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Rabbat et al. (43) **Pub. Date: Sep. 20, 2018**(54) **LUBRICANT COMPOSITION****Publication Classification**(71) Applicants: **BASF SE**, Ludwigshafen (DE);  
**University of Ottawa**, Ottawa (CA)(51) **Int. Cl.**  
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**2215/225** (2013.01); **C10N 2230/10** (2013.01);  
**C10M 2215/221** (2013.01)(72) Inventors: **Philippe Rabbat**, Maplewood, NJ (US);  
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**Antony Haidasz**, Ottawa (CA)(57) **ABSTRACT**

A lubricant composition includes a base oil present in an amount of greater than 70 parts by weight per 100 parts by weight of the lubricant composition and an antioxidant. The antioxidant has the structure: wherein each X is independently CH or N, so long as at least one X is N, wherein Y is CRR', NR'', PR'', S, or O, each R, R' and R'' is independently H, alkyl or aryl, and R'' is alkyl, aryl, alkoxy or aryloxy. Each A is independently an electron donating group. The electron donating group (1) has an atom having at least one lone pair of electrons that is bonded directly to the aromatic ring, (2) is an aryl or alkyl group, or (3) is a hydrogen atom.

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§ 371 (c)(1),

(2) Date: **Feb. 28, 2018****Related U.S. Application Data**

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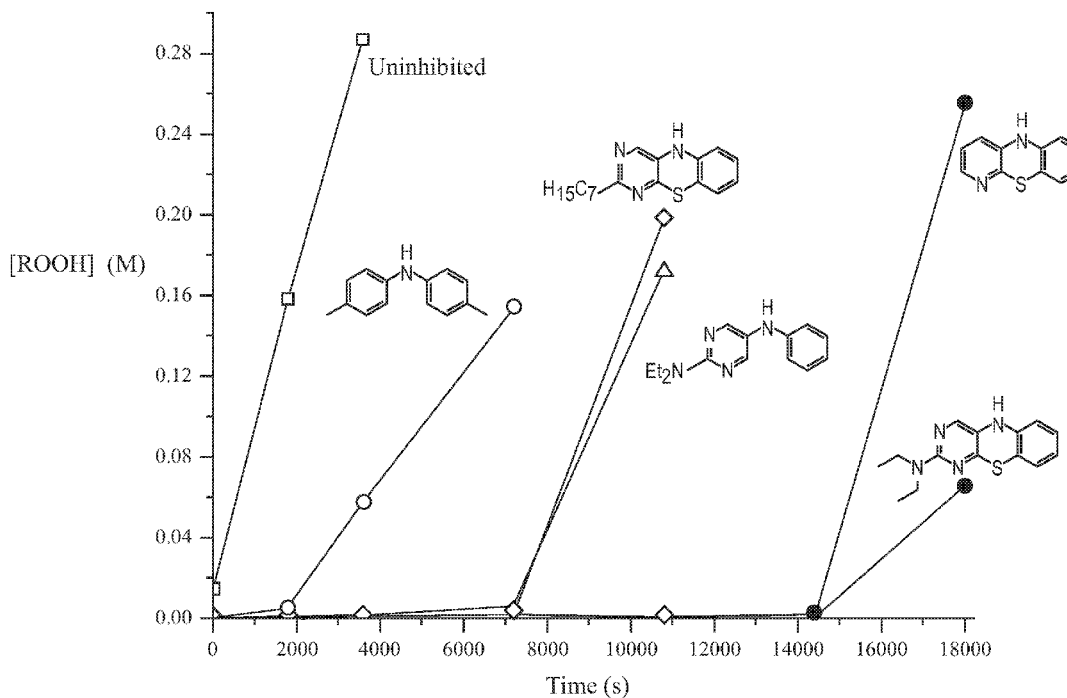
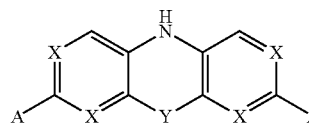


