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DeSantis et al.(10) **Pub. No.: US 2014/0106996 A1**(43) **Pub. Date: Apr. 17, 2014**(54) **LUBRICANT COMPOSITIONS COMPRISING
BOROXINES AND STERICALLY HINDERED
AMINES TO IMPROVE FLUOROPOLYMER
SEAL COMPATIBILITY****Publication Classification**(71) Applicant: **BASF SE**, Ludwigshafen (DE)(51) **Int. Cl.****C10M 141/12** (2006.01)(72) Inventors: **Kevin J. DeSantis**, Upper Nyack, NY
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12, 2012, provisional application No. 61/713,103,
filed on Oct. 12, 2012.

(57)

ABSTRACT

A lubricant composition including a boroxine compound is disclosed. A lubricant composition and additive package including a boroxine compound and a sterically hindered amine compound are also disclosed. A method of lubricating a system comprising a fluoropolymer seal with the lubricant composition is also disclosed. The boroxine compound of the lubricant composition acts to improve compatibility of the lubricant composition with a fluoropolymer seal.

LUBRICANT COMPOSITIONS COMPRISING BOROXINES AND STERICALLY HINDERED AMINES TO IMPROVE FLUOROPOLYMER SEAL COMPATIBILITY

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/713,088 filed on Oct. 12, 2012 and U.S. Provisional Patent Application No. 61/713,103 filed on Oct. 12, 2012, each of which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

[0002] The present invention generally relates to a lubricant composition that includes a base oil, a boroxine compound, and a sterically hindered amine compound. The invention also relates to an additive package for a lubricant composition.

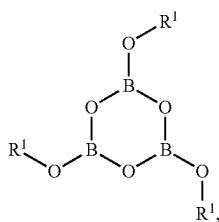
BACKGROUND OF THE INVENTION

[0003] It is known and customary to add stabilizers to lubricant compositions based on mineral or synthetic oils in order to improve their performance characteristics. Some conventional amine compounds are effective stabilizers for lubricants. These conventional amine compounds may help neutralize acids formed during the combustion process. However, these conventional amine compounds are generally not employed in combustion engines due to their detrimental effects on fluoropolymer seals.

[0004] It is an object of the present invention to provide new types of lubricant compositions having improved fluoropolymer seal compatibility.

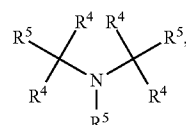
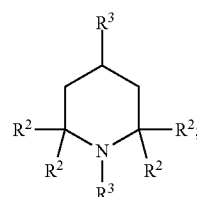
SUMMARY OF THE INVENTION

[0005] The present invention provides a lubricant composition including a base oil, a boroxine compound, and a sterically hindered amine compound. The boroxine compound has general formula (I):



wherein each R¹ is independently an alkyl group having from 1 to 7 carbon atoms.

[0006] The present invention is also directed to a lubricant composition including the base oil, the boroxine compound, and the sterically hindered amine compound having the general formula (II) or (III):



wherein each R² is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein at least two groups designated by R² are an alkyl group; wherein each R³ is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms; wherein each R⁴ is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein at least two groups designated by R⁴ are an alkyl group; wherein each R⁵ is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein said hydrocarbyl groups designated by R², R³, R⁴, and R⁵ are each independently an alcohol group, an alkyl group, an amide group, an ether group or an ester group.

[0007] The present invention also provides a method of lubricating a system comprising a fluoropolymer seal. The method includes providing the lubricant composition comprising the base oil, the boroxine compound, and the sterically hindered amine compound included in an amount ranging from 0.5 to 5 wt. % based on the total weight of the lubricant composition. The method also includes contacting the fluoropolymer seal with the lubricant composition.

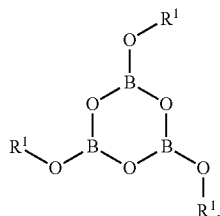
[0008] The present invention also provides an additive package for a lubricant composition including the boroxine compound and the sterically hindered amine compound.

[0009] Lubricant compositions including the boroxine compound demonstrate improved compatibility with fluoropolymer seals as demonstrated by CEC L-39-T96.

DETAILED DESCRIPTION OF THE INVENTION

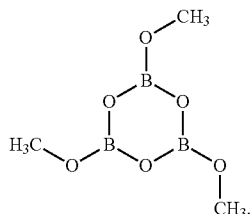
[0010] As described below, a boroxine compound may be included in a lubricant composition or an additive package for a lubricant composition to improve the seal compatibility of the lubricant composition. The boroxine compound may be combined in the lubricant composition with one or more sterically hindered amine compounds. It is believed that when present in a lubricant composition with a sterically hindered amine compound, the boroxine compound surprisingly interacts with these sterically hindered amine compounds so as to interfere with the tendency of the sterically hindered amine compound to negatively interact with a fluoropolymer seal in the lubricant composition as that lubricant composition contacts the fluoropolymer seal, without affecting the stabilizing effect of the sterically hindered amine compound.

[0011] The boroxine compound has general formula (I):

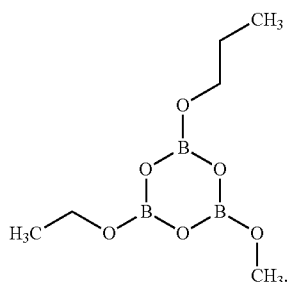


In general formula (I), each R^1 is independently an alkyl group having equal to or fewer than 7 carbon atoms. For example, each R^1 may independently be an alkyl group having from 1 to 7, 1 to 6, 1 to 5, 1 to 4, 1 to 3, or 1 to 2, carbon atoms. Each R^1 may independently be linear or branched. In one specific formulation, each R^1 may be a methyl group. Exemplary R^1 groups may independently include methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, tert-butyl, and n-hexyl groups.

[0012] The boroxine compound may be exemplified by trimethoxy boroxine, tripropoxy boroxine, triisopropoxy boroxine, tributoxy boroxine, tripentoxy boroxine, trihexoxy boroxine, and triheptoxy boroxine. By way of example, trimethoxy boroxine may be exemplified by the formula:



[0013] In certain embodiments, each R^1 may represent distinct alkyl groups. For example, the boroxine compound may be exemplified by the formula:



where one group designated by R^1 in formula (I) is methyl, one group designated by R^1 in formula (I) is ethyl, and one group designated by R^1 in formula (I) is propyl. Alternatively still, groups designated by R^1 may be the same, and one group designated by R^1 may be different in formula (I).

[0014] The boroxine compound may be included in the lubricant composition and/or additive package in an amount sufficient to provide a desired concentration of boron in the

lubricant composition and/or additive package. For example, the boroxine compound can be included in an amount sufficient to provide from 1 to 5000 ppm boron in the lubricant composition based on the total weight of the lubricant composition. Alternatively, the boroxine compound may be included in an amount in the lubricant composition or additive package sufficient to provide from 100 to 5000, 300 to 3000, 500 to 1500, or 700 to 1200, ppm boron, in the lubricant composition based the total weight of the lubricant composition. Alternatively still, the boroxine compound may be provided in an amount sufficient to provide from 1 to 100, 1 to 40, 1 to 20, or to 20, ppm boron, in the lubricant composition based on the total weight of the lubricant composition.

[0015] Alternatively, the boroxine compound may be present in the lubricant composition in an amount ranging from 0.1 to 10, 0.1 to 5, 0.1 to 1, 0.3 to 0.7, 0.5 to 3, or 0.5 to 1.5, wt. %, based on the total weight of the lubricant composition. In other embodiments, the boroxine compound is included in an amount greater than 1 wt. %, but less than 5 wt. %, based on the total weight of the lubricant composition. Mixtures of different boroxine compounds may also be used in combination in the lubricant composition or the additive package.

[0016] If formulated as an additive package, the boroxine compound may be present in an amount ranging from 0.1 to 75 wt. % based on the total weight of the additive package. The boroxine compound may also be present in the additive package in an amount ranging from 0.1 to 50, 0.1 to 33, or 0.1 to 25, wt. %, based on the total weight of the additive package.

[0017] The boroxine compound may be prepared via numerous methods. As but one example, the boroxine compound can be prepared by reacting 2 mole of orthoboric acid (H_3BO_3) with 1 mole tri-alkyl borate. The alkyl borate may have from 1 to 7 carbon atoms, depending on the number of carbon atoms desired in the groups designated by R^1 in general formula (I). The reaction can be conducted at a temperature ranging from 50 to 150° C. in order to remove 1 mol H_2O .

[0018] Conventional uses of conventional boron compounds involve forming a reaction product between a conventional amine compound and a conventional boron compound. The conventional boron compound may be exemplified by reactive borate esters and boric acids. In these applications, the conventional boron compound is consumed by chemical reactions such that the ultimately formed lubricant composition does not contain appreciable amounts of the conventional boron compound. Furthermore, in these applications, the conventional amine compound is reacted with the conventional boron compound to form a salt. The salt formation is evidenced by the electronic impact upon the reaction of the conventional boron compound and the conventional amine compound, which is visible as a chemical shift in NMR spectroscopy. There are also physical indications that a reaction takes place, such as the evolution of heat and the thickening of the solution (cross-linking).

[0019] In such applications of conventional boron compounds, more than 50 wt. % of the conventional boron compound is typically reacted with the conventional amine compounds, or is hydrolyzed, based on the total weight of the conventional boron compound before reaction. In contrast, the inventive lubricant compositions, additive packages, and inventive methods may contain a significant amount of the boroxine compound in an unreacted state. Furthermore, the inventive lubricant compositions, inventive additive packages, and inventive methods do not involve the formation of a

substantial amount of a salt of the boroxine compound. As such, the lubricant composition may be free from a salt formed through the reaction of the boroxine compound, or may contain less than 10, less than 5, or less than 1, wt. %, of the salt formed through the reaction of the boroxine compound based on the total weight of the lubricant composition after any reaction.

[0020] In certain embodiments, at least 50, at least 60, at least 70, at least 80, or at least 90, wt. %, of the boroxine compound remains unreacted in the lubricant composition based on a total weight of boroxine compound utilized to form the lubricant composition prior to any reaction in the lubricant composition. Alternatively, at least 95, at least 96, at least 97, at least 98, or at least 99, wt. %, of the boroxine compound remains unreacted in the lubricant composition based on a total weight of the boroxine compound prior to any reaction in the lubricant composition.

[0021] The term “unreacted” refers to the fact that the designated amount of the boroxine compound does not react with any components in the lubricant composition, such as the conventional amine compound or water. Accordingly, the unreacted amount of the boroxine compound remains in its virgin state when present in the lubricant composition before the lubricant composition has been used in an end-use application, such as an internal combustion engine.

[0022] The phrase “prior to any reaction in the lubricant composition” refers to the basis of the amount of the boroxine compound in the lubricant composition. This description does not require that the boroxine compound reacts with other components in the lubricant composition, i.e., 100 wt. % of the boroxine compound may remain unreacted in the lubricant composition based on a total weight of the boroxine compound prior to any reaction in the lubricant composition.

[0023] In one embodiment, the percentage of the boroxine compound that remains unreacted is determined after all of the components which are present in the lubricant composition reach equilibrium with one another. The time period necessary to reach equilibrium in the lubricant composition may vary widely. For example, the amount of time necessary to reach equilibrium may range from a single minute to many days, or even weeks. In certain embodiments, the percentage of the boroxine compound that remains unreacted in the lubricant composition is determined after 1 minute, 1 hour, 5 hours, 12 hours, 1 day, 2 days, 3 days, 1 week, 1 month, 6 months, or 1 year. Generally, the percentage of the boroxine compound that remains unreacted in the lubricant composition is determined before an end use.

