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(54) Title: HYDRAULIC OIL COMPOSITIONS WITH IMPROVED HYDROLYTIC AND THERMO-OXIDATIVE STABILITY

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<p>| Table 4: Formulation and characteristics of exemplary Examples and Comparative Examples |
|---------------------------------|------------------|------------------------|</p>
<table>
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<th>Formulations</th>
<th>Comparative Examples (C.E.)</th>
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<tr>
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<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Anionic surfactant</td>
<td>ZDDP 1</td>
<td>0.7</td>
</tr>
<tr>
<td>ZDDP 2</td>
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<td>0.3</td>
</tr>
<tr>
<td>Detergent</td>
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<td>...</td>
</tr>
<tr>
<td>Alkaline earth metal sulfonates (TB: 100-400)</td>
<td>...</td>
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<tr>
<td>Alkaline earth metal phosphates (TB: 50-200)</td>
<td>...</td>
<td>...</td>
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<tr>
<td>Rust inhibitor 1</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Rust inhibitor 2</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Dispersant</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Metal Passivator</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Foaming agent</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Permeation</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Performance Tests</td>
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(57) Abstract: The present disclosure provides a lubricating composition that includes at least one lubricating base oil, an effective amount of at least one overbased detergent, and an effective amount of at least one thermally stable zinc dialkyl dithiophosphate. The disclosure further provides methods of making and using the same.

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— with international search report (Art. 21(3))
HYDRAULIC OIL COMPOSITIONS WITH IMPROVED HYDROLYTIC AND THERMO-OXIDATIVE STABILITY

FIELD

[0001] The present disclosure relates to lubricating compositions and methods of using the same. In particular, the disclosure relates to a lubricating hydraulic composition and methods of lubricating a hydraulic pump and/or motor by using the same.

BACKGROUND

[0002] Hydraulic systems (pump, motor and ancillary systems) can be comprised of copper alloys which are susceptible to corrosion, which can inhibit system robustness. Maintaining lubricant and system compatibility enhances the equipment life and productivity.

[0003] Current lubricating compositions suitable for hydraulic systems, for example, circulating oil, or other industrial oils, however, employ a metal containing antiwear agent, such as a zinc containing antiwear agent, which decomposes to form deposits such as resins, sludge, and varnish in the hydraulic system. In particular, the hydraulic oil market is dominated by lubricating oils formulated with zinc dialkyl dithiophosphate (ZDDP) additive chemistries as the main additive.

[0004] The use of zinc containing antiwear agents result in the deterioration of the lubricating oils properties (e.g., oxidation), yellow metal corrosion, and poor oil life. For example, ZDDP containing fluids have poor performance when compared to non-ZDDP type oils with shorter drain intervals, poorer viscosity control, and varnish and sludge tendencies. The lack of viscosity control can also lead to poor energy efficiency in a hydraulic system over time due to an increase in oil viscosity from oxidation. The deposits further impair the performance of the hydraulic systems by causing valve sticking and unresponsive control.

[0005] The cleaning of these systems is also difficult because the deposits are difficult to remove without mechanical abrasion. Oxidized oils can also be comprised of acid species that have the potential to contribute to hydraulic system corrosion, rust and material compatibility issues.

[0006] Despite the significant issues that result from the use of ZDDP, ZDDP has continued to be used as an antiwear additive and/or oil stability additive because it is a cost effective additive chemistry with acceptable antiwear and stability properties. However, owner/operators and OEMs are starting to look toward the preservation of equipment health, minimize downtime,
and improve productivity, thereby challenging the current ZDDP based formulations to be improved.

[0007] Therefore, a need exists for a lubricating composition, such as a hydraulic oil or hydraulic fluid, with improved hydrolytic stability and thermo-oxidative stability, and that provides additional benefits, for example, one or more of reduced metal corrosion (e.g., reduced copper or yellow metal corrosion), reduced deposit formation, reduced rust formation, and reduced wear, thereby resulting in a longer life, extended oil drain intervals, reduced operational costs, and reduced environmental footprint.

SUMMARY

[0008] The present disclosure provides lubricating compositions, such as hydraulic oil compositions, that have the surprising and unexpected ability to reduce yellow metal corrosion, while having good lubricating properties, such as viscosity control and significant reductions in (e.g., little to no) deposits, rust, corrosion, and/or wear on the lubricated system. Therefore, an aspect of the present disclosure includes a hydraulic oil composition comprising: at least one lubricating base oil; an effective amount of an overbased detergent; and an effective amount of a thermally stable zinc dialkyl dithiophosphate (ZDDP).

[0009] In some embodiments the hydraulic oil composition comprises at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.% (e.g., from about 0.001 wt.% to about 1.5 wt.% or from about 0.01 wt.% to about 0.75 wt.%); (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.% (e.g. from about 0.05 wt.% to about 2 wt.% or from about 0.1 wt.% to about 1 wt.%); or (iii) a combination thereof.

[0010] In certain embodiments the hydraulic oil composition, at least one of: (i) the overbased detergent includes at least one of calcium, magnesium, sodium, barium, or a combination thereof; (ii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; or (iii) a combination thereof

[0011] In another embodiment, the overbased detergent includes at least one of overbased sulfurized calcium phenate detergent, overbased magnesium sulfonate detergent, overbased calcium phenate detergent, overbased calcium sulfonate detergent, or a combination thereof.

[0012] In other embodiments, the thermally stable ZDDP includes at least one of a primary ZDDP, a branched primary ZDDP, or a combination thereof.

[0013] In particular embodiments, the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil (e.g., at least one of Group II light neutral oil, Group II heavy neutral oil, or a
combination thereof), a Group III oil (e.g. a gas-to-liquid oil), a Group IV oil (e.g. a polyalphaolefin),
a Group V oil, or combinations thereof.

[0014] In an embodiment, the lubricating base oil or oils include at least one Group II oil.

[0015] In yet other embodiments, the composition further comprises at least one of a dispersant,
an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-
seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator,
an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier,
a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-
staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation
inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof.