FIG. 1

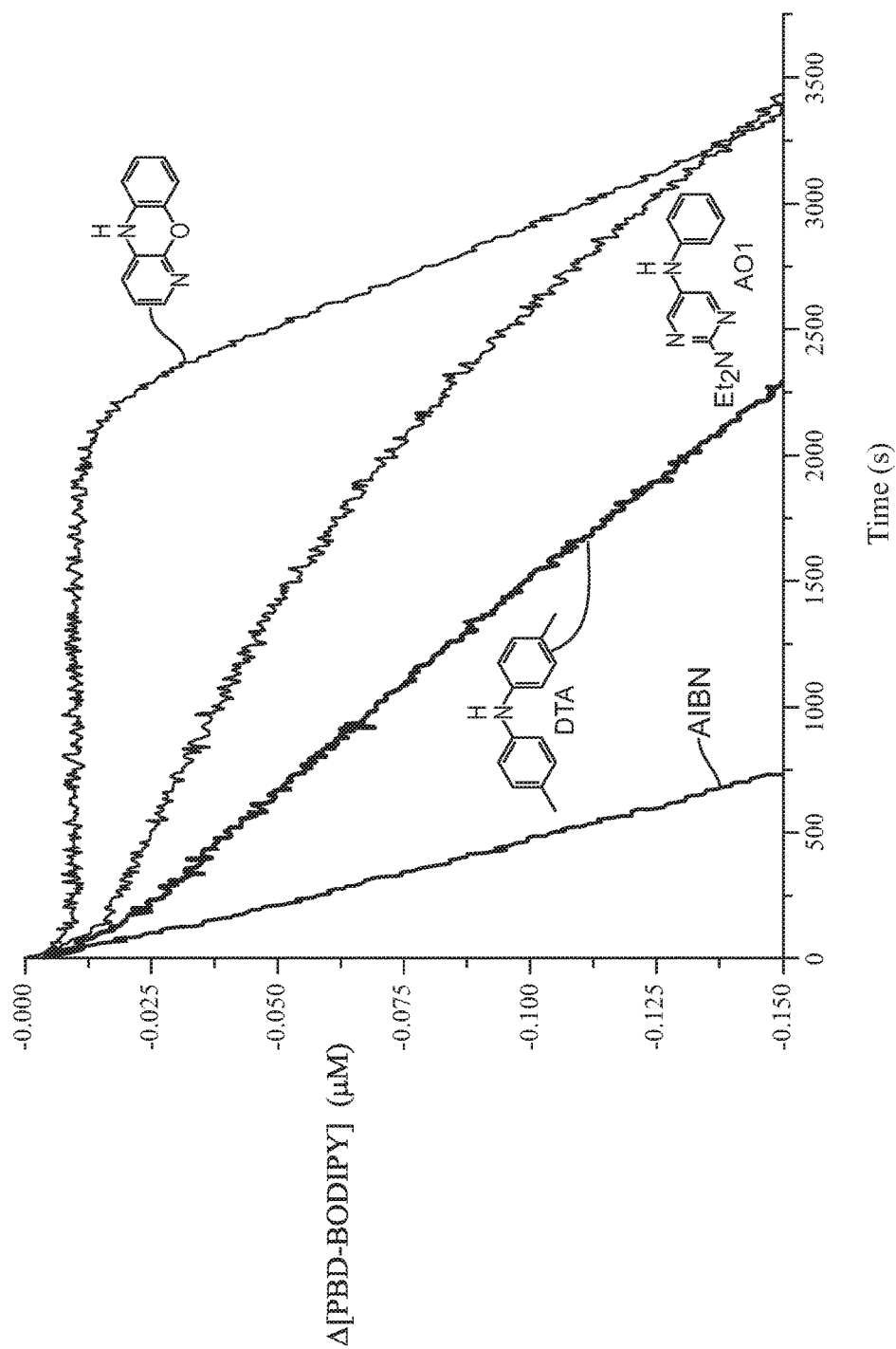


FIG. 2A

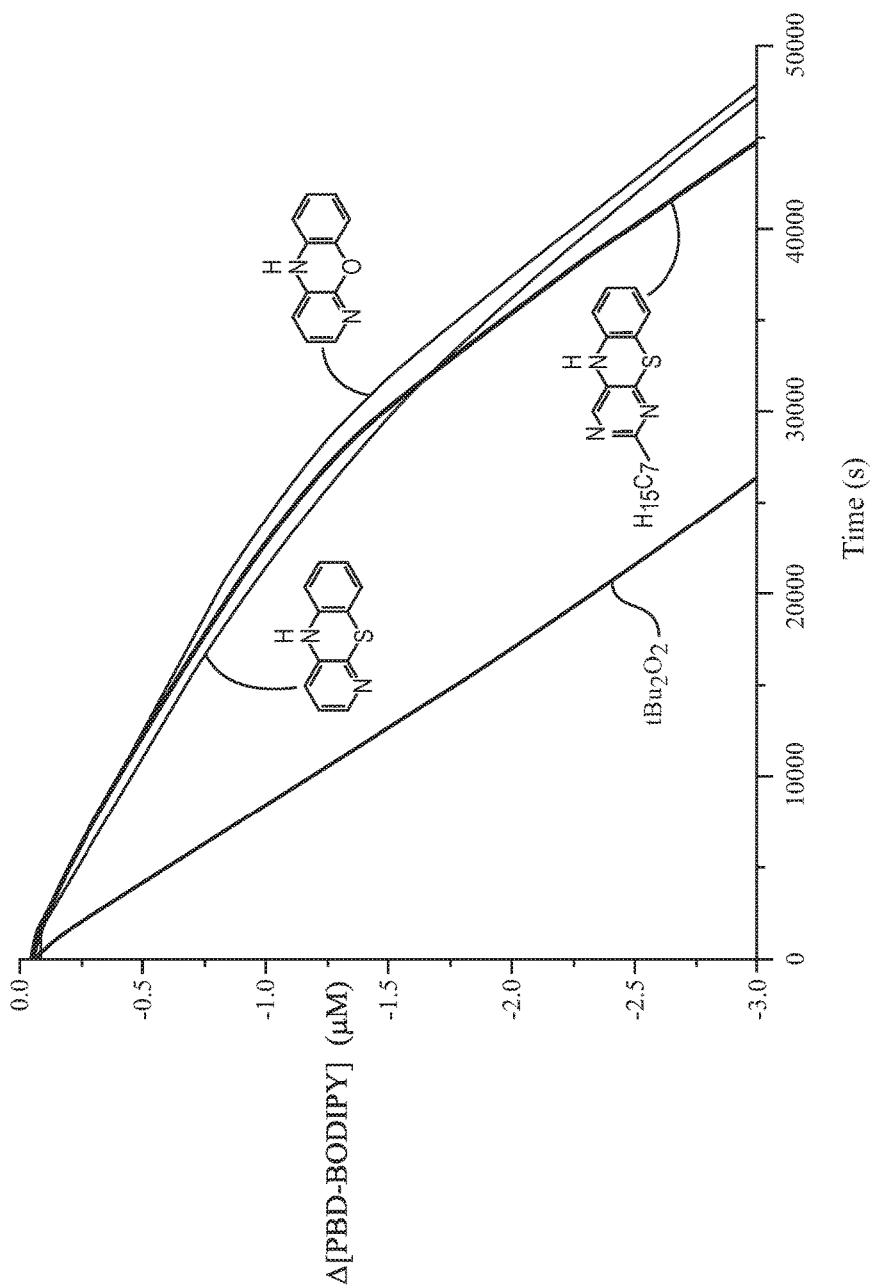
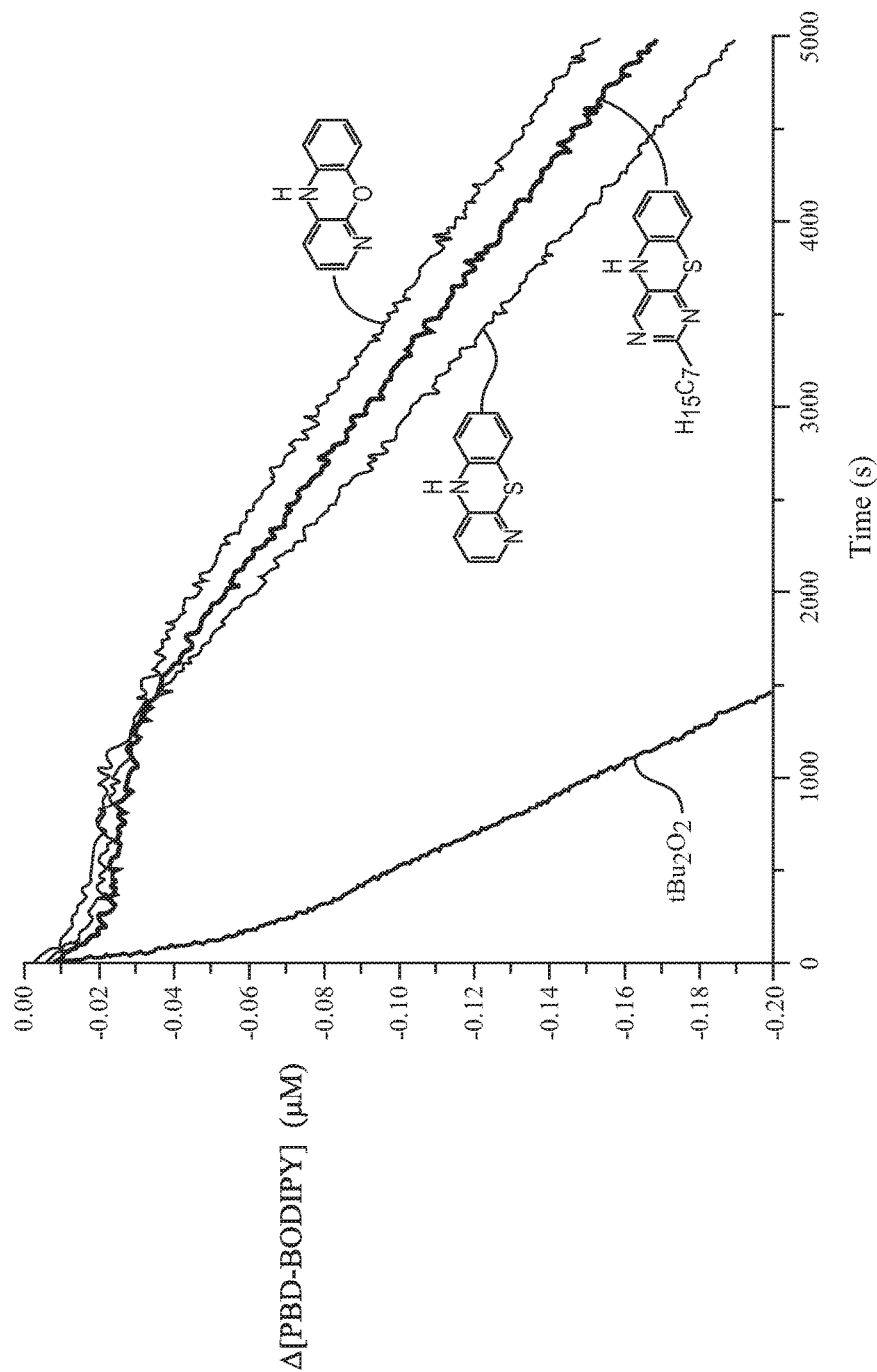
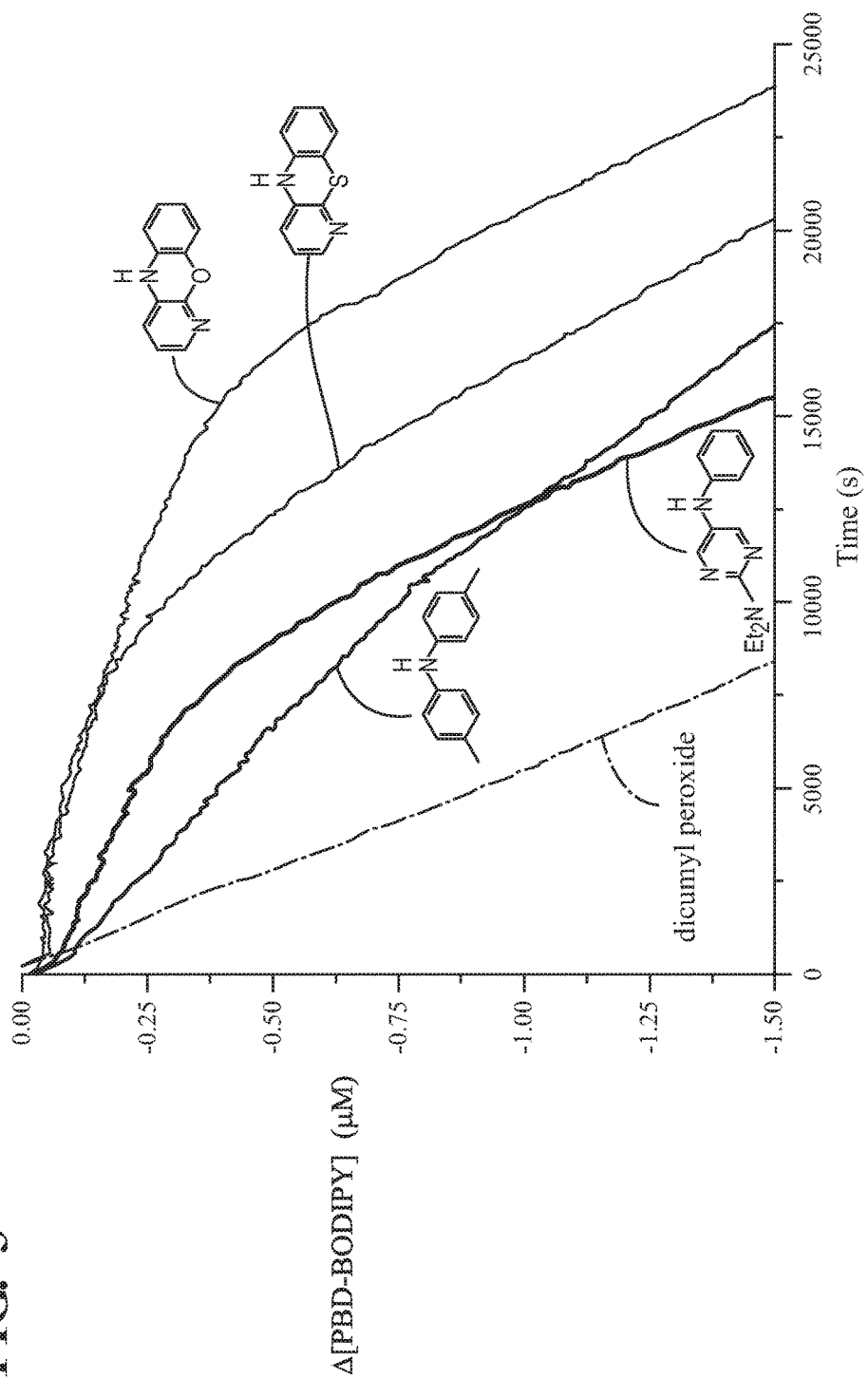
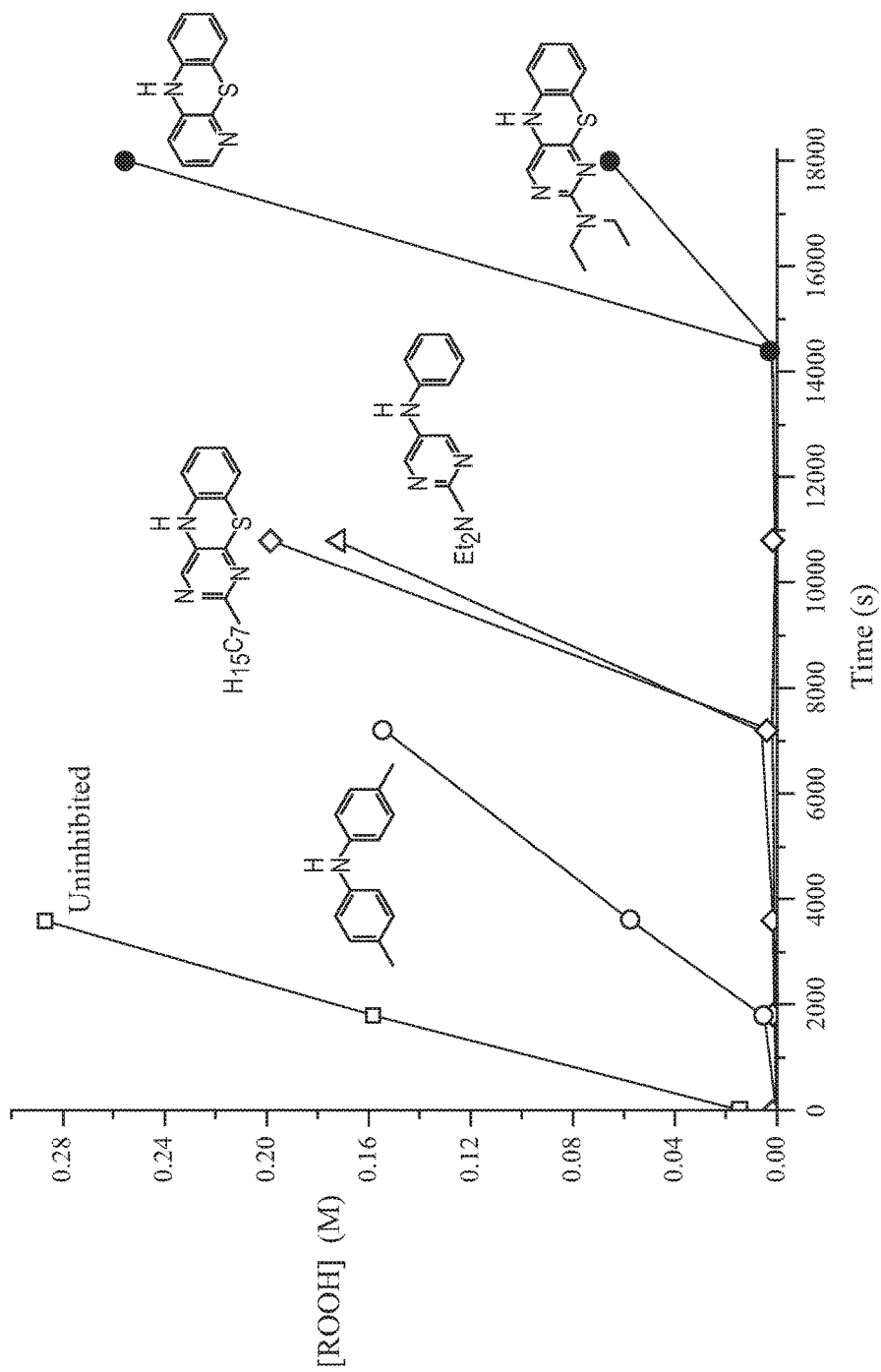


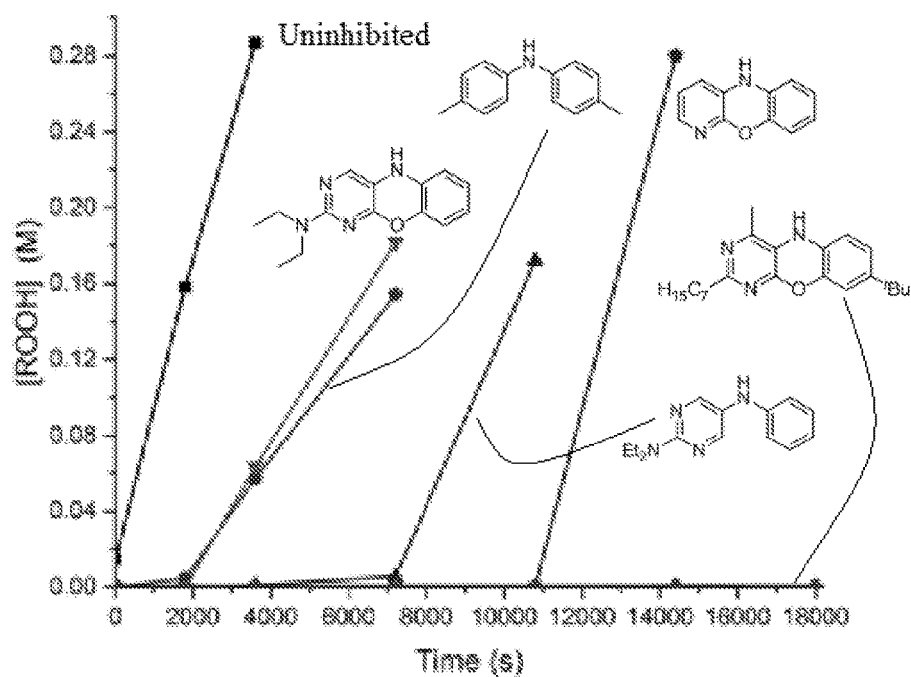
FIG. 2B



**FIG. 3**







**FIG. 5**

## LUBRICANT COMPOSITION

### FIELD OF THE DISCLOSURE

[0001] This disclosure generally relates to a lubricant composition. More specifically, the lubricant composition includes a particular antioxidant that includes an electron donating group.

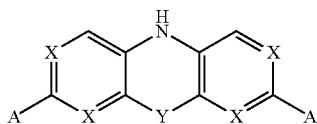
### BACKGROUND

[0002] Lubricant compositions are generally well known in the art and are broadly categorized as oil or water based compositions, i.e., compositions that include large weight percentages of non-polar compounds (such as (base) oils) or large weight percentages of water, respectively. Lubricant compositions are typically further categorized as engine oils, driveline system oils, gear oils, greases, automatic and manual transmission fluids and oils, hydraulic oils, industrial gear oils, turbine oils, rust and oxidation (R&O) inhibited oils, compressor oils, or paper machine oils, etc. Each of these compositions has particular specifications and design requirements and most are designed to minimize corrosion and wear, to resist thermal and physical breakdown, and to be able to minimize the effects of common contaminants such as oxidizing compounds and metal fragments.

[0003] Antioxidants are compounds that can retard oxidation, and thus are useful as additives in such lubricant compositions. Antioxidants are commonly utilized in lubricant compositions to assist in reducing unwanted oxidation and increasing performance standards. Combustion engine lubricants oxidize readily at the high operating temperatures of an engine, and in turn, have diminished lubricating capacity as the viscosity of the lubricant increases. Oxidation products also tend to accumulate to form deposits, which in turn leads to greater wear on engine parts. For example, peroxy radicals can lead to formation of radical chains and ultimately oxidative degradation. Antioxidants are used to react with such radicals, shorten radical chains, and reduce degradation. Unfortunately, many antioxidants do not react as fast as would be desired. Therefore, remains an opportunity for development of improved antioxidants.

### SUMMARY OF THE DISCLOSURE

[0004] This disclosure provides a lubricant composition that includes a base oil present in an amount of greater than 70 parts by weight per 100 parts by weight of the lubricant composition and also includes an antioxidant. The antioxidant has the structure:



wherein each X is independently CH or N, so long as at least one X is N, wherein Y is CRR', NR'', PR''', S, or O, each R, R' and R'' is independently H, alkyl or aryl, and R''' is alkyl, aryl, alkoxy or aryloxy. Each A is independently an electron donating group. The electron donating group (1) has an atom

having at least one lone pair of electrons that is bonded directly to the aromatic ring, (2) is an aryl or alkyl group, or (3) is a hydrogen atom.

### BRIEF DESCRIPTION OF THE FIGURES

[0005] Other advantages of the present disclosure will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

[0006] FIG. 1 is a graph that shows co-oxidation of 4.3 M styrene and 10  $\mu$ M PBD-BODIPY in PhCl at 37° C., initiated by 6.0 mM AIBN and inhibited by 2  $\mu$ M of the antioxidants shown ( $k_{inh} \gg 10^7$ ).

[0007] FIG. 2A is a graph that shows co-oxidation of 2.8M n-Hexadecene and 10  $\mu$ M PBD-BODIPY in PhCl at 70° C., initiated by 87 mM tBu<sub>2</sub>O<sub>2</sub>, and inhibited by 0.6  $\mu$ M of the various antioxidants shown.

[0008] FIG. 2B is a graph that shows co-oxidation of 2.8M n-Hexadecene and 10  $\mu$ M PBD-BODIPY in PhCl at 100° C., initiated by 87 mM tBu<sub>2</sub>O<sub>2</sub>, and inhibited by 0.6  $\mu$ M of the various antioxidants shown.

[0009] FIG. 3 is a graph that shows co-oxidation of 0.96M squalane and 10  $\mu$ M PBD-BODIPY in 1,2-dichlorobenzene at 100° C., initiated by 500  $\mu$ M dicumyl peroxide, and inhibited by 4  $\mu$ M of the antioxidants shown.

[0010] FIG. 4 is a graph that shows hydroperoxide formation in n-hexadecane at 160° C. including uninhibited autoxidation and inhibited autoxidation with 100  $\mu$ M of the antioxidants shown.

[0011] FIG. 5 is a graph that shows hydroperoxide formation in n-hexadecane at 160° C. including uninhibited and inhibited autoxidation with 100  $\mu$ M of the antioxidants shown.

### DETAILED DESCRIPTION OF THE DISCLOSURE

[0012] The present disclosure provides a lubricant composition. In various embodiments, the lubricant composition can be further described as a fully formulated lubricant or alternatively as an engine oil, a driveline system oil, a gear oil, a grease, an automatic and/or manual transmission fluid and/or oil, a hydraulic oil, an industrial gear oil, a turbine oil, a rust and oxidation (R&O) inhibited oil, a compressor oil, a paper machine oil, and/or combinations thereof.

[0013] In one embodiment, the terminology “fully formulated lubricant” refers to a total final composition that is a final commercial oil. This final commercial oil may include, for instance, detergents, dispersants, antioxidants, antifoam additives, pour point depressants, viscosity index improvers, anti-wear additives, friction modifiers, and other customary additives, depending on the formulation application. In the art, engine oils may be referred to as including a base oil as described below and performance additives. The lubricant composition of this disclosure includes a base oil and a particular antioxidant and may include any one or more of the aforementioned additives.