[0024] In certain embodiments, the lubricant composition includes less than 0.1, less than 0.01, less than 0.001, or less than 0.0001, wt. %, of compounds which would react with the boroxine compound based on the total weight of the lubricant composition. In certain embodiments, the lubricant composition may include a collective amount of acids, anhydrides, triazoles, and/or oxides which is less than 0.1 wt. %, of the total weight of the lubricant composition. Alternatively, the lubricant composition may include a collective amount of acids, anhydrides, triazoles, and/or oxides which is less than 0.01, less than 0.001, or less than 0.0001, wt. %, based on the total weight of the lubricant compositions. Alternatively still, the lubricant composition may be free of acids, anhydrides, triazoles, and/or oxides.

[0025] The term “acids” includes both traditional acids and Lewis acids. For example, acids include carboxylic acids, such as lactic acid and hydracrylic acid; alkylated succinic

acids; alkylaromatic sulfonic acids; and fatty acids. Exemplary Lewis acids include alkyl aluminates; alkyl titanates; molybdenumates, such as molybdenum thiocarbamates and molybdenum carbamates; and molybdenum sulfides.

[0026] “Anhydrides” are exemplified by alkylated succinic anhydrides and acrylates. Triazoles may be exemplified by benzotriazoles and derivatives thereof; toluotriazole and derivatives thereof; 2-mercaptobenzothiazole, 2,5-dimercaptothiadiazole, 4,4'-methylene-bis-benzotriazole, 4,5,6,7-tetrahydro-benzotriazole, and salts thereof. Oxides may be exemplified by alkylene oxides, such as ethylene oxide and propylene oxide; metal oxides; alkoxylated alcohols; or alkoxylated esters.

[0027] The lubricant composition may include less than 100, less than 50, less than 10, or less than 5, ppm $\text{B}(\text{OH})_3^-$ ions, based the total weight of the lubricant composition. Conventional boroxine compounds may be hydrolyzed before they are combined with a conventional lubricant composition such that more than 100 ppm $\text{B}(\text{OH})_3^-$ ions are present in the conventional lubricant composition. In such a hydrolyzed state, the inventors of the subject application surprisingly realized that the resultant conventional boroxine compounds do not provide the desired effect on seal compatibility. In other words, at least 50, at least 60, at least 70, at least 80, at least 90, at least 95, or at least 99, wt. %, of the boroxine compound is in an unhydrolyzed state in the lubricant composition based on the total weight of the boroxine compound. The amount of the boroxine compound which is hydrolyzed is accounted for when determining the amount of the boroxine compound which remains unreacted.

[0028] Furthermore, the boroxine compound does not negatively affect the total base number (TBN) of the lubricant composition. The TBN value of the lubricant composition can be determined according to ASTM D2896 and ASTM D4739 as will be described below.

[0029] As described above, the boroxine compound may be combined with at least one sterically hindered amine compound. It should be appreciated that mixtures of different sterically hindered amine compounds may also be combined with the boroxine compound. If included, the lubricant composition includes the sterically hindered amine compound in an amount ranging from 0.1 to 10 wt. %, based on the total weight of the lubricant composition. In some embodiments, the lubricant composition includes the sterically hindered amine compound in an amount ranging from 0.1 to 25, 0.1 to 20, or 0.1 to 15, wt. %, based on the total weight of the lubricant composition. Alternatively, the lubricant composition may comprise the sterically hindered amine compound in an amount ranging from 0.5 to 5, 1 to 3, or 1 to 2, wt. %, based on the total weight of the lubricant composition.

[0030] The sterically hindered amine compound does not substantially react with the boroxine compound to form a salt. The absence of salt formation is evidenced by the lack of a chemical shift in the NMR spectra of the boroxine compound and the sterically hindered amine compound when they are combined in the lubricant composition and/or additive package. In other words, at least 50, 60, 70, 80, 90, 95, or 99 wt. % of the sterically hindered amine compound remains unreacted after the lubricant composition and/or additive package reaches equilibrium.

[0031] The basicity of the sterically hindered amine compound can be determined by acid titration. The resulting neutralization number is expressed as the TBN, and can be measured using various methods. ASTM D4739 is a poten-

tiometric hydrochloric acid titration. The ASTM D4739 method is favored in engine tests and with used oils to measure TBN depletion/retention. When testing used engine lubricants, it should be recognized that certain weak bases are the result of the service rather than having been built into the oil. This test method can be used to indicate relative changes that occur in lubricant composition during use under oxidizing or other service conditions regardless of the color or other properties of the resulting lubricant composition.

[0032] The sterically hindered amine compound may have a TBN value of at least 70 mg KOH/g when tested according to ASTM D4739. Alternatively, the sterically hindered amine compound may have a TBN value of at least 80, at least 90, at least 100, at least 110, at least 120, at least 130, at least 140, at least 150, or at least 160, mg KOH/g, when tested according to ASTM D4739.

[0033] If the sterically hindered amine compound is included in the additive package, the additive package includes the sterically hindered amine compound in an amount ranging from 0.1 to 50 wt. %, based on the total weight of the additive package. Alternatively, the additive package may comprise the sterically hindered amine compound in an amount ranging from 1 to 25, 0.1 to 15, 1 to 10, 0.1 to 8, or 1 to 5, wt. %, based on the total weight of the additive package. Combinations of various sterically hindered amine compounds are also contemplated.

[0034] In some embodiments, the sterically hindered amine compound includes at least one nitrogen atom. In other embodiments, the sterically hindered amine compound does not include triazoles, triazines, or similar compounds where there are three or more nitrogens in the body of a cyclic ring.

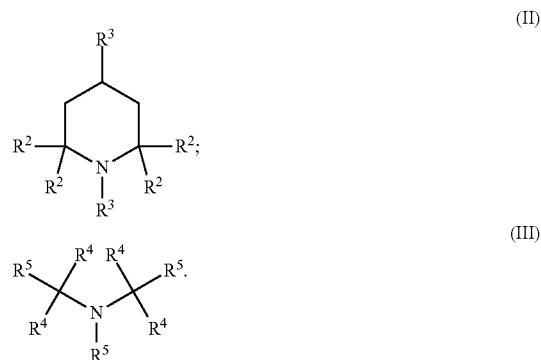
[0035] In some embodiments, the sterically hindered amine compound may consist of, or consist essentially of, hydrogen, carbon, nitrogen, and oxygen. Alternatively, the sterically hindered amine compound may consist of, or consist essentially of, hydrogen, carbon, and nitrogen. In the context of the sterically hindered amine compound, the phrase “consist essentially of” refers to compounds where at least 95 mole % of the sterically hindered amine compound are the recited atoms (i.e., hydrogen, carbon, nitrogen, and oxygen; or hydrogen, carbon, and nitrogen). For example, if the sterically hindered amine compound consists essentially of hydrogen, carbon, nitrogen, and oxygen, at least 95 mole % of the sterically hindered amine compound is hydrogen, carbon, nitrogen, and oxygen. In certain configurations, at least 96, at least 97, at least 98, at least 99, or at least 99.9, mole %, of the sterically hindered amine compound are hydrogen, carbon, nitrogen and oxygen, or, in other embodiments, are carbon, nitrogen, and hydrogen.

[0036] The sterically hindered amine compound may consist of covalent bonds. The phrase “consist of covalent bonds” is intended to exclude those compounds which bond to the sterically hindered amine compound through an ionic association with one or more ionic atoms or compounds. That is, in configurations where the sterically hindered amine compound consists of covalent bonds, the sterically hindered amine compound excludes salts of sterically hindered amine compounds, such as phosphate amine salts and ammonium salts. As such, in certain embodiments, the lubricant composition is free of a salt of the sterically hindered amine compound. More specifically, the lubricant composition may be free of a phosphate amine salt, ammonium salt, and/or sulfate amine salt.

[0037] In one or more embodiments, the sterically hindered amine compound may have a weight average molecular weight ranging from 100 to 1200. Alternatively, the sterically hindered amine compound may have a weight average molecular weight ranging from 200 to 800, or from 200 to 600. Alternatively still, the sterically hindered amine may have a weight average molecular weight of less than 500.

[0038] As used herein, the term “sterically hindered amine compound” means an organic molecule containing at least one nitrogen atom, and fewer than two hydrogen atoms on any carbon atom directly attached to a carbon atom that is bonded to a nitrogen atom. That is, there are either no hydrogen atoms or only one hydrogen atom on at least one beta-carbon with reference to the at least one nitrogen atom. In other embodiments, the term “sterically hindered amine compound” refers to molecules where there are no hydrogen atoms on any beta-carbon with respect to at least one nitrogen atom.

[0039] The sterically hindered amine compound may have general formula (II) or (III):



In general formula (II), each R^2 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, wherein at least two of R^2 are an alkyl group in one molecule; and R^3 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms. In general formula (III), each R^4 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, wherein at least two of R^4 are an alkyl group, and each R^5 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms.

[0040] Each R^2 , R^3 , R^4 , and R^5 may independently be an alcohol group, an alkyl group, an amide group, an ether group, or an ester group. Each R^2 , R^3 , R^4 , and R^5 may independently have from 1 to 17, 1 to 15, 1 to 12, 1 to 8, 1 to 6, or 1 to 4, carbon atoms. Each group designated by R^2 , R^3 , R^4 , and R^5 may independently be straight or branched. For example, each R^2 , R^3 , R^4 , and R^5 may be an alcohol group, amino group, alkyl group, amide group, ether group, or ester group having 1 to 17 carbon atoms, with the designated functional group (alcohol, etc) bonded at various positions on the carbon chain.

[0041] In certain embodiments, at least one group designated by R^2 , R^3 , R^4 , and R^5 is unsubstituted. Alternatively, at least two, three, four, five, or six groups designated by R^2 , R^3 , R^4 , and R^5 are unsubstituted. By “unsubstituted,” it is intended that the designated group is free from pendant functional groups, such as hydroxyl, carboxyl, oxide, thio, and

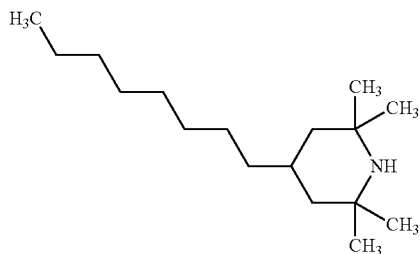
thiol groups, and that the designated group is free from acyclic heteroatoms, such as oxygen, sulfur, and nitrogen heteroatoms. In other embodiments, every group designated by R^2 , R^3 , R^4 , and R^5 is unsubstituted. Alternatively still, it is contemplated that one, two, three, four, five, or six groups designated by R^2 , R^3 , R^4 , and R^5 are substituted. The term “substituted” indicates that the designated group includes at least one pendant functional group, or that the designated group includes at least one acyclic heteroatom.

[0042] Exemplary R^2 , R^3 , R^4 , and R^5 groups may be independently selected from methyl, ethyl, n-propyl, n-butyl, sec-butyl, tert-butyl, n-hexyl, n-octyl, 2-ethylhexyl, n-nonyl, n-decyl, n-undecyl, n-dodecyl, n-tridecyl, n-tetradecyl, n-hexadecyl, or n-octadecyl.

