

TITLE**HIGH CONDUCTIVITY FLUID FOR AIR COMPRESSOR APPLICATIONS**BACKGROUND OF THE INVENTION

5 [0001] The disclosed technology relates to a lubricant composition containing a polyalkylene glycol in which greater than 50% of the repeating units in the polyalkylene glycol contain an alkylene oxide derived moiety comprising a C₄ or greater alkyl group. The lubricant compositions are particularly useful in compressors, such as a reciprocating rotary vane, scroll, or rotary screw air compressor.

10 [0002] Lubricating oils have been used in the past to lubricate the bearings of positive displacement compressors, to seal the rotors, and to cool the compressed gases. Lubricating oils typically used in the industry comprise a mineral oil or synthetic oil as a base oil, and various additives for a particular purpose. Oxidation stability and varnish and deposit control are some of the important properties desirable in a lubricant for maximizing the life of the lubricant, and hence, the life of the equipment, especially under the high temperature and pressure conditions that can be created when operating a positive displacement compressor, for example.

[0003] A known issue with air compressors is fires and possible explosions.

20 [0004] US Patent No. 6,127,324 to Tolfa et al., issued Oct. 3, 2000, provides a lubricating basestock or lubricant composition for use in a positive displacement compressor, where the basestock or lubricant contains a blend of a polyalkylene glycol and an alkyl aromatic. The '324 patent does not teach the prevention of fires or explosions in compressors or any direction on preparing a composition for preventing fires or explosions in compressors.

25 [0005] WO2001/90232A2 to Union Carbide Chemicals, published 29 November 2001, provides a method for improving the fire resistance of fluids. The fire resistance is directed to the fluid itself as measured by a spray flammability test. Although the WO'232 publication teaches a fire resistant fluid, it does not teach how to prevent fires or explosions in compressors in the first instance, or any direction on preparing a composition to preventing fires or explosions in compressors.

30 [0006] US Publication No. 2014/0249063 to Dow Global Technologies LLC, published September 4, 2014, provides an oil soluble polyalkylene glycol. It is taught in

the reference that the oil soluble polyalkylene glycol can be employed in hydrocarbon oils, but does not specify for what applications or what expected properties.

[0007] A need exists to prevent the ignition of fires or explosions in compressors.

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SUMMARY OF THE INVENTION

[0008] The inventors have found that the ignition of fires and/or explosions in compressors may be due to electrical charge buildup in the fluid used in the compressor. Without being bound by theory, it is believed one way to solve this problem may be to increase the electrical conductivity of the fluid to help dissipate the electrical charge building up in the compressor. The inventors have found that known anti-static additives do not work in compressors. For example, most commercial anti-static additives lose conductivity properties when subjected to the heating that occurs in such compressors.

[0009] The disclosed technology therefore provides, in one aspect, a lubricant composition containing (a) at least one oil of lubricating viscosity, and (b) at least one C₄ or greater polyalkylene glycol. Greater than 50% of the repeating units in the C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety comprising a C₄ or greater alkyl.

[0010] In an embodiment, less than 50% of the repeating units in the at least one C₄ or greater polyalkylene glycol can contain an alkylene oxide derived moiety comprising at least one C₁, C₂, C₃ alkyl group or combinations thereof.

[0011] In a further embodiment, the at least one C₄ or greater polyalkylene glycol of component (b) is soluble in the oil of lubricating viscosity.

[0012] In another embodiment, the at least one C₄ or greater polyalkylene glycol of component (b) can be present in the lubricant composition at about 5 percent by weight or greater, such as, for example, from about 5 to about 15 percent by weight.

[0013] In embodiments, the lubricant composition can further include at least one C₁ to C₃ polyalkylene glycol. Greater than 50% of the repeat units in the at least one C₁ to C₃ polyalkylene glycol can contain an alkylene oxide derived moiety having at least one of a C₁, C₂, or C₃ alkyl group or combination thereof.

[0014] In some embodiments, the ratio of the at least one C₄ or greater polyalkylene glycol to the at least one C₁ to C₃ polyalkylene glycol can be from about 1:1 to about 10:1 by weight.

[0015] In further embodiments, the oil of lubricating viscosity in the lubricant composition can be a mineral oil. In the same, or different embodiments, the oil of lubricating viscosity in the lubricant composition can be an ester.

[0016] The lubricant composition can, in some embodiments, contain (d) other additives. The other additives can be any of those commonly employed in compressor lubricants.

[0017] Another aspect of the present technology is a method of operating an air compressor. The method can include lubricating the air compressor with a lubricant composition containing (a) at least one oil of lubricating viscosity, and (b) at least one C₄ or greater polyalkylene glycol, wherein greater than 50% of the repeating units in the C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety comprising a C₄ or greater alkyl.