#### Base Oil:

[0014] The base oil is not particularly limited and may be further defined as including one or more oils of lubricating viscosity such as natural and synthetic lubricating or base oils and mixtures thereof. In one embodiment, the base oil



is further defined as a lubricant. In another embodiment, the base oil is further defined as an oil of lubricating viscosity. In still another embodiment, the base oil is further defined as a crankcase lubricating oil for spark-ignited and compression ignited internal combustion engines, including automobile and truck engines, two-cycle engines, aviation piston engines, and marine and railroad diesel engines. Alternatively, the base oil can be further defined as an oil to be used in gas engines, stationary power engines, and turbines. The base oil may be further defined as a heavy or light duty engine oil. In one embodiment, the base oil is further defined as a heavy duty diesel engine oil. Alternatively, the base oil may be described as an oil of lubricating viscosity or lubricating oil, for instance as disclosed in U.S. Pat. No. 6,787,663 and U.S. 2007/0197407, each of which is expressly incorporated herein by reference in one or more non-limiting embodiments. Alternatively, the base oil may be used in or as an engine oil, driveline system oil, gear oil, grease, automatic and manual transmission fluid or oil, hydraulic oil, industrial gear oil, turbine oil, rust and oxidation (R&O) inhibited oil, compressor oil, or paper machine oil, etc.

**[0015]** The base oil may be further defined as a base stock oil. Alternatively, the base oil may be further defined as a component that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location) that meets the same manufacturer's specification and that is identified by a unique formula, product identification number, or both. The base oil may be manufactured or derived using a variety of different processes including but not limited to distillation, solvent refining, hydrogen processing, oligomerization, esterification, and re-refining. Re-refined stock is typically substantially free from materials introduced through manufacturing, contamination, or previous use. In one embodiment, the base oil is further defined as a base stock slate, as is known in the art.

**[0016]** Alternatively, the base oil may be derived from hydrocracking, hydrogenation, hydrofinishing, refined and re-refined oils or mixtures thereof or may include one or more such oils. In one embodiment, the base oil is further defined as an oil of lubricating viscosity such as a natural or synthetic oil and/or combinations thereof. Natural oils include, but are not limited to, animal oils and vegetable oils (e.g., castor oil, lard oil) as well as liquid petroleum oils and solvent-treated or acid-treated mineral lubricating oils such as paraffinic, naphthenic or mixed paraffinic-naphthenic oils.

**[0017]** In various other embodiments, the base oil may be further defined as an oil derived from coal or shale. Non-limiting examples of suitable oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, poly(1-hexenes), poly(1-octenes), poly(1-decenes), and mixtures thereof; alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, and di(2-ethylhexyl)-benzenes); polyphenyls (e.g., biphenyls, terphenyls, and alkylated polyphenyls), alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs, and homologs thereof.

**[0018]** In still other embodiments, the base oil may be further defined as a synthetic oil which may include one or more alkylene oxide polymers and interpolymers and derivatives thereof wherein terminal hydroxyl groups are modified by esterification, etherification, or similar reac-

tions. 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 oils. For example, alkyl and aryl ethers of these polyoxyalkylene polymers (e.g., methylpolyisopropylene glycol ether having a weight average molecular weight of 1,000; diphenyl ether of polyethylene glycol having a weight average molecular weight of 500-1,000; and diethyl ether of polypropylene glycol having a weight average molecular weight of 1,000-1,500) and/or mono- and polycarboxylic esters thereof (e.g. 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) may also be utilized.

**[0019]** In even further embodiments, the base oil may include esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, and alkenyl malonic acids) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, and propylene glycol). Specific examples of these esters include, but are not limited to, dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dicosyl 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 combinations thereof. Esters useful as the base oil or as included in the base oil also include those formed from C<sub>5</sub> to C<sub>12</sub> monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol, and tripentaerythritol.

**[0020]** The base oil may be alternatively described as a refined and/or re-refined oil, or combinations thereof. Unrefined oils are typically obtained 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 distillation, or an ester oil obtained directly from an esterification process and used without further treatment, could all be utilized in this disclosure. Refined oils are similar to the unrefined oils except that they typically have undergone purification to improve one or more properties. Many such purification techniques are known to those of skill in the art such as solvent extraction, acid or base extraction, filtration, percolation, and similar purification techniques. Re-refined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives and oil breakdown products.

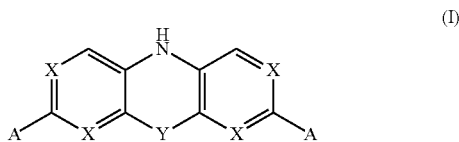
**[0021]** The base oil may alternatively be described as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. In other words, the base oil may be further described as one or a combination of more than one of five base oil groups: Group I (sulfur content >0.03 wt %, and/or <90 wt % saturates, viscosity index 80-120); Group II (sulfur content less than or equal to 0.03 wt %, and greater than or equal to 90 wt % saturates, viscosity index 80-120); Group III (sulfur 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 120); Group IV (all polyalphaolefins (PAO's)); and Group V (all others not included in Groups I, II, III, or IV). In one

embodiment, the base oil is chosen from API Group I, II, III, IV, V and combinations thereof. In another embodiment, the base oil is chosen from API Group II, III, IV, and combinations thereof. In still another embodiment, the base oil is further defined as an API Group II, III, or IV oil and includes a maximum of about 49.9 wt %, typically up to a maximum of about 40 wt %, more typically up to a maximum of about 30 wt %, even more typically up to a maximum of about 20 wt %, even more typically up to a maximum of about 10 wt % and even more typically up to a maximum of about 5 wt % of the lubricating oil an API Group I or V oil. It is also contemplated that Group II and Group II basestocks prepared by hydrotreatment, hydrofinishing, hydroisomerization or other hydrogenative upgrading processes may be included in the API Group II described above. Moreover, the base oil may include Fisher Tropsch or gas to liquid GTL oils. These are disclosed for example in U.S. 2008/0076687, which is expressly incorporated herein by reference in one or more non-limiting embodiments.

[0022] The base oil is typically present in the composition in an amount of from 70 to 99.9, from 80 to 99.9, from 90 to 99.9, from 75 to 95, from 80 to 90, or from 85 to 95, parts by weight per 100 parts by weight of the composition. Alternatively, the base oil may be present in amounts of greater than 70, 75, 80, 85, 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99, parts by weight per 100 parts by weight of the composition. In various embodiments, the amount of lubricating oil in a fully formulated lubricant (including diluent or carrier oils presents) is from about 80 to about 99.5 percent by weight, for example, from about 85 to about 96 percent by weight, for instance from about 90 to about 95 percent by weight. Of course, the weight percent of the base oil may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may vary from the values and/or range of values above by  $\pm 5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $\pm 20\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

Antioxidant:

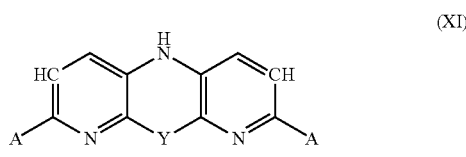
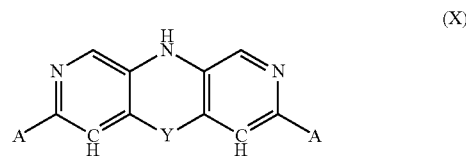
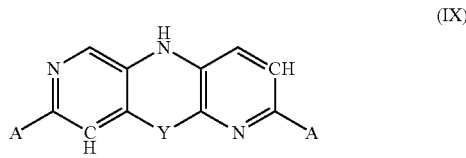
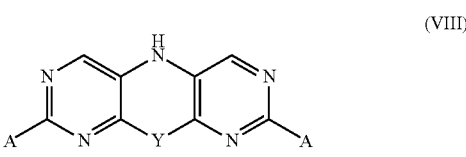
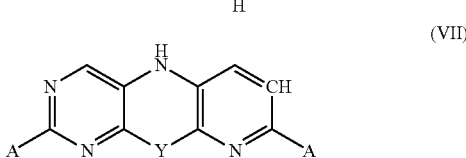
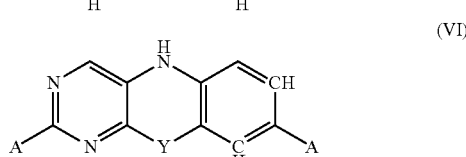
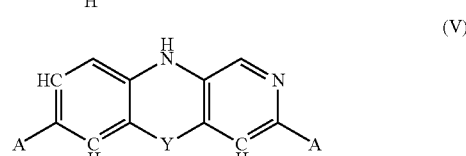
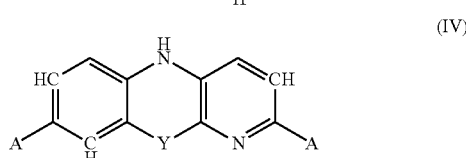
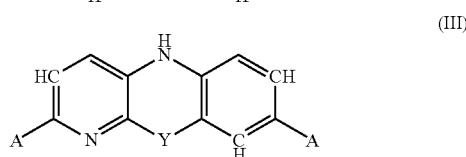
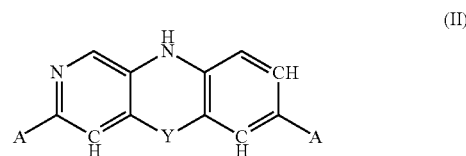
[0023] The lubricant composition also includes an antioxidant. One or more of such antioxidants can be used. The antioxidant has the structure:



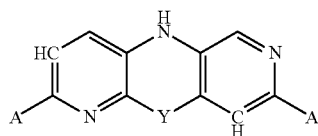
[0024] In various embodiments, each X is independently CH or N, so long as at least one X is N, Y is CRR', NR'', PR''', S, or O, each A is independently an electron donating group, and each R, R' and R'' is independently H, alkyl or aryl, and R''' is alkyl, aryl, alkoxy or aryloxy. The electron donating group (1) has an atom having at least one lone pair of electrons that is bonded directly to the aromatic ring, (2) is an aryl or alkyl group, or (3) is a hydrogen atom. In one embodiment, Y is PR''' and R''' is alkyl, aryl, alkoxy or aryloxy.

[0025] In other embodiments, each X is independently CH or N, so long as at least one X is N, Y is CH<sub>2</sub>, NH, S, or O, and each A is independently an electron donating group. In one embodiment, each X is N (i.e., a nitrogen atom). In other

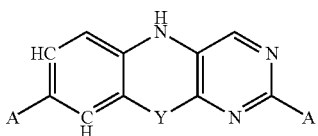
embodiments, two, three, at least two, or at least three, of X is N. In another embodiment, all four X are N. Examples of such embodiments are as follows:



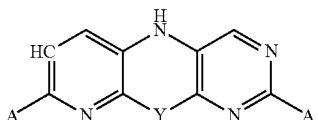
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(XIII)



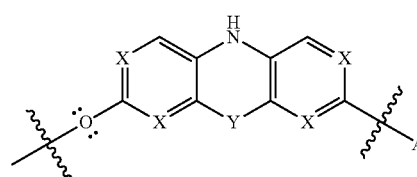
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**[0026]** The terminology “aryl” group describes any functional group or substituent derived from an aromatic ring, e.g. phenyl, naphthyl, thienyl, indolyl, etc. The terminology “aryloxy” is known in the art and in this disclosure may be based on any one or more of the aforementioned aryl groups. The alkyl group may be linear, branched, or cyclic and typically includes 1 to 20 carbon atoms. Although, the alkyl group may include more than 20 carbon atoms. In various embodiments, the alkyl group includes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 carbon atoms or any range thereof. The alkyl group may be further defined as an alkane, an alkene, or an alkyne. The alkyl group may be alternatively described using the formula  $G_nH_{2n+1}$  wherein  $n$  is 1 to 20, as described above. In various embodiments, the alkyl group may be described as methyl, ethyl propyl, butyl, t-butyl, pentyl, hexyl, octyl, nonyl, or any isomer thereof. The terminology “alkoxy” is known in the art and in this disclosure may be based on any one or more of the aforementioned alkyl groups.

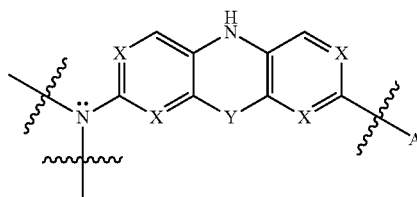
**[0027]** When one or more carbon atoms within the aromatic ring of the antioxidant is replaced with nitrogen, the resulting compounds may have improved estimated activation enthalpies ( $\Delta H^*$ ) for reactions with peroxy radicals, while also maintaining a relatively high estimated ionization enthalpy ( $\Delta H_{ion}$ ) which reflects their stability in air, as compared to the same compounds without the substitution of the nitrogen for carbon. Substitution of nitrogen atoms may produce an increase in the ionization enthalpy ( $\Delta H_{ion}^*$ ), thus stabilizing the compound to one-electron oxidation (such as by reaction with  $O_2$  in air or hydroperoxides arising from hydrocarbon oxidation). This stability may permit substitution with electron-donating groups to increase reactivities as radical-trapping antioxidants by lowering the activation enthalpy ( $\Delta H^*$ ) for reactions with peroxy radicals.

**[0028]** Each A is independently an electron donating group. Each electron donating group independently (1) has an atom having at least one lone pair of electrons that is bonded directly to the aromatic ring of the antioxidant, (2) is an aryl or alkyl group, or (3) is a hydrogen atom. Each electron donating group can be alternatively described as an “EDG”, as is appreciated in the art. Alternatively, the terminology “group” may be the individual hydrogen atom even though a singular atom is not typically considered to be a “group.” In other words, relative to this disclosure, it is contemplated that a single hydrogen atom can be an electron

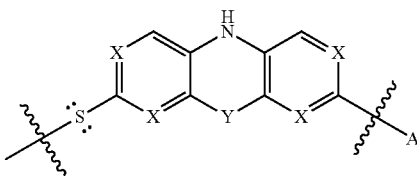
donating “group.” In various embodiments, each electron donating group independently has an atom, such a nitrogen atom, a phosphorous atom, an oxygen atom or a sulfur atom, that has at least one lone pair of electrons. For example, oxygen and sulfur each typically have two lone pairs of electrons while nitrogen and phosphorous each typically have only one lone pair of electrons. The terminology “lone pair” describes a pair of valence electrons that are not shared with other atoms and/or are not used in chemical bonding. These electrons may also be described as a non-bonding pair of electrons. Lone pair electrons are found in the outermost electron shell of atoms. The number of lone pair electrons plus the number of bonding electrons equals the total number of valence electrons around an atom. Non-limiting examples of antioxidants wherein there are atoms having at least one lone pair of electrons that are bonded directly to the aromatic ring of the antioxidant are as follows:



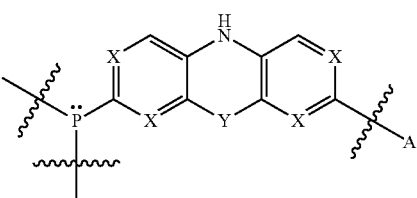
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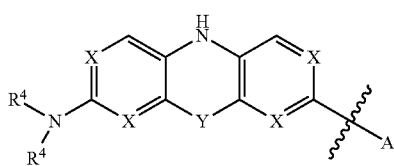
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**[0029]** In these examples, the “A” on the right side of the structures can be O, N, S, or P. Moreover, all combinations of compounds wherein one or both A’s are O, N, S, and/or P, are also hereby expressly contemplated even if not drawn above. It is also contemplated that any of the aforementioned may alternatively be a hydrogen atom, including all combinations even if not drawn above.