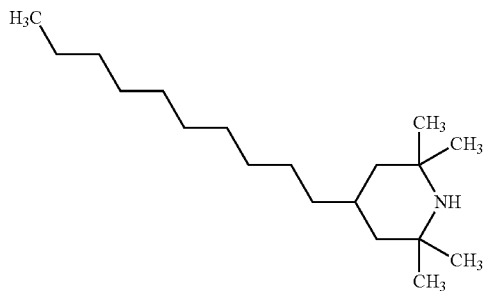
[0043] In general formula (II), at least two, at least three, or all four groups, designated by R^2 are independently an alkyl group. Similarly, in general formula (III), at least two groups designated by R^4 are an alkyl group. Alternatively, at least three, or all four groups, designated by R^4 are an alkyl group.

[0044] The sterically hindered amine compound of general formula (II) may be exemplified by the following compounds:

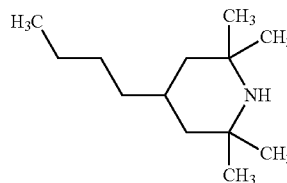
2,2,6,6-tetramethyl-4-octylpiperidine

[0045]

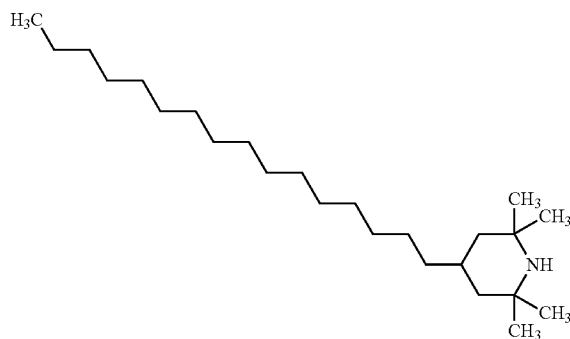
2,2,6,6-tetramethyl-4-decylpiperidine

[0046]

2,2,6,6-tetramethyl-4-butylpiperidine

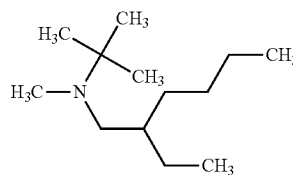
[0047]

2,2,6,6-tetramethyl-4-hexadecylpiperidine

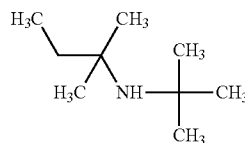
[0048]

[0049] The sterically hindered amine compound of general formula (III) is acyclic. In some embodiments, the term “acyclic” is intended to mean that the sterically hindered amine compound of general formula (III) does not include any cyclic structures and/or aromatic structures. The sterically hindered amine compound of general formula (III) can be exemplified by:

N-tert-butyl-2-ethyl-N-methyl-hexan-1-amine

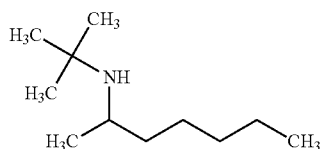
[0050]

tert-amyl-tert-butylamine

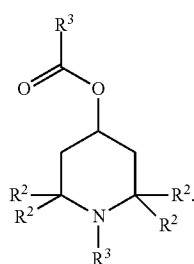
[0051]

N-tert-butylheptan-2-amine

[0052]



[0053] The sterically hindered amine compound may further alternatively be exemplified by the general formula (IV):

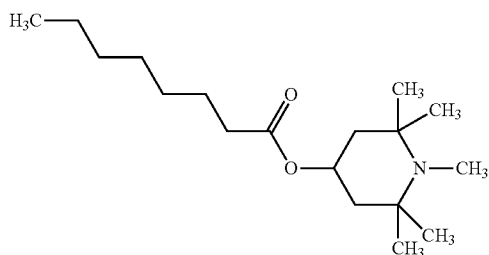


(IV)

In general formula (IV), each R^2 and R^3 are as described above, wherein at least three of R^2 are independently an alkyl group. The sterically hindered amine compound of general formula (IV) may be exemplified by the following compounds:

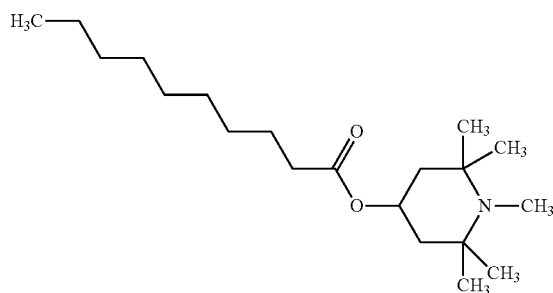
(1,2,2,6,6-pentamethyl-4-piperidyl)octanoate

[0054]



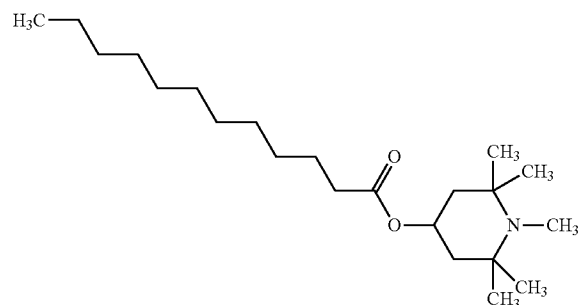
(1,2,2,6,6-pentamethyl-4-piperidyl)decanoate

[0055]



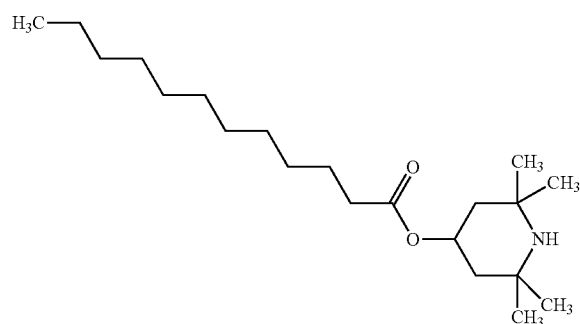
(1,2,2,6,6-pentamethyl-4-piperidyl)dodecanoate

[0056]



(2,2,6,6-tetramethyl-4-piperidyl)dodecanoate

[0057]



[0058] The sterically hindered amine compound may include a single ester group. However, the sterically hindered amine compound may alternatively be free from ester groups. In certain embodiments, the sterically hindered amine compound may include at least one, or only one, piperidine ring.

[0059] The boroxine compound and the sterically hindered amine compound may be provided in an amount such that 1 part of boron is provided for every 1 to 20 parts nitrogen in the sterically hindered amine compound within the lubricant composition. Alternatively, the boroxine compound and the sterically hindered amine compound may be provided in an amount such that 1 part of boron is provided for every 1 to 15, 1 to 10, or 1 to 5, parts nitrogen, in the sterically hindered amine compound within the lubricant composition.

[0060] In yet another embodiment, the lubricant composition may consist, or consist essentially of, a base oil, the boroxine compound, and the sterically hindered amine compound. It is also contemplated that the lubricant composition may consist of, or consist essentially of, the base oil, the boroxine compound, and the sterically hindered amine compound, in addition to one or more of additives that do not materially affect the functionality or performance of the boroxine compound. For example, compounds that materially affect the overall performance of the lubricant composition may include compounds which negatively impact the TBN boost, the lubricity, the fluoropolymer seal compatibility, the corrosion inhibition, or the acidity of the lubricant composition.

[0061] In other embodiments, the additive package may consist, or consist essentially of, the boroxine compound and the sterically hindered amine compound. It is also contemplated that the additive package may consist of, or consist essentially of, the boroxine compound, and the sterically hindered amine compound in addition to one or more of additives that do not compromise the functionality or performance of the boroxine compound. When used in reference to the additive package, the term “consisting essentially of” refers to the additive package being free of compounds that materially affect the overall performance of the lubricant composition. For example, compounds that materially affect the overall performance of the additive package may include compounds which negatively impact the TBN boost, the lubricity, the fluoropolymer seal compatibility, the corrosion inhibition, or the acidity of the additive package.

[0062] In some aspects, the lubricant composition includes a base oil. The base oil is classified in accordance with the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. In other words, the base oil may be further described as one or more of five types of base oils: Group I (sulphur content >0.03 wt. %, and/or <90 wt. %, saturates, viscosity index 80-119); Group II (sulphur content less than or equal to 0.03 wt. %, and greater than or equal to 90 wt. %, saturates, viscosity index 80-119); Group III (sulphur content less than or equal to 0.03 wt. %, and greater than or equal to 90 wt. %, saturates, viscosity index greater than or equal to 119); Group IV (all polyalphaolefins (PAO's)); and Group V (all others not included in Groups I, II, III, or IV).

[0063] The base oil is selected from the group of API Group I base oils; API Group II base oils; API Group III base oils; API Group IV base oils; API Group V base oils; and combinations thereof. In one specific formulation, the base oil includes API Group II base oils.

[0064] The base oil may have a viscosity ranging from 1 to 20 cSt when tested according to ASTM D445 at 100° C. Alternatively, the viscosity of the base oil may range from 3 to 17, or 5 to 14, cSt, when tested according to ASTM D445 at 100° C.

[0065] The base oil may be further defined as a crankcase lubrication oil for spark-ignited and compression-ignited internal combustion engines, including automobile and truck engines, two-cycle engines, aviation piston engines, marine engines, and railroad diesel engines. Alternatively, the base oil can be further defined as an oil to be used in gas engines, diesel engines, stationary power engines, and turbines. The base oil may be further defined as heavy or light duty engine oil.

[0066] In still other embodiments, the base oil may be further defined as synthetic oil that includes one or more alkylene oxide polymers and interpolymers, and derivatives thereof. The terminal hydroxyl groups of the alkylene oxide polymers may be modified by esterification, etherification, or similar reactions. Typically, these synthetic oils are prepared through polymerization of ethylene oxide or propylene oxide to form polyoxyalkylene polymers which can be further reacted to form the synthetic oil. For example, alkyl and aryl ethers of these polyoxyalkylene polymers may be used. For example, methylpolyisopropylene glycol ether having an average molecular weight of 1000; diphenyl ether of polyethylene glycol having a molecular weight of 500-1000; or diethyl ether of polypropylene glycol having a molecular weight of 1000-1500 and/or mono- and polycarboxylic esters thereof, such as acetic acid esters, mixed C₃-C₈ fatty acid

esters, and the C₁₃ oxo acid diester of tetraethylene glycol may also be utilized as the base oil.

[0067] In one embodiment, one or more of the components described herein are blended into the additive package that is subsequently blended into the base oil to make the lubricant composition. The additive package will typically be formulated to provide the desired concentration in the lubricant composition when the concentrate is combined with a predetermined amount of base oil. It is to be appreciated that most references to the lubricant composition throughout this disclosure also apply to the description of the additive package. For example, it is to be appreciated that the additive package may include, or exclude the same components as the lubricant composition albeit in different amounts.

[0068] The base oil may be present in the lubricant composition in an amount ranging from 50 to 99.9, 60 to 99.9, 70 to 99.9, 80 to 99.9, 90 to 99.9, 75 to 95, 80 to 90, or 85 to 95, wt. %, based on the total weight of the lubricant composition. Alternatively, the base oil may be present in the lubricant composition in amounts of greater than 50, 60, 70, 75, 80, 85, 90, 95, 98, or 99, wt. %, based on the total weight of the lubricant composition. In various embodiments, the amount of base oil in a fully formulated lubricant composition (including diluents or carrier oils presents) ranges from 50 to 99, 60 to 90, 80 to 99.5, 85 to 96, or 90 to 95, wt. %, based on the total weight of the lubricant composition. In various embodiments, the amount of base oil in an additive package, if included, (including diluents or carrier oils present) ranges from 0.1 to 50, 1 to 25, or 1 to 15, wt. %, based on the total weight of the additive package.

