13 grams of a 75% solution of Aerosol® OT surfactant (American Cyanamid, Stamford, Connecticut), and 3 grams of distilled deionized water to a bottle, and dispersing the contents with vigorous shaking. The ethyl acrylate, methacrylic acid and macromonomer M-1 were added in amounts identified in Table C below. A catalyst feed mixture comprised of 0.53 gram of sodium persulfate (Aldrich) and 52.47 grams of water was prepared in another container. To a 2 liter resin flask that had been immersed in a thermostated water bath and equipped with a 4-bladed stainless steel mechanical stirrer, Claisen connecting tube, water condenser, nitrogen sparge and bubble trap, thermometer and monomer and catalyst addition inlets, 1.20 grams of the sodium salt of vinyl sulfonic acid and 658.5 grams of water were charged. The monomer mixture was charged to a 1-liter graduated monomer feed cylinder, and the catalyst solution was charged to a 125 milliliter graduated catalyst feed cylinder. Under nitrogen purge, the reactor was heated to 70°C, whereupon 33 milliliters of the monomer mixture and 3 milliliters of the catalyst feed mixture were charged to the reaction vessel. The reaction vessel was subsequently heated to 80°C. After allowing the monomers to react for 20 minutes to form a seed product, the monomer and catalyst feed mixtures were conveyed to the reaction vessel by FMI pumps via 1/8" Teflon tubing at a rate of 1.94 and 0.27 milliliters/minute, respectively, under continuous stirring at a reaction temperature held between 76-82°C. The reaction was allowed to proceed for another hour, after which the product was cooled and filtered with a 200 mesh nylon cloth. The coagulum was collected from the reaction vessel and filter cloth. Thickening ability of the resulting product was monitored by Brookfield viscosity at 6 rpm by diluting the latex to 0.25%, 0.50% and 0.75% solids, and subsequently neutralizing the product to pH=9.0 with a 95% solution of 2-amino-2-methyl-1-propanol (AMP-95, Angus Chemical Company). The results are given in Table C.

Examples 36-131

Preparation of Alkali-Soluble Thickeners

In a manner similar to that described in Example 35, other alkali-soluble thickeners were prepared using the monomers identified in Tables C-J below in the amounts identified in Tables C-J. Table C illustrates the influence of m-TMI-containing macromonomer concentration and ethoxylation on thickening efficiency. Table D illustrates the influence of mixing m-TMI-

2136632

containing macromonomers of various ethoxylations on thickening efficiency. Table E illustrates the influence of unsaturation type of urethane-containing macromonomers on thickening efficiency. Table F illustrates the influence of macromonomer ester structure and ethoxylation on thickening efficiency. Table G illustrates the influence of acid type and concentration on thickening efficiency. Table H illustrates the influence of polymer glass transition temperature and water solubility on thickening efficiency. Table I illustrates the influence of cross-linkable monomer concentration on thickening efficiency. Table J illustrates the influence of mercaptan on thickening efficiency. As used in Tables C-J below, the following abbreviations have the indicated meanings: MM = Macromonomer; EA = Ethyl Acrylate; MAA = Methacrylic Acid; AA = Acrylic Acid; MA = Methyl Acrylate; t-BA = t-Butyl Acrylate; n-BA = n-Butyl Acrylate; MMA = Methyl Methacrylate; 2-EHP = 2-Ethylhexyl Propionate Mercaptan; and 2-HEA = 2-Hydroxy Ethyl Acrylate.

Table C

Example	Macromonomer	Thickener Composition by Weight %MM	%EA	%MAA	Brookfield Viscosity (CPS) @ pH=9.0 0.25%	0.50%	0.75%	Thickener Designation
35	M-1	10	50	40	90	380	1,000	P-1
36	M-2	5	55	40	270	11,400	103,600	P-2
37	M-2	10	50	40	120	3,100	60,000	P-3
38	M-2	10	50	40	105	10,400	130,000	P-3a
39	M-2	20	40	40	25	2,150	50,500	P-4
40	M-2	30	30	40	10	790	20,000	P-5
41	M-3	5	55	40	390	2,260	17,900	P-6
42	M-3	6.5	53.5	40	142	1,200	18,500	P-7
43	M-3	10	50	40	220	3,050	40,000	P-8
44	M-3	20	40	40	75	2,350	27,500	P-9
45	M-4	10	50	40	242	4,400	39,000	P-10
46	M-5	10	50	40	45	7,400	84,000	P-11
47	M-5	20	40	40	34	4,450	59,000	P-12
48	M-6	5	55	40	460	25,500	88,000	P-13
49	M-6	10	50	40	105	39,000	150,000	P-14
50	M-6	15	45	40	195	43,000	140,000	P-15
51	M-6	20	40	40	125	52,500	187,000	P-16
52	M-6	30	30	40	315	56,500	162,000	P-17
53	M-7	5	55	40	230	7,800	15,800	P-18
54	M-7	10	50	40	900	17,400	35,000	P-19

Table D

Example	Macromonomer	Thickener Composition by Weight			Brookfield Viscosity (CPS) @ pH=9.0			Thickener Designation
		%MM	%EA	%MAA	0.25%	0.50%	0.75%	
55	M-3:M-6 1:1	10	50	40	225	24,000	85,000	P-20
56	M-2:M-6 1:1	10	50	40	135	21,200	134,000	P-21

Table E

Example	Macromonomer	Thickener Composition by Weight			Brookfield Viscosity (CPS) @ pH=9.0			Thickener Designation
		%MM	%EA	%MAA	0.25%	0.50%	0.75%	
57	M-8	5	55	40	250	14,800	124,000	P-22
58	M-8	10	50	40	93	11,200	125,400	P-23
59	M-8	20	40	40	45	6,140	84,500	P-24
60	M-9	5	55	40	275	6,200	57,000	P-25
61	M-9	10	50	40	250	10,100	80,000	P-26
62	M-9	20	40	40	90	7,800	90,000	P-27
63	M-9	30	30	40	45	5,200	69,000	P-28

Table F

Example	Macromonomer	Thickener Composition by Weight %MM	%EA	%MAA	Brookfield Viscosity (CPS) @ pH=9.0 0.25%	0.50%	0.75%	Thickener Designation
64	M-10	10	50	40	130	285	410	P-29
65	M-11	10	50	40	190	19,500	152,000	P-30
66	M-11	20	40	40	120	13,500	146,000	P-31
67	M-11	30	30	40	96	8,000	73,000	P-32
68	M-12	5	55	40	260	5,400	51,000	P-33
69	M-12	10	50	40	175	9,200	71,000	P-34
70	M-12	20	40	40	100	7,400	77,000	P-35
71	M-12	30	30	40	62	4,500	63,000	P-36
72	M-13	5	55	40	320	25,600	79,000	P-37
73	M-13	10	50	40	97	28,000	125,000	P-38
74	M-13	20	40	40	300	58,200	171,000	P-39
75	M-13	30	30	40	730	63,000	163,000	P-40
76	M-14	10	50	40	410	22,700	130,000	P-41
77	M-14	20	40	40	1225	44,500	168,000	P-42
78	M-14	30	30	40	1010	42,500	180,000	P-43
79	M-15	5	55	40	84	1,680	29,000	P-44
80	M-15	10	50	40	350	12,000	83,000	P-45
81	M-15	20	40	40	220	24,500	122,000	P-46
82	M-15	30	30	40	1050	33,000	133,000	P-47
83	M-16	5	55	40	450	17,720	45,300	P-48
84	M-16	10	50	40	1,345	27,000	98,000	P-49
85	M-16	20	40	40	3,450	65,800	158,000	P-50
86	M-16	30	30	40	11,600	81,000	157,000	P-51
87	M-17	10	50	40	410	12,000	60,000	P-52
88	M-17	20	40	40	255	10,600	46,300	P-53
89	M-17	30	30	40	38	2,525	13,500	P-54
90	M-18	5	55	40	100	810	3,500	P-55
91	M-18	10	50	40	110	1,420	5,940	P-56
92	M-18	20	40	40	30	870	2,425	P-57