[0016] In certain embodiments, the dispersant includes succinimide-type dispersant.

[0017] In any aspect or embodiments described herein, the hydraulic oil composition results in
improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion
(such as, yellow metal corrosion) in a hydraulic motor relative to a hydraulic oil composition that does
not include the effective amount of a overbased detergent and/or the effective amount of a thermally
stable ZDDP.

[0018] Another aspect of the present disclosure provides a method of making a hydraulic oil
composition with at least one of improved hydrolytic stability, improved thermo-oxidative stability,
decreased metal corrosion (such as, yellow metal corrosion), or a combination thereof. The method
comprises mixing: at least one lubricating base oil; an overbased detergent in an amount no greater
than about 3 wt.%; and a thermally stable ZDDP in an amount from about 0.01 wt.% to about 3 wt.%. 

[0019] In some embodiments, at least one of: (i) the overbased detergent is present <from about
0.001 wt.% to about 1.5 wt.%; (ii) the thermally stable ZDDP is present in an amount from about 0.05
wt.% to about 2 wt.%; or (iii) a combination thereof.

[0020] In certain other embodiments, at least one of: (i) the thermally stable ZDDP is a primary
thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium;
(iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an
overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least
one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil,
a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a
dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent,
an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator,
an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

[0021] A further aspect of the disclosure provides a hydraulic oil composition produced according to the method(s) of the present disclosure.

[0022] An additional aspect of the disclosure provides a method for lubricating a hydraulic pump and/or motor requiring a hydraulic oil composition. The method comprises: supplying the hydraulic pump and/or motor with a hydraulic oil composition of the present disclosure, such as a hydraulic oil composition comprising: at least one lubricating base oil; an effective amount of an overbased detergent; and an effective amount of a thermally stable ZDDP.

[0023] In further embodiments, at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or (iii) a combination thereof.

[0024] In certain embodiments, at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

[0025] In additional embodiments, the lubricating base oil or oils are Group II oil.

[0026] In some embodiments, the method results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in the
hydraulic motor relative to a method using a hydraulic oil composition that does not include the
effective amount of the overbased detergent and/or the thermally stable ZDDP.

[0027] Where applicable or not specifically disclaimed, any one of the embodiments
described herein are contemplated to be able to combine with any other one or more
embodiments or aspects, even though the embodiments are described under different aspects of
the disclosure. These and other embodiments are disclosed or are understood to be encompassed
by, the following Detailed Description, including the Drawings and Examples herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The accompanying drawing, which is incorporated into and form a part of the
specification, illustrate several embodiments of the present disclosure and, together with the
description, serve to explain the principles of the disclosure. The drawings are only for the
purpose of illustrating an embodiment of the disclosure and are not to be construed as limiting
the disclosure. Further objects, features and advantages of the disclosure will become apparent
from the following detailed description taken in conjunction with the accompanying figure
showing illustrative embodiments of the disclosure, in which:

[0029] Fig. 1 is Table 4: Formulation and characteristics of Exemplary Examples and
Comparative Examples.

DETAILED DESCRIPTION

[0030] The present disclosure relates, in part, to the surprising and unexpected discovery that
the lubricating compositions of the present disclosure (e.g., a hydraulic oil composition)
significantly reduced or effectively eliminated corrosion, rust, and deposit formation, while
providing exceptional lubrication (i.e., viscosity control and a significant reduction or effective
elimination of wear on the lubricated system).

[0031] The following is a detailed description provided to aid those skilled in the art in
practicing the present disclosure. Those of ordinary skill in the art may make modifications and
variations in the embodiments described herein without departing from the spirit or scope of the
present disclosure. Unless otherwise defined, all technical and scientific terms used herein have
the same meaning as commonly understood by one of ordinary skill in the art to which this
disclosure belongs. The terminology used in the description of the disclosure herein is for
describing particular embodiments only and is not intended to be limiting of the disclosure. All
publications, patent applications, patents, figures and other references mentioned herein are
expressly incorporated by reference in their entirety.
It was surprising and unexpectedly discovered that a lubricating composition comprising an effective amount of overbased detergent and a thermally stable zinc dithiophosphate (ZDDP) reduced or effectively eliminated corrosion, rust, and deposit formation, while providing viscosity control and significantly reducing or effectively eliminating wear on the lubricated system. As such, an aspect of the present disclosure provides a lubricating composition comprising: at least one lubricating base oil; an effective amount of an overbased detergent; and an effective amount of a thermally stable zinc dialkyl dithiophosphate (ZDDP). It should be noted that the lubricating compositions of the present disclosure may be utilized in any application that would benefit from the advantages and benefits described herein, e.g., the lubricating composition may be utilized as or be included in an industrial fluid, hydraulic fluid, turbine oil, or circulating oil.

The following terms may have meanings ascribed to them below, unless specified otherwise. However, it should be understood that other meanings that are known or understood by those having ordinary skill in the art are also possible, and within the scope of the present disclosure. In the case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

The articles "a", "an", and "the" as used herein and in the appended claims are used herein to refer to one or to more than one (i.e., to at least one) of the grammatical object of the article unless the context clearly indicates otherwise. By way of example, "an element" means one element or more than one element.

The phrase "and/or," as used herein in the specification and in the claims, should be understood to mean "either or both" of the elements so conjoined, i.e., elements that are conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with "and/or" should be construed in the same fashion, i.e., "one or more" of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the "and/or" clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to "A and/or B", when used in conjunction with open-ended language such as "comprising" can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.
As used herein in the specification and in the claims, "or" should be understood to have the same meaning as "and/or" as defined above. For example, when separating items in a list, "or" or "and/or" shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as "only one of" or "exactly one of," or, when used in the claims, "consisting of," will refer to the inclusion of exactly one element of a number or list of elements. In general, the term "or" as used herein shall only be interpreted as indicating exclusive alternatives (i.e., "one or the other but not both") when preceded by terms of exclusivity, such as "either," "one of," "only one of," or "exactly one of."