[0069] In one or more embodiments, the lubricant composition may be classified as a low SAPS lubricant having a sulfated ash content of no more than 3, 2, 1, or 0.5, wt. %, based on the total weight of the lubricant composition. “SAPS” refers to sulfated ash, phosphorous, and sulfur.

[0070] The lubricant composition may have a TBN value of at least 1 mg KOH/g of lubricant composition. Alternatively, the lubricant composition has a TBN value ranging from 1 to 15, 5 to 15, or 9 to 12, mg KOH/g of lubricant composition, when tested according to ASTM D2896.

[0071] The lubricant composition or the additive package may further include a dispersant in addition to the boroxine compound and/or the sterically hindered amine compound. The dispersant may be a polyalkene amine. The polyalkene amine includes a polyalkene moiety. The polyalkene moiety is the polymerization product of identical or different, straight-chain or branched C₂₋₆ olefin monomers. Examples of suitable olefin monomers are ethylene, propylene, 1-butene, isobutene, 1-pentene, 2-methyl butene, 1-hexene, 2-methylpentene, 3-methylpentene, and 4-methylpentene. The polyalkene moiety has a weight average molecular weight of ranging from 200 to 10000, 500 to 10000, or 800 to 5000.

[0072] In one embodiment, the polyalkene amine is derived from polyisobutenes. Particularly suitable polyisobutenes are known as “highly reactive” polyisobutenes which feature a high content of terminal double bonds. Terminal double bonds are alpha-olefinic double bonds of the type shown in general formula (V):

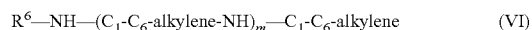


The bonds shown in general formulas (V) are known as vinylidene double bonds. Suitable highly reactive polypolyisobutenes are, for example, polyisobutenes which have a fraction of vinylidene double bonds of greater than 70, 80, 85, mole %. Preference is given in particular to polyisobutenes which have uniform polymer frameworks. Uniform polymer frameworks have in particular those polyisobutenes which are composed of at least 85, 90, or 95, wt. %, of isobutene units. Such highly reactive polyisobutenes preferably have a number-average molecular weight in the abovementioned range. In addition, the highly reactive polyisobutenes may have a polydispersity ranging from 1.05 to 7, or 1.1 to 2.5. The highly reactive polyisobutenes may have a polydispersity less than 1.9, or less than 1.5. Polydispersity refers to the quotients of weight-average molecular weight M_w divided by the number-average molecular weight M_n .

[0073] The amine dispersant may include moieties derived from succinic anhydride and having hydroxyl and/or amino and/or amido and/or imido groups. For example, the dispersant may be derived from polyisobutenylsuccinic anhydride which is obtainable by reacting conventional or highly reactive polyisobutene having a weight average molecular weight ranging from 500 to 5000 with maleic anhydride by a thermal route or via the chlorinated polyisobutene. Specific examples include derivatives with aliphatic polyamines such as ethylenediamine, diethylenetriamine, triethylenetetramine or tetraethylenepentamine.

[0074] To prepare the polyalkene amine, the polyalkene component may be aminated in a known manner. An exemplary process proceeds via the preparation of an oxo intermediate by hydroformylation and subsequent reductive amination in the presence of a suitable nitrogen compound.

[0075] The dispersant may be a poly(oxyalkyl) radical or a polyalkylene polyamine radical of the general formula (VI):



where m is an integer ranging from 1 to 5, R^6 is a hydrogen atom or a hydrocarbyl group having from 1 to 6 carbon atoms with C_1-C_6 alkylene representing the corresponding bridged analogs of the alkyl radicals. The dispersant may also be a polyalkylene imine radical composed of from 1 to 10 C_1-C_4 alkylene imine groups; or, together with the nitrogen atom to which they are bonded, are an optionally substituted 5- to 7-membered heterocyclic ring which is optionally substituted by one to three C_1-C_4 alkyl radicals and optionally bears one further ring heteroatom such as oxygen or nitrogen.

[0076] Examples of suitable alkenyl radicals include mono- or polyunsaturated, preferably mono- or diunsaturated analogs of alkyl radicals has from 2 to 18 carbon atoms, in which the double bonds may be in any position in the hydrocarbon chain.

[0077] Examples of C_4-C_{18} cycloalkyl radical include cyclobutyl, cyclopentyl and cyclohexyl, and also the analogs thereof substituted by 1 to 3 C_1-C_4 alkyl radicals. The C_1-C_4 alkyl radicals are, for example, selected from methyl, ethyl, iso- or n-propyl, n-, iso-, sec- or tert-butyl.

[0078] Examples of the arylalkyl radical include a C_1-C_{18} alkyl group and an aryl group which are derived from a

monocyclic or bicyclic fused or nonfused 4- to 7-membered, in particular 6 membered, aromatic or heteroaromatic group, such as phenyl, pyridyl, naphthyl and biphenyl.

[0079] If additional dispersants other than the dispersant described above are employed, these dispersants can be of various types. Suitable examples of dispersants include polybutenylsuccinic amides or -imides, polybutenylphosphonic acid derivatives and basic magnesium, calcium and barium sulfonates and phenolates, succinate esters and alkylphenol amines (Mannich bases), and combinations thereof.

[0080] If employed, the dispersant can be used in various amounts. The dispersant is typically present in the lubricant composition in an amount ranging from 0.01 to 15, 0.1 to 12, 0.5 to 10, or 1 to 8, wt. %, based on the total weight of the lubricant composition. Alternatively, the dispersant may be present in amounts of less than 15, less than 12, less than 10, less than 5, or less than 1, wt. %, each based on the total weight of the lubricant composition.

[0081] In the additive package, the total weight of the dispersant and the boroxine compound is less than 50, less than 45, less than 40, less than 35, or less than 30, wt. %, of the additive package based on the total weight of the additive package. Surprisingly, it has been found that if the combined concentration of the dispersant and boroxine compound is too high in the additive package, a reaction will take place between the dispersant and the boroxine compound which causes thickening and formation of a precipitate, along with a decrease in fluoropolymer seal compatibility of the lubricant composition.

[0082] The lubricant composition or the additive package may further comprise a dihydrocarbyl dithiophosphate salt. The dihydrocarbyl dithiophosphate salt may be represented by the following general formula: $[R^7O(R^8O)PS(S)]_2M$, where R^7 and R^8 are each hydrocarbyl groups having from 1 to 20 carbon atoms, wherein M is a metal atom or an ammonium group. For example, R^7 and R^8 may each independently be C_{1-20} alkyl groups, C_{2-20} alkenyl groups, C_{3-20} cycloalkyl groups, C_{1-20} aralkyl groups or C_{3-20} aryl groups. The groups designated by R^7 and R^8 may be substituted or unsubstituted. The metal atom may be selected from the group including aluminum, lead, tin, manganese, cobalt, nickel, or zinc. The ammonium group may be derived from ammonia or a primary, secondary, or tertiary amine. The ammonium group may be of the formula $R^9R^{10}R^{11}R^{12}N^+$, wherein R^9 , R^{10} , R^{11} , and R^{12} each independently represents a hydrogen atom or a hydrocarbyl group having from 1 to 150 carbon atoms. In certain embodiments, R^9 , R^{10} , R^{11} , and R^{12} may each independently be hydrocarbyl groups having from 4 to 30 carbon atoms. In one specific embodiment, the dihydrocarbyl dithiophosphate salt is zinc dialkyl dithiophosphate.

[0083] The dihydrocarbyl dithiophosphate salt can be present in the lubricant composition in an amount ranging from 0.1 to 20, 0.5 to 15, 1 to 10, 0.1 to 5, 0.1 to 1, 0.1 to 0.5, or 0.1 to 1.5, wt. %, each based on the total weight of the lubricant composition. Alternatively, the dihydrocarbyl dithiophosphate salt may be present in amounts of less than 20, less than 10, less than 5, less than 1, less than 0.5, or less than 0.1, wt. %, each based on the total weight of the lubricant composition. The additive package may also include the dihydrocarbyl dithiophosphate salt in an amount ranging from 0.1 to 20, 0.5 to 15, 1 to 10, 0.1 to 5, 0.1 to 1, 0.1 to 0.5, or 0.1 to 1.5, wt. %, each based on the total weight of the additive package.

[0084] The lubricant composition or the additive package may additionally include one or more additives to improve various chemical and/or physical properties of the lubricant composition. These additives may be in addition to the boroxine compound or in addition to the combination of the boroxine compound and the sterically hindered amine compound. Specific examples of the one or more additives include anti-wear additives, antioxidants, metal deactivators (or passivators), rust inhibitors, viscosity index improvers, pour point depressors, dispersants, detergents, and antifriction additives. Each of the additives may be used alone or in combination. The one or more additives can be used in various amounts, if employed. The lubricant composition may be formulated with the addition of several auxiliary components to achieve certain performance objectives for use in certain applications. For example, the lubricant composition may be a rust and oxidation lubricant formulation, a hydraulic lubricant formulation, turbine lubricant oil, and an internal combustion engine lubricant formulation. Accordingly, it is contemplated that the base oil may be formulated to achieve these objectives as discussed below.

[0085] If employed, the anti-wear additive can be of various types. The anti-wear additive may include sulfur- and/or phosphorus- and/or halogen-containing compounds, e.g., sulfurised olefins and vegetable oils, alkylated triphenyl phosphates, tritolyl phosphate, tricresyl phosphate, chlorinated paraffins, alkyl and aryl di- and trisulfides, amine salts of mono- and dialkyl phosphates, amine salts of methylphosphonic acid, diethanolaminomethyltolyltriazole, bis(2-ethylhexyl)aminomethyltolyltriazole, derivatives of 2,5-dimercapto-1,3,4-thiadiazole, ethyl 3-[(diisopropoxyphosphinothioyl)thio]propionate, triphenyl thiophosphate (triphenylphosphorothioate), tris(alkylphenyl) phosphorothioate and mixtures thereof, diphenyl monononylphenyl phosphorothioate, isobutylphenyl diphenyl phosphorothioate, the dodecylamine salt of 3-hydroxy-1,3-thiaphosphetane 3-oxide, trithiophosphoric acid 5,5,5-tris[isooctyl 2-acetate], derivatives of 2-mercaptobenzothiazole such as 1-[N,N-bis(2-ethylhexyl)aminomethyl]-2-mercapto-1H-1,3-benzothiazole, ethoxycarbonyl-5-octyldithio carbamate, and/or combinations thereof.

[0086] If employed, in addition or in exchange of the dihydrocarbyl dithiophosphate salt described above, the anti-wear additive can be used in various amounts. The anti-wear additive is typically present in the lubricant composition in an amount ranging from 0.1 to 20, 0.5 to 15, 1 to 10, 0.1 to 1, 0.1 to 0.5, or 0.1 to 1.5, wt. %, each based on the total weight of the lubricant composition. Alternatively, the anti-wear additive may be present in amounts of less than 20, less than 10, less than 5, less than 1, less than 0.5, or less than 0.1, wt. %, each based on the total weight of the lubricant composition.