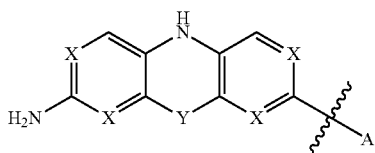
**[0030]** Each of the electron donating groups can alternatively and independently be an aryl or alkyl group. The terminology “aryl” group describes any functional group or substituent derived from an aromatic ring, e.g. phenyl,

naphthyl, thienyl, indolyl, etc. The alkyl group may be linear, branched, or cyclic and typically includes 1 to 20 carbon atoms. Although, the alkyl group may include more than 20 carbon atoms. In various embodiments, the alkyl group includes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 carbon atoms or any range thereof. The alkyl group may be further defined as an alkane, an alkene, or an alkyne. The alkyl group may be alternatively described using the formula  $C_nH_{2n+1}$  wherein n is 1 to 20, as described above. In various embodiments, the alkyl group may be described as methyl, ethyl propyl, butyl, t-butyl, pentyl, hexyl, octyl, nonyl, or any isomer thereof.

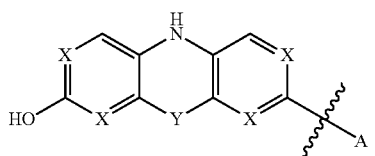
**[0031]** In other embodiments, each of the electron donating groups is independently  $-NR^4$ ,  $-NH_2$ ,  $-OH$ ,  $-OR^4$ ,  $-NHCOR^4$ , or  $-OCOR^4$ , wherein  $R^4$  is independently an alkyl group having 1 to 10 carbon atoms, as described above. For example, one or both of, or at least one of, the electron donating groups may be  $-NR^4$ , wherein each  $R^4$  is independently an alkyl group having 1 to 10 carbon atoms, as described above. In another embodiment, one or both of, or at least one of, the electron donating groups is  $-NH_2$ . In another embodiment, one or both of, or at least one of, the electron donating groups is  $-OH$ . In a further embodiment, one or both of, or at least one of, the electron donating groups is  $-OR^4$ , wherein  $R^4$  is an alkyl group having 1 to 10 carbon atoms, as described above. In another embodiment, one or both of, or at least one of, the electron donating groups is  $-H$ . In a further embodiment, one or both of, or at least one of, the electron donating groups is  $-NHCOR^4$ , wherein  $R^4$  is an alkyl group having 1 to 10 carbon atoms, as described above. In another embodiment, one or both of, or at least one of, the electron donating groups is  $-OCOR^4$ , wherein  $R^4$  is an alkyl group having 1 to 10 carbon atoms, as described above. Non-limiting examples of structures corresponding to such embodiments are set forth below:



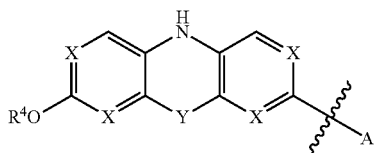
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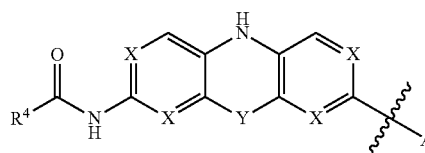
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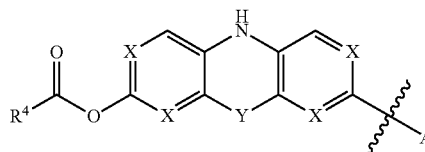
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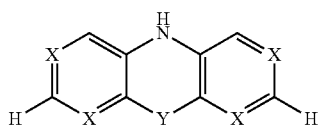
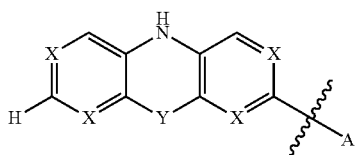
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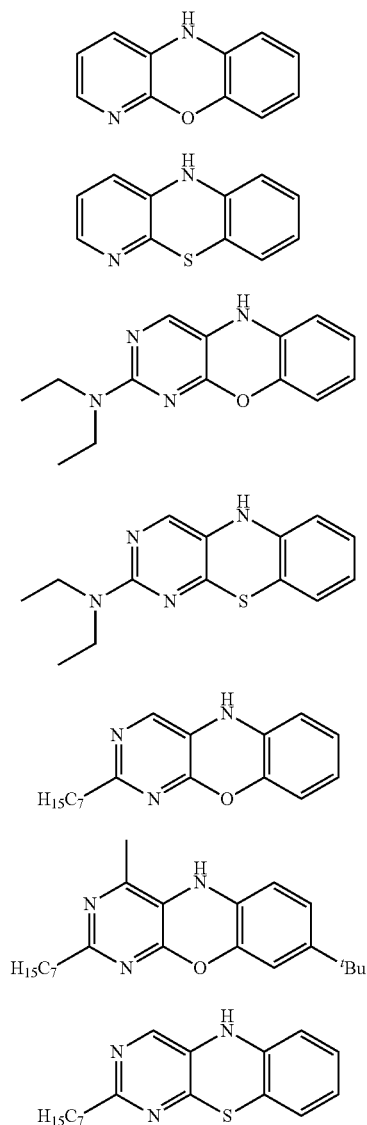
**[0032]** In other embodiments, each of the electron donating groups may be independently described as aromatic or aliphatic. In still other embodiments, one or both of, or at least one of, the electron donating groups includes or is a hydrocarbon group, an alkoxy group ( $OR^5$ ), an amine group, a monosubstituted amine group ( $NHR^5$ ), or a disubstituted amine group ( $NR^5_2$ ). In other embodiments, one or both of, or at least one of, the electron donating group is a diallyl amine group. The electron-donating strength of the alkoxy or amine group comes largely from the lone pairs of electrons on the O and N atoms, respectively, such that each of  $R^5$  groups can be a hydrogen or a saturated or unsaturated branched or straight chain hydrocarbon moiety and/or may include one or more cycloaliphatic groups and/or one or more aromatic hydrocarbons, or a combination thereof, while not detracting from the electron donating characteristic of the alkoxy or amine group. In such embodiments, the term “cycloaliphatic” describes a saturated or unsaturated carbocyclic moiety comprising mono- or bicyclic rings. Cycloaliphatic groups typically include a 3- to 7-membered saturated carbocyclic moiety. Examples of cycloaliphatic moieties include, but are not limited to, cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl, and the like, including partially unsaturated derivatives thereof such as cyclohexenyl, cyclopentenyl, and the like. Alternatively, the term “hydrocarbon group” may describe a hydrocarbon including from 1 to 20 carbon atoms, e.g. as described above, and includes saturated or unsaturated, branched or straight chain hydrocarbon moieties, including aliphatic moieties and/or one or more cycloaliphatic groups and/or one or more aromatic hydrocarbons, or a combination thereof.

**[0033]** One or both of, or at least one of, the electron donating groups may alternatively be a thiol, sulfide, thioether, or thioester (e.g. wherein the sulfur atom of the group is adjacent to the group being donated into). Alternatively, one or both of, or at least one of, the electron donating groups may be a phosphane. It is to be understood that one or both of, or at least one of, the electron withdrawing groups may be chosen from any of the above options such that both electron donating groups may be the same or they may be different from each other.

**[0034]** In other embodiments, one or both of the electron donating groups is a hydrogen atom. For the purpose of this disclosure, the hydrogen “atom” may be considered to be an electron donating “group.” Two non-limiting structural examples of such embodiments set forth below:



[0035] In still further embodiments, the antioxidant is chosen from one or more of those structures 1-7 set forth below, and combinations thereof:



[0036] The antioxidant is typically present in an amount of, or less than, 30, 25, 20, 15, 10, 5, 2, 1.5, 1, or 0.5, parts by weight per 100 parts by weight of the lubricant composition. In various embodiments, the antioxidant is present in an amount of from of from 0.1 to 2, 0.5 to 2, 1 to 2, or 1.5 to 2, parts by weight per 100 parts by weight of the lubricant composition. Of course, the weight percent of the antioxidant may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by  $\pm 5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $\pm 20\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

[0037] The Table below illustrates the effect of ring structure and nitrogen incorporation on the N—H bond dissociation energy and ionization potential of various antioxidants, and their derivatives, calculated at the CBS-QB3 level of theory.

	Structure	BDE (kcal/mol)	IP (kcal/mol)
1		86.4	168.3
2		86.6	174.7
3		86.4	179.3
4		78.7	154.0
5		75.1	164.9
6		75.7	167.1
7		74.7	164.2
		75.5	171.8

## Additives:

**[0038]** The composition can additionally include one or more additives to improve various chemical and/or physical properties. Non-limiting examples of the one or more additives include anti-wear additives, metal passivators, rust inhibitors, viscosity index improvers, pour point depressors, dispersants, detergents, and antifriction additives. One or more of the additives may be ash-including or ash-less.

## Anti-Wear Additive:

**[0039]** The anti-wear additive is not particularly limited and may be any known in the art. In one embodiment, the anti-wear additive is selected from the group of ZDDP, zinc dialkyl-dithio phosphates, and combinations thereof. Alternatively, the anti-wear additive may include sulfur- and/or phosphorus- and/or halogen-including compounds, e.g. sulfurised olefins and vegetable oils, zinc dialkyldithiophosphates, 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 (for example tris(isononylphenyl) phosphorothioate), 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-octylidithio carbamate, and/or combinations thereof. In one embodiment, the anti-wear additive include phosphorous and sulfur, e.g. in phosphorothionates and/or dithiophosphate esters.

**[0040]** The anti-wear additive is typically present in the composition in an amount of from 0.1 to 20, from 0.5 to 15, from 1 to 10, from 5 to 10, from 5 to 15, from 5 to 20, from 0.1 to 1, from 0.1 to 0.5, or from 0.1 to 1.5, parts by weight per 100 parts by weight of the composition. Alternatively, the anti-wear additive may be present in amounts of less than 20, less than 15, less than 10, less than 5, less than 1, less than 0.5, or less than 0.1, parts by weight per 100 parts by weight of the composition. It is also contemplated that the antiwear additive may be present in an amount of from 0.2 to 0.8, from 0.2 to 0.6, from 0.2 to 0.4, or from 0.3 to 0.5, parts by weight per 100 parts by weight of the composition. Of course, the weight percent of the anti-wear additive may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may vary from the values and/or range of values above by  $\pm 5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $\pm 20\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

## Additional Antioxidants:

**[0041]** The lubricant composition may include one or more additional antioxidants in addition to the antioxidant described above. Suitable, non-limiting, additional 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-( $\alpha$ -methylcyclohexyl)-4,6-dimethyl-

phenol, 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.

**[0042]** Other non-limiting examples of suitable additional antioxidants includes alkylthiomethylphenols, for example 2,4-dioctylthiomethyl-6-tert-butylphenol, 2,4-dioctylthioethyl-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.

**[0043]** 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-2-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.

**[0044]** 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-( $\alpha$ -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-( $\alpha$ -methylbenzyl)-4-nonylphenol], 2,2'-methylenebis[6-( $\alpha$ , $\alpha$ -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-methyl-phenyl)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-dodecylmercapto butane, 1,1,5,5-tetra-(5-tert-butyl-4-hydroxy-2-methyl phenyl)pentane, and combinations thereof may be utilized as additional antioxidants.

**[0045]** 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.

**[0046]** Hydroxybenzylated malonates, for example dioc-tadecyl-2,2-bis-(3,5-di-tert-butyl-2-hydroxybenzyl)-ma-lonate, di-octadecyl-2-(3-tert-butyl-4-hydroxy-5-methyl-

benzyl)-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 additional antioxidants.

**[0047]** 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.

**[0048]** Additional suitable, but non-limiting examples of additional 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, octyl N-(3,5-di-tert-butyl-4-hydroxyphenyl)carbamate may be used.

**[0049]** 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  $\beta$ -(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]oc-

tane, and combinations thereof, may also be used. Moreover, esters of 3,5-di-tert-butyl-4-hydroxyphenyl acetic 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 utilized.

**[0050]** Additional non-limiting examples of suitable additional antioxidants include those that include nitrogen, such as amides of  $\beta$ -(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 non-limiting examples of additional 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-dimethylbutyl)-N'-phenyl-p-phenylenediamine, N-(1-methylheptyl)-N'-phenyl-p-phenylenediamine, N-cyclohexyl-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-butylaminophenol, 4-nonanoylaminophenol, 4-dodecanoylaminophenol, 4-octadecanoylaminophenol, 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/isohexyldiphenylamines, 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, N,N-bis(2,2,6,6-tetramethylpiperid-4-yl)hexamethylenediamine, bis(2,2,6,6-tetramethyl piperid-4-yl)sebacate, 2,2,6,6-tetramethylpiperidin-4-one and 2,2,6,6-tetramethyl piperidin-4-ol, and combinations thereof.

**[0051]** Even further non-limiting examples of suitable additional antioxidants includes 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-3,7,10,14-trithiatridecane and 2,2,15,15-tetramethyl-5,12-dihydroxy-3,7,10,14-trithiahexadecane, and combinations thereof. Furthermore, sulfurized fatty esters, sulfurized fats and sulfurized olefins, and combinations thereof, may be used.

**[0052]** The one or more additional antioxidants are not particularly limited in amount in the composition but may be

present such that a total amount of antioxidants in the composition is about, or less than, 30, 25, 20, 15, 10, 5, 2, 1.5, 1, or 0.5, of from 0.1 to 2, 0.5 to 2, 1 to 2, or 1.5 to 2, parts by weight per 100 parts by weight of the composition. Alternatively, the total amount of antioxidants in the composition may be less than 2, less than 1.5, less than 1, or less than 0.5, parts by weight per 100 parts by weight of the composition. Of course, the weight percent of the one or more additional antioxidants may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by +5%, ±10%, ±15%, ±20%, ±25%, ±30%, etc.

#### Metal Deactivators:

**[0053]** In various embodiments, one or more metal deactivators can be included in the composition. Suitable, non-limiting examples of the one or more metal deactivators include benzotriazoles and derivatives thereof, for example 4- or 5-alkylbenzotriazoles (e.g. triazole) and derivatives thereof, 4,5,6,7-tetrahydrobenzotriazole and 5,5'-methylenebisbenzotriazole; Mannich bases of benzotriazole or triazole, e.g. 1-[bis(2-ethylhexyl)aminomethyl]triazole and 1-[bis(2-ethylhexyl)aminomethyl]benzotriazole; and alkoxyalkylbenzotriazoles such as 1-(nonyloxymethyl)benzotriazole, 1-(1-butoxyethyl)benzotriazole and 1-(1-cyclohexyloxybutyl) triazole, and combinations thereof.