In the claims, as well as in the specification above, all transitional phrases such as "comprising," "including," "carrying," "having," "containing," "involving," "holding," "composed of," and the like are to be understood to be open-ended, i.e., to mean including but not limited to. Only the transitional phrases "consisting of" and "consisting essentially of" shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2111.03.

As used herein in the specification and in the claims, the phrase "at least one," in reference to a list of one or more elements, should be understood to mean at least one element selected from anyone or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows that elements may optionally be present other than the elements specifically identified within the list of elements to which the phrase "at least one" refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, "at least one of A and B" (or, equivalently, "at least one of A or B," or, equivalently "at least one of A and/or B") can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

It should also be understood that, in certain methods described herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited
to the order in which the steps or acts of the method are recited unless the context indicates otherwise.

[0040] Unless specifically stated or obvious from context, as used herein, the term "about" or "approximately" is understood as within a range of normal tolerance in the art, for example within 2 standard deviations of the mean. "About" can be understood as within 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.5%, 0.1%, 0.05%, or 0.01% of the stated value. Unless otherwise clear from context, all numerical values provided herein are modified by the term "about."

[0041] Any compositions or methods provided herein can be combined with one or more of any of the other compositions and methods provided herein.

[0042] Ranges provided herein are understood to be shorthand for all of the values within the range. For example, a range of 1 to 50 is understood to include any number, combination of numbers, or sub-range from the group consisting 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, or 50.

[0043] Reference will now be made in detail to exemplary embodiments of the disclosure. While the disclosure will be described in conjunction with the exemplary embodiments, it will be understood that it is not intended to limit the disclosure to those embodiments. To the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the disclosure as defined by the appended claims.

[0044] It should however be noted that the lubricating compositions of the present disclosure may be utilized as industrial fluids, hydraulic fluids, turbine oils, or circulating oils.

COMPOSITIONS OF THE PRESENT DISCLOSURE

[0045] An aspect of the present disclosure provides a lubricating composition (such a hydraulic oil composition). The composition comprises: at least one (e.g., 1, 2, 3, 4, 5, or more) lubricating base oil; an effective amount of at least one (e.g., 1, 2, 3, 4, 5, or more) overbased detergent; and an effective amount of at least one (e.g., 1, 2, 3, 4, 5, or more) thermally stable zinc dialkyl dithiophosphate (ZDDP). In any aspect or embodiments described herein, the lubricating composition of the present disclosure results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased or substantially eliminated metal corrosion (such as, yellow metal or copper corrosion) in a hydraulic motor relative to a hydraulic oil composition that does not include the effective amount of a overbased detergent and/or the effective amount of a
thermally stable ZDDP. In any aspect or embodiment described herein, the composition of the present disclosure include at least one GP II base stock (e.g., 1, 2, 3, 4, or more), and forms a ISO VG 22 -100 mono or multi-grade hydraulic lubricating oil.

In any aspect or embodiment described herein, at least one of: (i) the overbased detergent includes at least one of calcium, magnesium, sodium, barium, or a combination thereof; (ii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; or (iii) a combination thereof. For example, the overbased detergent can include be at least one of overbased sulfurized calcium phenate detergent, overbased magnesium sulfonate detergent, overbased calcium phenate detergent, overbased calcium sulfonate detergent, or a combination thereof.

Detergent protect lubricated metal surfaces against chemical attack by water or other contaminants. Any overbased detergent that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. In certain embodiments, the overbased detergent includes at least two (e.g., 2, 3, 4, or more) overbased detergents. As used herein, the term "overbased detergent" means a detergent having excess amounts of alkaline reserve (e.g., an excess reserve of an alkali metal or an alkaline earth metal).

Illustrative overbased detergents useful in this disclosure include, for example, overbased alkali metal detergents, overbased alkaline earth metal detergents, mixtures of one or more overbased alkali metal detergents, mixtures of one or more overbased alkaline earth metal detergents, or combinations thereof. In an embodiment, the detergent of the overbased detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the overbased detergent may be derived from an organic acid, such as a sulfur-containing acid, carboxylic acid (e.g., salicylic acid), phosphorus-containing acid, phenol, or mixtures thereof. The counterion utilized to overbase the detergent may be an alkaline earth metal or alkali metal.

In other embodiments, the overbased detergent is at least one of a metal salt of an organic or inorganic acid, a metal salt of a phenol, or combinations thereof. The metal may be at least one of an alkali metal, an alkaline earth metal, or a combination thereof. For example, the metal may be at least one of calcium (Ca), sodium (Na), magnesium (Mg), barium (Ba), or combinations thereof.

The organic or inorganic acid may be at least one of an aliphatic organic or inorganic acid, a cycloaliphatic organic or inorganic acid, an aromatic organic or inorganic acid, or combinations thereof. The organic acid or inorganic acid may be at least one of a sulfur-containing
acid, a carboxylic acid, a phosphorus-containing acid, or combinations thereof. In a particular embodiment, the metal salt of an organic or inorganic acid or the metal salt of a phenol comprises at least one of calcium phenate, calcium sulfonate, calcium salicylate, magnesium phenate, magnesium sulfonate, magnesium salicylate, or mixtures thereof.

[0051] Salts that contain a substantially stochiometric amount of the metal are described as neutral salts and have a total base number (TBN, as measured by ASTM D2896) of from 0 to 80. Overbased detergents comprise large amounts of a metal base that is achieved by reacting an excess of a metal compound (e.g., a metal hydroxide or oxide) with an acidic gas (e.g. carbon dioxide). The overbased detergent of the present disclosure may be mildly overbased or highly overbased. In any aspect or embodiment described herein, the overbased detergent is at least one of a mildly or highly overbased calcium salicylate, a mildly or highly calcium sulfonates, a mildly or highly calcium phenates, a mildly or highly magnesium salicylate, a mildly or highly magnesium sulfonates, a mildly or highly magnesium phenates, a mildly or highly barium sulfonates, a mildly or highly barium phenate, or a combination thereof.