[0087] If employed, the antioxidant can be of various types. Suitable antioxidants include alkylated monophenols, for example 2,6-di-tert-butyl-4-methylphenol, 2-tert-butyl-4,6-dimethylphenol, 2,6-di-tert-butyl-4-ethylphenol, 2,6-di-tert-butyl-4-n-butylphenol, 2,6-di-tert-butyl-4-isobutylphenol, 2,6-dicyclopentyl-4-methylphenol, 2-(α -methylcyclohexyl)-4,6-dimethylphenol, 2,6-dioctadecyl-4-methylphenol, 2,4,6-tricyclohexylphenol, 2,6-di-tert-butyl-4-methoxymethylphenol, 2,6-di-nonyl-4-methylphenol, 2,4-dimethyl-6-(1'-methylundec-1'-yl)phenol, 2,4-dimethyl-6-(1'-methylheptadec-1'-yl)phenol, 2,4-dimethyl-6-(1'-methyltridec-1'-yl)phenol, and combinations thereof.

[0088] Further examples of suitable antioxidants includes alkylthiomethylphenols, for example 2,4-dioctylthiomethyl-6-tert-butylphenol, 2,4-dioctylthiomethyl-6-methylphenol, 2,4-dioctylthiomethyl-6-ethylphenol, 2,6-didodecylthiomethyl-4-nonylphenol, and combinations thereof. Hydroquinones and alkylated hydroquinones, for example 2,6-di-tert-butyl-4-methoxyphenol, 2,5-di-tert-butylhydroquinone, 2,5-di-tert-amylhydroquinone, 2,6-diphenyl-4-octadecyloxyphenol, 2,6-di-tert-butylhydroquinone, 2,5-di-tert-butyl-4-hydroxyanisole, 3,5-di-tert-butyl-4-hydroxyanisole, 3,5-di-tert-butyl-4-hydroxyphenyl stearate, bis-(3,5-di-tert-butyl-4-hydroxyphenyl)adipate, and combinations thereof, may also be utilized.

[0089] Furthermore, hydroxylated thiodiphenyl ethers, for example 2,2'-thiobis(6-tert-butyl-4-methylphenol), 2,2'-thiobis(4-octylphenol), 4,4'-thiobis(6-tert-butyl-3-methylphenol), 4,4'-thiobis(6-tert-butyl-2-methylphenol), 4,4'-thiobis(3,6-di-sec-amylphenol), 4,4'-bis-(2,6-dimethyl-4-hydroxyphenyl)disulfide, and combinations thereof, may also be used.

[0090] It is also contemplated that alkylidenebisphenols, for example 2,2'-methylenebis(6-tert-butyl-4-methylphenol), 2,2'-methylenebis(6-tert-butyl-4-ethylphenol), 2,2'-methylenebis[4-methyl-6-(α -methylcyclohexyl)phenol], 2,2'-methylenebis(4-methyl-6-cyclohexylphenol), 2,2'-methylenebis(6-nonyl-4-methylphenol), 2,2'-methylenebis(4,6-di-tert-butylphenol), 2,2'-ethylidenebis(4,6-di-tert-butylphenol), 2,2'-ethylidenebis(6-tert-butyl-4-isobutylphenol), 2,2'-methylenebis[6-(α -methylbenzyl)-4-nonylphenol], 2,2'-methylenebis[6-(α,α -dimethylbenzyl)-4-nonylphenol], 4,4'-methylenebis(2,6-di-tert-butylphenol), 4,4'-methylenebis(6-tert-butyl-2-methylphenol), 1,1-bis(5-tert-butyl-4-hydroxy-2-methylphenyl)butane, 2,6-bis(3-tert-butyl-5-methyl-2-hydroxybenzyl)-4-methylphenol, 1,1,3-tris(5-tert-butyl-4-hydroxy-2-methylphenyl)butane, 1,1-bis(5-tert-butyl-4-hydroxy-2-methylphenyl)-3-n-dodecylmercapto butane, ethylene glycol bis[3,3-bis(3'-tert-butyl-4'-hydroxyphenyl)butyrate], bis(3-tert-butyl-4-hydroxy-5-methylphenyl)dicyclopentadiene, bis[2-(3'-tert-butyl-2'-hydroxy-5'-methylbenzyl)-6-tert-butyl-4-methylphenyl]terephthalate, 1,1-bis-(3,5-dimethyl-2-hydroxyphenyl)butane, 2,2-bis-(3,5-di-tert-butyl-4-hydroxyphenyl)propane, 2,2-bis-(5-tert-butyl-4-hydroxy-2-methylphenyl)-4-n-dodecylmercaptobutane, 1,1,5,5-tetra-(5-tert-butyl-4-hydroxy-2-methylphenyl)pentane, and combinations thereof may be utilized as antioxidants in the lubricant composition.

[0091] O-, N- and S-benzyl compounds, for example 3,5,3',5'-tetra-tert-butyl-4,4'-dihydroxydibenzyl ether, octadecyl-4-hydroxy-3,5-dimethylbenzylmercaptoacetate, tris-(3,5-di-tert-butyl-4-hydroxybenzyl)amine, bis(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl)dithiol terephthalate, bis(3,5-di-tert-butyl-4-hydroxybenzyl)sulfide, isooctyl-3,5-di-tert-butyl-4-hydroxy benzylmercaptoacetate, and combinations thereof, may also be utilized.

[0092] Hydroxybenzylated malonates, for example dioctadecyl-2,2-bis-(3,5-di-tert-butyl-2-hydroxybenzyl)-malonate, di-octadecyl-2-(3-tert-butyl-4-hydroxy-5-methylbenzyl)-malonate, di-dodecylmercaptoethyl-2,2-bis-(3,5-di-tert-butyl-4-hydroxybenzyl)malonate, bis [4-(1,1,3,3-tetramethylbutyl)phenyl]-2,2-bis(3,5-di-tert-butyl-4-hydroxybenzyl)malonate, and combinations thereof are also suitable for use as antioxidants.

[0093] Triazine compounds, for example 2,4-bis(octylmercapto)-6-(3,5-di-tert-butyl-4-hydroxyanilino)-1,3,5-triazine, 2-octylmercapto-4,6-bis(3,5-di-tert-butyl-4-hydroxyanilino)-1,3,5-triazine, 2-octylmercapto-4,6-bis(3,5-di-tert-butyl-4-hydroxyphenoxy)-1,3,5-triazine, 2,4,6-tris(3,5-di-tert-butyl-4-hydroxyphenoxy)-1,2,3-triazine, 1,3,5-tris(3,5-di-tert-butyl-4-hydroxybenzyl)isocyanurate, 1,3,5-tris(4-tert-butyl-3-hydroxy-2,6-dimethylbenzyl 2,4,6-tris(3,5-di-tert-butyl-4-hydroxyphenylethyl)-1,3,5-triazine, 1,3,5-tris(3,5-di-tert-butyl-4-hydroxyphenyl propionyl)-hexahydro-1,3,5-triazine, 1,3,5-tris-(3,5-dicyclohexyl-4-hydroxybenzyl)-isocyanurate, and combinations thereof, may also be used.

[0094] Additional examples of antioxidants include aromatic hydroxybenzyl compounds, for example, 1,3,5-tris-(3,5-di-tert-butyl-4-hydroxybenzyl)-2,4,6-trimethylbenzene, 1,4-bis(3,5-di-tert-butyl-4-hydroxybenzyl)-2,3,5,6-tetramethylbenzene, 2,4,6-tris(3,5-di-tert-butyl-4-hydroxybenzyl)phenol, and combinations thereof. Benzylphosphonates, for example dimethyl-2,5-di-tert-butyl-4-hydroxybenzylphosphonate, diethyl-3,5-di-tert-butyl-4-hydroxybenzylphosphonate, dioctadecyl-3,5-di-tert-butyl-4-hydroxybenzylphosphonate, dioctadecyl-5-tert-butyl-4-hydroxy-3-methylbenzylphosphonate, the calcium salt of the monoethyl ester of 3,5-di-tert-butyl-4-hydroxybenzylphosphonic acid, and combinations thereof, may also be utilized. In addition, acylaminophenols, for example 4-hydroxylauranilide, 4-hydroxystearanilide, and octyl N-(3,5-di-tert-butyl-4-hydroxyphenyl)carbamate.

[0095] Esters of [3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionic acid with mono- or polyhydric alcohols, e.g. with methanol, ethanol, octadecanol, 1,6-hexanediol, 1,9-nonanediol, ethylene glycol, 1,2-propanediol, neopentyl glycol, thiodiethylene glycol, diethylene glycol, triethylene glycol, pentaerythritol, tris(hydroxyethyl)isocyanurate, N,N'-bis(hydroxyethyl)oxamide, 3-thiaundecanol, 3-thiapentadecanol, trimethylhexanediol, trimethylolpropane, 4-hydroxymethyl-1-phospha-2,6,7-trioxabicyclo[2.2.2]octane, and combinations thereof, may also be used. It is further contemplated that esters of β -(5-tert-butyl-4-hydroxy-3-methylphenyl)-propionic acid with mono- or polyhydric alcohols, e.g. with methanol, ethanol, octadecanol, 1,6-hexanediol, 1,9-nonanediol, ethylene glycol, 1,2-propanediol, neopentyl glycol, thiodiethylene glycol, diethylene glycol, triethylene glycol, pentaerythritol, tris(hydroxyethyl)isocyanurate, N,N'-bis(hydroxyethyl)oxamide, 3-thiaundecanol, 3-thiapentadecanol, trimethylhexanediol, trimethylolpropane, 4-hydroxymethyl-1-phospha-2,6,7-trioxabicyclo[2.2.2]octane, and combinations thereof, may be used.

[0096] Additional examples of suitable antioxidants include those that include nitrogen, such as amides of β -(3,5-di-tert-butyl-4-hydroxyphenyl)propionic acid, e.g., N,N-bis(3,5-di-tert-butyl-4-hydroxyphenylpropionyl)hexamethylenediamine, N,N'-bis(3,5-di-tert-butyl-4-hydroxyphenylpropionyl)trimethylenediamine, N,N'-bis(3,5-di-tert-butyl-4-hydroxyphenylpropionyl)hydrazine. Other suitable examples of antioxidants include aminic antioxidants such as N,N'-diisopropyl-p-phenylenediamine, N,N'-di-sec-butyl-p-phenylenediamine, N,N'-bis(1,4-dimethylpentyl)-p-phenylenediamine, N,N'-bis(1-ethyl-3-methylpentyl)-p-phenylenediamine, N,N'-bis(1-methylheptyl)-p-phenylenediamine, N,N'-dicyclohexyl-p-phenylenediamine, N,N'-diphenyl-p-phenylenediamine, N,N'-bis(2-naphthyl)-p-phenylenediamine, N-isopropyl-N'-phenyl-p-phenylenediamine, N-(1,3-dimethyl-butyl)-N'-phenyl-p-phenylenediamine,

N-(1-methylheptyl)-N'-phenyl-p-phenylenediamine, N-cyclohexyl-N'-phenyl-p-phenylenediamine, 4-(p-toluenesulfamoyl)diphenylamine, N,N'-dimethyl-N,N'-di-sec-butyl-p-phenylenediamine, diphenylamine, N-allyldiphenylamine, 4-isopropoxydiphenylamine, N-phenyl-1-naphthylamine, N-phenyl-2-naphthylamine, octylated diphenylamine, for example p,p'-di-tert-octyldiphenylamine, 4-n-butylaminophenol, 4-butyrylamino-phenol, 4-nonanoylamino-phenol, 4-dodecanoylamino-phenol, 4-octadecanoylamino-phenol, bis(4-methoxyphenyl)amine, 2,6-di-tert-butyl-4-dimethylamino methylphenol, 2,4'-diaminodiphenylmethane, 4,4'-diaminodiphenylmethane, N,N,N',N'-tetramethyl-4,4'-diaminodiphenylmethane, 1,2-bis[(2-methyl-phenyl)amino]ethane, 1,2-bis(phenylamino)propane, (o-tolyl)biguanide, bis[4-(1',3'-dimethylbutyl)phenyl]amine, tert-octylated N-phenyl-1-naphthylamine, a mixture of mono- and dialkylated tert-butyl/tert-octyldiphenylamines, a mixture of mono- and dialkylated isopropyl/isoheptyldiphenylamines, mixtures of mono- and dialkylated tert-butyl/diphenylamines, 2,3-dihydro-3,3-dimethyl-4H-1,4-benzothiazine, phenothiazine, N-allylphenothiazine, N,N,N',N'-tetraphenyl-1,4-diaminobut-2-ene, and combinations thereof.