**[0054]** Additional non-limiting examples of the one or more metal deactivators include 1,2,4-triazoles and derivatives thereof, for example 3-alkyl(or aryl)-1,2,4-triazoles, 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.

**[0055]** Further non-limiting examples of the one or more metal deactivators include sulfur-including 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 non-limiting examples of the one or more metal deactivators include amino compounds, for example salicylidenepropylenediamine, salicylamino guanidine and salts thereof, and combinations thereof.

**[0056]** The one or more metal deactivators are not particularly limited in amount in the composition but are typically present in an amount of from 0.01 to 0.1, from 0.05 to 0.01, or from 0.07 to 0.1, parts by weight per 100 parts by weight of the composition. Alternatively, the one or more metal deactivators may be present in amounts of less than 0.1, of less than 0.7, or less than 0.5, parts by weight per 100 parts by weight of the composition. The weight percent of the one or more metal deactivators may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by +5%, ±10%, ±15%, ±20%, ±25%, ±30%, etc.

#### Rust Inhibitors and Friction Modifiers:

**[0057]** In various embodiments, one or more additional rust inhibitors and/or one or more friction modifiers can be

included in the composition. Suitable, non-limiting examples of the one or more additional rust inhibitors and/or one or more friction modifiers include organic acids, their esters, metal salts, amine salts and anhydrides, 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 the amine salts thereof, and also N-oleoylsarcosine, sorbitan monooleate, lead naphthenate, alkenylsuccinic anhydrides, for example dodecenylsuccinic anhydride, 2-carboxymethyl-1-dodecyl-3-methylglycerol and the amine salts thereof, and combinations thereof. Additional suitable, non-limiting examples of the one or more rust inhibitors and/or friction modifiers include nitrogen-including compounds, for example, primary, secondary or tertiary aliphatic or cycloaliphatic amines and amine salts of organic and inorganic acids, for example oil-soluble alkylammonium carboxylates, and also 1-[N,N-bis(2-hydroxyethyl)amino]-3-(4-nonylphenoxy)propan-2-ol, and combinations thereof. Further suitable, non-limiting examples include heterocyclic compounds, for example: substituted imidazolines and oxazolines, and 2-heptadecenyl-1-(2-hydroxyethyl)imidazoline, phosphorus-including compounds, for example: Amine salts of phosphoric acid partial esters or phosphonic acid partial esters, and zinc dialkyldithiophosphates, molybdenum-including compounds, such as molybdenum dithiocarbamate and other sulfur and phosphorus including derivatives, sulfur-including 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.

**[0058]** The one or more additional rust inhibitors and/or one or more friction modifiers are not particularly limited in amount in the composition but may be present in an amount of from 0.05 to 0.5, 0.01 to 0.2, from 0.05 to 0.2, 0.1 to 0.2, 0.15 to 0.2, or 0.02 to 0.2, parts by weight per 100 parts by weight of the composition. Alternatively, the one or more additional rust inhibitors and/or one or more friction modifiers may be present in amounts of less than 0.5, less than 0.4, less than 0.3, less than 0.2, less than 0.1, less than 0.5, or less than 0.1, parts by weight per 100 parts by weight of the composition. The weight percent of the one or more rust inhibitors and friction modifiers may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by ±5%, ±10%, ±15%, ±20%, ±25%, ±30%, etc.

#### Viscosity Index Improvers:

**[0059]** In various embodiments, one or more viscosity index improvers can be included in the composition. Suitable, non-limiting examples of the one or more viscosity index improvers include polyacrylates, polymethacrylates, vinylpyrrolidone/methacrylate copolymers, polyvinylpyrrolidones, polybutenes, olefin copolymers, styrene/acrylate copolymers and polyethers, and combinations thereof. The one or more viscosity index improvers are not particularly limited in amount in the composition but are typically



present in an amount of from 1 to 1, from 2 to 8, from 3 to 7, from 4 to 6, or from 4 to 5, parts by weight per 100 parts by weight of the composition. Alternatively, the one or more viscosity index improvers may be present in an amount of less than 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1, part by weight per 100 parts by weight of the composition. The weight percent of the one or more viscosity index improvers may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by  $\pm 5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $2\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

#### Pour Point Depressants:

**[0060]** In various embodiments, one or more pour point depressants can be included in the composition. Suitable, non-limiting examples of the pour point depressants include polymethacrylate and alkylated naphthalene derivatives, and combinations thereof. The one or more pour point depressants are not particularly limited in amount in the composition but are typically present in an amount of from 0.1 to 1, from 0.5 to 1, or from 0.7 to 1, part by weight per 100 parts by weight of the composition. Alternatively, the one or more pour point depressants may be present in amounts of less than 1, less than 0.7, or less than 0.5, parts by weight per 100 parts by weight of the composition. The weight percent of the one or more pour point depressants may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by  $\pm 5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $\pm 20\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

#### Dispersants:

**[0061]** In various embodiments, one or more dispersants can be included in the composition. Suitable, non-limiting examples of the one or more 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.

**[0062]** The one or more dispersants are not particularly limited in amount in the composition but are typically present in an amount of from 0.1 to 5, from 0.5 to 4.5, from 1 to 4, from 1.5 to 3.5, from 2 to 3, or from 2.5 to 3, parts by weight per 100 parts by weight of the composition. Alternatively, the one or more dispersants may be present in an amount of less than 5, 4.5, 3.5, 3, 2.5, 2, 1.5, or 1, part by weight per 100 parts by weight of the composition. The weight percent of the one or more dispersants may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by  $\pm 5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $\pm 20\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

#### Detergents:

**[0063]** In various embodiments, one or more detergents can be included in the composition. Suitable, non-limiting examples of the one or more detergents include overbased or neutral metal sulfonates, phenates and salicylates, and combinations thereof.

**[0064]** The one or more detergents are not particularly limited in amount in the composition but are typically present in an amount of from 0.1 to 5, from 0.5 to 4.5, from

1 to 4, from 1.5 to 3.5, from 2 to 3, or from 2.5 to 3, parts by weight per 100 parts by weight of the composition. Alternatively, the one or more detergents may be present in an amount of less than 5, 4.5, 3.5, 3, 2.5, 2, 1.5, or 1, part by weight per 100 parts by weight of the composition. The weight percent of the one or more detergents may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by  $\pm 5\%$ ,  $10\%$ ,  $\pm 15\%$ ,  $2\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

**[0065]** In various embodiments, the composition is substantially free of water, e.g. includes less than 5, 4, 3, 2, or 1, weight percent of water. Alternatively, the composition may include less than 0.5 or 0.1 weight percent of water, less than 500, 100, 50, 20, 15, 10, or 5, parts by weight of water per one million parts by weight (ppm) of the composition, or may be free of water. Of course, the weight percent of the water may be any value or range of values, both whole and fractional, within those ranges and values described above and/or may be present in amounts that vary from the values and/or range of values above by  $+5\%$ ,  $\pm 10\%$ ,  $\pm 15\%$ ,  $\pm 20\%$ ,  $\pm 25\%$ ,  $\pm 30\%$ , etc.

**[0066]** The lubricant composition may be further defined as ash-including or ash-less, according to ASTM D 874 and known in the art. Typically, the terminology "ash-less" refers to the absence of (significant) amounts of metals such as sodium, potassium, calcium, and the like. Of course, it is to be understood that the lubricant composition is not particularly limited to being defined as either ash-including or ash-less.

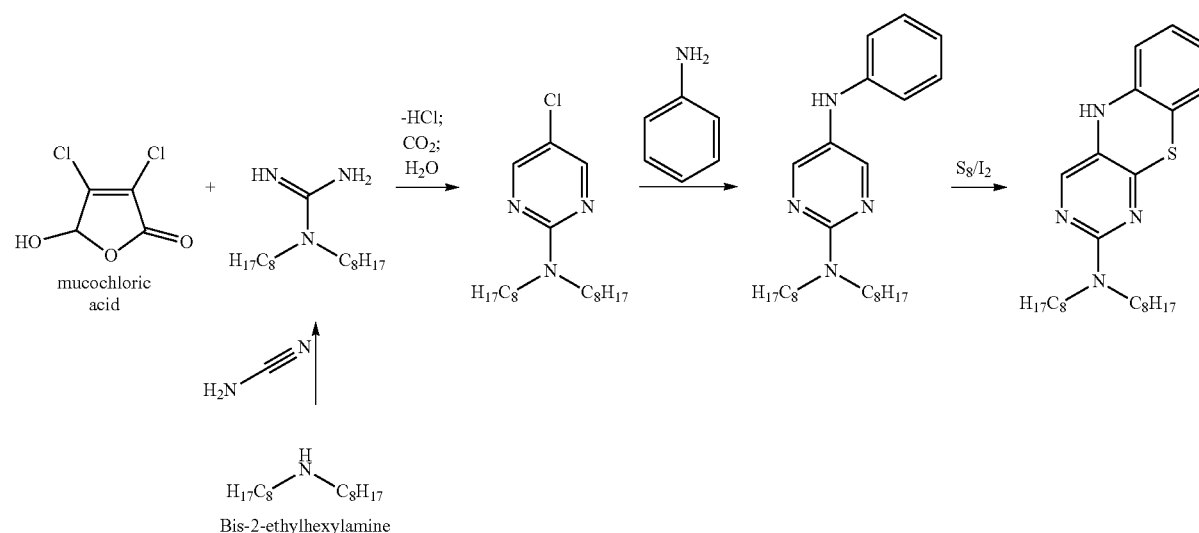
#### Additive Concentrate Package:

**[0067]** The instant disclosure also provides an additive concentrate package which includes the antioxidant of this disclosure and also includes one or more metal deactivators, one or more anti-wear additives, one or more additional antioxidants, and/or one or more of the aforementioned additives. The additive concentrate package may include the antioxidant of this disclosure and be free of any additional antioxidants. In one embodiment, the additive concentrate package is further defined as a hydraulic additive concentrate package. In another embodiment, the additive concentrate package is further defined as an engine oil additive concentrate package. In a further embodiment, the additive concentrate package is further defined as a driveline system oil additive concentrate package. In an additional embodiment, the additive concentrate package is further defined as a gear oil additive concentrate package. In still another embodiment, the additive concentrate package is further defined as a grease additive concentrate package. In a further embodiment, the additive concentrate package is further defined as an automatic and/or manual transmission fluid and/or oil additive concentrate package. In another embodiment, the additive concentrate package is further defined as an industrial gear oil additive concentrate package. In another embodiment, the additive concentrate package is further defined as a turbine oil additive concentrate package. In another embodiment, the additive concentrate package is further defined as a rust and oxidation inhibited oil additive concentrate package. In another embodiment, the additive concentrate package is further defined as a compressor oil additive concentrate package. In another embodiment, the additive concentrate package is further defined as a paper machine oil additive concentrate package. In another

embodiment, the additive concentrate package is further defined as an additive concentrate package for combinations of two or more of the aforementioned oils.

**[0068]** In another embodiment, the additive concentrate package includes 10-40 weight percent of the antioxidant, 0-15 weight percent of a metal deactivator (e.g. a yellow metal corrosion inhibitor), 0-15 weight percent of a corrosion inhibitor (e.g. the corrosion inhibitor of this disclosure and a ferrous metal corrosion inhibitor), 0-10 weight percent of a friction modifier (e.g. glycerol mono-oleate), 20-35 weight percent of an anti-wear additive, and 0-1 weight percent of an anti-foam additive. Additionally, 0-25 weight percent of a dispersant may also be included. Viscosity modifiers and pour point depressants may also be included but typically are not part of such packages.

**[0069]** Some of the compounds described above may interact in the lubricant composition, so 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 composition of this disclosure in its intended use, are not easily described or describable. Nevertheless, all such modifications, reaction products, and products formed upon employing the composition of this disclosure in its intended use, are expressly contemplated and hereby included herein in various non-limiting embodiments. Various embodiments of this disclosure include one



or more of the modification, reaction products, and products formed from employing the composition, as described above.

#### Method of Forming the Composition:

**[0070]** This disclosure also provides a method of forming the composition. The method includes the steps of providing the base oil, providing the antioxidant of this disclosure and combining the base oil and the antioxidant. The method may also include one or more steps of providing any one or more of the aforementioned additives and combining the one or more aforementioned additives with the base oil and/or antioxidant of this disclosure in any order and in any amounts.

#### Antioxidant Independent from Composition:

**[0071]** This disclosure also provides the antioxidant itself independent from any lubricant composition. The antioxidant may be any as described herein.

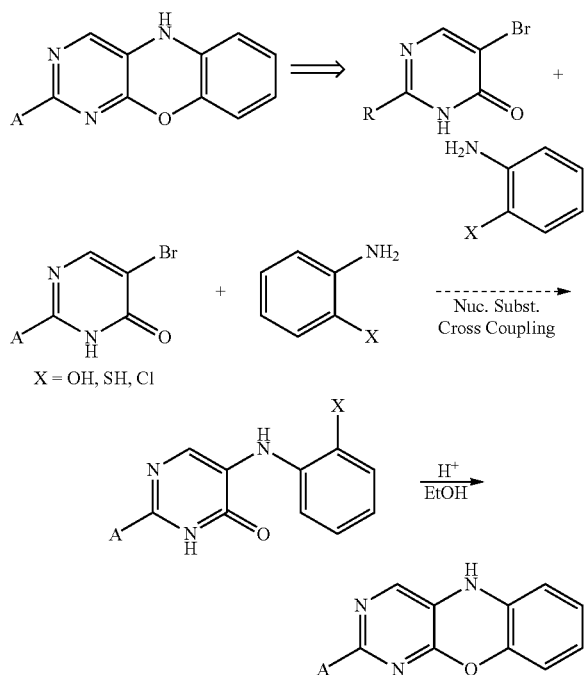
#### Method of Making the Antioxidant:

**[0072]** This disclosure also provides a method of making the antioxidant. In various embodiments, the method includes the steps of providing an N<sup>2</sup>, N<sup>2</sup>-dialkyl-N<sup>5</sup>-phenyl-2,5-pyrimidinediamine, providing elemental sulfur, providing sulfur dioxide, providing iodine, and providing a solvent. The method may also include the step of combining the pyrimidinediamine, sulfur, sulfur dioxide, and iodine in the solvent such as sulfolane, to form the antioxidant.

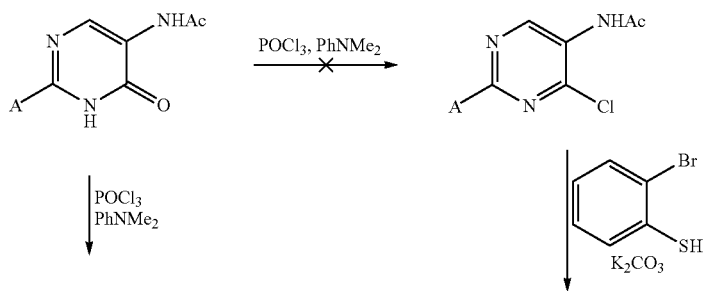
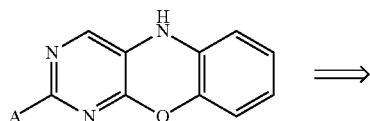
**[0073]** In other embodiments, the method may include one or more steps as outlined below. One of skill in the art may change the starting materials as needed. For example, any suitable second amine may be utilized in place of the bis-2-ethylhexylamine. In still other embodiments, the method includes one or more steps as described in U.S. Pat. No. 5,026,846, which is expressly incorporated herein in its entirety in various non-limiting embodiments. For example, one of skill in the art may select one or more synthetic steps from U.S. Pat. No. 5,026,846 to form the antioxidant of the instant disclosure.