[0052] The overbased detergent of the present disclosure may have TBN of about 100 to about 450 (e.g., about 150 to about 400, about 150 to about 350, or about 200 to about 350). For example, the TBN can be about 100 to about 450, about 100 to about 400, about 100 to about 350, about 100 to about 300, about 100 to about 250, about 100 to about 200, about 100 to about 150, about 150 to about 450, about 150 to about 400, about 150 to about 350, about 150 to about 300, about 150 to about 250, about 150 to about 200, about 200 to about 450, about 200 to about 400, about 200 to about 350, about 200 to about 300, about 200 to about 250, about 250 to about 450, about 250 to about 400, about 250 to about 350, about 250 to about 300, about 250 to about 450, about 300 to about 450, about 300 to about 400, about 350 to about 450, about 350 to about 400, or about 400 to about 450 in any aspect or embodiment described herein.

[0053] The overbased detergent may have a metal ratio of about 1 to about 30. For example, the overbased detergent can have a metal ratio of about 1 to about 25, about 1 to about 20, about 1 to about 15, about 1 to about 10, about 1 to about 5, about 5 to about 30, about 5 to about 25, about 5 to about 20, about 5 to about 15, about 5 to about 10, about 10 to about 30, about 10 to about 25, about 10 to about 20, about 10 to about 15, about 15 to about 30, about 15 to about 25, about 15 to about 20, about 20 to about 30, about 20 to about 25, or about 25 to about 30. The overbased detergent may have a metal ratio of about 1, about 2, about 3, about 4, about 5, about 6, about 7, about 8, about 9, about 10, about 11, about 12, about 13, about 14, about 15, about 16, about 17, about 18, about 19, about 20,
about 21, about 22, about 23, about 24, about 25, about 26, about 27, about 28, about 29, or about 30 in any aspect or embodiment described herein.

[0054] The overbased detergent may have a soap content of about 10 to about 45%. For example, the overbased detergent may have a soap content of about 10 to about 45%, about 10 to about 40%, about 10 to about 35%, about 10 to about 30%, about 10 to about 25%, about 10 to about 20%, about 10 to about 15%, about 15 to about 45%, about 15 to about 40%, about 15 to about 35%, about 15 to about 30%, about 15 to about 25%, about 15 to about 20%, about 20 to about 45%, about 20 to about 40%, about 20 to about 35%, about 20 to about 30%, about 20 to about 25%, about 25 to about 45%, about 25 to about 40%, about 25 to about 35%, about 25 to about 30%, about 30 to about 45%, about 30 to about 40%, about 30 to about 35%, about 35 to about 45%, about 35 to about 40%, or about 45 to about 45% in any aspect or embodiment described herein.

[0055] In certain embodiments, the overbased detergent is an alkaline earth phenates. These detergents can be made by reacting alkaline earth metal hydroxide or oxide (e.g. CaO, Ca(OH)₂, BaO, Ba(OH)₂, MgO, Mg(OH)₂) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight chain or branched C₁ - C₃₀ alkyl groups (e.g. C₄ - C₂₀ alkyl groups) or mixtures thereof. Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched and can be used from about 0.5 to about 6 weight percent. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (including elemental sulfur, sulfur halides, such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

[0056] In some embodiments, the overbased detergent is a metal salts of carboxylic acids. These carboxylic acid detergents may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing free water from the reaction product. Detergents made from salicylic acid are one class of detergents derived from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the formula:
wherein: R is an alkyl group having about 1 to about 30 carbon atoms, n is an integer from 1 to 4, and M is an alkaline earth metal. In certain embodiments, the R group or groups are alkyl chains of at least C11 (e.g. at least C13). R may be optionally substituted with substituents that do not interfere with the detergent's function. In an embodiment, the M is at least one of calcium, magnesium, barium, or combinations thereof. In a particular embodiment, the M is calcium.

[0057] Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Patent No. 3,595,791). The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent, such as water or alcohol.

[0058] Alkaline earth metal phosphates are also used as detergents and are known in the art.

[0059] Detergents may be simple detergents or what is known as hybrid or complex detergents. The latter detergents can provide the properties of two detergents without the need to blend separate materials. See U.S. Patent No. 6,034,039.

[0060] In an embodiment, the overbased detergent or overbased detergents (e.g., 1, 2, 3, 4, or more overbased detergents) includes at least one of overbased calcium sulfonates, overbased magnesium sulfonates, overbased sodium sulfonates, overbased barium sulfonates, overbased calcium salicylates, overbased magnesium salicylates, overbased calcium phenates, overbased magnesium phenates, overbased barium phenates, other related components (including borated detergents), or mixtures thereof. For example, a mixture of overbased detergents may include overbased magnesium sulfonate and overbased calcium salicylate, overbased magnesium sulfonate and overbased calcium sulfonate, overbased calcium sulfonate, overbased magnesium sulfonate and overbased calcium phenate, overbased calcium phenate and overbased calcium salicylate, overbased calcium phenate and overbased calcium sulfonate, overbased calcium phenate and overbased magnesium salicylate, or overbased calcium phenate and overbased magnesium phenate.

[0061] As used herein, the detergent concentrations are given on an "as delivered" basis. The active detergent may delivered within a process oil. The "as delivered" detergent can contain from
about 20 weight percent to about 100 weight percent, or from about 40 weight percent to about 60 weight percent, of active detergent in the "as delivered" detergent product.