Table G

Example	Macromonomer	Thickener Composition by Weight				Brookfield Viscosity (CPS) @ pH=9.0			Thickener Designation
		%MM	%EA	%MAA	Other	0.25%	0.50%	0.75%	
93	M-2	10	60	30	0	1520	12,200	102,000	P-58
94	M-2	10	70	20	0	45	3,800	50,000	P-59
95	M-2	10	80	10	0	<10	<10	<10	P-60
96	M-2	10	60	0	30	<10	95	6,800	P-61
97	M-6	20	60	20	0	15	13,500	43,500	P-62
98	M-6	5	65	30	0	210	13,000	56,500	P-63
99	M-6	10	60	30	0	77	24,000	88,000	P-64
100	M-6	20	50	30	0	17	7,600	79,000	P-65
101	M-6	5	45	50	0	130	7,060	28,000	P-66
102	M-6	10	40	50	0	86	16,700	52,500	P-67
103	M-6	20	30	50	0	130	28,000	122,000	P-68
104	M-11	10	70	0	20	<10	213	7300	P-69
105	M-17	10	50	20	20	710	16,500	66,000	P-70

Table H

Example	Macromonomer	Thickener Composition by Weight %MM	%EA	%MAA	%Other	Brookfield Viscosity (CPS) @ pH=9.0 0.25%	0.50%	0.75%	Thickener Designation
106	M-2	10	40	40	10 MMA	90	5,760	82,000	P-71
107	M-2	10	30	40	20 MMA	15	1,125	55,000	P-72
108	M-2	10	20	40	30 MMA	10	207	6,000	P-73
109	M-2	10	0	40	50 MMA	<10	<10	<10	P-74
110	M-2	10	30	40	20 styrene	20	310	1,330	P-75
111	M-2	10	40	40	10 styrene	95	7,540	75,500	P-76
112	M-2	10	40	40	10 n-BA	220	13,800	118,000	P-77
113	M-2	10	30	40	20 n-BA	185	7,400	66,500	P-78
114	M-2	10	40	40	10 t-BA	130	10,100	100,000	P-79
115	M-2	10	30	40	20 t-BA	125	7,200	77,500	P-80
116	M-2	10	40	40	10 MA	100	6,900	121,000	P-81
117	M-2	10	30	40	20 MA	73	5,000	90,000	P-82
118	M-6	20	30	40	10 MMA	33	15,400	150,000	P-83

Table I

Example	Macromonomer	Thickener Composition by Weight %MM	%EA	%MAA	%2-HEA	Brookfield Viscosity (CPS) @ pH=9.0 0.25%	0.50%	0.75%	Thickener Designation
119	M-2	10	47.7	40	2.3	97	9,060	127,000	P-84
120	M-2	10	57.7	30	2.3	62	6,300	76,000	P-85
121	M-2	20	37.5	40	2.5	27	6,200	116,600	P-86
122	M-2	20	35	40	5	<10	260	18,600	P-87
123	M-2	20	32.5	40	7.5	20	720	40,000	P-88
124	M-2	20	30	40	10	10	520	29,500	P-89

Table J

Example	Macromonomer	Thickener Composition by Weight %MM	%EA	%MAA	%2-HEP*	Brookfield Viscosity (CPS) @ pH=9.0 0.25%	0.50%	0.75%	Thickener Designation
125	M-2	10	40	50	.05	165	22,800	142,000	P-90
126	M-2	10	50	40	0.2	18	2,060	66,500	P-91
127	M-2	10	50	40	0.3	<10	115	9,700	P-92
128	M-2	10	50	40	0.5	<10	12	355	P-93
129	M-2	10	50	40	1	<10	<10	<10	P-94
130	M-6	10	50	40	.05	230	23,700	90,700	P-95
131	M-6	10	50	40	.2	30	5,170	33,000	P-96

*% charged to reactor based on monomer.

Examples 132-187

Co-Thickening with Surfactants

The addition of certain surfactants to an associative polymer solution produces a co-thickening effect. The results in Table L below show the co-thickening effect produced by the addition with thorough mixing of certain surfactants identified in Table K below in the amounts identified in Table L to a 0.5% alkaline solution of an alkali soluble thickener identified in Table L as measured with a Brookfield Viscometer at 6 rpm at pH = 9.0.

Table K

R_1-O-CH_2
|
CH-$(OCH_2CH_2)_x$$OCH_2CH_2OH$
|
R_2

R_2 = hydrogen or a R_3-O-CH_2- residue.

Surfactant	R_1	R_2/R_3	Moles of Ethoxylation
S-8	Nonylphenol	Nonylphenol (R_3)	20
S-9	Nonylphenol	Nonylphenol (R_3)	40
S-10	Nonylphenol	Nonylphenol (R_3)	80
S-11	Nonylphenol	Hydrogen (R_2)	25
S-12	Nonylphenol	Hydrogen (R_2)	40
S-13	Nonylphenol	Octylphenol (R_3)	20
S-14	Nonylphenol	Octylphenol (R_3)	40
S-15*	Nonylphenol	Nonylphenol (R_3)	40
S-16	Octylphenol	Hydrogen (R_2)	25

* Sulfated derivative.

2136632

Table L

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
132	S-8	0.0	P-3	3100
	S-8	0.2	P-3	32700
	S-8	0.4	P-3	45700
	S-8	0.8	P-3	63300
	S-8	1.0	P-3	65500
	S-8	2.0	P-3	>100000
133	S-9	0.2	P-3	24200
	S-9	0.4	P-3	18700
	S-9	0.8	P-3	6600
	S-9	1.0	P-3	4060
		2.0	P-3	1225
134	S-10	0.2	P-3	20600
	S-10	0.4	P-3	17300
	S-10	0.8	P-3	8500
	S-10	1.0	P-3	6300
	S-10	2.0	P-3	1850
135	S-11	0.2	P-3	12000
	S-11	0.4	P-3	3160
	S-11	0.8	P-3	700
	S-11	1.0	P-3	485
	S-11	2.0	P-3	480
136	S-12	0.2	P-3	9200
	S-12	0.4	P-3	4500
	S-12	0.8	P-3	1000
	S-12	1.0	P-3	875
	S-12	2.0	P-3	565
137	S-13	0.2	P-3	34300
	S-13	0.4	P-3	26700
	S-13	0.8	P-3	11500
	S-13	1.0	P-3	8600
	S-13	2.0	P-3	2450