[0097] Even further examples of suitable antioxidants include aliphatic or aromatic phosphites, esters of thiodipropionic acid or of thiodiacetic acid, or salts of dithiocarbamic or dithiophosphoric acid, 2,2,12,12-tetramethyl-5,9-dihydroxy-3,7,11-trithiamidecane and 2,2,15,15-tetramethyl-5,12-dihydroxy-3,7,10,14-tetrathiahexadecane, and combinations thereof. Furthermore, sulfurized fatty esters, sulfurized fats and sulfurized olefins, and combinations thereof, may be used.

[0098] If employed, the antioxidant can be used in various amounts. The antioxidant is typically present in the lubricant composition in an amount ranging from 0.01 to 5, 0.1 to 3, or 0.5 to 2, wt. %, based on the total weight of the lubricant composition. Alternatively, the antioxidant may be present in amounts of less than 5, less than 3, or less than 2, wt. %, based on the total weight of the lubricant composition.

[0099] If employed, the metal deactivator can be of various types. Suitable metal deactivators include benzotriazoles and derivatives thereof, for example 4- or 5 alkylbenzotriazoles (e.g. tolutriazole) and derivatives thereof, 4,5,6,7-tetrahydrobenzotriazole and 5,5'-methylenebisbenzotriazole; Mannich bases of benzotriazole or tolutriazole, e.g. 1-[bis(2-ethylhexyl)aminomethyl]tolutriazole and 1-[bis(2-ethylhexyl)aminomethyl]benzotriazole; and alkoxyalkylbenzotriazoles such as 1-(nonyloxymethyl)benzotriazole, 1-(1-butoxyethyl)benzotriazole and 1-(1-cyclohexyloxybutyl)tolutriazole, and combinations thereof.

[0100] Additional examples of suitable metal deactivators include 1,2,4-triazoles and derivatives thereof, and Mannich bases of 1,2,4-triazoles, such as 1-[bis(2-ethylhexyl)aminomethyl-1,2,4-triazole]; alkoxyalkyl-1,2,4-triazoles such as 1-(1-butoxyethyl)-1,2,4-triazole; and acylated 3-amino-1,2,4-triazoles, imidazole derivatives, for example 4,4'-methylenebis(2-undecyl-5-methylimidazole) and bis[(N-methyl)imidazol-2-yl]carbinol octyl ether, and combinations thereof. Further examples of suitable metal deactivators include sulfur-containing heterocyclic compounds, for example 2-mercaptobenzothiazole, 2,5-dimercapto-1,3,4-thiadiazole and derivatives thereof; and 3,5-bis[di(2-ethylhexyl)aminomethyl]-1,3,4-thiadiazolin-2-one, and combinations thereof. Even further examples of metal deactivators include amino

compounds, for example salicylidenepropylenediamine, salicylaminoguanidine and salts thereof, and combinations thereof.

[0101] If employed, the metal deactivator can be used in various amounts. The metal deactivator may be present in the lubricant composition in an amount ranging from 0.01 to 0.1, 0.05 to 0.01, or 0.07 to 0.1, wt. %, based on the total weight of the lubricant composition. Alternatively, the metal deactivator may be present in amounts of less than 1.0, less than 0.7, or less than 0.5, wt. %, based on the total weight of the lubricant composition.

[0102] If employed, the rust inhibitor and/or friction modifier can be of various types. Suitable examples of rust inhibitors and/or friction modifiers include organic acids, their esters, metal salts, for example alkyl- and alkenylsuccinic acids and their partial esters with alcohols, diols or hydroxycarboxylic acids, partial amides of alkyl- and alkenylsuccinic acids, 4-nonylphenoxyacetic acid, alkoxy- and alkoxyethoxycarboxylic acids such as dodecyloxyacetic acid, dodecyloxy(ethoxy)acetic acid, and also N-oleoylsarcosine, sorbitan monooleate, lead naphthenate, alkenylsuccinic anhydrides, for example, dodecenylsuccinic anhydride, 2-carboxymethyl-1-dodecyl-3-methylglycerol, and combinations thereof. Further examples include heterocyclic compounds, for example: substituted imidazolines and oxazolines, and 2-heptadecenyl-1-(2-hydroxyethyl)imidazoline, phosphorus-containing compounds, for example: amine salts of phosphoric acid partial esters or phosphonic acid partial esters, molybdenum-containing compounds, such as molybdenum dithiocarbamate and other sulphur and phosphorus containing derivatives, sulfur-containing compounds, for example: barium dinonylnaphthalenesulfonates, calcium petroleum sulfonates, alkylthio-substituted aliphatic carboxylic acids, esters of aliphatic 2-sulfocarboxylic acids and salts thereof, glycerol derivatives, for example: glycerol monooleate, 1-(alkylphenoxy)-3-(2-hydroxyethyl)glycerols, 1-(alkylphenoxy)-3-(2,3-dihydroxypropyl)glycerols and 2-carboxyalkyl-1,3-dialkylglycerols, and combinations thereof.

[0103] If employed, the rust inhibitor and/or friction modifier can be used in various amounts. The rust inhibitor and/or friction modifier may be present in the lubricant composition in an amount ranging from 0.01 to 0.1, 0.05 to 0.01, or 0.07 to 0.1, wt. %, based on the total weight of the lubricant composition. Alternatively, the rust inhibitor and/or friction modifier may be present in amounts of less than 1, less than 0.7, or less than 0.5, wt. %, based on the total weight of the lubricant composition.

[0104] If employed, the viscosity index improver can be of various types. Suitable examples of viscosity index improvers include polyacrylates, polymethacrylates, vinylpyrrolidone/methacrylate copolymers, polyvinylpyrrolidones, polybutenes, olefin copolymers, styrene/acrylate copolymers and polyethers, and combinations thereof.

[0105] If employed, the viscosity index improver can be used in various amounts. The viscosity index improver may be present in the lubricant composition in an amount ranging from 0.01 to 20, 1 to 15, or 1 to 10, wt. %, based on the total weight of the lubricant composition. Alternatively, the viscosity index improver may be present in amounts of less than 10, less than 8, or less than 5, wt. %, based on the total weight of the lubricant composition.

[0106] If employed, the pour point depressant can be of various types. Suitable examples of pour point depressants

include polymethacrylate and alkylated naphthalene derivatives, and combinations thereof.

[0107] If employed, the pour point depressant can be used in various amounts. The pour point depressant may be present in the lubricant composition in an amount ranging from 0.01 to 0.1, 0.05 to 0.01, or 0.07 to 0.1, wt. %, each based on the total weight of the lubricant composition. Alternatively, the pour point depressant may be present in amounts of less than 1.0, less than 0.7, or less than 0.5, wt. %, based on the total weight of the lubricant composition.

[0108] If employed, the detergent can be of various types. Suitable examples of detergents include overbased or neutral metal sulphonates, phenates and salicylates, and combinations thereof.

[0109] If employed, the detergent can be used in various amounts. The detergent may be present in the lubricant composition in an amount ranging from 0.01 to 5, 0.1 to 4, 0.5 to 3, or 1 to 3, wt. %, based on the total weight of the lubricant composition. Alternatively, the detergent may be present in amounts of less than 5, less than 4, less than 3, less than 2, or less than 1, wt. %, based on the total weight of the lubricant composition.

[0110] In various embodiments, the lubricant composition is substantially free of water, e.g., the lubricant composition includes less than 5, less than 4, less than 3, less than 2, less than 1, less than 0.5, or less than 0.1, wt. %, of water, based on the total weight of the lubricant composition. Alternatively, the lubricant composition may be completely free of water.

[0111] Preferred lubricant compositions provided for use and used pursuant to this invention include those which pass the CEC L-39-T96 seal compatibility test. The CEC L-39-T96 test involves keeping a test specimen of a fluoropolymer in a lubricant composition at 150° C. The seal specimens are then removed and dried and the properties of the seal specimens are assessed and compared to the seal specimens which were not heated in the lubricant composition. The percent change in these properties is assessed to quantify the compatibility of the fluoropolymer seal with the lubricant composition. The incorporation of the boroxine compound into the lubricant composition decreases the tendency of the lubricant composition to degrade the seals versus lubricant compositions which are free from the boroxine compound.

[0112] The pass/fail criteria include maximum variation of certain characteristics after immersion for 7 days in fresh oil without pre-aging. The maximum variation for each characteristic depends on the type of elastomer used, the type of engine used, and whether an after-treatment device is utilized.

[0113] The characteristics measured before and after immersion included Hardness DIDC (points); Tensile Strength (%); Elongation at Rupture (%); Volume Variation (%). For heavy-duty diesel engines, the pass/fail criteria are presented below in Table 1:

TABLE 1

Fluoropolymer Seal Compatibility for CEC L-39-T96 Heavy-Duty Diesel Engines	
Property	Elastomer Type RE1
Hardness DIDC, points	-1/+5
Tensile Strength, %	-50/+10
Elongation at Rupture, %	-60/+10
Volume Variation, %	-1/+5

[0114] In these tests, a conventional lubricant composition passes the test if the exposed test specimen exhibits a change in hardness from -1% to $+5\%$; a tensile strength (as compared to an untested specimen) from -50% to $+10\%$; a change in elongation at rupture (as compared to an untested specimen) from -60% to $+10\%$; and a volume variation (as compared to an untested specimen) from -1% to $+5\%$.

[0115] When the lubricant composition is tested according to CEC L-39-T96 for Heavy-Duty Diesel Engines, the change in hardness can range from -1 to 5% , -0.5 to 5% , -0.1 to 5% , 0.5 to 5% , or 1 to 5% ; the change in tensile strength can range from -50 to 10% , -45 to 10% , -40 to 10% , or -35 to 10% ; the change in elongation at rupture can range from -60 to 10% , -55 to 10% , -50 to 10% , or -45 to 10% ; and the change in volume variation can range from -1 to 5% , -0.75 to 5% , -0.5 to 5% , -0.1 to 5% , or 0 to 5% .

[0116] When the boroxine composition is used in the lubricant compositions described, the resulting lubricant composition has a fluoropolymer compatibility such that a fluoropolymer seal submerged in said lubricant composition exhibits a change in tensile strength of less than 10 , less than 15 , less than 20 , less than 25 , less than 30 , less than 35 , less than 40 , less than 45 , less than 50 , less than 55 , or less than 60 , %, when tested according to CEC L-39-T96 for Heavy-Duty Diesel Engines. Similarly, when the boroxine compound is used in the lubricant compositions described, the resulting lubricant composition has a fluoropolymer compatibility such that a fluoropolymer exhibits a change in tensile strength elongation at rupture of less than 20 , less than 25 , less than 30 , less than 35 , less than 40 , less than 45 , less than 50 , less than 55 , or less than 60 , %, when tested according to CEC L-39-T96 for Heavy-Duty Diesel Engines.