**[0074]** In various embodiments, the pyrimidinediamine has an alkyl group. The alkyl group may be linear, branched, or cyclic and typically includes 1 to 20 carbon atoms. The alkyl group may include more than 20 carbon atoms. In various embodiments, the alkyl group includes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 carbon atoms or any range thereof. The alkyl group may be further defined as an alkane, an alkene, or an alkyne. The alkyl group may be alternatively described using the formula C<sub>n</sub>H<sub>2n+1</sub> wherein n is 1 to 20, as described above. In various embodiments, the alkyl group may be described as methyl, ethyl propyl, butyl, t-butyl, pentyl, hexyl, octyl, nonyl, or any isomer thereof.

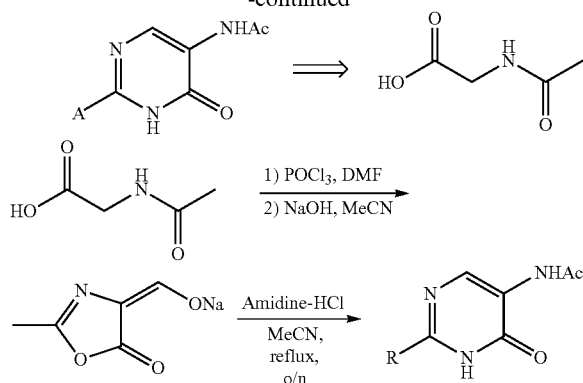
**[0075]** In various embodiments, the antioxidant is synthesized using nucleophilic substitution (e.g. of 5-Halopyrimidones) and dehydration. For example, a synthetic scheme such as the one set forth below may be utilized:



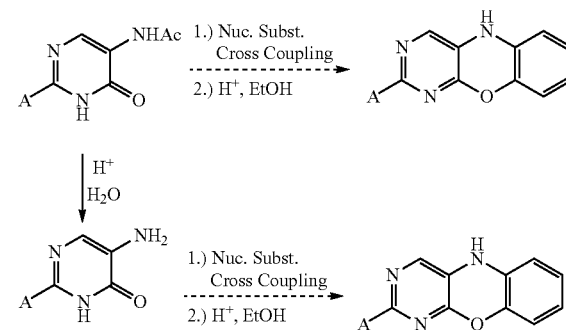
**[0076]** In other embodiments, the antioxidant is synthesized using cross-coupling and substitution, e.g., of 5-aminopyrimidones. For example, a synthetic scheme such as the one set forth below may be utilized:



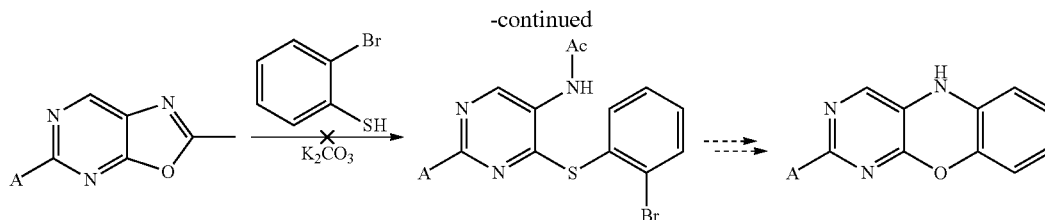
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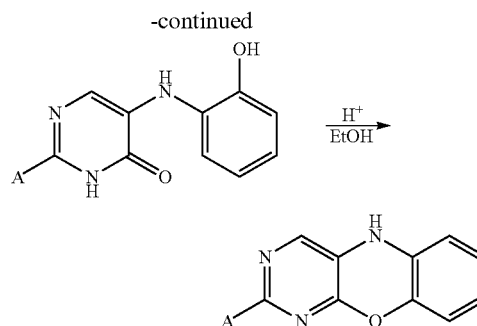
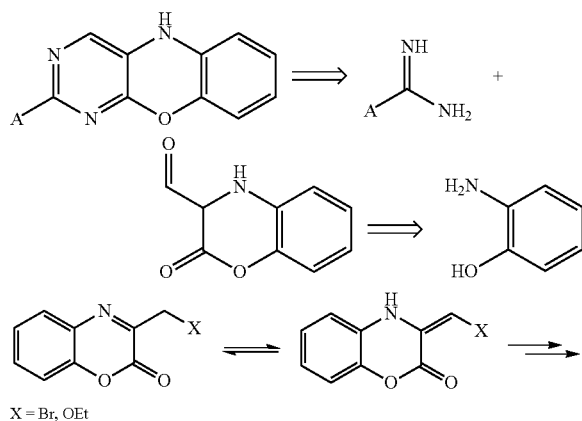
**[0077]** It is contemplated that protected 5-amino-4-pyrimidones can be prepared in two steps from commercially available N-acetyl glycine. Cross coupling or substitution with this intermediate can yield azaphenoxazines in a few as three steps.



**[0078]** It is contemplated that 5-amino-4-pyrimidones may be unreactive under general conditions for Cu, Pd, or Ni, cross coupling reactions, such as those set forth below. However, alternative similar reactions may be utilized. The reactions set forth immediately below are simply representative of some types of reactions that might be used to form the antioxidants of this disclosure, as modified by those of skill in the art.

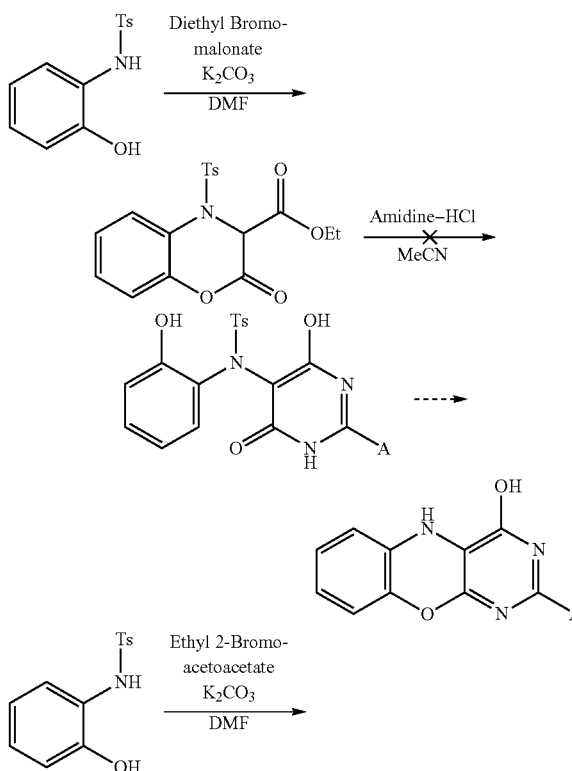
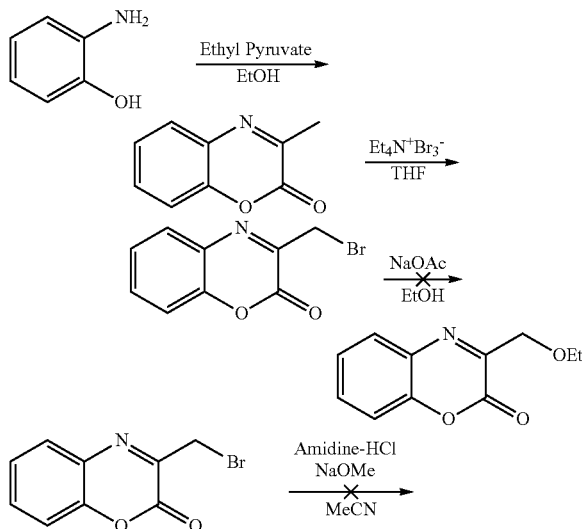


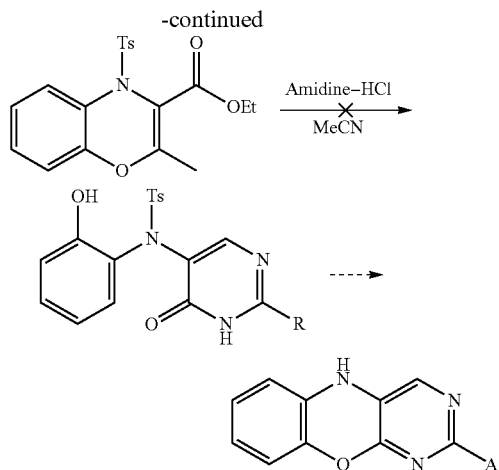
**[0079]** In other embodiments, the antioxidant is synthesized using direct condensation, e.g. on substituted 3-dicarbonyl compounds. For example, a synthetic scheme such as the one set forth below may be utilized:



**[0081]** In addition, direct reaction on 3-bromomethyl-1,4-benzoxazinone may yield a complex mixture of products. Attempts to replace the halide with a less reactive leaving group can lead to a rearrangement reaction. The reactions set forth immediately below are simply representative of some types of reactions that might be used to form the antioxidants of this disclosure, as modified by those of skill in the art.

**[0080]** For example, the tautomer of substituted 1,4-benzoxazinones may or may not provide an appropriate 1,3-dielectrophile for a condensation reaction. The reactions set forth immediately below are simply representative of some types of reactions that might be used to form the antioxidants of this disclosure, as modified by those of skill in the art.

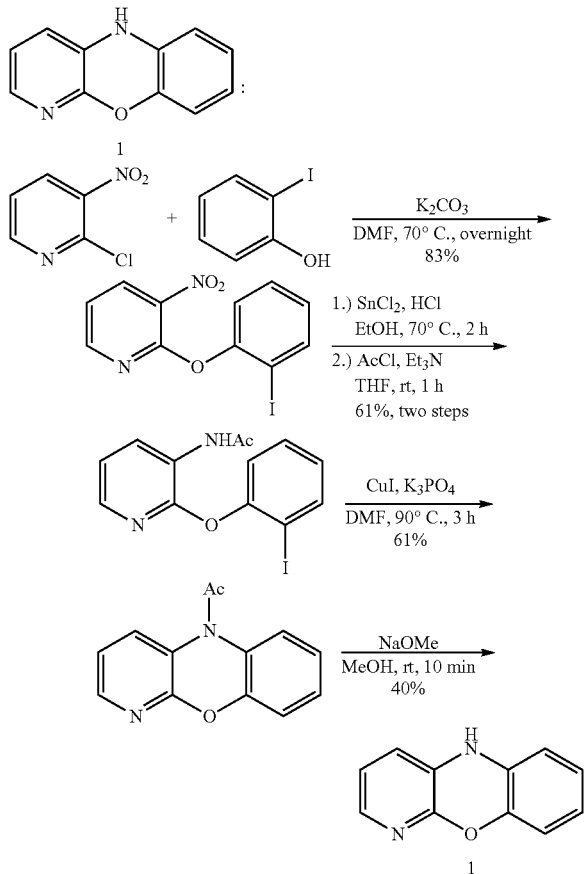




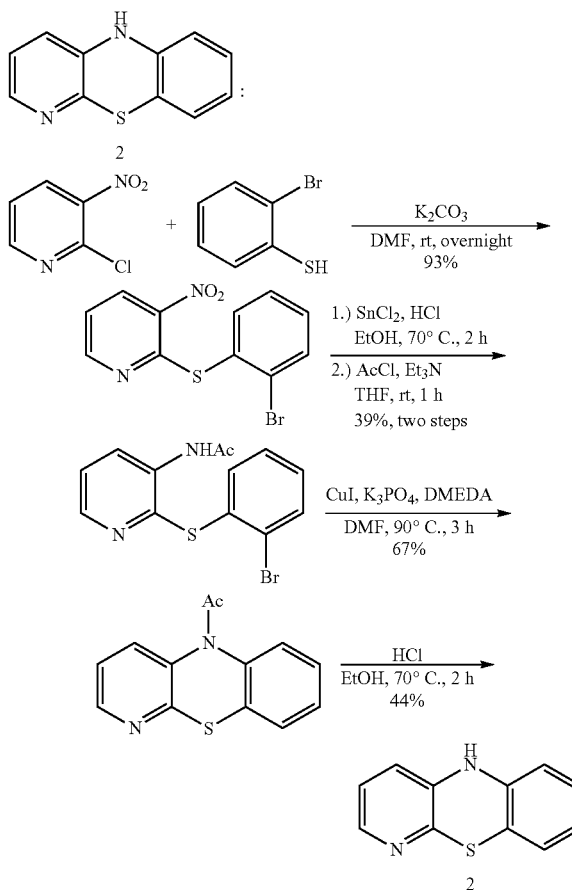
**[0082]** Moreover, substituted, protected 1,4-benzoxazinones can be prepared from N-tosyl 2-aminophenols.

**[0083]** In still other embodiments, the antioxidant is chosen from those set forth below and may be synthesized by one or more methods as set forth below.