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
138	S-14	0.2	P-3	22200
	S-14	0.4	P-3	17200
	S-14	0.8	P-3	6900
	S-14	1.0	P-3	4500
	S-14	2.0	P-3	1500
139	S-15	0.2	P-3	10500
	S-15	0.4	P-3	4940
	S-15	0.8	P-3	2160
	S-15	1.0	P-3	1450
	S-15	2.0	P-3	355
140	S-16	0.2	P-3	14300
	S-16	0.4	P-3	4080
	S-16	0.8	P-3	1075
	S-16	1.0	P-3	735
	S-16	2.0	P-3	485
141	S-8	0.0	P-2	11400
	S-8	0.2	P-2	23500
	S-8	0.4	P-2	34000
	S-8	0.8	P-2	64000
	S-8	1.0	P-2	71000
	S-8	2.0	P-2	93000
142	S-9	0.2	P-2	11000
	S-9	0.4	P-2	4000
	S-9	0.8	P-2	2000
	S-9	1.0	P-2	1400
	S-9	2.0	P-2	850
143	S-10	0.2	P-2	10500
	S-10	0.4	P-2	5000
	S-10	0.8	P-2	2000
	S-10	1.0	P-2	1600
	S-10	2.0	P-2	950

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight %)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
144	S-11	0.2	P-2	2700
	S-11	0.4	P-2	1000
	S-11	0.8	P-2	800
	S-11	1.0	P-2	660
	S-11	2.0	P-2	620
145	S-12	0.2	P-2	2800
	S-12	0.4	P-2	1000
	S-12	0.8	P-2	850
	S-12	1.0	P-2	660
	S-12	2.0	P-2	650
146	S-8	0.0	P-4	2150
	S-8	0.2	P-4	19000
	S-8	0.4	P-4	31000
	S-8	0.8	P-4	55000
	S-8	1.0	P-4	61000
	S-8	2.0	P-4	85000
147	S-9	0.2	P-4	19500
	S-9	0.4	P-4	21500
	S-9	0.8	P-4	11500
	S-9	1.0	P-4	7400
	S-9	2.0	P-4	2250
148	S-10	0.2	P-4	12600
	S-10	0.4	P-4	17400
	S-10	0.8	P-4	12600
	S-10	1.0	P-4	6600
	S-10	2.0	P-4	2600
149	S-11	0.2	P-4	17400
	S-11	0.4	P-4	7800
	S-11	0.8	P-4	1650
	S-11	1.0	P-4	860
	S-11	2.0	P-4	560

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
150	S-12	0.2	P-4	14600
	S-12	0.4	P-4	7800
	S-12	0.8	P-4	1500
	S-12	1.0	P-4	960
	S-12	2.0	P-4	450
151	S-8	0.0	P-5	790
	S-8	0.2	P-5	4600
	S-8	0.4	P-5	19600
	S-8	0.8	P-5	42000
	S-8	1.0	P-5	50000
	S-8	2.0	P-5	90000
152	S-9	0.2	P-5	5800
	S-9	0.4	P-5	13200
	S-9	0.8	P-5	9200
	S-9	1.0	P-5	5200
	S-9	2.0	P-5	1600
153	S-10	0.2	P-5	4050
	S-10	0.4	P-5	10400
	S-10	0.8	P-5	9400
	S-10	1.0	P-5	5000
	S-10	2.0	P-5	1600
154	S-11	0.2	P-5	10600
	S-11	0.4	P-5	4200
	S-11	0.8	P-5	1400
	S-11	1.0	P-5	970
	S-11	2.0	P-5	410
155	S-12	0.2	P-5	6000
	S-12	0.4	P-5	4200
	S-12	0.8	P-5	1150
	S-12	1.0	P-5	600
	S-12	2.0	P-5	340

2136632

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight %)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
156	S-8	0	P-7	1200
	S-8	0.2	P-7	9000
	S-8	0.4	P-7	21000
	S-8	0.8	P-7	37000
	S-8	1.0	P-7	49000
	S-8	2.0	P-7	78000
157	S-9	0.2	P-7	1600
	S-9	0.4	P-7	1350
	S-9	0.8	P-7	900
	S-9	1.0	P-7	762
	S-9	2.0	P-7	565
158	S-10	0.2	P-7	1100
	S-10	0.4	P-7	1150
	S-10	0.8	P-7	900
	S-10	1.0	P-7	823
	S-10	2.0	P-7	650
159	S-11	0.2	P-7	1175
	S-11	0.4	P-7	685
	S-11	0.8	P-7	503
	S-11	1.0	P-7	495
	S-11	2.0	P-7	502
160	S-12	0.2	P-7	950
	S-12	0.4	P-7	675
	S-12	0.8	P-7	525
	S-12	1.0	P-7	500
	S-12	2.0	P-7	480
161	S-8	0.0	P-13	25500
	S-8	0.2	P-13	31500
	S-8	0.4	P-13	46500
	S-8	0.8	P-13	60000
	S-8	1.0	P-13	60000
	S-8	2.0	P-13	62500

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
162	S-9	0.2	P-13	8640
	S-9	0.4	P-13	2940
	S-9	0.8	P-13	1200
	S-9	1.0	P-13	1000
	S-9	2.0	P-13	750
163	S-10	0.2	P-13	10100
	S-10	0.4	P-13	4200
	S-10	0.8	P-13	1450
	S-10	1.0	P-13	1300
	S-10	2.0	P-13	900
164	S-12	0.2	P-13	2540
	S-12	0.4	P-13	1125
	S-12	0.8	P-13	750
	S-12	1.0	P-13	670
	S-12	2.0	P-13	610
165	S-8	0.0	P-14	39000
	S-8	0.2	P-14	61000
	S-8	0.4	P-14	73500
	S-8	0.8	P-14	87000
	S-8	1.0	P-14	93500
	S-8	2.0	P-14	122000
166	S-9	0.2	P-14	41000
	S-9	0.4	P-14	13700
	S-9	0.8	P-14	6200
	S-9	1.0	P-14	3500
	S-9	2.0	P-14	1200
167	S-10	0.2	P-14	38200
	S-10	0.4	P-14	20500
	S-10	0.8	P-14	7300
	S-10	1.0	P-14	5400
	S-10	2.0	P-14	1950

2136632

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight %)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
168	S-12	0.2	P-14	13000
	S-12	0.4	P-14	4300
	S-12	0.8	P-14	975
	S-12	1.0	P-14	950
	S-12	2.0	P-14	660
169	S-8	0.0	P-16	52500
	S-8	0.2	P-16	95000
	S-8	0.4	P-16	92000
	S-8	0.8	P-16	122000
	S-8	1.0	P-16	125000
	S-8	2.0	P-16	138000
170	PS-9	0.2	P-16	73500
	PS-9	0.4	P-16	53000
	PS-9	0.8	P-16	25000
	PS-9	1.0	P-16	21000
	PS-9	2.0	P-16	5400
171	S-10	0.2	P-16	52800
	S-10	0.4	P-16	34500
	S-10	0.8	P-16	5400
	S-10	1.0	P-16	2925
	S-10	2.0	P-16	775
172	S-13	0.2	P-16	45800
	S-13	0.4	P-16	54000
	S-13	0.8	P-16	50800
	S-13	1.0	P-16	54500
	S-13	2.0	P-16	63000
173	S-14	0.2	P-16	22700
	S-14	0.4	P-16	2480
	S-14	0.8	P-16	710
	S-14	1.0	P-16	532
	S-14	2.0	P-16	415