In any aspect or embodiment described herein, the effective amount of the overbased detergent is no greater than about 3 wt.% (e.g., from about 0.001 wt.% to about 1.5 wt.% or from about 0.01 wt.% to about 0.75 wt.%). For example, the overbased detergent may be present in an amount of no greater than 2.5 wt.%, no greater than 2 wt.%, no greater than 1.5 wt.%, no greater than 1 wt.%, no greater than 0.75 wt.%, no greater than 0.5 wt.%, about 0.01 to about 2.5 wt.%, about 0.001 to about 1.5 wt.%, about 0.001 to about 1 wt.%, about 0.001 to about 0.75 wt.%, about 0.001 to about 0.5 wt.%, about 0.005 to about 3 wt.%, about 0.005 to about 2.5 wt.%, about 0.005 to about 2 wt.%, about 0.005 to about 1.5 wt.%, about 0.005 to about 1 wt.%, about 0.005 to about 0.75 wt.%, about 0.005 to about 0.5 wt.%, about 0.01 to about 3 wt.%, about 0.01 to about 2.5 wt.%, about 0.01 to about 2 wt.%, about 0.01 to about 1.5 wt.%, about 0.01 to about 1 wt.%, about 0.01 to about 0.75 wt.%, about 0.01 to about 0.5 wt.%, about 0.02 to about 3 wt.%, about 0.02 to about 2.5 wt.%, about 0.02 to about 2 wt.%, about 0.02 to about 1.5 wt.%, about 0.02 to about 1 wt.%, about 0.02 to about 0.75 wt.%, about 0.02 to about 0.5 wt.%, about 0.05 to about 3 wt.%, about 0.05 to about 2.5 wt.%, about 0.05 to about 2 wt.%, about 0.05 to about 1.5 wt.%, about 0.05 to about 1 wt.%, about 0.05 to about 0.75 wt.%, about 0.05 to about 0.5 wt.%, about 0.5 to about 3 wt.%, about 0.5 to about 2.5 wt.%, about 0.5 to about 2 wt.%, about 0.5 to about 1.5 wt.%, about 0.5 to about 1 wt.%, about 1 to about 3 wt.%, about 1 to about 2.5 wt.%, about 1 to about 2 wt.%, about 1.5 to about 3 wt.%, about 1.5 to about 2.5 wt.%, or about 2 to about 3 wt.% in any aspect or embodiment described herein.

ZDDP compounds can be represented by the following formula:

\[ \text{Zn}[(\text{S})(\text{OR1})(\text{OR2})]_2 \]

wherein R1 and R2 are C1 - C18 alkyl groups (e.g. C2 - C12 alkyl groups).

The alkyl groups of ZDDP may be straight chain or branched. Alcohols used in the ZDDP can be propanol, 2-propanol, butanol, secondary butanol, pentanols, hexanols such as 4-methyl-2-pentanol or n-hexanol, n-octanol, 2-ethyl hexanol, alkylated phenols, and the like. Mixtures of secondary alcohols or of primary and secondary alcohol can be utilized. Alkyl aryl groups may also be used. In any aspect or embodiment described herein, the thermally stable ZDDP includes at least one of a primary ZDDP (i.e., ZDDP prepared with primary alcohol), a branched primary ZDDP (i.e., ZDDP prepared with a primary, branched alcohol), or a combination thereof.
In any aspect or embodiment described herein, the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.% (e.g. from about 0.05 wt.% to about 2 wt.% or from about 0.1 wt.% to about 1 wt.%). For example, the thermally stable ZDDP may be present in an amount of about 0.01 wt.% to about 5 wt.%, about 0.01 wt.% to about 4.5 wt.%, about 0.01 wt.% to about 4 wt.%, about 0.01 wt.% to about 3.5 wt.%, about 0.01 wt.% to about 3 wt.%, about 0.01 wt.% to about 2.5 wt.% about 0.01 wt.% to about 2 wt.%, about 0.01 wt.% to about 1.5 wt.%, about 0.01 wt.% to about 1 wt.%, about 0.1 wt.% to about 5 wt.%, about 0.1 wt.% to about 4.5 wt.%, about 0.1 wt.% to about 4 wt.%, about 0.1 wt.% to about 3.5 wt.%, about 0.1 wt.% to about 3 wt.%, about 0.1 wt.% to about 2.5 wt.%, about 0.1 wt.% to about 2 wt.%, about 0.1 wt.% to about 1.5 wt.%, about 0.1 wt.% to about 1 wt.%, about 0.25 wt.% to about 5 wt.%, about 0.25 wt.% to about 4.5 wt.%, about 0.25 wt.% to about 4 wt.%, about 0.25 wt.% to about 3.5 wt.%, about 0.25 wt.% to about 3 wt.%, about 0.25 wt.% to about 2.5 wt.%, about 0.25 wt.% to about 2 wt.%, about 0.25 wt.% to about 1.5 wt.%, about 0.25 wt.% to about 1 wt.%, about 0.4 wt.% to about 5 wt.%, about 0.4 wt.% to about 4.5 wt.%, about 0.4 wt.% to about 4 wt.%, about 0.4 wt.% to about 3.5 wt.%, about 0.4 wt.% to about 3 wt.%, about 0.4 wt.% to about 2.5 wt.%, about 0.4 wt.% to about 2 wt.%, about 0.4 wt.% to about 1.5 wt.%, about 0.4 wt.% to about 1 wt.%, about 1 wt.% to about 5 wt.%, about 1 wt.% to about 4.5 wt.%, about 1 wt.% to about 4 wt.%, about 1 wt.% to about 3.5 wt.%, about 1 wt.% to about 3 wt.%, about 1 wt.% to about 2.5 wt.%, about 1 wt.% to about 2 wt.%, about 1 wt.% to about 1.5 wt.%, about 1 wt.% to about 5 wt.%, about 1.5 wt.% to about 4.5 wt.%, about 1.5 wt.% to about 4 wt.%, about 1.5 wt.% to about 3.5 wt.%, about 1.5 wt.% to about 3 wt.%, about 1.5 wt.% to about 2.5 wt.%, about 2 wt.% to about 5 wt.%, about 2 wt.% to about 4.5 wt.%, about 2 wt.% to about 4 wt.%, about 2 wt.% to about 3.5 wt.%, about 2 wt.% to about 3 wt.%, about 2.5 wt.% to about 5 wt.%, about 2.5 wt.% to about 4.5 wt.%, about 2.5 wt.% to about 4 wt.%, about 2.5 wt.% to about 3.5 wt.%, about 2.5 wt.% to about 3 wt.%, about 3 wt.% to about 4.5 wt.%, about 3 wt.% to about 4 wt.%, about 3 wt.% to about 5 wt.%, about 3.5 wt.% to about 4.5 wt.%, or about 2 wt.% to about 5 wt.% in any aspect or embodiments described herein.