[0018] In a further aspect of the technology there is provided the use of a polyalkylene glycol in a lubricant for an air compressor, wherein greater than 50% of the repeating units in the C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety comprising a C₄ or greater alkyl.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Various preferred features and embodiments will be described below by way of non-limiting illustration.

[0020] In one aspect, the disclosed technology provides a lubricant composition containing (a) at least one oil of lubricating viscosity, and (b) at least one C₄ or greater polyalkylene glycol.

C₄ or Greater Polyalkylene Glycol

[0021] Polyalkylene glycols have the general formula HO-(R₁-O)_n-H, where R₁ is an alkyl group, R₁-O represents an alkylene oxide derived moiety, and (R₁-O)_n represents a repeating unit. The lubricant composition comprises at least one C₄ or greater polyalkylene glycol. By “C₄ or greater polyalkylene glycol,” it is meant that greater than 50% of the repeating units in the polyalkylene glycol contain an alkylene

oxide derived moiety having a C₄ or greater alkyl group. In some embodiments, more than 60%, or 70%, or even 80% or 90% of the repeating units in the C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety having a C₄ or greater alkyl group. In an embodiment, 100% of the repeating units in the C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety having a C₄ or greater alkyl group.

[0022] By “C₄ or greater alkyl group” it is meant the alkyl group has at least 4 carbon atoms, for example, from 4 to 8 carbon atoms, or from 4 to 7 carbon atoms, or 4, 5 or 6 carbon atoms. The C₄ or greater alkyl group in the alkylene oxide derived moiety may be straight chain or branched, and is preferably straight chain.

[0023] The C₄ or greater polyalkylene glycol can be a single polyalkylene glycol, or a mixture of polyalkylene glycols. Thus, the percentage of repeating units containing an alkylene oxide derived moiety having a C₄ or greater alkyl group can be calculated based on a single polyalkylene glycol, or a mixture of polyalkylene glycols. A mixture of polyalkylene glycols may contain polyalkylene glycols in which less than 50% of the repeating units therein contain an alkylene oxide derived moiety having a C₄ or greater alkyl group and the mixture can still be considered a C₄ or greater polyalkylene glycol so long as the total number of repeating units from all polyalkylene glycols in the mixture containing an alkylene oxide derived moiety having a C₄ or greater alkyl group is greater than 50%.

[0024] In some embodiments, less than 50% of the repeating units in the C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety having at least one of a C₁, C₂, or C₃ alkyl group or combinations thereof, or less than 40%, or less than 30 or 20%, or even less than 10%. In some embodiments, the C₄ or greater polyalkylene glycol is completely free of alkylene oxide derived moieties having any C₁, C₂, or C₃ alkyl groups.

[0025] In an embodiment, the C₄ or greater polyalkylene glycol can include units derived from butylene oxide to units derived from propylene oxide from about 3:1 to about 1:1, such as, for example, 3:1, 2.7:1, 2.5:1, 2.3:1, 2.1:1, 1.9:1, 1.7:1, 1.5:1, 1.3:1, 1.1:1 or 1:1.

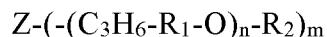
[0026] In some embodiments, the C₄ or greater polyalkylene glycol can have a carbon to oxygen ratio of at least 3.5:1, or of at least 4:1, or in the alternative of at least 5:1, or of at least 6:1.

[0027] In some embodiments, the C₄ or greater polyalkylene glycol can have an unsaturation level of less than about 0.05 meq/g, or less than 0.04 meq/g, or in the alternative less than 0.03 meq/g.

[0028] The C₄ or greater polyalkylene glycol has a number average molecular weight of about 200 to about 8000, preferably about 500 to 5000. Here, as well as elsewhere in the specification, the ratio and range limits may be combined.

[0029] The polyaklyene glycol can have a kinematic viscosity at 40°C of about 15 to about 500 cSt, preferably of about 22 to about 500 cSt, more preferably of about 22 to about 370 cSt, and most preferably of about 22 to about 220 cSt. In some embodiments, polyaklyene glycol can have a kinematic viscosity at 40°C of less than 100 cSt, or from about 5 to about 95 or 100, and in some instances from about 10 to about 80 or 90.

[0030] In a preferred embodiment, the C₄ or greater polyalkylene glycol may be represented by the following formula:



wherein Z is a residue of a non-amine initiator having from 1-8 active hydrogens, and R₁ is a C₁ to C₁₂ alkyl or aromatic, such as, for example, a phenol or alkylated phenol, or a C₁ to C₁₀ alkyl or aromatic, or even a C₁ to C₆ or C₈ alkyl or aromatic, but preferably a C₁, C₂ or C₃ alkyl. The integer n has a value from 8 to 25, preferably from 10 to 20. The number average molecular weight of the polyalkylene glycol is from about 200 to about 8,000, preferably from about 500 to about 5000. R₂ is H, an alkyl having from about 1 about 30 carbons, preferably from about 1 to about 24 carbons, more preferably from about 1 to about 12 carbons, and most preferably from about 1 to about 6 carbons, or an acyl having from about 1 to about 30 carbons, preferably from about 1 to about 24 carbons, more preferably from about 1 to about 12, and most preferably from about 1 to about 6 carbons, and m is from 1 to 8.