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
174	S-8	0.0	P-29	285
	S-8	0.2	P-29	285
	S-8	0.4	P-29	360
	S-8	0.8	P-29	477
	S-8	1.0	P-29	505
	S-8	2.0	P-29	837
175	S-9	0.2	P-29	282
	S-9	0.4	P-29	285
	S-9	0.8	P-29	284
	S-9	1.0	P-29	298
	S-9	2.0	P-29	322
176	S-10	0.2	P-29	272
	S-10	0.4	P-29	278
	S-10	0.8	P-29	285
	S-10	1.0	P-29	297
	S-10	2.0	P-29	315
177	S-12	0.2	P-29	267
	S-12	0.4	P-29	279
	S-12	0.8	P-29	298
	S-12	1.0	P-29	311
	S-12	2.0	P-29	320
178	S-8	0.0	P-30	19500
	S-8	0.2	P-30	79000
	S-8	0.4	P-30	71200
	S-8	0.8	P-30	81000
	S-8	1.0	P-30	89500
	S-8	2.0	P-30	175000
179	S-9	0.2	P-30	52000
	S-9	0.4	P-30	35500
	S-9	0.8	P-30	16500
	S-9	1.0	P-30	15600
	S-9	2.0	P-30	5620

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
180	S-10	0.2	P-30	47200
	S-10	0.4	P-30	26300
	S-10	0.8	P-30	20300
	S-10	1.0	P-30	13400
	S-10	2.0	P-30	4700
181	S-12	0.2	P-30	23000
	S-12	0.4	P-30	6840
	S-12	0.8	P-30	3125
	S-12	1.0	P-30	1750
	S-12	2.0	P-30	1225
182	S-8	0.0	P-46	24500
	S-8	0.2	P-46	79000
	S-8	0.4	P-46	75000
	S-8	0.8	P-46	86000
	S-8	1.0	P-46	95000
	S-8	2.0	P-46	150000
183	S-9	0.2	P-46	40500
	S-9	0.4	P-46	31000
	S-9	0.8	P-46	15300
	S-9	1.0	P-46	9400
	S-9	2.0	P-46	2300
184	S-11	0.2	P-46	20000
	S-11	0.4	P-46	7300
	S-11	0.8	P-46	1350
	S-11	1.0	P-46	900
	S-11	2.0	P-46	380
185	S-13	0.2	P-46	63500
	S-13	0.4	P-46	42000
	S-13	0.8	P-46	23000
	S-13	1.0	P-46	16000
	S-13	2.0	P-46	4850

Table L (Continued)

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
186	S-14	0.2	P-46	36000
	S-14	0.4	P-46	25000
	S-14	0.8	P-46	11000
	S-14	1.0	P-46	9300
	S-14	2.0	P-46	1900
187	S-16	0.2	P-46	19000
	S-16	0.4	P-46	9300
	S-16	0.8	P-46	1250
	S-16	1.0	P-46	750
	S-16	2.0	P-46	290

Examples 188-232

Co-Thickening with Surfactants

The degree of ethoxylation of a surfactant added to an associative polymer solution influences the co-thickening effect. The results in Table N below show the co-thickening effect produced by the addition with thorough mixing of certain surfactants identified in Table M below in the amounts identified in Table N to a 0.3% (Examples 172-189), 0.5% (Examples 190-215) or 0.75% (Example 216) alkaline solution of an alkali soluble thickener identified in Table N as measured with a Brookfield Viscometer at 6 rpm at pH = 9.0.

$$\begin{array}{l} R_1\text{-O-}CH_2 \\ \quad\;\; | \\ \quad\;\; CH\text{-}(OCH_2CH_2)_xOCH_2CH_2OH \\ \quad\;\; | \\ \quad\;\; R_2 \end{array}$$

R_2 = hydrogen or a R_3-O-CH_2- residue.

Table M

Surfactant	R_1	R_2/R_3	Moles of Ethoxylation
S-17	Nonylphenol	Hydrogen (R_2)	4
S-18	Nonylphenol	Hydrogen (R_2)	6
S-19	Nonylphenol	Hydrogen (R_2)	7
S-20	Nonylphenol	Hydrogen (R_2)	8
S-21	Nonylphenol	Hydrogen (R_2)	9
S-22	Nonylphenol	Hydrogen (R_2)	10
S-23	Nonylphenol	Hydrogen (R_2)	15
S-24	Nonylphenol	Hydrogen (R_2)	25
S-25	Nonylphenol	Hydrogen (R_2)	40
S-26	Octylphenol	Hydrogen (R_2)	1
S-27	Octylphenol	Hydrogen (R_2)	3
S-28	Octylphenol	Hydrogen (R_2)	5
S-29	Octylphenol	Hydrogen (R_2)	7
S-30	Octylphenol	Hydrogen (R_2)	9
S-31	Octylphenol	Hydrogen (R_2)	12
S-32	Octylphenol	Hydrogen (R_2)	16
S-33	C11-C15 Secondary Alcohol	Hydrogen (R_2)	5
S-34	C11-C15 Secondary Alcohol	Hydrogen (R_2)	9

Table N

Example	Surfactant	Surfactant Concentration (weight.%)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
188	S-17	0.8	P-1	890
189	S-18	0.8	P-1	1340
190	S-19	0.8	P-1	630
191	S-20	0.8	P-1	205
192	S-21	0.8	P-1	143
193	S-22	0.8	P-1	113
194	S-23	0.8	P-1	85
195	S-24	0.8	P-1	57
196	S-25	0.8	P-1	68
197	S-17	0.8	P-3	17800
198	S-18	0.8	P-3	35800
199	S-19	0.8	P-3	21300
200	S-20	0.8	P-3	820
201	S-21	0.8	P-3	230
202	S-22	0.8	P-3	147
203	S-23	0.8	P-3	118
204	S-24	0.8	P-3	82
205	S-25	0.8	P-3	77
206	S-17	0.8	P-42	57000
207	S-18	0.8	P-42	134000
208	S-19	0.8	P-42	112000
209	S-21	0.8	P-42	2450
210	S-22	0.8	P-42	800
211	S-23	0.8	P-42	3250
212	S-26	0.8	P-42	43000
213	S-27	0.8	P-42	37000
214	S-28	0.8	P-42	71000
215	S-29	0.8	P-42	5800
216	S-30	0.8	P-42	375
217	S-31	0.8	P-42	650
218	S-32	0.8	P-42	2400
219	S-17	0.8	P-46	68000
220	S-18	0.8	P-46	13000
221	S-19	0.8	P-46	88000
222	S-21	0.8	P-46	2900
223	S-22	0.8	P-46	1400
224	S-23	0.8	P-46	
	2400			

2136632

Table N (Cont.)