In any aspect or embodiment described herein, the lubricating base stock, base oil or oils comprise at least one of: a Group I oil, a Group II oil (e.g., at least one of Group II light neutral oil such as a Group II oil with a KV100 of about 4-6 cSt, Group II heavy neutral oil such as a Group II oil with a KV100 of ≥11 cSt, or a combination thereof), a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalapholefin, or combinations thereof. For example, the lubricating base oil or oils include at least one Group II oil.
Groups I, II, III, IV and V are broad base oil stock categories, the characteristics of which are summarized in Table 1 below, developed and defined by the American Petroleum Institute (API Publication 1509; www.API.org) to create guidelines for lubricant base oils. Group I base stocks have a viscosity index of between about 80 to about 120 and contain greater than about 0.03% sulfur and/or less than about 90% saturates. Group II base stocks have a viscosity index of between about 80 to about 120, and contain less than or equal to about 0.03% sulfur and greater than or equal to about 90% saturates. Group III stocks have a viscosity index greater than about 120 and contain less than or equal to about 0.03% sulfur and greater than about 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stock includes base stocks not included in Groups I-IV.

Table 1. Properties of Base Oil Groups

<table>
<thead>
<tr>
<th>Base Oil Properties</th>
<th>Saturates</th>
<th>Sulfur</th>
<th>Viscosity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>&lt;90 and/or</td>
<td>&gt;0.03% and</td>
<td>≥80 and &lt;120</td>
</tr>
<tr>
<td>Group II</td>
<td>≥90 and</td>
<td>≤0.03% and</td>
<td>≥80 and &lt;120</td>
</tr>
<tr>
<td>Group III</td>
<td>≥90 and</td>
<td>≤0.03% and</td>
<td>≥120</td>
</tr>
<tr>
<td>Group IV</td>
<td></td>
<td>polyalphaolefins (PAO)</td>
<td></td>
</tr>
<tr>
<td>Group V</td>
<td></td>
<td>All other base oil stocks not included in Groups I, II, III or IV</td>
<td></td>
</tr>
</tbody>
</table>

Natural oils include animal oils, vegetable oils (castor oil and lard oil, for example), and mineral oils. Animal and vegetable oils possessing favorable thermal oxidative stability can be used. Of the natural oils, mineral oils are preferred. Mineral oils vary widely as to their crude source, for example, as to whether they are paraffinic, naphthenic, or mixed paraffinic-naphthenic. Oils derived from coal or shale are also useful. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrefined, or solvent extracted.

Group II and/or Group III hydroprocessed or hydrocracked base stocks are also well known base stock oils.

Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers, for example). Polyalphaolefin (PAO) oil base stocks are commonly used synthetic hydrocarbon oil.
By way of example, PAOs derived from Cs, Cio, C12, C14 olefins or mixtures thereof may be utilized. See U.S. Patent Nos. 4,956,122; 4,827,064; and 4,827,073.

The average molecular weights of the PAOs, which are known materials and generally available on a major commercial scale from suppliers such as ExxonMobil Chemical Company, Chevron Phillips Chemical Company, BP, and others, can vary from about 250 to about 3,000, although PAO's may be made in viscosities up to about 150 cSt (100°C). The PAOs are typically comprised of relatively low molecular weight hydrogenated polymers or oligomers of alphaolefins which include, but are not limited to, C2 to about C32 alphaolefins with the C8 to about C16 alphaolefins, such as 1-octene, 1-decene, 1-dodecene and the like. For example, the polyalphaolefins can be poly-l-octene, poly-l-decene, poly-l-dodecene, a combination thereof, or mixed olefin-derived polyolefins. However, the dimers of higher olefins in the range of C12 to C18 may be used to provide low viscosity base stocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly dimers, trimers and tetramers of the starting olefins, with minor amounts of the lower and/or higher oligomers, having a viscosity range of 1.5 cSt to 12 cSt. PAO fluids of particular use may include 3 cSt, 3.4 cSt, and/or 3.6 cSt and combinations thereof. Mixtures of PAO fluids having a viscosity range of 1.5 cSt to approximately 150 cSt or more may be used if desired. Unless indicated otherwise, all viscosities cited herein are measured at 100°C.

The PAO fluids may be conveniently made by the polymerization of an alphaolefin in the presence of a polymerization catalyst such as the Friedel-Crafts catalysts including, for example, aluminum trichloride, boron trifluoride or complexes of boron trifluoride with water, alcohols such as ethanol, propanol or butanol, carboxylic acids or esters such as ethyl acetate or ethyl propionate. For example the methods disclosed by U.S. Patent Nos. 4,149,178 or 3,382,291 may be conveniently used herein. Other descriptions of PAO synthesis are found in the following U.S. Patent Nos. 3,742,082; 3,769,363; 3,876,720; 4,239,930; 4,367,352; 4,413,156; 4,434,408; 4,910,355; 4,956,122; and 5,068,487. The dimers of the C14 to C18 olefins are described in U.S. Patent No. 4,218,330.