[0031] Although the C₄ or greater polyalkylene glycol can be prepared in a number of ways, suitable examples of the C₄ or greater polyalkylene glycol are polyalkylene glycols prepared with initiators containing from 1-8 active hydrogens prepared from alkylene oxides having from 2 to about 12 carbons, including ethylene oxide, propylene oxide or butylene oxide. The oxides may be polymerized alone (homopolymers) or as mixtures (co- or tri- polymers). Another suitable polyalkylene glycol is prepared from a non-amine initiator having 1-4 active hydrogens, and having a kinematic viscosity at 40°C of about 22 to about 220 cSt. Commercially available examples of polyalkylene glycols used for component (A) are WI 165[®] and WI 285[®], available at BASF.

[0032] The meaning of the term "non-amine initiator" is explained as follows. Polyalkylene glycols are polymeric products where the monomers are epoxides of low carbon number olefins (ethylene, propylene, and butylene oxides are the typical ones used). An initiator must be used to start the polymerization reaction which is used to prepare the polyalkylene glycol products. The initiators are typically described as chemicals having active hydrogens. This means chemicals which have hydrogens which can be relatively easily removed with base. Active hydrogens are ones which are bonded to heteroatoms (e.g. oxygen, nitrogen, sulphur, phosphorous). It is common in the industry when making polyalkylene glycols to use oxygen initiators, referred to as non-amine initiators, (alcohols, water, diols, glycerols and/or other polyols), although some products are made using nitrogen initiators, referred to as amine initiators, (alkyl amines, aryl amines, diamines, and polyamines). Sulfur and phosphorous initiators are not typically used to make polyalkylene glycols. U.S. 4,302,343 sets forth oxidation stability data showing that amine initiated polyalkylene glycols are not oxidatively stable even when typical antioxidant packages are present. In an embodiment, the present technology employs non-amine initiators.

Lubricating Composition

[0033] The C₄ or greater polyalkylene glycol can be combined with one or more oils of lubricating viscosity, including natural and synthetic lubricating oils, and mixtures thereof, with or without additives. The C₄ or greater polyalkylene glycol can be combined with both oils of lubricating viscosity and additives. When combined

with other additives, the C₄ or greater polyalkylene glycol can be used in an amount sufficient to achieve the desired electrical conductivity in the lubricating composition, such as, for example from about 1 wt.% or greater of the total weight of the lubricating composition, that is, from about 1 wt.% to about 100 wt.%. In an embodiment, the C₄ or greater polyalkylene glycol can be employed in the lubricating composition from about 0.01 to about 10 wt%, or from about 0.1 to about 8 or 9 wt.%, or from about 0.5 or 1 to about 6 or 7 wt.%. In an embodiment, the C₄ or greater polyalkylene glycol can be employed in the lubricating composition from about 5 wt.% to about 25 wt.%, or from about 6 wt.% to about 20 wt.%, or alternatively from about 7 to about 15 wt.%. One of ordinary skill in the art can readily formulate the C₄ or greater polyalkylene glycol into a lubricating composition to balancing the desired conductivity with the costs.

[0034] The oil of lubricating viscosity refers to an oil that provides lubrication to moving parts. Desirably the lubricant will be an aliphatic or cycloaliphatic oil with less than 10, more desirably less than 5 and preferably less than 1 weight percent of aryl and alkaryl molecules. Aryl and alkaryl molecules will be defined to be compounds having one or more aromatic rings, either as individual rings or as fused rings such as benzene, substituted benzenes, naphthalene, substituted naphthalenes, anthracene etc. Desirably these lubricants would have less than 10, more desirably less than 5 mole percent, and preferably less than 1 mole percent of compounds with unsaturated carbon to carbon double bonds, i.e. they would be relatively free of unsaturation. They can specifically include mineral oils with less than the specified amounts of aryl and alkaryl compounds, hydrotreated mineral oils with less than the specified amounts of aryl and alkaryls, hydrocracked mineral oils, and polyalphaolefins. Desirably these aliphatic or cycloaliphatic lubricants would have viscosities at 40 °C of from about 5 or 20 to about 200 cSt and preferably from about 5 or 20 to about 100 or 150 cSt. These aliphatic oils have better thermal and chemical stability than oils having higher concentrations of unsaturation and/or aryl groups.

