

## **LUBRICANT COMPOSITIONS CONTAINING A FUNCTIONALIZED DISPERSANT RELATED APPLICATIONS**

**[0001]** This application is related to U.S. Provisional Application No. 61/522,276, filed August 11, 2011, and U.S. Provisional Application No. 61/532,129, filed September 8, 2011.

### **TECHNICAL FIELD**

**[0002]** The disclosure relates to lubricant compositions and in particular to additives for improving the soot or sludge handling characteristics of an engine lubricant composition, while minimizing the deleterious effects of the additive on engine seals.

### **BACKGROUND AND SUMMARY**

**[0003]** Engine lubricant compositions may be selected to provide an increased engine protection while providing an increase in fuel economy and reduced emissions. However, in order to achieve benefits of improved fuel economy and reduced emissions, a balance between engine protection and lubricating properties is required for the lubricant composition. For example, an increase in the amount of friction modifiers may be beneficial for fuel economy purposes but may lead to reduced ability of the lubricant composition to handle water. Likewise, an increase in the amount of anti-wear agent in the lubricant may provide improved engine protection against wear but may be detrimental to catalyst performance for reducing emissions.

**[0004]** The same is true for soot and sludge handling components of the lubricant composition. As the amount of dispersant in the lubricant composition is increased, typically, the soot and sludge handling properties of the lubricant are improved. However, increasing the amount of dispersant may adversely affect elastomeric seals since dispersants are typically aminic nitrogen containing-compounds that are detrimental to seals. It is believed that by introducing polyaromatic functionality into a dispersant improves the dispersant's ability to control soot related viscosity increase. Accordingly dispersants reacted with phthalic anhydride or naphthalic anhydride and capped with a cyclic carbonate are believed to provide better soot handling capabilities than conventional dispersants. However, such functionalized dispersants often exhibit poor elastomeric seal compatibility even at relatively low treat rates. Accordingly, there is a need for dispersants that can provide improved soot handling as well as improved seal compatibility and that are suitable for meeting or exceeding currently proposed and future lubricant performance standards.

**[0005]** With regard to the foregoing, embodiments of the disclosure provide an engine lubricant composition, a method for maintaining the soot handling capability of an engine lubricant while not adversely affecting elastomeric seal material in the engine and a method of operating an engine. The engine lubricant includes a base oil and a dispersant that is a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride.

**[0006]** Another embodiment of the disclosure provides a method for maintaining the soot handling capability of an engine lubricant for an engine without adversely affecting elastomeric seals in the engine. The method includes formulating a lubricant composition for the engine with a base oil and an additive that is a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride.

**[0007]** A further embodiment of the disclosure provides a method for operating an engine including formulating an engine lubricant for the engine having a base oil and a lubricant additive package containing a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride; and operating the engine with the engine lubricant.

**[0008]** An unexpected advantage of the use of the functionalized dispersant of the disclosed embodiments is that while the functionalized dispersant is suitable for handling soot, the functionalized dispersant has superior elastomeric seal protection properties. A further advantage of the use of the functionalized dispersant described herein is that a lower amount of functionalized dispersant may be used to achieve the soot handling capability compared to a conventional dispersant.

**[0009]** The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

**[00010]** As used herein, the terms “oil composition,” “lubrication composition,” “lubricating oil composition,” “lubricating oil,” “lubricant composition,” “lubricating composition,” “fully formulated lubricant composition,” and “lubricant” are considered synonymous, fully interchangeable terminology referring to the finished lubrication product comprising a major amount of a base oil plus a minor amount of an additive composition.

**[00011]** As used herein, the terms “additive package,” “additive concentrate,” and “additive composition” are considered synonymous, fully interchangeable terminology referring the portion of the lubricating composition excluding the major amount of base oil stock mixture.

**[00012]** As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of the molecule and having predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

- (1) hydrocarbon substituents, that is, aliphatic (e.g., alkyl or alkenyl), alicyclic (e.g., cycloalkyl, cycloalkenyl) substituents, and aromatic-, aliphatic-, and alicyclic-substituted aromatic substituents, as well as cyclic substituents wherein the ring is completed through another portion of the molecule (e.g., two substituents together form an alicyclic radical);
- (2) substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of this invention, do not alter the predominantly hydrocarbon substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulfoxy);
- (3) hetero substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this invention, contain other than carbon in a ring or chain otherwise composed of carbon atoms. Heteroatoms include sulfur, oxygen, nitrogen, and encompass substituents such as pyridyl, furyl, thienyl, and imidazolyl. In general, no more than two, for example, no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; typically, there will be no non-hydrocarbon substituents in the hydrocarbyl group.

**[00013]** As used herein, the term "percent by weight", unless expressly stated otherwise, means the percentage the recited component represents to the weight of the entire composition.

**[00014]** The terms "oil-soluble" or "dispersible" used herein may but do not necessarily indicate that the compounds or additives are soluble, dissolvable, miscible, or capable of being suspended in the oil in all proportions. The foregoing terms do mean, however, that they are, for instance, soluble or stably dispersible in oil to an extent sufficient to exert their intended effect in the environment in which the oil is employed. Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired.

**[00015]** Lubricating oils, engine lubricating oils, and/or crankcase lubricating oils of the present disclosure may be formulated by the addition of one or more additives, as described in detail below, to an appropriate base oil formulation. The additives may be combined with a base oil in the form of an additive package (or concentrate) or, alternatively, may be combined individually with a base oil. The fully formulated lubricant, engine lubricant, and/or crankcase lubricant may exhibit improved performance properties, based on the additives added and their respective proportions.

**[00016]** Additional details and advantages of the disclosure will be set forth in part in the description which follows, and/or may be learned by practice of the disclosure. The details and advantages of the disclosure may be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

**[00017]** It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure, as claimed.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[00018]** FIG. 1 is a graphical representation of viscosity versus shear rate for determining soot dispersancy of compositions according to the disclosed embodiments.

#### **DESCRIPTION OF THE EXEMPLARY EMBODIMENTS**

**[00019]** The present disclosure will now be described in the more limited aspects of embodiments thereof, including various examples of the formulation and use of the present disclosure. It will be understood that these embodiments are presented solely for the purpose of illustrating the invention and shall not be considered as a limitation upon the scope thereof.

**[00020]** Engine or crankcase lubricant compositions are used in vehicles containing spark ignition and compression ignition engines. Such engines may be used in automotive, truck, and/or train applications and may be operated on fuels including, but not limited to, gasoline, diesel, alcohol, compressed natural gas, and the like. The disclosure is may describe lubricants suitable for use as engine lubricants, such as automotive crankcase lubricants that meet or exceed the ILSAC GF-5 and/or API CJ-4 lubricant standards.

## Base Oil

**[00021]** Base oils suitable for use in formulating engine lubricant compositions may be selected from any of suitable synthetic oils, animal oils, vegetable oils, mineral oils or mixtures thereof. Animal oils and vegetable oils (e.g., lard oil, castor oil) as well as mineral lubricating oils such as liquid petroleum oils and solvent treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types may be used. Oils derived from coal or shale may also be suitable. The base oil typically may have a viscosity of about 2 to about 15 cSt or, as a further example, about 2 to about 10 cSt at 100° C. Further, an oil derived from a gas-to-liquid process is also suitable.

**[00022]** Suitable synthetic base oils may include alkyl esters of dicarboxylic acids, polyglycols and alcohols, poly-alpha-olefins, including polybutenes, alkyl benzenes, organic esters of phosphoric acids, and polysilicone oils. Synthetic oils include hydrocarbon oils such as polymerized and interpolymers of olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, etc.); poly(1-hexenes), poly(1-octenes), poly(1-decenes), etc. and mixtures thereof; alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, di-nonylbenzenes, di-(2-ethylhexyl)benzenes, etc.); polyphenyls (e.g., biphenyls, terphenyl, alkylated polyphenyls, etc.); alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof and the like.