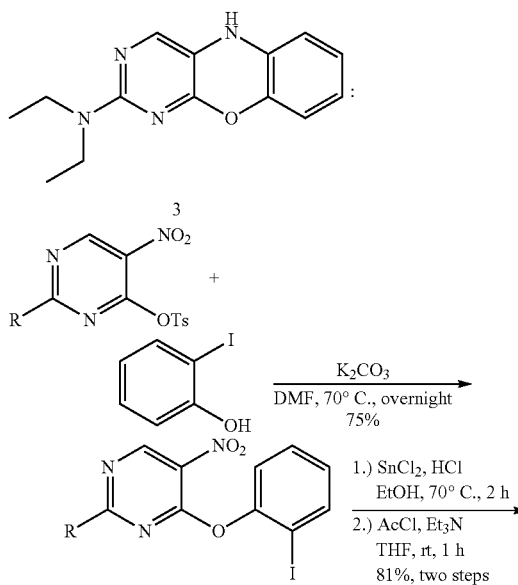
**[0084]** Synthesis of



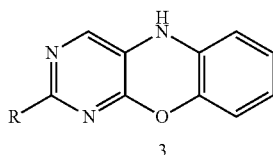
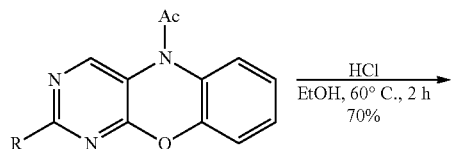
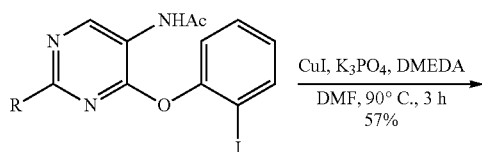
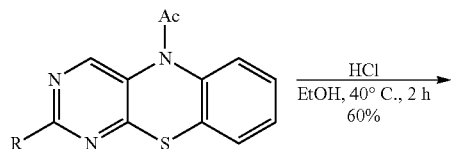
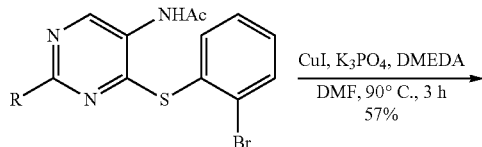
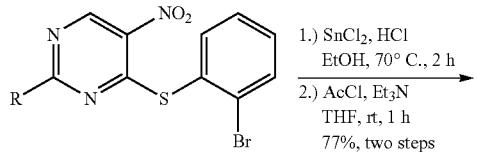
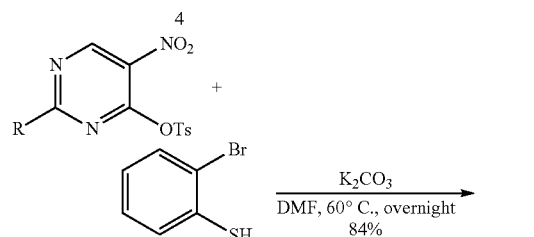
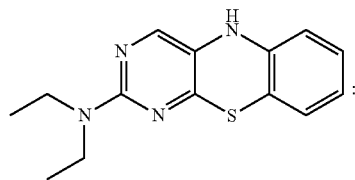
**[0085]** Synthesis of



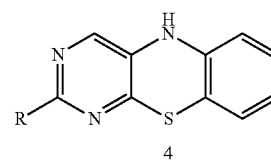
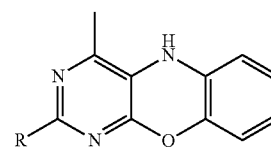
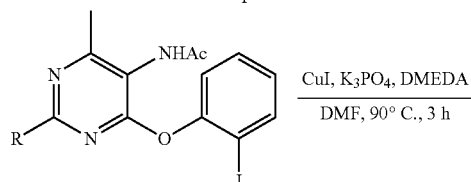
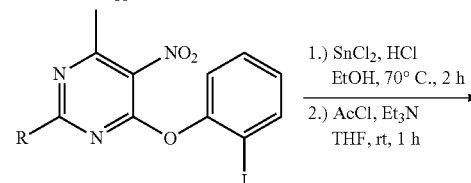
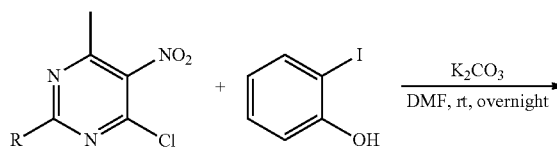
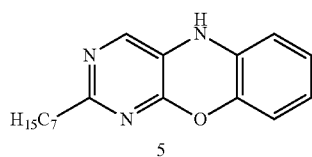
**[0086]** Synthesis of



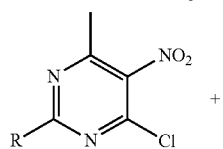
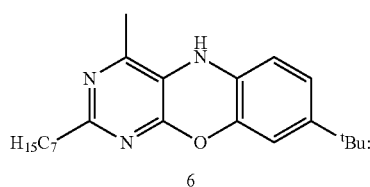
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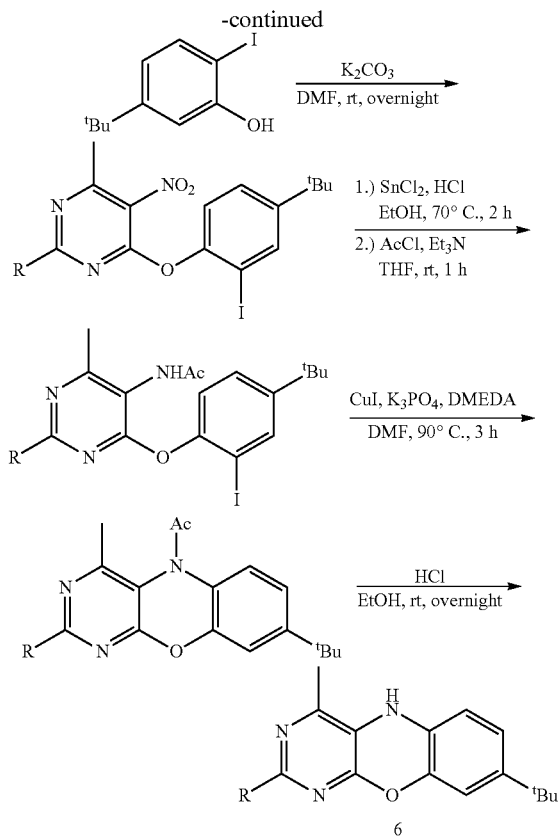
R = Et<sub>2</sub>N**[0087]** Synthesis of

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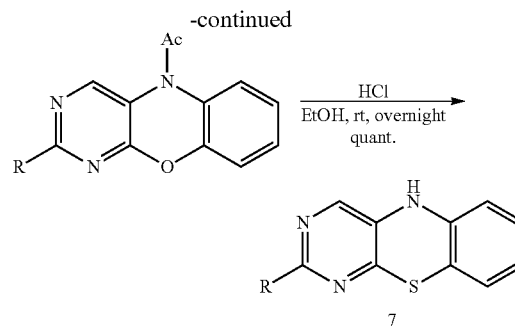
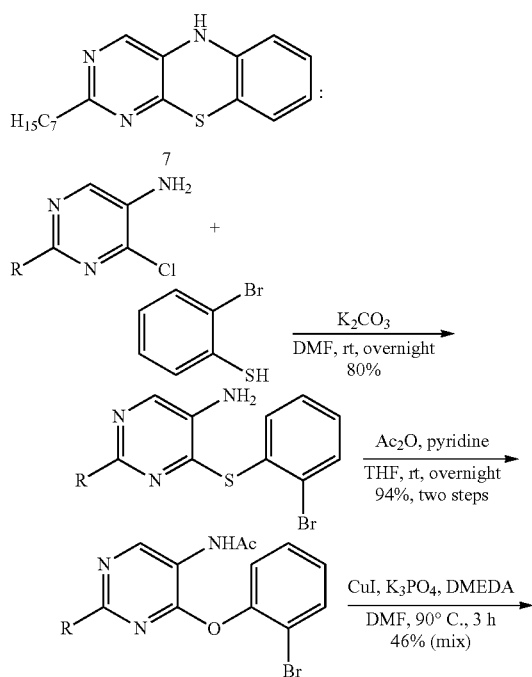
R = Et<sub>2</sub>N**[0088]** Synthesis of

R = n-Heptyl

**[0089]** Synthesis of



R = n-Heptyl

**[0090]** Synthesis of

R = n-Heptyl

**[0091]** In addition, these antioxidants can be characterized as follows in various non-limiting embodiments:

**[0092]** 4-Azaphenoxazine (1): <sup>1</sup>H-NMR (500 MHz; DMSO-d<sub>6</sub>): δ 8.47 (s, 1H), 7.36 (dd, J=4.8, 1.8 Hz, 1H), 6.78-6.72 (m, 3H), 6.68 (dd, J=7.9, 1.4 Hz, 1H), 6.61 (td, J=7.7, 1.4 Hz, 1H), 6.47 (dd, J=7.7, 1.4 Hz, 1H). <sup>13</sup>C NMR (126 MHz; DMSO): δ 150.8, 143.2, 137.6, 131.7, 128.6, 124.9, 121.33, 121.17, 119.8, 116.0, 113.7

**[0093]** 4-Azaphenothiazine (2): <sup>1</sup>H-NMR (400 MHz; DMSO-d<sub>6</sub>): δ 8.61 (s, 1H), 7.75 (dd, J=4.7, 1.5 Hz, 1H), 6.99-6.91 (m, 2H), 6.88 (dd, J=7.7, 1.4 Hz, 1H), 6.83 (dd, J=8.0, 1.5 Hz, 1H), 6.74 (td, J=7.5, 1.3 Hz, 1H), 6.62 (dd, J=7.9, 1.1 Hz, 1H). <sup>13</sup>C NMR (76 MHz; DMSO): δ 141.5, 140.2, 139.7, 137.5, 127.6, 126.3, 122.5, 121.8, 119.4, 116.2, 114.3

**[0094]** 3-Diethylamino-2,4-Diazaphenoxazine (3): <sup>1</sup>H-NMR (500 MHz; DMSO-d<sub>6</sub>): δ 8.01 (s, 1H), 7.47 (s, 1H), 6.80-6.74 (m, 2H), 6.56 (td, J=7.7, 1.3 Hz, 1H), 6.47 (dd, J=7.8, 1.3 Hz, 1H), 3.43 (q, J=7.0 Hz, 4H), 1.06 (t, J=7.0 Hz, 6H). <sup>13</sup>C NMR (126 MHz; DMSO): δ 158.0, 156.3, 141.7, 140.8, 132.6, 125.5, 119.9, 116.4, 115.8, 114.0, 41.7, 13.6

**[0095]** 3-Diethylamino-2,4-Diazaphenothiazine (4): <sup>1</sup>H-NMR (500 MHz; DMSO-d<sub>6</sub>): δ 8.21 (s, 1H), 7.54 (s, 1H), 6.95 (td, J=7.6, 1.4 Hz, 1H), 6.86 (dd, J=7.7, 1.3 Hz, 1H), 6.67 (td, J=7.5, 1.2 Hz, 1H), 6.58 (dd, J=8.0, 1.2 Hz, 1H), 3.44 (q, J=7.0 Hz, 4H), 1.05 (t, J=7.0 Hz, 6H). <sup>13</sup>C NMR (126 MHz; DMSO): δ 156.8, 152.6, 141.17, 140.99, 128.5, 127.0, 125.7, 121.2, 114.8, 114.5, 41.7, 13.5

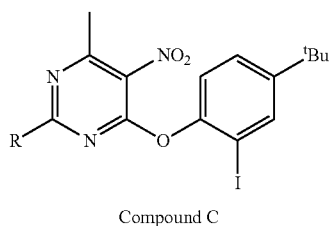
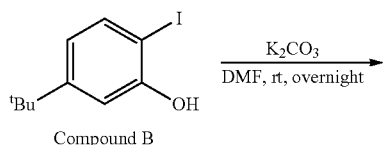
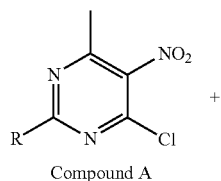
**[0096]** 3-Heptyl-2,4-Diazaphenoxazine (5): <sup>1</sup>H-NMR (400 MHz; DMSO-d<sub>6</sub>): δ 7.84 (s, 1H), 6.83-6.79 (m, 1H), 6.69 (td, J=8.1, 1.5 Hz, 2H), 6.63 (ddd, J=7.8, 7.4, 1.6 Hz, 1H), 2.50-2.47 (m, 2H), 2.18 (s, 3H), 1.60 (quintet, J=7.3 Hz, 2H), 1.26 (t, J=4.6 Hz, 8H), 0.86 (t, J=6.7 Hz, 3H). <sup>13</sup>C-NMR (76 MHz; DMSO): δ 161.0, 156.6, 147.9, 142.5, 132.0, 125.5, 121.6, 121.3, 116.3, 114.9, 37.8, 31.6, 29.06, 28.96, 28.3, 22.5, 19.5, 14.4 HRMS: Calc for C<sub>18</sub>H<sub>23</sub>N<sub>3</sub>O, 297.18411; Found: 297.18398

**[0097]** 7-tert-Butyl-3-Heptyl-1-Methyl-2,4-Diazaphenoxazine (6): <sup>1</sup>H-NMR (300 MHz; DMSO-d<sub>6</sub>): δ 7.76 (s, 1H), 6.82 (dd, J=8.2, 2.1 Hz, 1H), 6.72 (d, J=2.1 Hz, 1H), 6.60 (d, J=8.2 Hz, 1H), 2.49-2.46 (m, 2H), 2.16 (s, 3H), 1.59 (t, J=7.8 Hz, 2H), 1.25 (s, 8H), 1.19 (s, 9H), 0.85 (t, J=6.7 Hz, 3H). <sup>13</sup>C NMR (76 MHz; DMSO): δ 160.8, 156.6, 147.8, 144.3, 142.1, 129.3, 121.81, 121.70, 114.4, 113.5, 37.8, 34.2, 31.6, 31.4, 29.04, 28.97, 28.3, 22.5, 19.5, 14.4

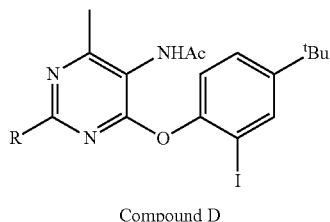
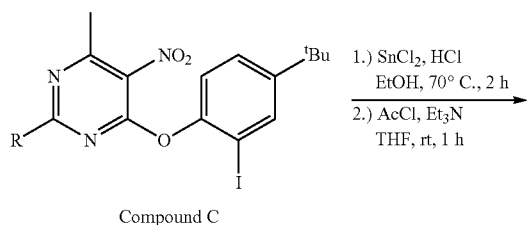
**[0098]** 3-Heptyl-2,4-Diazaphenothiazine (7): <sup>1</sup>H-NMR (300 MHz; DMSO-d<sub>6</sub>): δ 8.64 (s, 1H), 7.65 (s, 1H), 7.00-6.94 (m, 1H), 6.87 (dd, J=7.7, 1.4 Hz, 1H), 6.74 (dd, J=7.5,

1.2 Hz, 1H), 6.58 (dd, J=8.0, 1.2 Hz, 1H), 2.56 (t, J=7.6 Hz, 2H), 1.60 (m, 2H), 1.24 (m, 8H), 0.85 (t, J=6.7 Hz, 3H).  
 13-C NMR (76 MHz; DMSO):  $\delta$  163.1, 151.4, 139.7, 138.7, 133.7, 128.8, 127.2, 122.5, 115.3, 114.9, 37.7, 31.6, 28.97, 28.91, 28.3, 22.5, 14.4

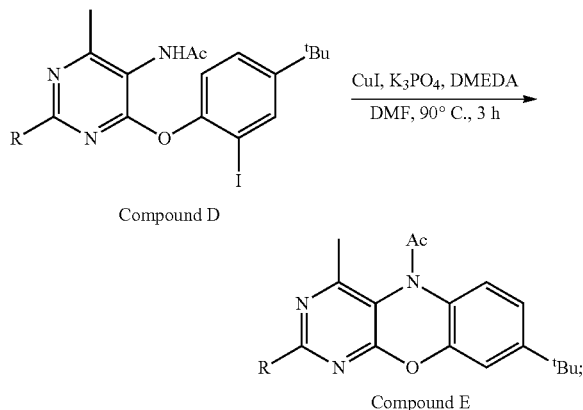
**[0099]** In other embodiments, the antioxidant is synthesized as described using a method including the steps of:  
 I. reacting Compound A and Compound B to form Compound C according to the following reaction:



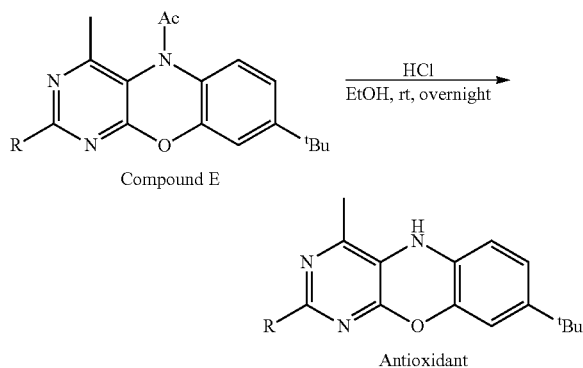
II. reacting Compound C to form Compound D according to the following reaction:



III. reacting Compound D to form Compound E according to the following reaction:



IV. reacting Compound E to form the antioxidant according to the following reaction:



wherein R is an n-heptyl group. In related non-limiting embodiments, it is expressly contemplated that any one or more reactants, intermediates, solvents, catalysts, additives, salts, temperatures, times of reaction, and/or any other method steps described above, or known by those of skill in the art as being related to the above, may be substituted, altered or otherwise modified using any other suitable reactants, intermediates, solvents, catalysts, additives, salts, temperatures, times of reaction, and/or any other method steps suitable to form the antioxidant described above. In other words, all derivations of the aforementioned reactions that would be known by those of skill in the art as being suitable substitutes or alternatives for producing the same reactants, compounds, or the final antioxidants, e.g. using similar reactants, catalysts, times, solvents, temperatures, etc., are hereby expressly contemplated in various non-limiting embodiments.