[0035] Suitable mineral oils that can be used in conjunction with the C₄ or greater polyalkylene glycol include those having a viscosity range from about 20 to about 100 cSt at 40°C, preferably from about 30 cSt to about 80 cSt at 40°C. Such oils are refined from crude oil of any source. Standard refinery operations may be used in

processing the mineral oil. Among the general types of petroleum oils useful in the compositions of this invention are solvent neutrals, bright stocks, cylinder stocks, residual oils, hydrocracked basestocks, and paraffin oils including pale oils. Such oils and blends of them are produced by a number of conventional techniques which are widely known by those skilled in the art.

[0036] Suitable synthetic lubricating oils include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and interpolymerized olefins [e.g., hydrogenated polybutylenes, hydrogenated polypropylenes, hydrogenated propylene-isobutylene copolymers, chlorinated hydrogenated polybutylenes, hydrogenated poly(1-hexenes), hydrogenated poly(1-octenes), hydrogenated poly(1-decenes)]; alkylbenzenes [e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl) benzenes]; polyphenyls (e.g., biphenyls, terphenyls, alkylated polyphenyls); and alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof.

[0037] The term polyalphaolefins (PAO) is used to define the polymers derived from polymerizing alpha olefin monomers and these polymers are conventionally used as oils of lubricating viscosity and lubricant additives. The polyalphaolefin has similar saturated chains with good thermal stability to the aliphatic mineral oils low in unsaturation. These polyolefins are polymers from olefins having unsaturation between their alpha and beta carbon atoms before the polymerization reaction. The polymerization and any subsequent treatments (hydrogenation) convert the unsaturated carbons to saturated carbons. The use of enough olefins of sufficient length and the polymerization process provides many alkyl branches of 2 to 20 carbon atoms that prevent crystallization of the polyolefins when used as lubricants. Polyalphaolefin is not used in this application to describe polymeric polyolefins that are solids at room temperature and are used as plastics.

[0038] Polyalkylene glycols, other than the C₄ or greater polyalkylene glycol, that are useful as oils of lubricating viscosity include alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification. These constitute another class of known synthetic lubricating oils. These are exemplified by polyoxyalkylene polymers prepared by polymerization of ethylene oxide (POE) or propylene oxide (PPO), the alkyl and

aryl ethers of these polyoxyalkylene polymers (e.g., methyl-polyisopropylene glycol ether having an average molecular weight of 1000, diphenyl ether of polyethylene glycol having a molecular weight of 500-1000, diethyl ether of polypropylene glycol having a molecular weight of 1000-1500); and mono- and polycarboxylic esters thereof, for example, the acetic acid esters, mixed C₃ – C₈ fatty acid esters and C₁₃ Oxo acid diester of tetraethylene glycol.

[0039] Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids and hydrogenated alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkylmalonic acids) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol). Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid.

[0040] Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol and tripentaerythritol.

[0041] Silicon-based oils such as the polyalkyl-, polyaryl-, polyalkoxy-, or polyaryloxysiloxane oils and silicate oils comprise another useful class of synthetic lubricants; they include tetraethyl silicate, tetraisopropyl silicate, tetra-(2-ethylhexyl) silicate, tetra-(4-methyl-2-ethylhexyl) silicate, tetra-(p-tert-butylphenyl) silicate, hexa-(4-methyl-2-pentoxo)disiloxane, poly(methyl)siloxanes and poly(methylphenyl) siloxanes. Other synthetic lubricating oils include liquid esters of phosphorus-containing acids (e.g., tricresyl phosphate, trioctyl phosphate, diethyl ester of decylphosphonic acid) and polymeric tetrahydrofurans.

[0042] Typical vegetable oils that may be used as base oils or as components of the base oils include castor oil, olive oil, peanut oil, rapeseed oil, corn oil, sesame oil, cottonseed oil, soybean oil, sunflower oil, safflower oil, hemp oil, linseed oil,

tung oil, oiticica oil, jojoba oil, meadowfoam oil, and the like. Such oils may be partially or fully hydrogenated, if desired.

[0043] The fact that the base oils used in the lubricant compositions may be composed of (i) one or more mineral oils, (ii) one or more synthetic oils, (iii) one or more vegetable oils, or (iv) a blend of (i) and (ii), or (i) and (iii), or (ii) and (iii), or (i), (ii) and (iii) does not mean that these various types of oils are necessarily equivalents of each other. Certain types of base oils may be used in certain compositions for the specific properties they possess such as biodegradability, high temperature stability, non-flammability or lack of corrosivity towards specific metals (e.g. silver or cadmium). In other compositions, other types of base oils may be preferred for reasons of availability or low cost. Thus, the skilled artisan will recognize that while the various types of base oils discussed above may be used in the compositions of this invention, they are not necessarily functional equivalents of each other in every instance. Oils of lubricating viscosity that cannot be used are those that are not miscible with one another.