**[00023]** Alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification, etc., constitute another class of known synthetic oils that may be used. Such oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers (e.g., methyl-polyisopropylene glycol ether having an average molecular weight of about 1000, diphenyl ether of polyethylene glycol having a molecular weight of about 500-1000, diethyl ether of polypropylene glycol having a molecular weight of about 1000-1500, etc.) or mono- and polycarboxylic esters thereof, for example, the acetic acid esters, mixed C<sub>3</sub>-C<sub>8</sub> fatty acid esters, or the C<sub>13</sub> oxo-acid diester of tetraethylene glycol.

**[00024]** Another class of synthetic oils that may be used includes the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid

dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, etc.) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc.) Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl)sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid and the like.

**[00025]** Esters useful as synthetic oils also include those made from C<sub>5</sub> to C<sub>12</sub> monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, etc.

**[00026]** Hence, the base oil used which may be used to make the engine lubricant compositions as described herein may be selected from any of the base oils in Groups I-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. Such base oil groups are as follows:

**Table 1**

| Base Oil Group <sup>1</sup> | Sulfur (wt%)                           |        | Saturates (wt%) | Viscosity Index |
|-----------------------------|----------------------------------------|--------|-----------------|-----------------|
| Group I                     | > 0.03                                 | And/or | < 90            | 80 to 120       |
| Group II                    | ≤ 0.03                                 | And    | ≥ 90            | 80 to 120       |
| Group III                   | ≤ 0.03                                 | And    | ≥ 90            | ≥ 120           |
| Group IV                    | all polyalphaolefins (PAOs)            |        |                 |                 |
| Group V                     | all others not included in Groups I-IV |        |                 |                 |

<sup>1</sup> Groups I-III are mineral oil base stocks.

**[00027]** The base oil may contain a minor or major amount of a poly-alpha-olefin (PAO). Typically, the poly-alpha-olefins are derived from monomers having from about 4 to about 30, or from about 4 to about 20, or from about 6 to about 16 carbon atoms. Examples of useful PAOs include those derived from octene, decene, mixtures thereof, and the like. PAOs may have a viscosity of from about 2 to about 15, or from about 3 to about 12, or from about 4 to about 8 cSt at 100° C. Examples of PAOs include 4 cSt at 100° C poly-alpha-olefins, 6 cSt at 100° C poly-

alpha-olefins, and mixtures thereof. Mixtures of mineral oil with the foregoing poly-alpha-olefins may be used.

**[00028]** The base oil may be an oil derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing H<sub>2</sub> and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. For example, the hydrocarbons may be hydroisomerized using processes disclosed in U.S. Pat. Nos. 6,103,099 or 6,180,575; hydrocracked and hydroisomerized using processes disclosed in U.S. Pat. Nos. 4,943,672 or 6,096,940; dewaxed using processes disclosed in U.S. Pat. No. 5,882,505; or hydroisomerized and dewaxed using processes disclosed in U.S. Pat. Nos. 6,013,171; 6,080,301; or 6,165,949.

**[00029]** Unrefined, refined, and rerefined oils, either natural or synthetic (as well as mixtures of two or more of any of these) of the type disclosed hereinabove can be used in the base oils. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from primary distillation or ester oil obtained directly from an esterification process and used without further treatment would be an unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, etc. Rerefined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives, contaminants, and oil breakdown products.

**[00030]** The base oil may be combined with an additive composition as disclosed in embodiments herein to provide an engine lubricant composition. Accordingly, the base oil may be present in the engine lubricant composition in an amount ranging from about 50 wt% to about 95 wt % based on a total weight of the lubricant composition.

### Functionalized Dispersant

**[00031]** In an aspect of the disclosed embodiments, the dispersant additive is a functionalized dispersant additive that is a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride.

### Component A

**[00032]** The hydrocarbyl moiety of the hydrocarbyl-dicarboxylic acid or anhydride of Component A may be derived from butene polymers, for example polymers of isobutylene. Suitable polyisobutenes for use herein include those formed from polyisobutylene or highly reactive polyisobutylene having at least about 60%, such as about 70% to about 90% and above, terminal vinylidene content. Suitable polyisobutenes may include those prepared using  $\text{BF}_3$  catalysts. The average number molecular weight of the polyalkenyl substituent may vary over a wide range, for example from about 100 to about 5000, such as from about 500 to about 5000, as determined by GPC using polystyrene as a calibration reference as described above.

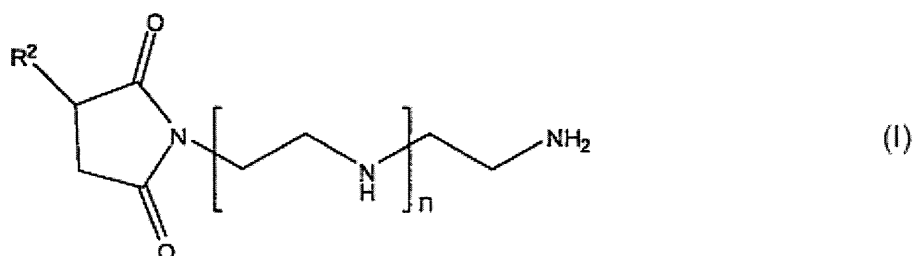
**[00033]** The dicarboxylic acid or anhydride of Component A may be selected from maleic anhydride or from carboxylic reactants other than maleic anhydride, such as maleic acid, fumaric acid, malic acid, tartaric acid, itaconic acid, itaconic anhydride, citraconic acid, citraconic anhydride, mesaconic acid, ethylmaleic anhydride, dimethylmaleic anhydride, ethylmaleic acid, dimethylmaleic acid, hexylmaleic acid, and the like, including the corresponding acid halides and lower aliphatic esters. A suitable dicarboxylic anhydride is maleic anhydride. A mole ratio of maleic anhydride to hydrocarbyl moiety in a reaction mixture used to make Component A may vary widely. Accordingly, the mole ratio may vary from about 5:1 to about 1:5, for example from about 3:1 to about 1:3, and as a further example, the maleic anhydride may be used in stoichiometric excess to force the reaction to completion. The unreacted maleic anhydride may be removed by vacuum distillation.

### Component B

**[00034]** Any of numerous polyamines can be used as Component B in preparing the functionalized dispersant. Non-limiting exemplary polyamines may include aminoguanidine bicarbonate (AGBC), diethylene triamine (DETA), triethylene tetramine (TETA), tetraethylene pentamine (TEPA), pentaethylene hexamine (PEHA) and heavy polyamines. A heavy

polyamine may comprise a mixture of polyalkylenepolyamines having small amounts of lower polyamine oligomers such as TEPA and PEHA, but primarily oligomers having seven or more nitrogen atoms, two or more primary amines per molecule, and more extensive branching than conventional polyamine mixtures. Additional non-limiting polyamines which may be used to prepare the hydrocarbyl-substituted succinimide dispersant are disclosed in U.S. Pat. No. 6,548,458, the disclosure of which is incorporated herein by reference in its entirety. In an embodiment of the disclosure, the polyamine may be selected from tetraethylene pentamine (TEPA).

**[00035]** In an embodiment, the functionalized dispersant may be derived from compounds of formula (I):



wherein  $n$  represents 0 or an integer of from 1 to 5, and  $R^2$  is a hydrocarbyl substituent as defined above. In an embodiment,  $n$  is 3 and  $R^2$  is a polyisobutenyl substituent, such as that derived from polyisobutylenes having at least about 60%, such as about 70% to about 90% and above, terminal vinylidene content. Compounds of formula (I) may be the reaction product of a hydrocarbyl-substituted succinic anhydride, such as a polyisobutenyl succinic anhydride (PIBSA), and a polyamine, for example tetraethylene pentamine (TEPA).