Example	Surfactant	Surfactant Concentration (weight %)	Thickener	Brookfield Viscosity (cps) @ pH=9.0
225	S-26	0.8	P-46	25000
226	S-27	0.8	P-46	38500
227	S-28	0.8	P-46	77000
228	S-29	0.8	P-46	7200
229	S-30	0.8	P-46	550
230	S-31	0.8	P-46	690
231	S-32	0.8	P-46	1775
232	Aerosol® OT	0.0	P-4	50500
	Aerosol® OT	0.1	P-4	93500
	Aerosol® OT	0.2	P-4	42000
	Aerosol® OT	0.4	P-4	11200
	Aerosol® OT	0.8	P-4	3700
	Aerosol® OT	1.0	P-4	7200
	Aerosol® OT	2.0	P-4	10600

Examples 233-245

Co-Thickening with Solvents and Non-Solvents

Solvents and non-solvents added to an associative polymer solution influence the co-thickening effect. The results in Table P below show the co-thickening effect produced by the addition with thorough mixing of certain solvents and non-solvents identified in Table O below in the amounts identified in Table P to a 0.75% alkaline solution of an alkali-soluble thickener identified in Table P as measured with a Brookfield Viscometer at 6 rpm at pH = 9.0.

Table O

Solvent Designation	Solvent
O-1	mineral spirits
O-2	butanol
O-3	Isobutanol
O-4	Isopropanol
O-5	2-Ethylhexanol
O-6	Butyl Carbitol
O-7	Butyl DiPropasol
O-8	Butyl Propasol
O-9	Propyl DiPropasol
O-10	Propyl Propasol
O-11	Methyl DiPropasol
O-12	Methyl Propasol

Table P

Example	Thickener	Solvent	Solvent Concentration (weight %)	Solvent O-1 Concentration (weight %)	Brookfield Viscosity (cps) @ pH = 9.0
233	P-3	O-6	5	0	29200
	P-3	O-6	10	0	865
	P-3	O-6	20	0	625
	P-3	O-6	40	0	720
	P-3	O-6	5	5	15400
	P-3	O-6	10	5	1125
	P-3	O-6	20	5	735
	P-3	O-6	40	5	780
	P-3	O-6	5	10	56500
	P-3	O-6	10	10	1050
	P-3	O-6	20	10	835
	P-3	O-6	40	10	832
	P-3	O-6	5	20	41500
	P-3	O-6	10	20	1625
234	P-3	O-7	0	0	76000
	P-3	O-7	5	0	2150
	P-3	O-7	10	0	3700
	P-3	O-7	20	0	2000
	P-3	O-7	0	5	89000

2136632

Table P (Cont.)

Example	Thickener	Solvent	Solvent Concentration (weight.%)	Solvent O-1 Concentration (weight.%)	Brookfield Viscosity (cps) @ pH = 9.0
	P-3	O-7	5	5	88000
	P-3	O-7	10	5	50000
	P-3	O-7	20	5	46500
	P-3	O-7	0	10	102400
	P-3	O-7	5	10	122000
	P-3	O-7	10	10	72000
	P-3	O-7	0	20	113000
	P-3	O-7	5	20	158000
	P-3	O-7	10	20	138000
235	P-3	O-8	5	0	1925
	P-3	O-8	10	0	1150
	P-3	O-8	20	0	2000
	P-3	O-8	40	0	6200
236	P-3	O-9	5	0	36000
	P-3	O-9	10	0	1200
	P-3	O-9	20	0	440
	P-3	O-9	40	O	1375
237	P-3	O-10	5	0	1375
	P-3	O-10	10	0	45500
	P-3	O-10	20	0	625
	P-3	O-10	40	0	510
238	P-3	O-11	5	0	36000
	P-3	O-11	10	0	20500
	P-3	O-11	20	0	4200
	P-3	O-11	40	0	550
239	P-3	O-12	0	0	76000
	P-3	O-12	5	0	45000
	P-3	O-12	10	0	24500
	P-3	O-12	20	0	5800
	P-3	O-12	40	0	675
	P-3	O-12	5	5	51500
	P-3	O-12	10	5	28500
	P-3	O-12	20	5	7100
	P-3	O-12	40	5	810
	P-3	O-12	5	10	61200

Table P (Cont.)

Example	Thickener	Solvent	Solvent Concentration (weight.%)	Solvent O-1 Concentration (weight.%)	Brookfield Viscosity (cps) @ pH = 9.0
	P-3	O-12	10	10	33500
	P-3	O-12	20	10	6400
	P-3	O-12	40	10	950
	P-3	O-12	5	20	86800
	P-3	O-12	10	20	40500
	P-3	O-12	20	20	7100
	P-3	O-12	40	20	1350
240	P-14	O-7	0	0	150000
	P-14	O-7	5	0	1350
	P-14	O-7	10	0	4500
	P-14	O-7	20	0	7000
	P-14	O-7	0	5	140000
	P-14	O-7	5	5	120000
	P-14	O-7	10	5	78000
	P-14	O-7	0	5	140000
	P-14	O-7	5	10	158000
	P-14	O-7	10	10	124000
	P-14	O-7	0	20	136000
	P-14	O-7	5	20	152000
	P-14	O-7	10	20	142000
241	P-3a	O-2	0	0	132600
	P-3a	O-2	5	0	17300
	P-3a	O-2	10	0	850
	P-3a	O-2	20	0	1425
	P-3a	O-2	40	0	4750
	P-3a	O-2	0	5	140000
	P-3a	O-2	5	5	67000
	P-3a	O-2	10	5	2500
	P-3a	O-2	20	5	3000
	P-3a	O-2	0	10	134000
	P-3a	O-2	5	10	33000
	P-3a	O-2	10	10	4000
	P-3a	O-2	20	10	4900
	P-3a	O-2	0	20	144000
	P-3a	O-2	5	20	49000
	P-3a	O-2	10	20	8000

Table P (Cont.)

Example	Thickener	Solvent	Solvent Concentration (weight.%)	Solvent O-1 Concentration (weight.%)	Brookfield Viscosity (cps) @ pH = 9.0
242	P-3a	O-3	5	0	28500
	P-3a	O-3	10	0	880
	P-3a	O-3	20	0	1425
	P-3a	O-3	40	0	4600
	P-3a	O-3	5	5	80000
	P-3a	O-3	10	5	2950
	P-3a	O-3	20	5	3200
	P-3a	O-3	40	5	6200
	P-3a	O-3	5	10	78000
	P-3a	O-3	10	10	5200
	P-3a	O-3	20	10	6400
	P-3a	O-3	5	20	136000
	P-3a	O-3	10	20	20500
243	P-3a	O-4	5	0	94000
	P-3a	O-4	10	0	29000
	P-3a	O-4	20	0	1050
	P-3a	O-4	40	0	850
	P-3a	O-4	5	5	107400
	P-3a	O-4	10	5	39000
	P-3a	O-4	20	5	1225
	P-3a	O-4	40	5	900
	P-3a	O-4	5	10	134000
	P-3a	O-4	10	10	41000
	P-3a	O-4	20	10	1350
	P-3a	O-4	40	10	1050
	P-3a	O-4	5	20	164000
	P-3a	O-4	10	20	33000
	P-3a	O-4	20	20	1825
	P-3a	O-4	40	20	1350
244	P-3a	O-5	5	0	93500
	P-3a	O-5	10	0	136000
	P-3a	O-5	20	0	178000
245	P-3a	O-7	5	0	2700
	P-3a	O-7	10	0	6100
	P-3a	O-7	20	0	11900

Example 246
Polymer Solution Characterization For Aircraft Anti-Icing Fluids

Polymer solutions were titrated with water, and 30 RPM Brookfield viscosities (centipoise) were measured at room temperature (20°C) and at 0°C in a thermostated bath. The results are given in Table Q below. The polymer solutions at 0 grams added water contained 0.5% polymer solids identified in Table Q, 1:1 ethylene glycol: water solvent mixture and a pH = 9.0. Negative grams water added simulates water evaporation (the "dry-out" phenomenon).