Additives

[0044] Effective amounts of additives that can be employed in and with the lubricant compositions can include, for example, antioxidants, rust and corrosion inhibitors, metal deactivators, lubricity additives, antiwear additives, or such additives as may be required. Commercially available examples of antiwear additives are additives such as tricresyl phosphate (TCP) available at Syn-O-Add, 8484[®] available at Akzo-Nobel, or triphenyl phosphorothionate (TPPT) available at Ciba Geigy. In general, the lubricant composition will contain the additive components in minor amounts sufficient to improve the performance characteristics and properties of the oil of lubricating viscosity or basestock blend, or to both the base oil and basestock blend. The amounts of the respective components may vary in accordance with such factors as the type and characteristics of the base oil or basestock blend employed, the type and severity of the service conditions for which the finished product is intended, for example, for use in a positive displacement compressor, such as a rotary screw compressor, a reciprocating rotary vane, or scroll, and the specific performance properties desired in the finished product. In an embodiment, the lubricating composition does not contain naphthol.

[0045] Generally, additives used for their known purpose can comprise from about 10% to about 0.01% by weight of the total weight of the lubricant composition, and preferably from about 5% to about .001% by weight based on the total weight of the lubricating composition.

5 [0046] Examples of useful antioxidants include phenyl naphthyl amines (alpha and/or beta), diphenyl amines, including alkylated diphenyl amines. Commercially available examples of such antioxidants are Irganox L-57® available at Ciba Geigy, and Vanlube 81® available at Vanderbilt Chemical. Suitable antioxidants are also exemplified by phenolic antioxidants, aromatic amine antioxidants, sulfurized phe-
10 nolic antioxidants, and organic phosphites, among others. Examples of the phenolic antioxidants include 2,6-di-tert-butylphenol, liquid mixtures of tertiary butylated phenols, 2,6-di-tert-butyl-4-methylphenol, 4,4'-methylenebis(2,6-di-tert-butylphenol), 2,2'-methylenebis(4-methyl-6-tert-butyl-phenol), mixed methylene-bridged polyalkyl phenols, and 4,4'-thiobis(2-methyl-6-tert-butylphenol). N,N'-Di-see-butyl-
15 p-phenylenediamine, 4-isopropylaminodiphenyl amine, phenyl-alpha-naphthyl mine, phenyl-beta-naphthyl amine, and ring-alkylated diphenylamines serve as examples of aromatic amine antioxidants. Commercially available antioxidants useful for the present invention also include Ethanox® 702 available at the Ethyl Corporation, Irganox® L-135 and Irganox® L-118, Irganox L-06® available at Ciba Geigy, and RC-
20 7130® available at Rhein Chemie.

[0047] Examples of suitable rust and corrosion inhibitors are neutral metal sulfonates such as calcium sulfonate, magnesium sulfonate, sodium sulfonate, barium dinonylnaphthalene sulfonate, and calcium petroleum sulfonate. Other types of rust or corrosion inhibitors which may be used comprise monocarboxylic acids and poly-
25 carboxylic acids. Examples of suitable monocarboxylic acids are oleic acids, octanoic acid, decanoic acid and dodecanoic acid. Suitable polycarboxylic acids include dimer and trimer acids such as are produced from such acids as tall oil fatty acids, oleic acid, and linoleic acid. Also useful are carboxylic acid based, metal free materials, such as hydroxy alkyl carboxylic esters. Another useful type of rust inhibitor for use
30 in the practice of this invention is comprised of the alkenyl succinic acid and alkenyl succinic anhydride corrosion inhibitors such as, for example, tetrapropenylsuccinic

acid, tetrapropenylsuccinic anhydride, tetradecenylsuccinic acid, tetradecenylsuccinic anhydride, hexadecenylsuccinic acid, hexadecenylsuccinic anhydride, and the like. Also useful are the half esters of alkenyl succinic acids having about 8 to about 24 carbon atoms in the alkenyl group with alcohols such as the polyglycols. Other
5 suitable rust or corrosion inhibitors include ether amines; acid phosphates; amines; polyethoxylated compounds such as ethoxylated amines, ethoxylated phenols, and ethoxylated alcohols; imidazolines; and aminosuccinic acids or derivatives thereof. Mixtures of such rust or corrosion inhibitors can be used. U.S. Patent No. 5,773,393 is incorporated in its entirety herein for its disclosure regarding rust and corrosion
10 inhibitor additives. A commercially available example of a corrosion inhibitor is L-859[®] available at the Lubrizol Corporation.

[0048] Examples of suitable metal deactivators are complex organic nitrogen, oxygen and sulfur-containing compounds. For copper, compounds such as substituted benzotriazole, alkyl or acyl substituted 5,5'-methylene-bis-benzotriazole, alkyl or
15 acyl substituted 2,5-dimercaptothiazole, salts of salicylaminoguanidine, and quini-zarin are useful. Propylgallate is an example of a metal deactivator for magnesium, and sebacic acid is an example of a deactivator for lead. A commercially available example of a triazole metal deactivator is Irgamet 39[®] available at Ciba Geigy.