**[00036]** The foregoing compound of formula (I) may have a molar ratio of (A) polyisobutenyl-substituted succinic anhydride to (B) polyamine in the range of about 4:3 to about 1:10 in the compound. A particularly useful dispersant contains polyisobutenyl group of the polyisobutenyl-substituted succinic anhydride having a number average molecular weight ( $M_n$ ) in the range of from about 500 to 5000 as determined by GPC using polystyrene as a calibration reference and a (B) polyamine having a general formula  $H_2N(CH_2)_m-[NH(CH_2)_m]_n-NH_2$ , wherein  $m$  is in the range from 2 to 4 and  $n$  is in the range of from 1 to 2.

### Component C

**[00037]** Component C is a carboxyl or polycarboxyl acid or polyanhydride wherein the carboxyl acid or anhydride functionalities are directly fused to an aromatic group. Such carboxyl-containing aromatic compound may be selected from 1,8-naphthalic acid or anhydride and 1,2-naphthalenedicarboxylic acid or anhydride, 2,3-dicarboxylic acid or anhydride, naphthalene-1,4-dicarboxylic acid, naphthalene-2,6-dicarboxylic acid, phthalic anhydride, pyromellitic anhydride, 1,2,4-benzene tricarboxylic acid anhydride, diphenic acid or anhydride, 2,3-pyridine dicarboxylic acid or anhydride, 3,4-pyridine dicarboxylic acid or anhydride, 1,4,5,8-naphthalenetetracarboxylic acid or anhydride, perylene-3,4,9,10-tetracarboxylic anhydride, pyrene dicarboxylic acid or anhydride, and alike. The moles of Component C reacted per mole of Component B may range from about 0.1:1 to about 2:1. A typical molar ratio of component C to Component B in the reaction mixture may range from about 0.2:1 to about 2.0:1. Another molar ratio of Component C to Component B that may be used may range from 0.25:1 to about 1.5:1. Component C may be reacted with the other components at a temperature ranging from about 140° to about 180° C.

### Component D

**[00038]** Component D is a non-aromatic carboxylic acid or anhydride. Suitable dicarboxylic acids or anhydrides thereof may include, but are not limited to acetic acid or anhydride, oxalic acid and anhydride, malonic acid and anhydride, succinic acid and anhydride, alkenyl succinic acid or anhydride, glutaric acid an anhydride, adipic acid and anhydride, pimelic acid and anhydride, suberic acid and anhydride, azelaic acid and anhydride, sebacic acid and anhydride, maleic acid and anhydride, fumaric acid and anhydride, tartaric acid or anhydride, glycolic acid or anhydride, 1,2,3,6-tetrahydronaphthalic acid or anhydride, and the like. Component D is reacted on a molar ratio with Component B ranging from about 0.1 to about 2.5 moles of Component D per mole of Component B reacted. Typically, the amount of Component D used will be relative to the number of secondary amino groups in Component B. Accordingly, from about 0.2 to about 2.0 moles of Component D per secondary amino group in Component B may be reacted with the other components to provide the dispersant according to embodiments of the disclosure. Another molar ratio of Component D to component B that may be used may range from 0.25:1 to about 1.5:1 moles of Component D per mole of Component B. Component

D may be reacted with the other components at a temperature ranging from about 140° to about 180° C.

**[00039]** The lubricant composition may contain from about 0.5 weight percent to about 10.0 weight of the functionalized dispersant described above based on a total weight of the lubricant composition. A typical range of dispersant may be from about 2 weight percent to about 5 weight percent based on a total weight of the lubricant composition. In addition to the foregoing functionalized dispersant, the lubricant composition may include other conventional ingredients, including but not limited to, friction modifiers, additional dispersants, metal detergents, antiwear agents, antifoam agents, antioxidants, viscosity modifiers, pour point depressants, corrosion inhibitors and the like.

#### Metal-Containing Detergents

**[00040]** Metal detergents that may be used with the dispersant reaction product described above generally comprise a polar head with a long hydrophobic tail where the polar head comprises a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal, in which case they are usually described as normal or neutral salts, and would typically have a total base number or TBN (as measured by ASTM D2896) of from about 0 to less than about 150. Large amounts of a metal base may be included by reacting an excess of a metal compound such as an oxide or hydroxide with an acidic gas such as carbon dioxide. The resulting overbased detergent comprises micelles of neutralized detergent surrounding a core of inorganic metal base (e.g., hydrated carbonates). Such overbased detergents may have a TBN of about 150 or greater, such as from about 150 to about 450 or more.

**[00041]** Detergents that may be suitable for use in the present embodiments include oil-soluble overbased, low base, and neutral sulfonates, phenates, sulfurized phenates, and salicylates of a metal, particularly the alkali or alkaline earth metals, e.g., sodium, potassium, lithium, calcium, and magnesium. More than one metal may be present, for example, both calcium and magnesium. Mixtures of calcium and/or magnesium with sodium may also be suitable. Suitable metal detergents may be overbased calcium or magnesium sulfonates having a TBN of from 150 to 450 TBN, overbased calcium or magnesium phenates or sulfurized phenates

having a TBN of from 150 to 300 TBN, and overbased calcium or magnesium salicylates having a TBN of from 130 to 350. Mixtures of such salts may also be used.

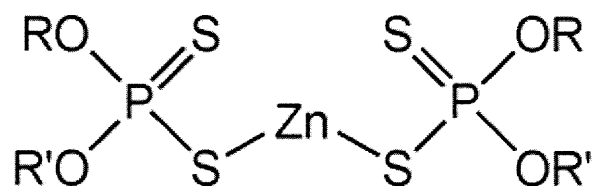
**[00042]** The metal-containing detergent may be present in a lubricating composition in an amount of from about 0.5 wt % to about 5 wt %. As a further example, the metal-containing detergent may be present in an amount of from about 1.0 wt % to about 3.0 wt %. The metal-containing detergent may be present in a lubricating composition in an amount sufficient to provide from about 500 to about 5000 ppm alkali and/or alkaline earth metal to the lubricant composition based on a total weight of the lubricant composition. As a further example, the metal-containing detergent may be present in a lubricating composition in an amount sufficient to provide from about 1000 to about 3000 ppm alkali and/or alkaline earth metal.

#### Phosphorus-Based Antiwear Agents

**[00043]** Phosphorus-based wear preventative agents may be used and may comprise a metal dihydrocarbyl dithiophosphate compound, such as but not limited to a zinc dihydrocarbyl dithiophosphate compound. Suitable metal dihydrocarbyl dithiophosphates may comprise dihydrocarbyl dithiophosphate metal salts wherein the metal may be an alkali or alkaline earth metal, or aluminum, lead, tin, molybdenum, manganese, nickel, copper, or zinc.

**[00044]** Dihydrocarbyl dithiophosphate metal salts may be prepared in accordance with known techniques by first forming a dihydrocarbyl dithiophosphoric acid (DDPA), usually by reaction of one or more alcohol or a phenol with  $P_2S_5$  and then neutralizing the formed DDPA with a metal compound. For example, a dithiophosphoric acid may be made by reacting mixtures of primary and secondary alcohols. Alternatively, multiple dithiophosphoric acids can be prepared where the hydrocarbyl groups on one are entirely secondary in character and the hydrocarbyl groups on the others are entirely primary in character. To make the metal salt, any basic or neutral metal compound could be used but the oxides, hydroxides and carbonates are most generally employed. Commercial additives frequently contain an excess of metal due to the use of an excess of the basic metal compound in the neutralization reaction.