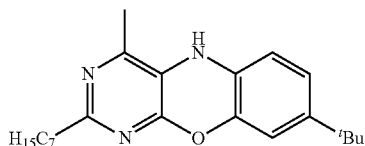
**[0100]** In various non-limiting embodiments, one or more of the antioxidants of the instant disclosure may be utilized in combination with one or more antioxidants described in provisional application Ser. No. 62/213,245, provisional application Ser. No. 62/213,241, provisional application Ser. No. 62/213,239, provisional application Ser. No. 62/347,907, a PCT application filed concurrently herewith having the BASF Docket Number: PF76496WO01, and/or a PCT application filed concurrently herewith having the BASF



Docket Number: PF76497WO01, each of which is expressly incorporated herein by reference in its entirety in various non-limiting embodiments.

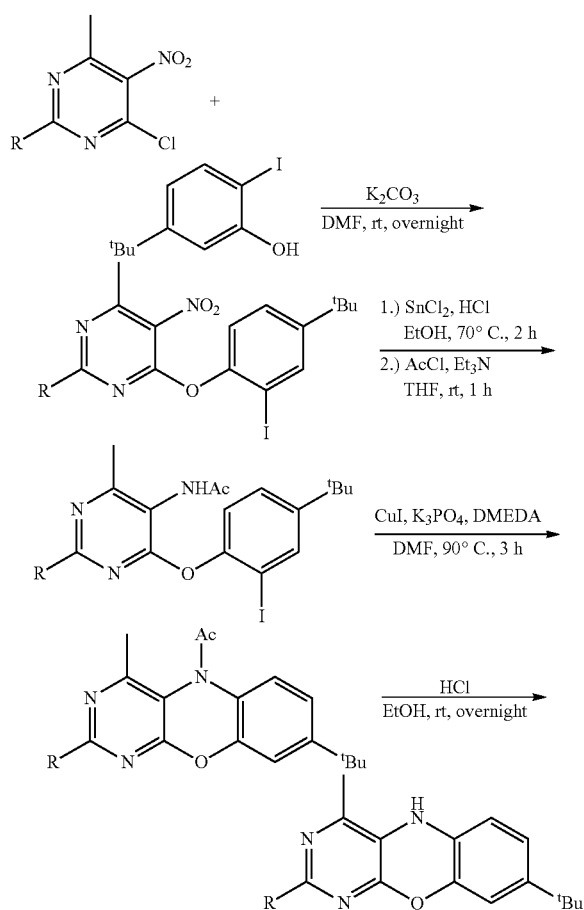
### EXAMPLES

**[0101]** An example of the antioxidant of this disclosure is formed as set forth in the reaction schematic below.



Example

**[0102]**



R = n-Heptyl

### Additional Examples

**[0103]** Various antioxidants are evaluated to determine how they affect oxidation of various compounds. For example, in a first series of experiments, Styrene/PBD-

BODIPY Autoxidation is evaluated at 37° C. The results of this evaluation is set forth in FIG. 1 which shows co-oxidation of 4.3 M styrene and 10 μM PBD-BODIPY in PhCl at 37° C., initiated by 6.0 mM AIBN and inhibited by 2 μM of the antioxidants shown ( $k_{inh} \gg 10^7$ ). Under these conditions, the antioxidant that is representative of this disclosure completely suppresses autoxidation of the PBD-BODIPY exhibiting inhibition rate constants,  $k_{inh}$ , above the measurable limit of the autoxidation experiments ( $k_{inh} \gg 10^7 \text{ M}^{-1} \text{ s}^{-1}$ ).

**[0104]** In a second series of experiments, Hexadecene/PBD-BODIPY autoxidation is evaluated at 70° C. and 100° C. The results of these evaluations are set forth in FIGS. 2A and 2B which show co-autoxidation of 2.8M n-Hexadecene and 10 M PBD-BODIPY in PhCl at 70° C., initiated by 87 mM  $t\text{Bu}_2\text{O}_2$ , and inhibited by 0.6 μM of the various antioxidants shown.

**[0105]** In a third series of experiments, Squalane/PBD-BODIPY autoxidation is evaluated at 100° C. The results of this evaluation is set forth in FIG. 3 which shows co-oxidation of 0.96M squalane and 10 M PBD-BODIPY in 1,2-dichlorobenzene at 100° C., initiated by 500 M dicumyl peroxide, and inhibited by 4 μM of the antioxidants shown. In a fourth series of experiments, Hexadecane autoxidation is evaluated at 160° C. Hydroperoxide formation in n-hexadecane at 160° C. is set forth in FIG. 4 showing uninhibited autoxidation and inhibited autoxidation with 100 μM of the antioxidants shown.

**[0106]** In a fifth series of experiments, hydroperoxide formation in n-hexadecane at 160° C. is evaluated and set forth in FIG. 5 which shows uninhibited and inhibited autoxidation with 100 μM of the antioxidants shown.

**[0107]** The data described above and set forth in the Figures demonstrates the enhanced antioxidant performance of the molecules of this disclosure compared to traditional alkylated diphenylamine antioxidants.

**[0108]** All combinations of the aforementioned embodiments throughout the entire disclosure are hereby expressly contemplated in one or more non-limiting embodiments even if such a disclosure is not described verbatim in a single paragraph or section above. In other words, an expressly contemplated embodiment may include any one or more elements described above selected and combined from any portion of the disclosure.

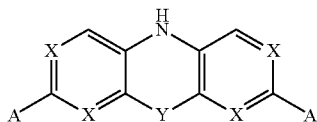
**[0109]** One or more of the values described above may vary by ±5%, ±10%, ±15%, ±20%, ±25%, etc. so long as the variance remains within the scope of the disclosure. Unexpected results may be obtained from each member of a Markush group independent from all other members. Each member may be relied upon individually and or in combination and provides adequate support for specific embodiments within the scope of the appended claims. The subject matter of all combinations of independent and dependent claims, both singly and multiply dependent, is herein expressly contemplated. The disclosure is illustrative including words of description rather than of limitation. Many modifications and variations of the present disclosure are possible in light of the above teachings, and the disclosure may be practiced otherwise than as specifically described herein.

**[0110]** It is also to be understood that any ranges and subranges relied upon in describing various embodiments of the present disclosure 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 disclosure, and such ranges and subranges may be further delineated into relevant halves, thirds, quarters, fifths, and so on. As just one example, a range “of 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. 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 of from at least 10 to 35, a subrange of from at least 10 to 25, a subrange of 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 “of 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.

**1.** A lubricant composition comprising:

- a base oil present in an amount of greater than 70 parts by weight per 100 parts by weight of said lubricant composition; and
- an antioxidant having the structure;



wherein each X is independently CH or N, so long as at least one X is N;

wherein Y is CRR', NR'', PR''', S, or O;

wherein each R, R' and R'' is independently H, alkyl or aryl, and R''' is alkyl, aryl, alkoxy or aryloxy; and wherein each A is independently an electron donating group that:

- (1) has an atom having at least one lone pair of electrons that is bonded directly to the aromatic ring;
- (2) is an aryl or alkyl group; or
- (3) is a hydrogen atom.

**2.** The lubricant composition of claim 1 wherein each A is an electron donating group that has an oxygen atom or nitrogen atom that is bonded directly to the aromatic ring.

**3.** The lubricant composition of claim 1 wherein each of said electron donating groups is chosen from —NR<sup>4</sup><sub>2</sub>, —NH<sub>2</sub>, —OH, —OR<sup>4</sup>, —NHCOR<sup>4</sup>, and —OCOR<sup>4</sup>, wherein R<sup>4</sup> is an alkyl group having 1 to 10 carbon atoms.

**4-9.** (canceled)

**10.** The lubricant composition of claim 1 wherein at least one of said electron donating groups is an alkyl group having 1 to 20 carbon atoms.

**11.** The lubricant composition of claim 1 wherein at least one of said electron donating groups is an aryl group.

**12.** The lubricant composition of claim 1 wherein at least one of said electron donating groups is a hydrogen atom.

**13.** The lubricant composition of claim 1 wherein each X is N.

**14.** The lubricant composition of claim 1 wherein at least two of X are N.

**15.** The lubricant composition of claim 1 wherein at least three of X are N.

**16.** The lubricant composition of claim 1 wherein Y is CRR' and each R and R' is independently H, alkyl or aryl.

**17.** The lubricant composition of claim 1 wherein Y is NR'' and R'' is H, alkyl or aryl.

**18.** The lubricant composition of claim 1 wherein Y is S.

**19.** The lubricant composition of claim 1 wherein Y is O.

**20.** The lubricant composition of claim 1 wherein Y is PR''' and R''' is alkyl, aryl, alkoxy or aryloxy.

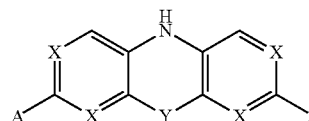
**21.** The lubricant composition of claim 1 wherein said antioxidant is present in an amount of from 0.1 to 2 parts by weight per 100 parts by weight of said lubricant composition.

**22.** The lubricant composition of claim 1 wherein said base oil is further defined as an API Group I, Group II or Group III oil.

**23.** (canceled)

**24.** A method of forming the lubricant composition of claim 1 comprising the steps of providing the base oil, providing the antioxidant, and combining the base oil and the antioxidant to form the lubricant composition.

**25.** An antioxidant having the structure:



wherein each X is independently CH or N, so long as at least one X is N;

wherein Y is CRR', NR'', PR''', S, or O;

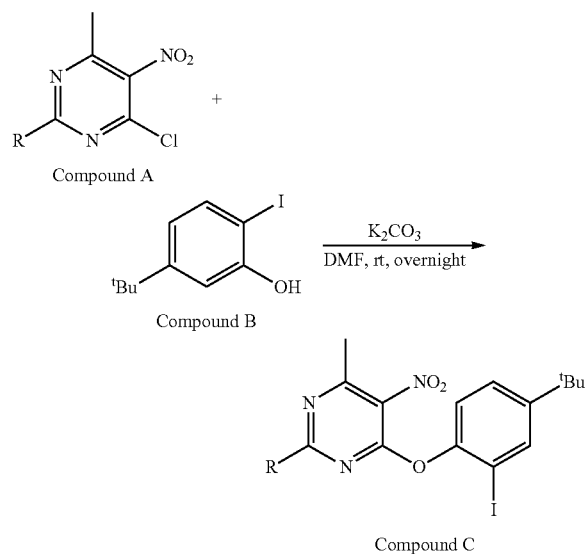
wherein each R, R' and R'' is independently H, alkyl or aryl, and R''' is alkyl, aryl, alkoxy or aryloxy; and

wherein each A is independently an electron donating group that:

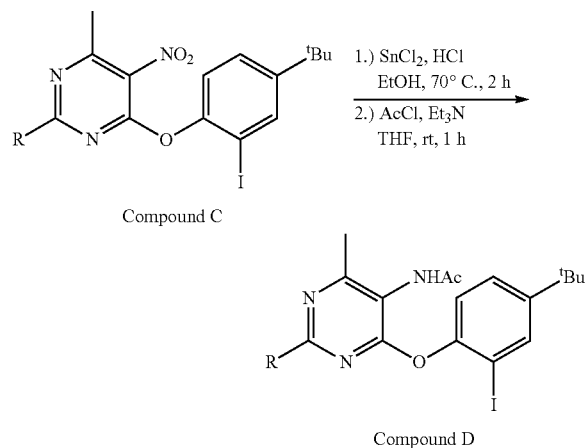
- (1) has an atom having at least one lone pair of electrons that is bonded directly to the aromatic ring;
- (2) is an aryl or alkyl group; or
- (3) is a hydrogen atom.

26. A method of forming the antioxidant of claim 25 comprising the following steps:

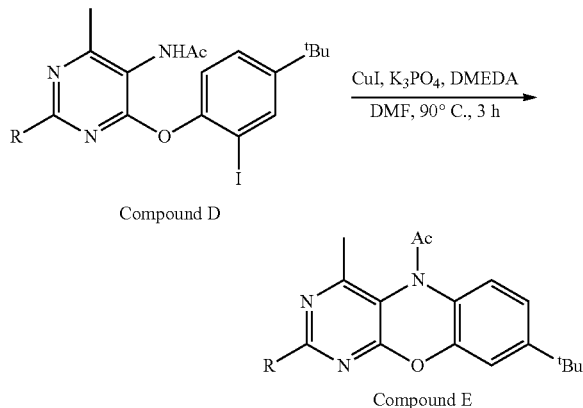
I. reacting Compound A and Compound B to form Compound C according to the following reaction:



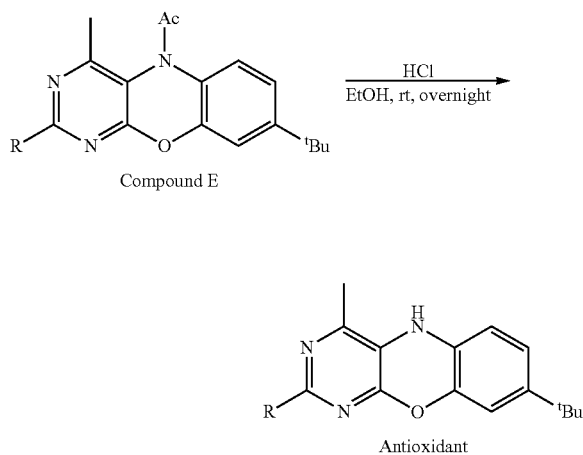
II. reacting Compound C to form Compound D according to the following reaction:



III. reacting Compound D to form Compound E according to the following reaction: and



IV. reacting Compound E to form the antioxidant according to the following reaction:



wherein R is an n-heptyl group.

27. An additive concentrate package comprising said antioxidant of claim 25 and one or more metal deactivators, one or more anti-wear additives, and/or one or more additional antioxidants.

\* \* \* \* \*