[0049] An effective amount of the foregoing additives is generally in the range
20 from about 0.005% to about 5% by weight of the total weight of the lubricant composition for the antioxidants, from about 0.005% to about 0.5% percent by weight based on the total weight of the lubricant composition for the corrosion inhibitors, and from about 0.001% to about 0.5% percent by weight of the total weight of the lubricant composition for the metal deactivators. It is to be understood that more or
25 less of the additives may be used depending upon the circumstances for which the lubricant compositions are to be used.

[0050] In one embodiment, the lubricating composition comprises, consists essentially of, or consists of a blend of (A) at least one C₄ or greater polyalkylene glycol, as described above, and (B) at least one C₁ to C₃ polyalkylene glycol, wherein
30 greater than 50%, or greater than 60% or 70%, or even greater than 80% or 90%, and in some instances 100% of the repeat units in said at least one C₁ to C₃ polyalkylene glycol contains an alkylene oxide derived moiety comprising at least one of a C₁, C₂,

or C₃ alkyl group or combination thereof. The ratio of the at least one C₄ or greater polyalkylene glycol to the at least one C₁ to C₃ polyalkylene glycol can be from about 1:1 to about 10:1 by weight. In some embodiments the ratio can be 1.5:1 to about 8:1, or from about 2:1 to 6:1, and in some embodiments from about 2.5:1 to about 4:1.

[0051] In an embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol along with polymerized and/or interpolymerized olefin base oils, such as, for example, a poly alphaolefin ("PAO"). In an embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol along with an ester base oil, such as, for example, esters of dicarboxylic acids, esters made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol ethers, and/or vegetable oil esters. In a further embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol along with a mineral oil base oil.

[0052] In an embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 0.01 to about 10 wt.%, from about 0.005 to about 5 wt.% of an antioxidant, and the balance of a base oil. In an embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 5 to about 25 wt.%, from about 0.005 to about 5 wt.% of an antioxidant, and the balance of a base oil.

[0053] In another embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 0.01 to about 10 wt.%, from about 0.005 to about 0.5 wt.% of a corrosion inhibitor, and the balance of a base oil. In another embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 5 to about 25 wt.%, from about 0.005 to about 0.5 wt.% of a corrosion inhibitor, and the balance of a base oil.

[0054] In another embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 0.01 to about 10 wt.%, from about 0.001 to about 0.5 wt.% of a metal deactivator,

and the balance of a base oil. In another embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 5 to about 25 wt.%, from about 0.001 to about 0.5 wt.% of a metal deactivator, and the balance of a base oil.

5 **[0055]** In a further embodiment, the lubricating composition can comprise, consist of, or consist essentially of at least one C₄ or greater polyalkylene glycol from about 0.01 to about 10 wt.%, or from about 5 to about 25 wt.%; along with an additive package comprising, consisting essentially of, or consisting of from about 0.005 to about 5 wt.% of an antioxidant, from about 0.005 to about 0.5 wt.% of a corrosion
10 inhibitor, and from about 0.001 to about 0.5 wt.% of a metal deactivators; and a base oil to the balance of the lubricating composition.

[0056] The lubricating compositions, when used in a positive displacement compressor, such as a reciprocating rotary vane, a scroll, or a rotary screw air compressor, are selected so as to have a viscosity in the range of about 10 to about 150 centistokes
15 at 40°C, preferably from about 22 to about 100 centistokes at 40°C, and most preferably of about 32 to about 68 centistokes at 40°C, and a pour point in the range of about -10°C to about -100°C, and preferably from about -20 °C to about -70°C, and in some embodiments from about -10 °C to about -40 °C or -60 °C.

[0057] The technology also is directed to a process of lubricating a piece of equipment, for example, a positive displacement compressor such as a reciprocating rotary
20 vane, a scroll, or a rotary screw air compressor.

[0058] The technology additionally includes a method of operating a piece of equipment, for example, a positive displacement compressor such as a reciprocating rotary vane, a scroll, or a rotary screw air compressor. The method can include lubricating the piece of equipment with a lubricant composition as herein disclosed,
25 and operating the piece of equipment. A compressor operated with the lubricant composition herein disclosed will have a lower electro-static charge build-up during operation than a compressor operating without the lubricant composition.

[0059] The lubricant compositions are useful as thermally and oxidatively stable
30 compressor lubricants that can maintain the conductivity of the lubricant when heated, particularly when heated for extended periods, such as, for example, for about

8 hours or more. In an embodiment, the lubricant compositions can increase the conductivity to greater than 50 Ps/m at room temperature (i.e., 25 °C).