**[00045]** The zinc dihydrocarbyl dithiophosphates (ZDDP) are oil soluble salts of dihydrocarbyl dithiophosphoric acids and may be represented by the following formula:



wherein R and R' may be the same or different hydrocarbyl radicals containing from 1 to 18, for example 2 to 12, carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl, and cycloaliphatic radicals. R and R' groups may be alkyl groups of 2 to 8 carbon atoms. Thus, the radicals may, for example, be ethyl, n-propyl, i-propyl, n-butyl, i-butyl, sec-butyl, amyl, n-hexyl, i-hexyl, n-octyl, decyl, dodecyl, octadecyl, 2-ethylhexyl, phenyl, butylphenyl, cyclohexyl, methylcyclopentyl, propenyl, butenyl. In order to obtain oil solubility, the total number of carbon atoms (i.e., R and R') in the dithiophosphoric acid will generally be about 5 or greater. The zinc dihydrocarbyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates.

**[00046]** Other suitable components that may be utilized as the phosphorus-based wear preventative include any suitable organophosphorus compound, such as but not limited to, phosphates, thiophosphates, di-thiophosphates, phosphites, and salts thereof and phosphonates. Suitable examples are tricresyl phosphate (TCP), di-alkyl phosphite (e.g., dibutyl hydrogen phosphite), and amyl acid phosphate.

**[00047]** Another suitable component is a phosphorylated succinimide such as a completed reaction product from a reaction between a hydrocarbyl substituted succinic acylating agent and a polyamine combined with a phosphorus source, such as inorganic or organic phosphorus acid or ester. Further, it may comprise compounds wherein the product may have amide, amidine, and/or salt linkages in addition to the imide linkage of the type that results from the reaction of a primary amino group and an anhydride moiety.

**[00048]** The phosphorus-based wear preventative may be present in a lubricating composition in an amount sufficient to provide from about 200 to about 2000 ppm phosphorus. As a further example, the phosphorus-based wear preventative may be present in a lubricating composition in an amount sufficient to provide from about 500 to about 800 ppm phosphorus.

**[00049]** The phosphorus-based wear preventative may be present in a lubricating composition in an amount sufficient to provide a ratio of alkali and/or alkaline earth metal content (ppm) based on the total amount of alkali and/or alkaline earth metal in the lubricating

composition to phosphorus content (ppm) based on the total amount of phosphorus in the lubricating composition of from about 1.6 to about 3.0 (ppm/ppm).

#### Friction Modifiers

**[00050]** Embodiments of the present disclosure may include one or more friction modifiers. Suitable friction modifiers may comprise metal containing and metal-free friction modifiers and may include, but are not limited to, imidazolines, amides, amines, succinimides, alkoxyated amines, alkoxyated ether amines, amine oxides, amidoamines, nitriles, betaines, quaternary amines, imines, amine salts, amino guanadine, alkanolamides, phosphonates, metal-containing compounds, glycerol esters, and the like.

**[00051]** Suitable friction modifiers may contain hydrocarbyl groups that are selected from straight chain, branched chain, or aromatic hydrocarbyl groups or admixtures thereof, and may be saturated or unsaturated. The hydrocarbyl groups may be composed of carbon and hydrogen or hetero atoms such as sulfur or oxygen. The hydrocarbyl groups may range from about 12 to about 25 carbon atoms and may be saturated or unsaturated.

**[00052]** Aminic friction modifiers may include amides of polyamines. Such compounds can have hydrocarbyl groups that are linear, either saturated or unsaturated, or a mixture thereof and may contain from about 12 to about 25 carbon atoms.

**[00053]** Further examples of suitable friction modifiers include alkoxyated amines and alkoxyated ether amines. Such compounds may have hydrocarbyl groups that are linear, either saturated, unsaturated, or a mixture thereof. They may contain from about 12 to about 25 carbon atoms. Examples include ethoxyated amines and ethoxyated ether amines.

**[00054]** The amines and amides may be used as such or in the form of an adduct or reaction product with a boron compound such as a boric oxide, boron halide, metaborate, boric acid or a mono-, di- or tri-alkyl borate. Other suitable friction modifiers are described in US 6,300,291, herein incorporated by reference.

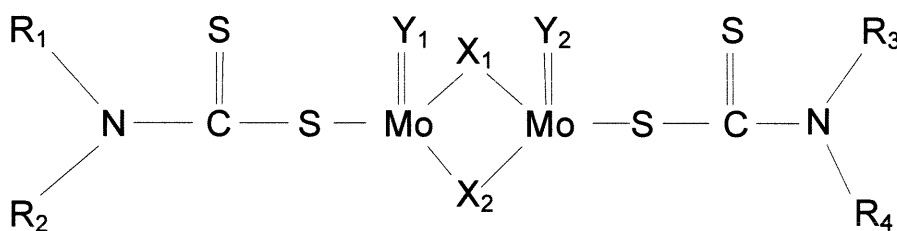
**[00055]** Other suitable friction modifiers may include an organic, ashless (metal-free), nitrogen-free organic friction modifier. Such friction modifiers may include esters formed by reacting carboxylic acids and anhydrides with alkanols. Other useful friction modifiers generally include a polar terminal group (e.g. carboxyl or hydroxyl) covalently bonded to an oleophilic hydrocarbon chain. Esters of carboxylic acids and anhydrides with alkanols are described in

U.S. 4,702,850. Another example of an organic ashless nitrogen-free friction modifier is known generally as glycerol monooleate (GMO) which may contain mono- and diesters of oleic acid. Other suitable friction modifiers are described in US 6,723,685, herein incorporated by reference. The ashless friction modifier may be present in the lubricant composition in an amount ranging from about 0.1 to about 0.4 percent by weight based on a total weight of the lubricant composition.

**[00056]** Suitable friction modifiers may also include one or more molybdenum compounds. The molybdenum compound may be selected from the group consisting of molybdenum dithiocarbamates (MoDTC), molybdenum dithiophosphates, molybdenum dithiophosphinates, molybdenum xanthates, molybdenum thioxanthates, molybdenum sulfides, a trinuclear organo-molybdenum compound, molybdenum/amine complexes, and mixtures thereof.

**[00057]** Additionally, the molybdenum compound may be an acidic molybdenum compound. Included are molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate, and other alkaline metal molybdates and other molybdenum salts, e.g., hydrogen sodium molybdate,  $\text{MoOCl}_4$ ,  $\text{MoO}_2\text{Br}_2$ ,  $\text{Mo}_2\text{O}_3\text{Cl}_6$ , molybdenum trioxide or similar acidic molybdenum compounds. Alternatively, the compositions can be provided with molybdenum by molybdenum/sulfur complexes of basic nitrogen compounds as described, for example, in U.S. Pat. Nos. 4,263,152; 4,285,822; 4,283,295; 4,272,387; 4,265,773; 4,261,843; 4,259,195 and 4,259,194; and WO 94/06897.

**[00058]** Suitable molybdenum dithiocarbamates may be represented by the formula:



where  $\text{R}_1$ ,  $\text{R}_2$ ,  $\text{R}_3$ , and  $\text{R}_4$  each independently represent a hydrogen atom, a  $\text{C}_1$  to  $\text{C}_{20}$  alkyl group, a  $\text{C}_6$  to  $\text{C}_{20}$  cycloalkyl, aryl, alkylaryl, or aralkyl group, or a  $\text{C}_3$  to  $\text{C}_{20}$  hydrocarbyl group containing an ester, ether, alcohol, or carboxyl group; and  $\text{X}_1$ ,  $\text{X}_2$ ,  $\text{Y}_1$ , and  $\text{Y}_2$  each independently represent a sulfur or oxygen atom.