[0117] Some of the compounds described above may interact in the lubricant composition, so that the components of the lubricant composition in final form may be different from those components that are initially added or combined together. Some products formed thereby, including products formed upon employing the lubricant composition of this invention in its intended use, are not easily described or describable. Nevertheless, all such modifications, reaction products, and products formed upon employing the lubricant composition of this invention in its intended use, are expressly contemplated and hereby included herein. Various embodiments of this invention include one or more of the modification, reaction products, and products formed from employing the lubricant composition, as described above.

[0118] A method of lubricating a system is provided. The method includes contacting the system with the lubricant composition described above. The system may further comprise an internal combustion engine. Alternatively, the system may further comprise any combustion engine or application that utilizes a lubricant composition. The system includes at least one fluoropolymer seal.

[0119] The fluoropolymer seal may comprise a fluoroelastomer. The fluoroelastomer may be categorized under ASTM D1418 and ISO 1629 designation of FKM for example. The fluoroelastomer may comprise copolymers of hexafluoropropylene (HFP) and vinylidene fluoride (VDF or VF₂), terpolymers of tetrafluoroethylene (TFE), vinylidene fluoride and hexafluoropropylene, perfluoromethylvinylether (PMVE), copolymers of TFE and propylene and copolymers of TFE, PMVE and ethylene. The fluorine content varies for example between 66 to 70 wt. %, based on the total weight of the fluoropolymer seal. FKM is fluoro-rubber of the polymeth-

ylene type having substituent fluoro and perfluoroalkyl or perfluoroalkoxy groups on the polymer chain.

[0120] In addition, a method of forming the lubricant composition is provided. The method includes combining the base oil and the boroxine compound, and, optionally, the sterically hindered amine compound. The boroxine compound may be incorporated into the base oil in any convenient way. Thus, the boroxine compound can be added directly to the base oil by dispersing or dissolving it in the base oil at the desired level of concentration. Alternatively, the base oil may be added directly to the boroxine compound in conjunction with agitation until the boroxine compound is provided at the desired level of concentration. Such blending may occur at ambient or lower temperatures, such as 30 , 25 , 20 , 15 , 10 , or 5°C .

EXAMPLES

[0121] Without being limited, in the below examples, exemplary lubricant compositions were formulated by blending each of the components together until homogeneity was achieved. A fully formulated lubricating oil composition containing dispersant, detergent, aminic antioxidant, phenolic antioxidant, anti-foam, base oil, antiwear additive, pour point depressant and viscosity modifier was prepared. This lubricant composition, which is representative of a commercial crankcase lubricant, is designated as the "reference lubricant" and used as a baseline to compare the effects of different components on seal compatibility.

[0122] The reference lubricant was combined with various different boron-containing compounds and various different nitrogen-containing compounds to demonstrate the effect of the boron-containing compounds and the effect of nitrogen-containing compounds on seal compatibility. Practical Examples #1, #2, #3, and #4 each include one of the practical boroxine compounds and one of the practical amine compounds. Comparative Examples #1-5 do not include any of the practical boroxine compounds. Comparative Examples #6-8 do not include any of the practical amine compounds. Comparative Examples #9-#12 do not include either the practical amine compounds or the practical boroxine compounds.

[0123] The boron-containing compound added to the reference lubricant in Practical Examples #1 and #2 is trimethoxyboroxine. The boron-containing compound added to the reference lubricant in Practical Example #3 is triethoxyboroxine. The boron-containing compound added to the reference lubricant in Practical Example #4 is tri-n-butoxyboroxine.

[0124] As described above, Comparative Examples #1-5 do not include the practical boroxine compounds. Instead, the compositions of both Comparative Example #1 and Comparative Example #2 are free of any boron-containing compound. Comparative Example #1 includes the practical amine compound, whereas Comparative Example #2 does not include the practical amine compound. The boron-containing compound added to the reference lubricant in Comparative Example #3 was tris-(2-ethylhexyl)boroxine. The boron-containing compound added to the reference lubricant in Comparative Example #4 is tributyl borate. The boron-containing compound added to the reference lubricant in Comparative Example #5 is tri-isopropyl borate.

[0125] Comparative Examples #6-9 include the practical boroxine compounds but do not include the practical amine compounds. The boroxine compound added to the reference lubricant in Comparative Examples #6 and 7 is trimethoxy-

boroxine. The boroxine compound added to the reference lubricant in Comparative Example #8 is triethoxyboroxine. The boroxine compound added to the reference lubricant in Comparative Example #9 is tri-n-butoxyboroxine.

[0126] Comparative Examples #10-12 do not include either the practical boroxine compound or the practical amine compound. The boron-containing compound in Comparative Example #10 is tris-(2-ethylhexyl)boroxine. The boron-containing compound in Comparative Example #11 is tributyl borate. The boron-containing compound in Comparative Example #12 is tri-isopropyl borate.

[0127] The amine compound included in Practical Examples #1-4 and Comparative Examples #1 and 3-5 is (2,2,6,6-tetramethyl-4-piperidyl)dodecanoate.

[0128] The respective amount of the reference lubricant and any additional components for each of the Practical and Comparative Examples are shown in Tables 2, 3, and 4 below:

TABLE 2

Formulations of Practical Examples #1-#4				
	Practical #1	Practical #2	Practical #3	Practical #4
Reference Lubricant (g)	80	80	80	80
Additional Base Oil (g)	18	16.5	18	18
Boron-containing Compound (g)	0.5	2	0.5	0.5
Practical Amine Compound (g)	1.5	1.5	1.5	1.5
Total Weight (g)	100	100	100	100

TABLE 3

Formulations of Comparative Examples #1-5 (C1-C5)					
	C1	C2	C3	C4	C5
Reference Lubricant (g)	80	80	80	80	80
Additional Base Oil (g)	18.5	20	18	18	18
Boron-containing Compound (g)	0	0	0.5	0.5	0.5
Practical Amine Compound (g)	1.5	0	1.5	1.5	1.5
Total Weight (g)	100	100	100	100	100

TABLE 4

Formulations of Comparative Examples #6-11 (C6-C12)							
	C6	C7	C8	C9	C10	C11	C12
Reference Lubricant (g)	80	80	80	80	80	80	80
Additional Base Oil (g)	19.5	18	19.5	19.5	19.5	19.5	19.5
Boron-containing Compound (g)	0.5	2	0.5	0.5	0.5	0.5	0.5
Practical Amine Compound (g)	0	0	0	0	0	0	0
Total Weight (g)	100	100	100	100	100	100	100

[0129] The seal compatibility of the practical and comparative examples was evaluated using an industry-standard CEC L-39-T96 seal compatibility test. The CEC-L-39-T96 seal compatibility test is performed by submitting the seal or gaskets in the lubricant composition, heating the lubricant

composition with the seal contained therein to an elevated temperature, and maintaining the elevated temperature for a period of time. The seals are then removed and dried, and the mechanical properties of the seal are assessed and compared to the seal specimens which were not heated in the lubricant composition. The percent change in these properties is analyzed to assess the compatibility of the seal with the lubricant composition. Each formulation was tested twice (Run #1 and Run #2) under the same conditions. The results of the seal compatibility test are shown below in Tables 5-10.

TABLE 5

Seal Compatibility Test Results (Run 1) - Practical Examples #1-#4				
	Practical #1	Practical #2	Practical #3	Practical #4
Volume Change (%)	0.5	0.8	0.5	0.5
Points Hardness DIDC	4	0	5	6
Tensile Strength (%)	-39	-2	-41	-39
Elongation at Rupture (%)	-54	8	-61	-66

TABLE 6

Seal Compatibility Test Results (Run 2) - Practical Examples #1-#4				
	Practical #1	Practical #2	Practical #3	Practical #4
Volume Change (%)	0.5	0.7	0.7	0.4
Points Hardness DIDC	4	-1	5	6
Tensile Strength (%)	-32	-5	-41	-40
Elongation at Rupture (%)	-51	-5	-59	-66

TABLE 7

Seal Compatibility Test Results (Run 1) - Comparative Examples #1-#6 (C1-C6)						
	C1	C2	C3	C4	C5	C6
Volume Change (%)	0.3	0.2	0.8	0.4	0.7	0.5
Points Hardness DIDC	7	5	7	6	8	2
Tensile Strength (%)	-44	-32	-47	-39	-44	-29
Elongation at Rupture (%)	-69	-40	-72	-64	-66	-38

TABLE 8

Seal Compatibility Test Results (Run 2) - Comparative Examples #1-#6 (C1-C6)						
	C1	C2	C3	C4	C5	C6
Volume Change (%)	0.4	0.2	0.8	0.6	0.7	0.4
Points Hardness DIDC	8	4	8	6	7	2
Tensile Strength (%)	-49	-31	-44	-41	-42	-23
Elongation at Rupture (%)	-71	-40	-68	-61	-67	-34

TABLE 9

Seal Compatibility Test Results (Run 1) - Comparative Examples #7-#12 (C7-C12)						
	C7	C8	C9	C10	C11	C12
Volume Change (%)	0.7	0.3	0.2	0.5	0.4	0.6
Points Hardness DIDC	1	1	2	3	4	4
Tensile Strength (%)	5	-26	-21	-29	-31	-29
Elongation at Rupture (%)	-25	-40	-40	-43	-42	-49

TABLE 10

Seal Compatibility Test Results (Run 2) - Comparative Examples #7-#12 (C7-C12)						
	C7	C8	C9	C10	C11	C12
Volume Change (%)	0.7	0.6	0.4	0.6	0.3	0.5
Points Hardness DIDC	1	2	2	4	4	3
Tensile Strength (%)	0	-23	-25	-27	-28	-26
Elongation at Rupture (%)	-20	-33	-42	-45	-43	-51

[0130] Comparative Example #1 is illustrative of the effect of an amine compound on the seal compatibility of a lubricant composition. By comparing the tensile strength and elongation at rupture of Comparative Example #1, which includes the practical amine compound, and Comparative Example #2, which does not include the practical amine compound, the inventors realized that the addition of a practical amine compound to the reference lubricant negatively impacts the seal compatibility of the reference lubricant. The negative impact is quantified by the fact that the tensile strength and elongation at rupture is much worse for Comparative Example #1 when compared to Comparative Example #2.

[0131] Practical Examples #1, #2, #3, and #4 each include the same practical amine compound as Comparative Example #1, in conjunction with one species of the practical boroxine compound. As can be seen in the results shown in Tables 4-7, the seal compatibility of Practical Examples #1-4 is significantly improved over the seal compatibility of Comparative Example #1 in terms of both tensile strength and elongation at rupture. This significant improvement in seal compatibility is evidenced by the fact that the tensile strength and elongation at rupture is much worse for Comparative Example #1 when compared to Practical Examples #1-4.

[0132] Tables 5-8 also demonstrate that the seal compatibility of Practical Examples #1 and 2 was improved in terms of tensile strength and elongation at rupture as compared to the seal compatibility of Comparative Examples #3-5. The tensile strength of Practical Example #1 was -39 and -32%; and the tensile strength of Practical Example #2 was -2 and -5%; whereas the tensile strength of Comparative Examples #3, 4, and 5, was -47 and -44%; -39 and -41%; and -44 and -42%, respectively. Similarly, the elongation at rupture for Practical Example #1 was -54 and -51%; the elongation at rupture for Practical Example #2 was 8 and -5%; whereas the elongation at rupture of Comparative Examples #3, 4, and 5, was -72 and -68%; -64 and -61%; and -66% and -67%, respectively. This testing shows that the lubricant compositions of Practical Examples #1 and 2 were much more compatible with seals in terms of tensile strength and elongation at rupture than the lubricant compositions of Comparative Examples #3-5. This comparison also provides evidence that the combination of trimethoxyboroxine and the practical

amine compounds in a lubricant composition yields much improved seal compatibility over a lubricant composition that includes other boron-containing compounds, such as those boron-containing compounds utilized in Comparative Examples #3-5.