Table Q

Polymer P-2

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	1260	2450
-5	1100	2125
0	1000	1925
5	925	1750
10	845	1505
15	790	1400

Polymer P-3b

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	1400	4400
-5	1250	4240
0	1085	3060
5	935	2960
10	900	2550
15	825	2100

2136632

Polymer P-4

Grams Added Water	Viscosity at ≅20°C	Viscosity at 0°C
-10	1475	5200
-5	1225	4100
0	925	3000
5	840	2400
10	705	2005
15	522	1450

Polymer P-5

Grams Added Water	Viscosity at ≅20°C	Viscosity at 0°C
-10	503	2125
-5	459	1415
0	395	1250
5	283	1000
10	230	865
15	191	760

Polymer P-6

Grams Added Water	Viscosity at ≅20°C	Viscosity at 0°C
-10	1095	2150
-5	897	1790
0	853	1700
5	755	1475
10	723	1365
15	660	1215

Polymer P-8

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	1390	3188
-5	1175	2125
0	1060	1960
5	910	1900
10	855	1490
15	765	1350

Polymer P-9

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	3750	7660
-5	2820	5100
0	2425	4620
5	1970	3700
10	1660	2770
15	1425	2360

Polymer P-13

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	475	2375
-5	850	2260
0	810	2150
5	760	2025
10	685	1990
15	590	1835

Polymer P-14

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	1190	4225
-5	1085	3825
0	975	4050
5	940	3850
10	880	4225
15	815	3975

Polymer P-16

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	3550	16700
-5	3525	11540
0	3450	11520
5	3460	11900
10	3300	13200
15	3025	11400

Polymer P-17

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	3575	13900
-5	3900	13800
0	4000	13640
5	3865	13200
10	3675	12000
15	3500	11300

Polymer P-65

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	650	2060
-5	645	1815
0	638	1500
5	550	1490
10	483	1225
15	397	1050

Polymer P-68

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	1370	8100
-5	1450	8800
0	1550	7800
5	1635	8140
10	1525	7200
15	1550	7000

Polymer P-71

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	975	2700
-5	875	2100
0	815	1835
5	745	1720
10	625	1365
15	570	1225

Polymer P-81

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	2130	6240
-5	1780	5200
0	1560	4580
5	1365	4160
10	1210	3580
15	1070	3240

Polymer P-91

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	95	215
-5	75	208
0	84	206
5	55	202
10	54	175
15	44	165

Example 247

Temperature Sensitivity of Polymers In Aircraft Anti-Icing Fluids

Polymer solutions were heated and 30 RPM Brookfield viscosities were measured at various temperatures in a thermostated bath. The activation energy was measured for a change in viscosity with respect to temperature. ΔH was determined by fitting the temperature dependence of the specific viscosity for 0.5% polymer solutions identified in Table R below in a 50/50 ethylene glycol/water solvent mixture to equation (3) herein by a standard least squares method. The results are given in Table R.

Table R

Polymer	ΔH (KJ/mole)
P-2	-3.3
P-3b	9.5
P-4	14.2
P-5	13.4
P-6	-2.1

Polymer	ΔH (KJ/mole)
P-8	-4.6
P-9	-3.6
P-13	3.3
P-14	22.5
P-16	15.1
P-17	15.7
P-65	3.4
P-68	28.8
P-71	2.0
P-81	10.8
P-91	5.1

Example 248
Co-Thickening in Polymer Solution
Characterization for Aircraft Anti-Icing Fluids

Polymer solutions were titrated with water and 30 RPM Brookfield viscosities (centipoise) were measured at room temperature (20°C) and at 0°C in a thermostated bath. The results are given in Table S below. The polymer solutions at 0 grams added water contained 0.5% polymer solids identified in Table S, an amount (weight percent based on total solution) of Tergitol® 15-S-5 nonionic surfactant identified in Table S, 1:1 ethylene glycol: water solvent mixture and a pH = 9.0. Negative grams water added simulated water evaporation (the "dry-out" phenomenon).

2136632

Table S

Polymer P-24 with No Surfactant

Grams Added Water	Viscosity at ≅20°C	Viscosity at 0°C
-10	1945	6960
-5	1770	5540
0	1600	5260
5	1410	4650
10	1175	4300
15	1075	3200

Polymer P-24 with 0.25% Surfactant

Grams Added Water	Viscosity at ≅20°C	Viscosity at 0°C
-10	15,700	60,000
-5	15,360	57,200
0	14,900	57,800
5	14,500	57,600
10	13,920	56,000
15	13,200	52,500

Polymer P-24 with 0.5% Surfactant

Grams Added Water	Viscosity at ≅20°C	Viscosity at 0°C
-10	22,500	90,500
-5	25,500	91,800
0	25,700	91,000
5	24,000	77,500
10	22,500	74,000
15	22,200	67,000

2136632

Polymer P-24 with 1.0% Surfactant

Grams Added Water	Viscosity at ≈20°C	Viscosity at 0°C
-10	52,000	85,000
-5	52,700	92,500
0	49,000	84,500
5	46,600	90,500
10	40,800	75,600
15	40,000	69,700

Example 249

Influence of Added Surfactant on the Temperature Sensitivity of Aircraft Anti-Icing Fluids

Polymer solutions were heated and 30 RPM Brookfield viscosities (centipoise) were measured at various temperatures in a thermostated bath. The activation energy was measured for a change in viscosity with respect to temperature. ΛH was determined by fitting the temperature dependence of the specific viscosity for 0.5% polymer solutions identified in Table T below and an amount (weight percent based on total solution) of Tergitol® 15-S-5 nonionic surfactant identified in Table T in a 50/50 ethylene glycol/water solvent mixture to equation (3) herein by a standard least squares method. The results are given in Table T.

Table T

Polymer	% Surfactant	ΛH (KJ/mole)
P-24	0	14.6
P-24	0.25	20.1
P-24	0.5	17.1
P-24	1.0	-6.91

2136632

The surfactant influences not only the magnitude of viscosity but also how sensitive viscosity is to temperature change.

Example 250
Influence of Temperature and Surfactant on the Steady Shear Viscosity Profile of Aircraft Anti-Icing Fluids

A steady shear viscosity profile was obtained with a standard Bohlin VOR rheolometer equipped with a temperature control and Mooney-Couette shearing geometry. The polymer solutions contained 0.4% polymer solids identified in Table U below, a amount (weight percent based on total solution) of Tergitol® 15-S-5 nonionic surfactant identified in Table U and a 1:1 ethylene glycol: water solvent mixture. The results are given in Table U. The viscosity is given in centipoise (cps).