**[00059]** Examples of suitable groups for each of  $\text{R}_1$ ,  $\text{R}_2$ ,  $\text{R}_3$ , and  $\text{R}_4$  include 2-ethylhexyl, nonylphenyl, methyl, ethyl, n-propyl, iso-propyl, n-butyl, t-butyl, n-hexyl, n-octyl, nonyl, decyl,

dodecyl, tridecyl, lauryl, oleyl, linoleyl, cyclohexyl and phenylmethyl.  $R_1$  to  $R_4$  may each have  $C_6$  to  $C_{18}$  alkyl groups.  $X_1$  and  $X_2$  may be the same, and  $Y_1$  and  $Y_2$  may be the same.  $X_1$  and  $X_2$  may both comprise sulfur atoms, and  $Y_1$  and  $Y_2$  may both comprise oxygen atoms.

**[00060]** Further examples of molybdenum dithiocarbamates include  $C_6$  -  $C_{18}$  dialkyl or diaryldithiocarbamates, or alkyl-aryldithiocarbamates such as dibutyl-, diamyl-di-(2-ethyl-hexyl)-, dilauryl-, dioleyl-, and dicyclohexyl-dithiocarbamate.

**[00061]** Another class of suitable organo-molybdenum compounds are trinuclear molybdenum compounds, such as those of the formula  $Mo_3S_kL_nQ_z$  and mixtures thereof, wherein L represents independently selected ligands having organo groups with a sufficient number of carbon atoms to render the compound soluble or dispersible in the oil, n is from 1 to 4, k varies from 4 through 7, Q is selected from the group of neutral electron donating compounds such as water, amines, alcohols, phosphines, and ethers, and z ranges from 0 to 5 and includes non-stoichiometric values. At least 21 total carbon atoms may be present among all the ligands' organo groups, such as at least 25, at least 30, or at least 35 carbon atoms. Additional suitable molybdenum compounds are described in US 6,723,685, herein incorporated by reference.

**[00062]** The molybdenum compound may be present in a fully formulated engine lubricant in an amount to provide about 5 ppm to 200 ppm molybdenum. As a further example, the molybdenum compound may be present in an amount to provide about 50 to 100 ppm molybdenum.

#### Anti-foam Agents

**[00063]** In some embodiments, a foam inhibitor may form another component suitable for use in the compositions. Foam inhibitors may be selected from silicones, polyacrylates, and the like. The amount of antifoam agent in the engine lubricant formulations described herein may range from about 0.001 wt% to about 0.1 wt% based on the total weight of the formulation. As a further example, antifoam agent may be present in an amount from about 0.004 wt% to about 0.008 wt%.

### Dispersant Components

**[00064]** Additional dispersants contained in the lubricant composition may include, but are not limited to, an oil soluble polymeric hydrocarbon backbone having functional groups that are capable of associating with particles to be dispersed. Typically, the dispersants comprise amine, alcohol, amide, or ester polar moieties attached to the polymer backbone often via a bridging group. Dispersants may be selected from Mannich dispersants as described in U.S. Pat. Nos. 3,697,574 and 3,736,357; ashless succinimide dispersants as described in U.S. Pat. Nos. 4,234,435 and 4,636,322; amine dispersants as described in U.S. Pat. Nos. 3,219,666, 3,565,804, and 5,633,326; Koch dispersants as described in U.S. Pat. Nos. 5,936,041, 5,643,859, and 5,627,259, and polyalkylene succinimide dispersants as described in U.S. Pat. Nos. 5,851,965; 5,853,434; and 5,792,729.

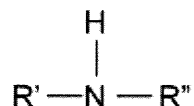
### Oxidation Inhibitor Components

**[00065]** Oxidation inhibitors or antioxidants reduce the tendency of base stocks to deteriorate in service which deterioration can be evidenced by the products of oxidation such as sludge and varnish-like deposits that deposit on metal surfaces and by viscosity growth of the finished lubricant. Such oxidation inhibitors include hindered phenols, sulfurized hindered phenols, alkaline earth metal salts of alkylphenolthioesters having C<sub>5</sub> to C<sub>12</sub> alkyl side chains, sulfurized alkylphenols, metal salts of either sulfurized or nonsulfurized alkylphenols, for example calcium nonylphenol sulfide, ashless oil soluble phenates and sulfurized phenates, phosphosulfurized or sulfurized hydrocarbons, phosphorus esters, metal thiocarbamates, and oil soluble copper compounds as described in U.S. Pat. No. 4,867,890.

**[00066]** Other antioxidants that may be used include sterically hindered phenols and esters thereof, diarylamines, alkylated phenothiazines, sulfurized compounds, and ashless dialkyldithiocarbamates. Non-limiting examples of sterically hindered phenols include, but are not limited to, 2,6-di-tertiary butylphenol, 2,6 di-tertiary butyl methylphenol, 4-ethyl-2,6-di-tertiary butylphenol, 4-propyl-2,6-di-tertiary butylphenol, 4-butyl-2,6-di-tertiary butylphenol, 4-pentyl-2,6-di-tertiary butylphenol, 4-hexyl-2,6-di-tertiary butylphenol, 4-heptyl-2,6-di-tertiary butylphenol, 4-(2-ethylhexyl)-2,6-di-tertiary butylphenol, 4-octyl-2,6-di-tertiary butylphenol, 4-nonyl-2,6-di-tertiary butylphenol, 4-decyl-2,6-di-tertiary butylphenol, 4-undecyl-2,6-di-tertiary butylphenol, 4-dodecyl-2,6-di-tertiary butylphenol, methylene bridged sterically hindered

phenols including but not limited to 4,4-methylenebis(6-tert-butyl-o-cresol), 4,4-methylenebis(2-tert-amyl-o-cresol), 2,2-methylenebis(4-methyl-6 tert-butylphenol, 4,4-methylene-bis(2,6-di-tert-butylphenol) and mixtures thereof as described in U.S Publication No. 2004/0266630.

**[00067]** Diarylamine antioxidants include, but are not limited to diarylamines having the formula:



wherein R' and R'' each independently represents a substituted or unsubstituted aryl group having from 6 to 30 carbon atoms. Illustrative of substituents for the aryl group include aliphatic hydrocarbon groups such as alkyl having from 1 to 30 carbon atoms, hydroxy groups, halogen radicals, carboxylic acid or ester groups, or nitro groups.

**[00068]** The aryl group is preferably substituted or unsubstituted phenyl or naphthyl, particularly wherein one or both of the aryl groups are substituted with at least one alkyl having from 4 to 30 carbon atoms, preferably from 4 to 18 carbon atoms, most preferably from 4 to 9 carbon atoms. It is preferred that one or both aryl groups be substituted, e.g. mono-alkylated diphenylamine, di-alkylated diphenylamine, or mixtures of mono- and di-alkylated diphenylamines.

**[00069]** The diarylamines may be of a structure containing more than one nitrogen atom in the molecule. Thus the diarylamine may contain at least two nitrogen atoms wherein at least one nitrogen atom has two aryl groups attached thereto, e.g. as in the case of various diamines having a secondary nitrogen atom as well as two aryls on one of the nitrogen atoms.

**[00070]** Examples of diarylamines that may be used include, but are not limited to: diphenylamine; various alkylated diphenylamines; 3-hydroxydiphenylamine; N-phenyl-1,2-phenylenediamine; N-phenyl-1,4-phenylenediamine; monobutyldiphenyl-amine; dibutyldiphenylamine; mono-octyldiphenylamine; dioctyldiphenylamine; monononyldiphenylamine; dinonyldiphenylamine; monotetradecyldiphenylamine; ditetradecyldiphenylamine, phenyl-alpha-naphthylamine; mono-octyl phenyl-alpha-naphthylamine; phenyl-beta-naphthylamine; monoheptyldiphenylamine; diheptyldiphenylamine; p-oriented styrenated diphenylamine; mixed butyloctyldi-phenylamine; and mixed octylstyryldiphenylamine.