Other useful lubricant oil base stocks include wax isomerate base stocks and base oils, comprising hydroisomerized waxy stocks (e.g. waxy stocks such as gas oils, slack waxes, fuels hydrocracker bottoms, etc.), hydroisomerized Fischer-Tropsch waxes, Gas-to-Liquids (GTL) base stocks and base oils, and other wax isomerate hydroisomerized base stocks and base oils, or mixtures thereof. Fischer-Tropsch waxes, the high boiling point residues of Fischer-Tropsch
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synthesis, are highly paraffinic hydrocarbons with very low sulfur content. The hydroprocessing used for the production of such base stocks may use an amorphous hydrocracking/hydroisomerization catalyst, such as one of the specialized lube hydrocracking (LHDC) catalysts or a crystalline hydrocracking/hydroisomerization catalyst, such as a zeolitic catalyst. For example, one useful catalyst is ZSM-48 as described in U.S. Patent No. 5,075,269, the disclosure of which is incorporated herein by reference in its entirety. Processes for making hydrocracked/hydroisomerized distillates and hydrocracked/hydroisomerized waxes are described, for example, in U.S. Patent Nos. 2,817,693; 4,975,177; 4,921,594 and 4,897,178 as well as in British Patent Nos. 1,429,494; 1,350,257; 1,440,230 and 1,390,359. Each of the aforementioned patents is incorporated herein in their entirety. Particularly favorable processes are described in European Patent Application Nos. 464546 and 464547, also incorporated herein by reference. Processes using Fischer-Tropsch wax feeds are described in U.S. Patent Nos. 4,594,172 and 4,943,672, the disclosures of which are incorporated herein by reference in their entirety.

[0074] Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and other wax-derived hydroisomerized (wax isomerate) base oils may be used in the present disclosure, and may have kinematic viscosities at 100°C of about 2 cSt to about 50 cSt, e.g. about 2 cSt to about 30 cSt or about 3 cSt to about 25 cSt, as exemplified by GTL 4 with kinematic viscosity of about 4.0 cSt at 100°C and a viscosity index of about 141. These Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and other wax-derived hydroisomerized base oils may have useful pour points of about -20°C or lower, and under some conditions may have advantageous pour points of about -25°C or lower, with useful pour points of about -30°C to about -40°C or lower. Useful compositions of Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and wax-derived hydroisomerized base oils are recited in U.S. Patent Nos. 6,080,301; 6,090,989, and 6,165,949 for example, and are incorporated herein in their entirety by reference.

[0075] The hydrocarbyl aromatics can be used as a base oil or base oil component and can be any hydrocarbyl molecule in which at least about 5% of its weight is derived from an aromatic moiety, such as a benzenoid moiety or naphthenoid moiety, or their derivatives. These hydrocarbyl aromatics include alkyl benzenes, alkyl naphthalenes, alkyl biphenyls, alkyl diphenyl oxides, alkyl naphthols, alkyl diphenyl sulfides, alkylated bis-phenol A, alkylated thiodiphenol, and the like. The aromatic can be mono-alkylated, dialkylated, polyalkylated, and
the like. The aromatic can be mono- or poly-functionalized. The hydrocarbyl groups can also be comprised of mixtures of alkyl groups, alkenyl groups, alkynyl, cycloalkyl groups, cycloalkenyl groups and other related hydrocarbyl groups. The hydrocarbyl groups can range from about C6 up to about C60 with a range of about C8 to about C20 often being preferred. A mixture of hydrocarbyl groups may be utilized, and up to about three such substituents may be present. The hydrocarbyl group can optionally contain sulfur, oxygen, and/or nitrogen containing substituents. The aromatic group can also be derived from natural (petroleum) sources, provided at least about 5% of the molecule is comprised of an above-type aromatic moiety. In certain embodiments, the viscosity at 100°C is approximately 2 cSt to about 50 cSt, e.g. approximately 3 cSt to about 20 cSt for the hydrocarbyl aromatic component. In one embodiment, an alkyl naphthalene where the alkyl group is primarily comprised of 1-hexadecene is used. Other alkylates of aromatics can be advantageously used. Naphthalene or methyl naphthalene, for example, can be alkylated with olefins such as octene, decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like. Alkylated naphthalene and analogues may also comprise compositions with isomeric distribution of alkylating groups on the alpha and beta carbon positions of the ring structure. Distribution of groups on the alpha and beta positions of a naphthalene ring may range from 100:1 to 1:100, more often 50:1 to 1:50. Useful concentrations of hydrocarbyl aromatic in a lubricant oil composition can be about 2% to about 25%, e.g. about 4% to about 20% or about 4% to about 15%, depending on the application.

[0076] Alkylated aromatics such as the hydrocarbyl aromatics of the present disclosure may be produced by well-known Friedel-Crafts alkylation of aromatic compounds. See Friedel-Crafts and Related Reactions, Olah, G. A. (ed.), Inter-science Publishers, New York, 1963. For example, an aromatic compound, such as benzene or naphthalene, is alkylated by an olefin, alkyl halide or alcohol in the presence of a Friedel-Crafts catalyst. See Friedel-Crafts and Related Reactions, Vol. 2, part 1, chapters 14, 17, and 18, See Olah, G. A. (ed.), Inter-science Publishers, New York, 1964. Many homogeneous or heterogeneous, solid catalysts are known to one skilled in the art. The choice of catalyst depends on the reactivity of the starting materials and product quality requirements. For example, strong acids such as AlCh, BF3, or HF may be used. In some cases, milder catalysts such as FeCh or SnCU are preferred. Newer alkylation technology uses zeolites or solid super acids.

[0077] Esters comprise a useful base stock. Additive solvency and seal compatibility
characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid, alkyl succinic acid, alkenyl succinic acid, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.

Particularly useful synthetic esters are those which are obtained by reacting one or more polyhydric alcohols, such as hindered polyols (including the neopentyl polyols, e.g., neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol and dipentaerythritol) with alkanoic acids containing at least about 4 carbon atoms, e.g. C5 to C30 acids such as saturated straight chain fatty acids including caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, and behenic acid, or the corresponding branched chain fatty acids or unsaturated fatty acids such as oleic acid, or mixtures of any of these materials.

Suitable synthetic ester components include the esters of trimethylol propane, trimethylol butane, trimethylol ethane, pentaerythritol and/or dipentaerythritol with one or more monocarboxylic acids containing from about 5 to about 10 carbon atoms. These esters are widely available commercially, for example, the Mobil P-41 and P-51 esters of ExxonMobil Chemical Company (Irving, Texas, USA).