Table U

Polymer P-4 with No Surfactant

Shear Rate (1/sec)	Viscosity at Temperature 20°C	0°C	-10°C
0.2	2400	2600	2700
1.0	1000	1200	1300
10.0	400	600	900

Polymer P-4 with 0.1% Surfactant

Shear Rate (1/sec)	Viscosity at Temperature 20°C	0°C	-10°C
0.2	9000	12000	16000
1.0	2300	4100	5800
10.0	600	1000	1200

2136632

Example 251

Influence of Water Dilution, Temperature, Shear Rate and Surfactant Type and Concentration on the Steady Shear Viscosity Profile of Aircraft Anti-Icing Fluids

A steady shear viscosity profile was obtained with a standard Bohlin VOR rheolometer equipped with temperature control and Mooney-Couette shearing geometry. The initial fluids contained 49.75 grams of ethylene glycol (polyester grade), 38.90 grams of distilled water, 0.85 grams of latex containing 30 weight percent of P-8 polymer solids and an amount of Tergitol® NP-6 nonionic surfactant identified in Table V below. The fluids were adjusted to a pH of about 8.5 with a 45 percent aqueous solution of potassium hydroxide. The results are given in Table V. The viscosity is given in centipoise (cps).

Table V

Polymer P-8 with 0.2 Grams Tergitol® 15-S-5 Nonionic Surfactant

Added Water, grams	Viscosity at Temperature and Shear Rate: Viscosity at 20°C, 1.0 sec^{-1}	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0	1420	--	--
5	1189	--	--
10	781	4582	864
15	595	3553	735
20	430	2355	642
25	362	1635	619

2136632

Polymer P-8 with 0.4 Grams Tergitol® 15-S-5 Nonionic Surfactant

Added Water, grams	Viscosity at Temperature and Shear Rate: Viscosity at 20°C, 1.0 sec^{-1}	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0	4185	--	--
5	4094	--	--
10	3660	42500	1323
15	3472	26800	1182
20	2432	29280	998
25	1925	21190	858

Polymer P-8 with 0.2 Grams Tergitol® NP-6 Nonionic Surfactant

Added Water, grams	Viscosity at Temperature and Shear Rate: Viscosity at 20°C, 1.0 sec^{-1}	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0	871	--	--
5	761	--	--
10	568	3373	871
15	563	2808	815
20	441	2330	691
25	370	1778	614

Polymer P-8 with 0.4 Grams Tergitol® NP-6 Nonionic Surfactant

Added Water, grams	Viscosity at Temperature and Shear Rate: Viscosity at 20°C, 1.0 sec^{-1}	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0	2373	--	--
5	2310	--	--
10	1948	21490	1333
15	2171	18340	1217
20	1880	20360	1095
25	1707	17230	990

Example 252

Influence of Polymer Type on the Steady Shear Viscosity Profile of Aircraft Anti-Icing Fluids.

A steady shear viscosity profile was obtained with a standard Bohlin VOR rheolometer equipped with temperature control and Mooney-Couette shearing geometry. The fluids contained 54.0 grams of ethylene glycol (polyester grade), 46.0 grams of distilled water, an amount of latex containing 30 weight percent of P-8 or P-31 polymer solids identified in Table W below, an amount of Tergitol® 15-S-5 nonionic surfactant identified in Table W, 0.25 grams of Sandocarin 8132C corrosion inhibitor and 0.01 grams of Sag 7133 corrosion inhibitor. The fluids were adjusted to a pH of about 8.5 with a 45 percent aqueous solution of potassium hydroxide. The results are given in Table W. The viscosity is given in centipoise (cps).

Table W

Polymer P-8 with 0.3 Grams Tergitol® 15-S-5 Nonionic Surfactant

Latex, grams	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0.85	3179	701
0.75	1463	446

Polymer P-31 with 0.3 Grams Tergitol® 15-S-5 Nonionic Surfactant

Latex, grams	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0.85	203	277

Polymer P-31 with 0.5 Grams Tergitol® 15-S-5 Nonionic Surfactant

Latex, grams	Viscosity at 0°C, 0.1 sec^{-1}	Viscosity at -20°C, 10 sec^{-1}
0.85	272	284

Example 253
Shear Stability and Water Spray Endurance of Aircraft Anti-Icing Fluids

A shear stability test and water spray endurance test were performed by following the Association of European Airlines Anti-Icing Performance Test Specification for shear stability and water spray endurance as set forth in AEA Material Specification of De-/Anti-Icing Fluid for Aircraft, G6807/R. The fluid contained 49.75 grams of ethylene glycol (polyester grade), 38.90 grams of distilled water, 0.85 grams of latex containing 30 weight percent of P-8 polymer solids and 0.4 grams of Tergitol® 15-S-5 nonionic surfactant. The fluid was adjusted to a pH of about 8.5 with a 45 percent aqueous solution of potassium hydroxide. The results showed less than 5 percent change in viscosity and 70 minutes for water spray endurance. For the shear stability test, the rotation speed and mixing time were twice the specification value (7000 rpm rotation speed and 10 minutes mixing time).

Although the invention has been illustrated by certain of the preceding examples, it is not to be construed as being limited thereby; but rather, the invention encompasses the generic area as hereinbefore disclosed. Various modifications and embodiments can be made without departing from the spirit and scope thereof.

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

1. An aircraft anti-icing fluid comprising, in admixture, a glycol, water, and a hydrophobe-bearing, alkali-swellable, macromonomer-containing polymeric thickener being present in said anti-icing fluid in an amount less than 5 wt% and which thickens by an inter-molecular associative mechanism among hydrophobe groups, said fluid being sufficiently viscous to adhere to the airfoil surfaces of an aircraft at rest, but becoming sufficiently fluid under the influence of wind shear forces to flow off the airfoil surfaces when they are at or near take-off speed.

2. A fluid of claim 1 wherein the thickener comprises a carboxylic backbone to which the hydrophobes are attached by flexible, pendant chains.

3. A fluid of claim 2 in which the flexible pendant chain comprises a hydrophilic polymer.

4. A fluid of claim 1 in which the thickener is alkali-soluble.

5. A fluid of claim 2 in which two or more hydrophobe groups are attached to each flexible, pendant chain.

6. A fluid of claim 2 in which the flexible, pendant chain is sufficiently long to place the hydrophobes beyond the carboxyl environment of the backbone.

7. A fluid of claim 1 further comprising a surfactant, solvent, or non-solvent which increases the viscosity of the fluid when the aircraft is at rest, but does not significantly increase the viscosity of the fluid when the aircraft is at or near take-off speed.

8. A fluid of claim 1 wherein the water spray endurance time is at least about 30 minutes but wherein the boundary layer displacement thickness is less than about 8 mm at -20°C.

9. A fluid of claim 1 wherein each repeating unit of the thickener has a molecular weight of no more than about 6,000.

10. A composition comprising an anti-icing fluid suitable for ground treatment of aircraft which comprises an admixture of glycol, water and less than about 5 wt% of a macromonomer-containing polymer thickener which is a hydrophobe-bearing, alkali-swellable, polymeric thickener which thickens by an inter-molecular associative mechanism among hydrophobe groups, said macromonomer-containing polymer thickener being present in an amount sufficient to thicken the fluid to promote its adherence to aircraft surfaces when applied to a stationary aircraft but also allow for its wind shear-induced removal during the takeoff run prior to rotation, wherein the macromonomer-containing polymer comprises:

(A) about 1-99.9 weight percent of one or more alpha, beta-monoethylenically unsaturated carboxylic acids;

(B) about 0-98.9 weight percent of one or more monoethylenically unsaturated monomers;

(C) about 0.1-99 weight percent of one or more monoethylenically unsaturated macromonomers; and

(D) about 0-20 weight percent or greater of one or more polyethylenically unsaturated monomers.