**[00071]** The sulfur containing antioxidants include, but are not limited to, sulfurized olefins that are characterized by the type of olefin used in their production and the final sulfur content of the antioxidant. High molecular weight olefins, i.e. those olefins having an average molecular weight of 168 to 351 g/mole, are preferred. Examples of olefins that may be used include alpha-olefins, isomerized alpha-olefins, branched olefins, cyclic olefins, and combinations of these.

**[00072]** Alpha-olefins include, but are not limited to, any C<sub>4</sub> to C<sub>25</sub> alpha-olefins. Alpha-olefins may be isomerized before the sulfurization reaction or during the sulfurization reaction. Structural and/or conformational isomers of the alpha olefin that contain internal double bonds and/or branching may also be used. For example, isobutylene is a branched olefin counterpart of the alpha-olefin 1-butene.

**[00073]** Sulfur sources that may be used in the sulfurization reaction of olefins include: elemental sulfur, sulfur monochloride, sulfur dichloride, sodium sulfide, sodium polysulfide, and mixtures of these added together or at different stages of the sulfurization process.

**[00074]** Unsaturated oils, because of their unsaturation, may also be sulfurized and used as an antioxidant. Examples of oils or fats that may be used include corn oil, canola oil, cottonseed oil, grapeseed oil, olive oil, palm oil, peanut oil, coconut oil, rapeseed oil, safflower seed oil, sesame seed oil, soybean oil, sunflower seed oil, tallow, and combinations of these.

**[00075]** The amount of sulfurized olefin or sulfurized fatty oil delivered to the finished lubricant is based on the sulfur content of the sulfurized olefin or fatty oil and the desired level of sulfur to be delivered to the finished lubricant. For example, a sulfurized fatty oil or olefin containing 20 weight % sulfur, when added to the finished lubricant at a 1.0 weight % treat level, will deliver 2000 ppm of sulfur to the finished lubricant. A sulfurized fatty oil or olefin containing 10 weight % sulfur, when added to the finished lubricant at a 1.0 weight % treat level, will deliver 1000 ppm sulfur to the finished lubricant. It is desirable that the sulfurized olefin or sulfurized fatty oil to deliver between 200 ppm and 2000 ppm sulfur to the finished lubricant.

**[00076]** In general terms, a suitable engine lubricant may include additive components in the ranges listed in the following table.

**Table 2**

| Component                                                  | Wt. %<br>(Broad) | Wt. %<br>(Typical) |
|------------------------------------------------------------|------------------|--------------------|
| Dispersant (Reaction product of Components A, B, C, and D) | 0.5 – 10.0       | 1.0 – 5.0          |
| Additional Dispersants                                     | 0 - 10%          | 1.0 – 6.0%         |
| Antioxidants                                               | 0 – 5.0          | 0.01 – 3.0         |
| Metal Detergents                                           | 0.1 – 15.0       | 0.2 – 8.0          |
| Corrosion Inhibitor                                        | 0 – 5.0          | 0 – 2.0            |
| Metal dihydrocarbyl dithiophosphate                        | 0.1 – 6.0        | 0.5 – 4.0          |
| Ash-free amine phosphate salt                              | 0 – 6.0          | 0.0 – 4.0          |
| Antifoaming agents                                         | 0 – 5.0          | 0.001 – 0.15       |
| Antiwear agents                                            | 0 - 1.0          | 0 – 0.8            |
| Pour point depressant                                      | 0.01 – 5.0       | 0.01 – 1.5         |
| Viscosity modifier                                         | 0.01 – 20.00     | 0.25 – 10.0        |
| Friction modifiers                                         | 0 - 2.0          | 0.1 - 1.0          |
| Base oil                                                   | Balance          | Balance            |
| Total                                                      | 100              | 100                |

**[00077]** Additional optional additives that may be included in lubricant compositions described herein include, but are not limited to, rust inhibitors, emulsifiers, demulsifiers, and oil-soluble titanium-containing additives.

**[00078]** Additives used in formulating the compositions described herein may be blended into the base oil individually or in various sub-combinations. However, it may be suitable to blend all of the components concurrently using an additive concentrate (i.e., additives plus a diluent, such as a hydrocarbon solvent). The use of an additive concentrate may take advantage of the mutual compatibility afforded by the combination of ingredients when in the form of an additive concentrate. Also, the use of a concentrate may reduce blending time and may lessen the possibility of blending errors.

**[00079]** The present disclosure provides novel lubricating oil blends specifically formulated for use as automotive engine lubricants. Embodiments of the present disclosure may provide lubricating oils suitable for engine applications that provide improvements in one or more of the following characteristics: antioxidancy, antiwear performance, rust inhibition, fuel economy, water tolerance, air entrainment, seal protection, and foam reducing properties.

**[00080]** In order to demonstrate the benefits and advantages of lubricant compositions according to the disclosure, the following non-limiting examples are provided.

### Example 1

**[00081]** The set-up requires a 1 L 4-neck flask with agitator, addition funnel, temperature probe, temperature controller, heating mantle, Dean-Stark trap, and a condenser. The flask was charged with 2100 M<sub>n</sub> polyisobutylene succinic anhydride (PIBSA) (195.0 g; 0.135 moles) and heated to 160° C. under a nitrogen blanket. Polyethylene amine mixture (21.17 g; 0.112 moles) was added drop-wise over 30 min. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at mm of Hg. Process oil (172.0 g) was added and the mixture was stirred for 15 min. 1, 8-Naphthalic anhydride (13.39 g; 0.068 ;moles) was added in one portion at 160° C. The reaction mixture was heated to 165° C. and allowed to stir for 4 hours. Vacuum was applied (771 mm Hg) for 1 hours to remove any residual water. The reaction product was pressure filtered over Hiflow Super Cel Celite to yield 364 g of a dark brown viscous liquid (% N, 1.75; TBN, 36.0).

### Example 2

**[00082]** A 500 mL flask was charged with material from Example 1 (200.0 g; 0.102 moles) and heated to 160° C. under a nitrogen blanket. Ethylene carbonate (4.0 g; 0.045 moles) was added in one portion. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. Process oil (4.0 g) was added and the mixture was stirred for 15 min. The reaction product was pressure filtered over Hiflow Super Cel Celite to yield 171 g of a dark brown viscous liquid (% N, 1.69; TBN, 34.3).

### Example 3

**[00083]** A 500 mL flask was charged with material from Example 1 (200.0 g; 0.102 moles) and heated to 160° C. under a nitrogen blanket. Boric acid (2.81 g; 0.045 moles) was added in one portion. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. Process oil (2.81 g) was added and the mixture was stirred for 15 min. The reaction product was pressure filtered over Hiflow Super Cel Celite to yield 162 g of a dark brown viscous liquid (% N, 1.75; TBN, 36.7).

#### Example 4

**[00084]** A 500 mL flask was charged with material from Example 1 (200.0 g; 0.102 moles) and heated to 160° C. under a nitrogen blanket. Maleic anhydride (4.48 g; 0.045 moles) was added in one portion. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. Process oil (4.48 g) was added and the mixture was stirred for 15 min. The reaction product was pressure filtered over Hiflow Super Cel Celite to yield 165 g of a dark brown viscous liquid (% N, 1.67; TBN, 24.1).