[0133] Finally, the comparison of Comparative Example #2 and Comparative Examples #6-12 demonstrates that lubricant compositions which include boron-containing compounds but do not include the practical amine compound do not negatively affect the seal compatibility of the lubricant composition in a significant way. Accordingly, the inventors of the subject application have surprisingly realized that the combination of the practical amine compound and the practical boroxine compounds have a synergistic impact on seal compatibility when present in the reference lubricant.

[0134] It is to be understood that the appended claims are not limited to express and particular compounds, compositions, or methods described in the detailed description, which may vary between particular embodiments that fall within the scope of the appended claims. With respect to any Markush groups relied upon herein for describing particular features or aspects of various embodiments, it is to be appreciated that different, special, and/or unexpected results may be obtained from each member of the respective Markush group independent from all other Markush members. Each member of a Markush group may be relied upon individually and/or in combination and provides adequate support for specific embodiments within the scope of the appended claims.

[0135] It is also to be understood that any ranges and subranges relied upon in describing various embodiments of the present invention independently and collectively fall within the scope of the appended claims and are understood to describe and contemplate all ranges, including whole and/or fractional values therein, even if such values are not expressly written herein. One of skill in the art readily recognizes that the enumerated ranges and subranges sufficiently describe and enable various embodiments of the present invention and such ranges and subranges may be further delineated into relevant halves, thirds, quarters, fifths, and so on. As just one example, a range "ranging from 0.1 to 0.9" may be further delineated into a lower third, i.e., from 0.1 to 0.3, a middle third, i.e., from 0.4 to 0.6, and an upper third, i.e., from 0.7 to 0.9, which individually and collectively are within the scope of the appended claims and may be relied upon individually and/or collectively and provide adequate support for specific embodiments within the scope of the appended claims.

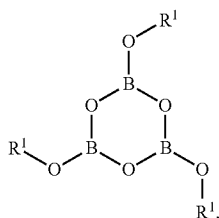
[0136] In addition, with respect to the language which defines or modifies a range, such as "at least," "greater than," "less than," "no more than," and the like, it is to be understood that such language includes subranges and/or an upper or lower limit. As another example, a range of "at least 10" inherently includes a subrange ranging from at least 10 to 35, a subrange ranging from at least 10 to 25, a subrange from 25 to 35, and so on, and each subrange may be relied upon individually and/or collectively and provides adequate support for specific embodiments within the scope of the appended claims. Finally, an individual number within a disclosed range may be relied upon and provides adequate support for specific embodiments within the scope of the appended claims. For example, a range "ranging from 1 to 9" includes various individual integers, such as 3, as well as individual numbers including a decimal point (or fraction),

such as 4.1, which may be relied upon and provide adequate support for specific embodiments within the scope of the appended claims.

[0137] The invention has been described in an illustrative manner and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation. Many modifications and variations of the present invention are possible in light of the above teachings and the invention may be practiced otherwise than as specifically described.

What is claimed:

1. A lubricant composition having improved fluoropolymer compatibility, said lubricant composition comprising:
 - a base oil;
 - a boroxine compound having general formula (I):



wherein each R¹ is independently an alkyl group having from 1 to 7 carbon atoms; and

- a sterically hindered amine compound included in an amount ranging from 0.5 to 5 wt. % based on a total weight of said lubricant composition.

2. The lubricant composition of claim 1 wherein each R¹ is independently an alkyl group having from 1 to 5 carbon atoms.

3. The lubricant composition of claim 1 wherein said boroxine compound is included in an amount ranging from 0.1 to 5 wt. % based on said total weight of said lubricant composition.

4. The lubricant composition of claim 1 wherein at least 50 wt. % of said boroxine compound remains unreacted in said lubricant composition based on a total weight of said boroxine compound utilized to form said lubricant composition prior to any reaction in said lubricant composition.

5. The lubricant composition of claim 1 wherein said sterically hindered amine compound comprises at least one piperidine ring and at least one ester group.

7. The lubricant composition of claim 1 wherein said sterically hindered amine compound is (2,2,6,6-tetramethyl-4-piperidyl)dodecanoate.

8. The lubricant composition of claim 1 wherein said sterically hindered amine compound has a total base number of at least 70 mg KOH/g when tested according to ASTM D4739.

9. The lubricant composition of claim 1 wherein said base oil has a viscosity ranging from 1 to 20 cSt when tested at 100° C. according to ASTM D445 and is selected from the group of API group I oils, API group II oils, API group III oils, API group IV oils, API group V oils, and combinations thereof.

10. The lubricant composition of claim 1 further comprising a dispersant.

11. The lubricant composition of claim 10 wherein said dispersant is included in said lubricant composition in an

amount ranging from 0.01 to 15 wt. % based on said total weight of said lubricant composition.

12. The lubricant composition of claim 11 wherein said dispersant is a polyalkene amine derived from a polyisobutene.

13. The lubricant composition of claim 1 further comprising a dihydrocarbyldithiophosphate salt.

14. The lubricant composition of claim 13 wherein said dihydrocarbyldithiophosphate salt comprises a zinc dihydrocarbyldithiophosphate salt.

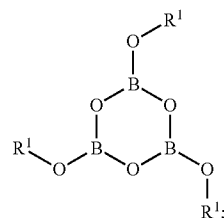
15. The lubricant composition of claim 13 wherein said dihydrocarbyldithiophosphate salt is included in said lubricant composition in an amount ranging from 0.1 to 10 wt. % based on said total weight of said lubricant composition.

16. The lubricant composition of claim 1 wherein said lubricant composition has a fluoropolymer seal compatibility such that a fluoropolymer seal submerged in said lubricant composition exhibits a change in tensile strength of less than 45% when tested according to CEC L-39-T96.

17. The lubricant composition of claim 1 wherein said lubricant composition has a fluoropolymer seal compatibility such that a fluoropolymer seal submerged in said lubricant composition exhibits a change in elongation at rupture of less than 60% when tested according to CEC L-39-T96.

18. A method of lubricating a system comprising a fluoropolymer seal, said method comprising:

- providing a lubricant composition comprising a base oil, a boroxine compound, and a sterically hindered amine compound included in an amount ranging from 0.5 to 5 wt. % based on the total weight of the lubricant composition; and
 - contacting the fluoropolymer seal with the lubricant composition,
- wherein the boroxine compound has general formula (I):

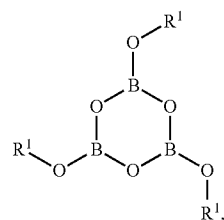


and

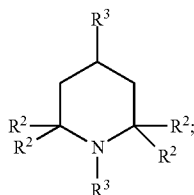
wherein each R¹ is independently an alkyl group having from 1 to 7 carbon atoms.

19. A lubricant composition comprising:

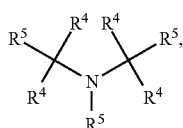
- a base oil;
- a boroxine compound having general formula (I):



wherein each R^1 is independently an alkyl group having from 1 to 7 carbon atoms; and
a sterically hindered amine compound having the general formula (II) or (III):



(II)



(III)

wherein each R^2 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein at least two groups designated by R^2 are an alkyl group;

wherein each R^3 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms; wherein each R^4 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein at least two groups designated by R^4 are an alkyl group;

wherein each R^5 is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and

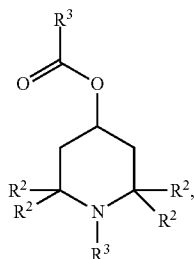
wherein said hydrocarbyl groups designated by R^2 , R^3 , R^4 , and R^5 are each independently an alcohol group, an alkyl group, an amide group, an ether group or an ester group.

20. The lubricant composition of claim **19** wherein each R^1 has independently from 1 to 5 carbon atoms.

21. The lubricant composition of claim **19** wherein said boroxine compound is included in an amount ranging from 0.1 to 5 wt. % based on a total weight of said lubricant composition.

22. The lubricant composition of claim **19** wherein at least 50 wt. % of said boroxine compound remains unreacted in said lubricant composition based on a total weight of said boroxine compound utilized to form said lubricant composition prior to any reaction in said lubricant composition.

23. The lubricant composition of claim **19** wherein said sterically hindered amine compound has the general formula (IV):



(IV)

wherein each R^2 and R^3 are as described above, and wherein at least three of R^2 are independently an alkyl group.

24. The lubricant composition of claim **19** wherein said sterically hindered amine has a total base number of at least 70 mg KOH/g when tested according to ASTM D4739.

25. The lubricant composition of claim **19** wherein said base oil has a viscosity ranging from 1 to 20 cSt when tested at 100° C. according to ASTM D445 and is selected from the group of API group I oils, API group II oils, API group III oils, API group IV oils, API group V oils, and combinations thereof.

26. The lubricant composition of claim **19** further comprising a dispersant.

27. The lubricant composition of claim **26** wherein said dispersant is included in said lubricant composition in an amount ranging from 0.01 to 15 wt. % based on a total weight of said lubricant composition.

28. The lubricant composition of claim **27** wherein said amine dispersant is a polyalkene amine derived from a polyisobutene.

29. The lubricant composition of claim **19** further comprising a dihydrocarbyldithiophosphate salt.

30. The lubricant composition of claim **29** wherein said dihydrocarbyldithiophosphate salt comprises a zinc dihydrocarbyldithiophosphate salt.

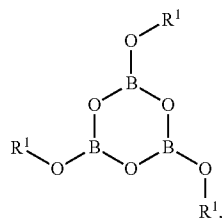
31. The lubricant composition of claim **29** wherein said dihydrocarbyldithiophosphate salt is included in said lubricant composition in an amount ranging from 0.1 to 10 wt. % based on a total weight of said lubricant composition.

32. The lubricant composition of claim **19** wherein said lubricant composition has a fluoropolymer seal compatibility such that a fluoropolymer seal submerged in said lubricant composition exhibits a change in tensile strength of less than 45% when tested according to CEC L-39-T96.

33. The lubricant composition of claim **19** wherein said lubricant composition has a fluoropolymer seal compatibility such that a fluoropolymer seal submerged in said lubricant composition exhibits a change in elongation at rupture of less than 60% when tested according to CEC L-39-T96.

34. An additive package for a lubricant composition, said additive package comprising:

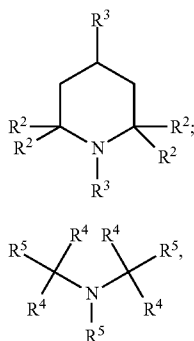
a boroxine compound having general formula (I):



(I)

wherein each R^1 is independently an alkyl group having from 1 to 7 carbon atoms; and

a sterically hindered amine compound having the general formula (II) or (III):



(II)

wherein each R² is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein at least two groups designated by R² are an alkyl group;

wherein each R³ is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms;

wherein each R⁴ is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and wherein at least two groups designated by R⁴ are an alkyl group;

(III)

wherein each R⁵ is independently a hydrogen atom or a hydrocarbyl group having from 1 to 17 carbon atoms, and

wherein said hydrocarbyl groups designated by R², R³, R⁴, and R⁵ are each independently an alcohol group, an alkyl group, an amide group, an ether group, or an ester group.

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