[0060] The lubricant compositions are also useful to reduce or prevent the buildup of static charge in a compressor, such as a reciprocating rotary vane, scroll, rotary screw air, centrifugal, or axial compressor. The lubricants can be used alone as a lubricant, or they can be combined with effective amounts of additives useful in compressors. In an embodiment, the C₄ or greater polyalkylene glycol can be employed to prevent electrostatically ignited fires in a compressor lubricant, wherein greater than 50% of the repeating units in said at least one C₄ or greater polyalkylene glycol contain a C₄ or greater alkylene oxide moiety.

[0061] A compressor operated according to the present invention runs at a discharge operating temperature range of from about 150°F to about 250°F or 300°F (about 65°C to about 120°C or 150°C). The compressor can run as much as 24 hrs/day, seven days/wk, for many years. In the most extreme case, shutdown will occur only for maintenance.

[0062] The lubricant compositions are useful in compressor oils.

[0063] The amount of each chemical component described is presented exclusive of any solvent or diluent oil, which may be customarily present in the commercial material, that is, on an active chemical basis, unless otherwise indicated. However, unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers, by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade.

[0064] It is known that some of the materials described above may interact in the final formulation, so that the components of the final formulation may be different from those that are initially added. The products formed thereby, including the products formed upon employing the composition of the present invention in its intended use, may not be susceptible of easy description. Nevertheless, all such modifications and reaction products are included within the scope of the present invention; the present invention encompasses the composition prepared by admixing the components described above.

[0065] The invention herein is useful, *inter alia*, for reducing the electro-static charge build-up in a positive displacement compressor, which may be better understood with reference to the following examples.

EXAMPLES

5 [0066] Example 1

[0067] The electrical conductivity results of air compressor lubricant compositions are shown in Tables 1 and 2. All formulations were combinations of the base oils listed with and without anti-static additives. All formulations described contained a standard commercial additive package providing antioxidancy, corrosion inhibition
10 and foam control to the finished air compressor fluid. Anti-stat#1 is a mixture of kerosene, o-xylene, dodecylbenzene sulfonic acid, heavy aromatic naptha, and other chemicals, available from Innospec™ under the trade name STADIS™ 425. Anti-stat#2 is a mixture of polyalkylene glycols containing C₄ or greater polyalkylene glycols, available from Dow™ as OSP-46™.

15 [0068] Results show the raising of electrical conductivity as desired with the use of both additives in various base oil types and combinations.

Table 1

Formulation Number	Base Oil Composition	Anti-Stat Additive	Electrical Conductivity (pS/m)
1	90% PAO 10% Diester	None	<1
2	70% PAO 30% POE	None	3
3	60% PAO 40% POE	None	19
4	40% PAO 60% POE	None	24
5	100% POE	None	33
6	70% PAO 30% POE	10 ppm #1	13
7	70% PAO 30% POE	50 ppm #1	252
8	70% PAO 30% POE	100 ppm #1	843
9	40% PAO 60% POE	100 ppm #1	525
10	40% PAO 60% POE	500 ppm #1	1950
11	100% PAO	10% #2	20
12	100% PAO	30% #2	116
13	100% PAO	54% #2	765
14	100% POE	66% #2	2510
15	None	100% #2	1235

[0069] Samples of the select air compressor fluids from Table 1 were then heated in an oven to 91°C, and then allowed to cool to 23°C. After cooling, the samples were tested for electrical conductivity according to ASTM D2624. Results of the tests are shown in Table 2 below. This is to study the effect of fluid usage on electrical conductivity and is intended to simulate conductivity stability of the fluid in use in a working air compressor.

Table 2

Formulation Number	Heat Cycles	Electrical Conductivity (pS/m)
2	0	5
	1	8
	2	5
7	0	252
	1	200
	2	125
13	0	759
	1	770
15	0	1235
	1	1525
	2	1701

[0070] The results show that operating an air compressor on the lubricant composition disclosed herein containing a C₄ or greater polyalkylene glycol will increase the electrical conductivity of the lubricant, thereby reducing the electro-static build-up of charge within the air compressor and reducing the risk of fire hazards in a working compressor. The results also show that known anti-stat additives lose their efficacy as the fluid is used and heated in a working compressor.

[0071] Each of the documents referred to above is incorporated herein by reference, including any prior applications, whether or not specifically listed above, from which priority is claimed. The mention of any document is not an admission that such document qualifies as prior art or constitutes the general knowledge of the skilled person in any jurisdiction. Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about." It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. Similarly, the ranges and amounts for each element of the invention can be used together with ranges or amounts for any of the other elements.

[0072] As used herein, the transitional term "comprising," which is synonymous with "including," "containing," or "characterized by," is inclusive or open-ended and does not exclude additional, un-recited elements or method steps. However, in each

recitation of “comprising” herein, it is intended that the term also encompass, as alternative embodiments, the phrases “consisting essentially of” and “consisting of,” where “consisting of” excludes any element or step not specified and “consisting essentially of” permits the inclusion of additional un-recited elements or steps that do not materially affect the essential or basic and novel characteristics of the composition or method under consideration.