#### Example 5

**[00085]** A 500 mL flask was charged with material from Example 1 (200.0 g; 0.102 moles) and heated to 160° C. under a nitrogen blanket. 1,8-Naphthalic anhydride (9.02 g; 0.045 moles) was added in one portion. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. Process oil (9.02 g) was added and the mixture was stirred for 15 min. The reaction product was pressure filtered over Hiflow Super Cel Celite to yield 159 g of a dark brown viscous liquid (% N, 1.62; TBN, 25.1).

#### Example 6

**[00086]** A 4L four-necked flask with agitator, addition funnel, temperature probe, temperature controller, heating mantle, Dean-Stark trap, and a condenser was assembled. The flask was charged with 2100 M<sub>n</sub> PIBSA (975 g; 0.677 moles) and heated to 160° C. under a nitrogen blanket. Polyethylene amine mixture (85.81 g; 0.454 moles) was added drop-wise over 30 minutes to the reaction mixture. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at 771 mm of Hg. Process oil (850 g) was added and the mixture was stirred for 15 minutes. The reaction product was pressure filtered over Hiflow Super Cel Celite to yield 1700 g of a dark brown viscous liquid.

#### Example 7

**[00087]** A 1L four necked flask was charged with material from Example 6 (565.0 g; 0.200 moles) and heated to 160° C. under a nitrogen blanket. Phthalic anhydride (14.82 g; 0.100 moles) was added in one portion to the flask. The reaction mixture was allowed to stir for 2 hours and then was vacuum stripped for 1 hour at 660 mm of Hg. Acetic anhydride (10.20 g;

0.100 moles) was then added drop wise and the mixture was stirred for 2 hours at 160° C. The reaction product was pressure filtered hot over Hiflow Super Cel Celite to yield 500 g of a dark brown viscous liquid (% N, 1.46; TBN, 18.2)

#### Example 8

**[00088]** A 1L four necked flask was charged with material from Example 6 (293.8 g; 0.104 moles) and heated to 160° C. under a nitrogen blanket. 1,2,4-Benzenetricarboxylic anhydride (10.01 g; 0.052 moles) was added to the flask in one portion. The reaction mixture was allowed to stir for 2 hours and then was vacuum stripped for 1 hour at 660 mm of Hg. Acetic anhydride (5.30 g; 0.052 moles) was then added drop wise and the mixture was stirred for 2 hours at 160° C. The reaction product was pressure filtered hot over Hiflow Super Cel Celite to yield 300 g of a dark brown viscous liquid (% N, 1.49; TBN, 26.6)

#### Example 9

**[00089]** A 1L four necked flask was charged with material from Example 6 (565.0 g; 0.200 moles) and heated to 160° C. under a nitrogen blanket. 1,8-Naphthalic anhydride (19.8 g; 0.100 moles) was added in one portion. The reaction mixture was allowed to stir for 2 hours and then was vacuum stripped for 1 hour at 660 mm of Hg. Acetic anhydride (10.20 g; 0.100 moles) was then added drop wise and the mixture was stirred for 2 hours at 160° C. The reaction product was pressure filtered hot over Hiflow Super Cel Celite to yield 500 g of a dark brown viscous liquid (% N, 1.63; TBN, 19.5)

#### Example 10

**[00090]** A 125 mL 3-necked flask was charged with material from Example 6 (50.6 g; 0.018 moles) and heated to 160° C. under a nitrogen blanket. 1,4,5,8-Naphthalenetetracarboxylic dianhydride (2.40 g; 0.009 moles) was added in one portion. The reaction mixture was allowed to stir for 4 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. cis-1,2,3,6-Tetrahydrophthalic anhydride (1.40 g; 0.009 moles) was then added in one portion and the mixture was stirred for 4 hours. The reaction product was vacuum filtered hot over Hiflow Super Cel Celite to yield 17.8 g of a dark brown viscous liquid (% N, 1.65; TBN, 21.5)

### Example 11

**[00091]** A 125 mL 3-necked flask was charged with material from Example 6 (49.3 g; 0.018 moles) and heated to 160° C. under a nitrogen blanket. 1,4,5,8-Naphthalenetetracarboxylic dianhydride (2.33 g; 0.009 moles) was added in one portion. The reaction mixture was allowed to stir for 3 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. Acetic anhydride (0.889 g; 0.009 moles) was then added in one portion and the mixture was stirred for 3 hours. The reaction product was vacuum filtered hot over Hiflow Super Cel Celite to yield 21.7 g of a dark brown viscous liquid (% N, 1.39; TBN, 14.5)

### Example 12

**[00092]** A 125 mL 3-necked flask was charged with material from Example 6 (55.6 g; 0.020 moles) and heated to 160° C. under a nitrogen blanket. Phthalic anhydride (1.46 g; 0.010 moles) was added in one portion. The reaction mixture was allowed to stir for 3 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. (2-Dodecen-1-yl)succinic anhydride (2.61 g; 0.010 moles) was then added in one portion and the mixture was stirred for 3 hours. The reaction product was vacuum filtered hot over Hiflow Super Cel Celite to yield 20.4 g of a dark brown viscous liquid (% N, 1.65; TBN, 21.5)

### Example 13

**[00093]** A 125 mL 3-necked flask was charged with material from Example 6 (50.6 g; 0.018 moles) and heated to 160° C. under a nitrogen blanket. 1,8-Naphthalic anhydride (1.81 g; 0.009 moles) was added in one portion. The reaction mixture was allowed to stir for 3 hours and then was vacuum stripped for 1 hour at 711 mm of Hg. (2-Dodecen-1-yl)succinic anhydride (2.40 g; 0.009 moles) was then added in one portion and the mixture was stirred for 3 hours. The reaction product was vacuum filtered hot over Hiflow Super Cel Celite to yield 26.9 g of a dark brown viscous liquid (% N, 1.46; TBN, 16.3)

### Test to Assess Soot Dispersancy

**[00094]** In order to evaluate lubricant formulations according to the disclosure, various dispersants were tested for their ability to disperse soot. A sooted oil having 4.3 wt.% soot was generated from a fired diesel engine using a fluid that contained no dispersants. The sooted oil

was then top treated with 3.5 wt.% of dispersants from Examples 1-5 and then tested by a shear rate sweep in a rheometer with a cone on plate to look for Newtonian/non-Newtonian behavior. The results may be seen in Figure 1.

**[00095]** The untreated sooted oil (Curve A containing no dispersant) showed a curve for viscosity as a function of shear rate, which means that it is a non-Newtonian fluid and the soot is agglomerating. The higher viscosity as lower shear is a sign of soot agglomeration. All of the dispersants of Example 1-5 (Curves B-F), on the other hand, exhibited viscosity versus shear rate curves that did not change as shear was increased. Furthermore, viscosity at low shear is lower than for Curve A. These results show that Examples 1-5 effectively disperse the soot at a treat rate of 3.5 wt.%.