11. The composition of claim 10 wherein said monoethylenically unsaturated macromonomer is represented by the formula:

$$R^1\text{-}(OR^2)_z\text{-}R^3\text{-}\underset{}{\overset{R^4}{\overset{|}{C}}}=CR^5R^6$$

wherein:

R^1 is a monovalent residue of a substituted or unsubstituted complex hydrophobe compound;

each R^2 is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue;

R^3 is a substituted or unsubstituted divalent hydrocarbon residue;

R^4, R^5 and R^6 are the same or different and are hydrogen or a substituted or unsubstituted monovalent hydrocarbon residue; and

z is a value of 0 or greater.

12. The composition of claim 11 wherein the substituted or unsubstituted complex hydrophobe compound is represented by the formula selected from:

$$\begin{array}{l} R_1\text{-}(O\text{-}CH_2)_a \\ \qquad\qquad\quad \backslash \\ \qquad\qquad\quad R_3\text{-}(OR_4)_x\text{-}(OR_5)_y\text{-}OR_6 \\ \qquad\qquad\quad / \\ R_2\text{-}(O\text{-}CH_2)_b \end{array}$$

wherein R_1 and R_2 are the same or different and are hydrogen or a substituted or unsubstituted monovalent hydrocarbon residue, R_3 is a substituted or unsubstituted divalent or trivalent hydrocarbon residue, each R_4 is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, each R_5 is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, R_6 is hydrogen, a substituted or unsubstituted monovalent hydrocarbon residue or an ionic substituent, a and b are the same or different and are a value of 0 or 1, and x and y are the same or different and are a value of 0 or greater; provided at least two of R_1, R_2, R_3, R_4, R_5 and R_6 are a hydrocarbon residue having greater than 2 carbon atoms in the case of R_1, R_2 and R_6 or having greater than 2 pendant carbon atoms in the case of R_3, R_4 and R_5; and

$$\begin{array}{c} R_7\text{-}(OCH_2)_d\text{-}R_9\text{-}(OR_{10})_f\text{-}OR_{11} \\ | \\ R_{15} \\ | \\ R_8\text{-}(OCH_2)_e\text{-}R_{12}\text{-}(OR_{13})_g\text{-}OR_{14} \end{array}$$

wherein R_7 and R_8 are the same or different and are hydrogen or a substituted or unsubstituted monovalent hydrocarbon residue, R_9 and R_{12} are the same or different and are a substituted or unsubstituted divalent or trivalent hydrocarbon residue, each R_{10} is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, each R_{13} is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, R_{11} and R_{14} are the same or different and are hydrogen, a substituted or unsubstituted monovalent hydrocarbon residue or an ionic substituent, R_{15} is a substituted or unsubstituted divalent hydrocarbon residue, d and e are the same or different and are a value of 0 or 1, and f and g are the same or different and are a value of 0 or greater; provided at least two of R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14} and R_{15} are a hydrocarbon residue having greater than 2 carbon atoms in the case of R_7, R_8, R_{11} an R_{14} or having greater than 2 pendant carbon atoms in the case of R_9, R_{10}, R_{12}, R_{13} and R_{15}.

13. The composition of claim 12 wherein at least one of R_4, R_5, R_{10} and R_{13} is a hydrocarbon radical represented by the formula:

$$-CH[(OR_{19})_jOR_{20}]-$$

wherein each R_{19} is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue, R_{20} is hydrogen, a substituted or unsubstituted monovalent hydrocarbon residue or an ionic substituent, and j is a value of 0 or greater.

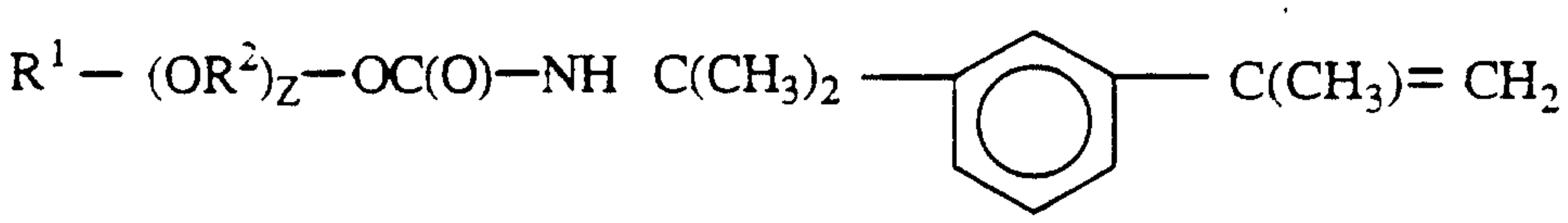
14. The composition of claim 12 wherein each R_4, R_5, R_{10} and R_{13} is selected from $-CH_2CH_2-$, $-CH_2CH(CH_3)-$, or mixtures thereof, and wherein R_{15} is selected from -phenylene-$(CH_2)_m(Q)_n(CH_2)_m$- phenylene- and -naphthylene-$(CH_2)m(Q)_n(CH_2)_m$- naphthylene-, wherein Q individually represents a substituted or unsubstituted divalent bridging group selected from $-CR_{21}R_{22}-$, -O-, -S-, $-NR_{23}-$, $-SiR_{24}R_{25}-$ and -CO-, wherein R_{21} and R_{22} individually represent a radical selected from hydrogen, alkyl of 1 to 12 carbon atoms, phenyl, tolyl and anisyl; R_{23}, R_{24} and R_{25} individually represent a radical selected from hydrogen and methyl, and each m and n individually have a value of 0 or 1.

15. The composition of claim 11 in which said monoethylenically unsaturated macromonomer is represented by the formula:

$$R^1\text{-}(OR^2)_z\text{-}CH_2\underset{\displaystyle (OR_{19})_jOH}{\underset{|}{C}H}CH_2OCH_2\overset{\displaystyle R^4}{\overset{|}{C}}{=}CH_2$$

wherein R^1, R^2, R^4, and z are as defined in claim 5, each R_{19} is the same or different and is a substituted or unsubstituted divalent hydrocarbon residue and j is a value of 0 or greater.

16. The composition of claim 11 in which said monoethylenically unsaturated macromonomer is represented by the formula:



wherein R^1, R^2, and z are as defined in claim 11.

17. The composition of claim 11 in which said monoethylenically unsaturated macromonomer is represented by the formula:

$$R^1\text{-}(OR^2)_z\text{-}OC(O)\text{-}\overset{\displaystyle R^4}{\overset{|}{C}}{=}CH_2$$

wherein R^1, R^2, R^4, and z are as defined in claim 11.

18. The composition of claim 10 in which said component (A) is methacrylic acid, said component (B) is ethyl acrylate, and said component (C) contains styryl, acrylic, allylic, methacrylic or crotonic unsaturation.

19. The composition of claim 10 in which said component (C) is a urethane of said complex hydrophobe compound with alpha, alpha-dimethyl-m-isopropenyl benzyl isocyanate.

20. The composition of claim 10 which is thickened further by an effective amount of a surfactant, solvent or non-solvent.