[0073] While certain representative embodiments and details have been shown for the purpose of illustrating the subject invention, it will be apparent to those skilled in this art that various changes and modifications can be made therein without departing from the scope of the subject invention. In this regard, the scope of the invention is to be limited only by the following claims.

What is claimed is:

1. A lubricant composition comprising:

(a) at least one oil of lubricating viscosity, and

5 (b) at least one C₄ or greater polyalkylene glycol, wherein greater than 50% of the repeating units in said at least one C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety comprising C₄ or greater alkyl.

2. The lubricant of claim 1, wherein less than 50% of the repeating units in said
10 at least one C₄ or greater polyalkylene glycol contain an alkylene oxide derived moiety comprising at least one C₁, C₂, C₃ alkyl group or combinations thereof.

3. The lubricant of any previous claim, wherein said C₄ or greater polyalkylene glycol of component (b) is soluble in the oil of lubricating viscosity.

15 4. The lubricant of any previous claim, wherein said C₄ or greater polyalkylene glycol of component (b) is present at 5 percent by weight or greater.

5. The lubricant of any previous claim, further comprising at least one C₁ to C₃
20 polyalkylene glycol, wherein greater than 50% of the repeat units in said at least one C₁ to C₃ polyalkylene glycol contains an alkylene oxide derived moiety comprising at least one of a C₁, C₂, or C₃ alkyl group or combination thereof.

6. The lubricant of claim 5, wherein the ratio of the at least one C₄ or greater
25 polyalkylene glycol to the at least one C₁ to C₃ polyalkylene glycol is from about 1:1 to about 10:1 by weight.

7. The lubricant of any previous claim wherein the oil of lubricating viscosity comprises a mineral oil base oil.

30 8. The lubricant of any previous claim wherein the oil of lubricating viscosity comprises an ester base oil.

9. The lubricant of claim 8, wherein the ester base oil comprises at least one of esters of dicarboxylic acids; esters made from C₅ to C₁₂ monocarboxylic acids and polyols, C₅ to C₁₂ monocarboxylic acids and polyol ethers, C₅ to C₁₂ monocarboxylic acids and vegetable oil esters, or mixtures thereof.

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10. The lubricant of any previous claim wherein the oil of lubricating viscosity comprises a polymerized and/or interpolymerized olefin base oil.

11. The lubricant of claim 10, wherein the polymerized and/or interpolymerized
10 olefin base oil is a polyalphaolefin base oil

12. The lubricant of any previous claim, further comprising (d) other additives.

13. The lubricant of claim 12, wherein the other additive comprises at least one
15 (i) antioxidant, (ii) corrosion inhibitor, (iii) metal deactivator, or (iv) combinations thereof.

14. The lubricant of claim 13, wherein the other additives comprises at least one antioxidant present from about 0.005 to about 5 wt.%.

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15. The lubricant of claim 13, wherein other additives comprises at least one corrosion inhibitor present from about 0.005 to about 5 wt.%

16. The lubricant of claim 13, wherein other additives comprises at least one metal
25 deactivator present from about 0.001 to about 0.5 wt.%.

17. The lubricant of claim 13, wherein the lubricant composition comprises from about 0.01 to about 10 wt.% of the at least one C₄ or greater polyalkylene glycol; an additive package comprising from about 0.005 to about 5 wt.% of at least one anti-
30 oxidant, from about 0.005 to about 5 wt.% of at least one corrosion inhibitor, and from about 0.001 to about 0.5 wt.% of at least one metal deactivator; and the balance of at least one base oil.

18. A method of operating an air compressor comprising lubricating said air compressor with a lubricant composition comprising (a) at least one oil of lubricating viscosity, and (b) at least one C₄ or greater polyalkylene glycol, wherein greater than
5 50% of the repeating units in said at least one C₄ or greater polyalkylene glycol contain a C₄ or greater alkylene oxide moiety.

19. A method of maintaining the conductivity of a compressor lubricant through multiple heat cycles, comprising lubricating said air compressor with a lubricant
10 composition comprising (a) at least one oil of lubricating viscosity, and (b) at least one C₄ or greater polyalkylene glycol, wherein greater than 50% of the repeating units in said at least one C₄ or greater polyalkylene glycol contain a C₄ or greater alkylene oxide moiety.

15 20. The use of a polyalkylene glycol in a lubricant for an air compressor, wherein greater than 50% of the repeating units in said at least one C₄ or greater polyalkylene glycol contain a C₄ or greater alkylene oxide moiety.

21. The use of a polyalkylene glycol to prevent in a lubricant to prevent electro-
20 statically ignited fires, wherein greater than 50% of the repeating units in said at least one C₄ or greater polyalkylene glycol contain a C₄ or greater alkylene oxide moiety.