### **Seal Compatibility Test**

**[00096]** Dispersants of Example 1-5 were tested for AK-6 seal compatibility in a reference fluid as listed in Table 3 at 3.5 and 4.0 wt% . The fluoroelastomeric rubber was cut into bone-shaped pieces with a Type L die. The rubber pieces were then immersed in 30 mL scintillation vials containing about 22 grams of the oil composition to be tested. The vials were covered with foil and placed in a 150° C. oven for seven days. After seven days, the vials were drained and the rubber pieces were blotted to remove excess oil. An elongation rupture test was conducted on each of the rubber pieces and the results recorded in Table 4:

**Table 3**

| <b>Component</b>                    | <b>Wt. %</b> |
|-------------------------------------|--------------|
| Dispersants of Examples 1-5         | 3.5 or 4.0   |
| Alkylated diphenylamine antioxidant | 1.0          |
| Phenolic antioxidant                | 1.5          |
| Metal detergents                    | 2.5          |
| Zinc dihydrocarbyl dithiophosphates | 1.2          |
| Pour point depressant               | 0.1          |
| Viscosity modifiers                 | 9.5          |
| Antifoam agent                      | 0.01         |
| Base oils                           | Balance      |
| Total                               | 100          |

**Table 4**

| <b>Run No.</b> | <b>Dispersant</b>                                                                                              | <b>Treat Rate (wt. %)</b> | <b>Elongation Rupture (%)</b> |
|----------------|----------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------------|
| 1              | Base Dispersant of Example 1 (reaction product of Components A, B, and C)                                      | 3.5                       | -52.77                        |
| 2              | Dispersant of Example 2 (dispersant of Example 1 reacted with ethylene carbonate)                              | 3.5                       | -59.08                        |
| 3              | Dispersant of Example 3 (dispersant of Example 1 reacted with boric acid)                                      | 3.5                       | -60.40                        |
| 4              | Dispersant of Example 5 (dispersant of Example 1 reacted with naphthalic anhydride)                            | 3.5                       | -57.09                        |
| 5              | Dispersant of Example 4 (dispersant of Example 1 reacted with maleic anhydride)                                | 3.5                       | -27.15                        |
| 6              | Base Dispersant of Example 1 (dispersant of Example 1 reacted with reaction product of Components A, B, and C) | 4.0                       | -56.44                        |
| 7              | Dispersant of Example 2 (dispersant of Example 1 reacted with ethylene carbonate)                              | 4.0                       | -55.76                        |
| 8              | Dispersant of Example 3 (dispersant of Example 1 reacted with boric acid)                                      | 4.0                       | -64.74                        |
| 9              | Dispersant of Example 5 (dispersant of Example 1 reacted with naphthalic anhydride)                            | 4.0                       | -56.76                        |
| 10             | Dispersant of Example 4 (dispersant of Example 1 reacted with maleic anhydride)                                | 4.0                       | -37.80                        |

**[00097]** As shown by the foregoing results, Dispersant of Example 4 (Base dispersant reacted with maleic anhydride) exhibited superior elongation rupture results compared to Base Dispersant of Example 1, as well as those reacted with ethylene carbonate (Example 2), boric acid (Example 3), and aromatic naphthalic anhydride (Example 5). For example, at a treat rate of 3.5 wt.% in the reference oil, Dispersant 4 was about 49 % better than the base dispersant (Dispersant 1) and as much as 54 to 55 % better than the boric acid treated dispersant (Dispersant 3) or the ethylene carbonate treated dispersant (Dispersant 2). At a treat rate of 4 wt.% in the reference oil, Dispersant 4 was about 32 to about 41% better than Dispersants 1, 2, 3, and 5. Accordingly, the functionalized dispersant according to the disclosure was superior in seal compatibility compared to other functionalized dispersants.

**[00098]** At numerous places throughout this specification, reference has been made to a number of U.S. Patents. All such cited documents are expressly incorporated in full into this disclosure as if fully set forth herein.

**[00099]** Other embodiments of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the embodiments disclosed herein. As used throughout the specification and claims, “a” and/or “an” may refer to one or more than one. Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, percent, ratio, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

**[000100]** The foregoing embodiments are susceptible to considerable variation in practice. Accordingly, the embodiments are not intended to be limited to the specific exemplifications set forth hereinabove. Rather, the foregoing embodiments are within the spirit and scope of the appended claims, including the equivalents thereof available as a matter of law.

**[000101]** The patentees do not intend to dedicate any disclosed embodiments to the public, and to the extent any disclosed modifications or alterations may not literally fall within the scope of the claims, they are considered to be part hereof under the doctrine of equivalents.

What is claimed is:

1. An engine lubricant composition comprising a base oil and a dispersant comprising a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride.
2. The engine lubricant composition of claim 1, wherein component C comprises 1,8-naphthalic anhydride.
3. The engine lubricant composition of claim 1, wherein from about 0.25 to about 1.5 moles of the fused aromatic compound are reacted per mole of component B.
4. The engine lubricant composition of claim 1, wherein the lubricant composition comprises from about 0.5 to about 5 percent by weight of the dispersant.
5. The engine lubricant composition of claim 1, wherein component A comprises a polyalkenyl-substituted succinic acid or anhydride.
6. The engine lubricant composition of claim 5, wherein component A comprises a polyisobutenyl succinic acid or anhydride, component C comprises 1,8-naphthalic anhydride, and component D comprises maleic anhydride.
7. The engine lubricant composition of claim 1, wherein from about 0.25 to about 1.5 moles of component D is reacted per mole of component B.
8. The engine lubricant composition of claim 1, further comprising one or more of the members of the group selected from detergents, dispersants, friction modifiers, antioxidants, rust inhibitors, viscosity index improvers, emulsifiers, demulsifiers, corrosion inhibitors, antiwear agents, metal dihydrocarbyl dithiophosphates, ash-free amine phosphate salts, antifoam agents, and pour point depressants.

9. The engine lubricant composition of claim 1, further comprising an oil-soluble titanium-containing additive.
10. A method for maintaining the soot or sludge handling capability of an engine lubricant while not adversely affecting elastomeric seal material in the engine, comprising lubricating an engine with a lubricant composition comprising a base oil and an additive that comprises a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride.
11. The method of claim 10, wherein component C comprises 1,8-naphthalic anhydride.
12. The method of claim 10, wherein component A comprises maleic anhydride.
13. The method of claim 10, wherein the lubricant composition comprises from about 0.5 to about 5 percent by weight of the dispersant.
14. The method of claim 10, wherein the imide reaction product comprises a reaction product of a polyisobutenyl succinic acid or anhydride and a polyamine containing from 3 to 5 nitrogen atoms.
15. The method of claim 10, wherein a mole ratio of fused aromatic compound reacted with the imide reaction product ranges from about 0.25 to about 1.5 and a mole ratio of non-aromatic dicarboxylic acid or anhydride reacted with the bis-imide reaction product ranges from about 0.25 to about 1.5.
16. The method of claim 10, wherein the lubricant composition further comprises one or more of the members of the group selected from detergents, dispersants, friction modifiers, antioxidants, rust inhibitors, viscosity index improvers, emulsifiers, demulsifiers, corrosion inhibitors, antiwear agents, metal dihydrocarbyl dithiophosphates, ash-free amine phosphate salts, antifoam agents, and pour point depressants.

17. The method of claim 10, wherein the lubricant composition further comprises an oil-soluble titanium-containing additive.

18. A method for maintaining the soot or sludge handling capability of an engine lubricant, comprising lubricating an engine with a lubricant composition comprising a base oil and an additive that comprises a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride.

19. A method for protecting elastomeric seal material in the engine, comprising lubricating an engine with a lubricant composition comprising a base oil and an additive that comprises a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride

20. A method for operating an engine comprising;

lubricating an engine with an engine lubricant comprising a base oil and a lubricant additive package comprising a reaction product of A) a hydrocarbyl-dicarboxylic acid or anhydride, B) a polyamine, C) a dicarboxyl-containing fused aromatic compound, and D) a non-aromatic dicarboxylic acid or anhydride; and

operating the engine.

21. The method of claim 20, wherein from about 0.25 to about 1.5 moles of non-aromatic dicarboxylic acid or anhydride are reacted per mole of component B.

22. The method of claim 20, wherein the reaction product exhibits improved fluoroelastomeric seal compatibility compared to reaction product made in the absence component D.

23. The method of claim 20, wherein the lubricant composition comprises from about 0.5 to about 5 percent by weight of the dispersant.

24. The method of claim 20, wherein the hydrocarbyl dicarboxylic acid or anhydride comprises a reaction product of polyisobutylene having greater than 60 mole percent terminal vinylidene content and succinic acid or anhydride.