Also useful are esters derived from renewable material, such as coconut, palm, rapeseed, soy, sunflower and the like. These esters may be monoesters, di-esters, polyol esters, complex esters, or mixtures thereof. These esters are widely available commercially, for example, the Mobil P-51 ester of ExxonMobil Chemical Company (Irving, Texas, USA).

Turbine oil formulations containing renewable esters are contemplated by the present disclosure. For such formulations, the renewable content of the ester is typically greater than about 70 weight percent, preferably more than about 80 weight percent and most preferably more than about 90 weight percent.

Other useful fluids of lubricating viscosity include non-conventional or unconventional base stocks that have been processed, e.g. catalytically, or synthesized to provide
high performance lubrication characteristics.

[0083] Non-conventional or unconventional base stocks/base oils include one or more of a mixture of base stock(s) derived from one or more Gas-to-Liquids (GTL) materials, as well as isomerate/isodewaxate base stock(s) derived from natural wax or waxy feeds, mineral and or non-mineral oil waxy feed stocks such as slack waxes, natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials received from coal liquefaction or shale oil, and mixtures of such base stocks.

[0084] GTL materials are materials that are derived via one or more synthesis, combination, transformation, rearrangement, and/or degradation/deconstructive processes from gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks such as hydrogen, carbon dioxide, carbon monoxide, water, methane, ethane, ethylene, acetylene, propane, propylene, propyne, butane, butylene, and butynes. GTL base stocks and/or base oils are GTL materials of lubricating viscosity that are generally derived from hydrocarbons; for example, waxy synthesized hydrocarbons, that are themselves derived from simpler gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks. GTL base stock(s) and/or base oil(s) include oils boiling in the lube oil boiling range (1) separated/fractionated from synthesized GTL materials such as, for example, by distillation and subsequently subjected to a final wax processing step which involves either or both of a catalytic dewaxing process, or a solvent dewaxing process, to produce lube oils of reduced/low pour point; (2) synthesized wax isomerates, comprising, for example, hydrodewaxed or hydroisomerized cat and/or solvent dewaxed synthesized wax or waxy hydrocarbons; (3) hydrodewaxed or hydroisomerized cat and/or solvent dewaxed Fischer-Tropsch (F-T) material (i.e., hydrocarbons, waxy hydrocarbons, waxes and possible analogous oxygenates); such as hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxing dewaxed F-T waxy hydrocarbons, or hydrodewaxed or hydroisomerized/followed by cat (or solvent) dewaxing dewaxed, F-T waxes, or mixtures thereof.

[0085] GTL base stock(s) and/or base oil(s) derived from GTL materials, especially, hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxed wax or waxy feed, preferably F-T material derived base stock(s) and/or base oil(s), are characterized typically as having kinematic viscosities at 100°C of from about 2 mm²/s to about 50 mm²/s (ASTM D445).
They are further characterized typically as having pour points of -5°C to about -40°C or lower (ASTM D97). They are also characterized typically as having viscosity indices of about 80 to about 140 or greater (ASTM D2270).

In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffins. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than about 10 ppm, and more typically less than about 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorus and aromatics make this materially especially suitable for the formulation of low SAP products.

The term GTL base stock and/or base oil and/or wax isomerate base stock and/or base oil is to be understood as embracing individual fractions of such materials of wide viscosity range as recovered in the production process, mixtures of two or more of such fractions, as well as mixtures of one or two or more low viscosity fractions with one, two or more higher viscosity fractions to produce a blend wherein the blend exhibits a target kinematic viscosity.

The GTL material, from which the GTL base stock(s) and/or base oil(s) is/are derived is preferably an F-T material (i.e., hydrocarbons, waxy hydrocarbons, wax).

Base oils for use in the formulated lubricating oils useful in the present disclosure are any of the variety of oils corresponding to API Group I, Group II, Group III, Group IV, and Group V oils and mixtures thereof, e.g. API Group II oil may be utilized in the compositions of the present disclosure.

The base oil constitutes the major component of the lubricating composition of the present disclosure and can be present in an amount ranging from about 80 to about 99.8 weight percent, e.g. from about 90 to about 99.5 weight percent or from about 95 to about 99 weight percent, based on the total weight of the composition. The base oil may be selected from any of the synthetic or natural oils typically used as lubricating oils for industrial oils and turbomachines. The base oil conveniently has a kinematic viscosity, according to ASTM standards (e.g., ASTM D445 or ASTM D7042), of about 7 cSt to about 46 cSt (or mm²/s) at 40°C and preferably of about 10 cSt to about 32 cSt (or mm²/s) at 40°C, often from about 15 cSt to about 22 cSt. Mixtures of synthetic and natural base oils may be used if desired. Bi-
modal, tri-modal, and additional combinations of mixtures of Group I, II, III, IV, and/or V base stocks may be used if desired.

[0091] The co-base stock component is present in an amount sufficient for providing solubility, compatibility and dispersancy of polar additives in the lubricating oil. The co-base stock component is present in the lubricating oils of the disclosure in an amount from about 1 to about 99 weight percent, e.g. from about 5 to about 95 weight percent or from about 10 to about 90 weight percent.

[0092] Table 2 below summarizes useful and preferred amounts of illustrative lubricating base oils in accordance with this disclosure.

Table 2. Useful and Preferred Amounts of Illustrative Lubricating Base Oils

<table>
<thead>
<tr>
<th>Illustrative Base Oils</th>
<th>Approximate wt% (Useful)</th>
<th>Approximate wt% (Preferred)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral Oil API Group I, II/II+</td>
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<td>3-95</td>
</tr>
<tr>
<td>Naphthenic</td>
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<tr>
<td>API Group III/III+ = GTL</td>
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<td>3-95</td>
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<tr>
<td>API Group IV PAO</td>
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<td>3-95</td>
</tr>
<tr>
<td>API Group V (examples listed below):</td>
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<td>3-95</td>
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<tr>
<td>Ethylene-propylene copolymer (EPC)</td>
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<td>3-95</td>
</tr>
<tr>
<td>Polyol Esters</td>
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<tr>
<td>Phosphate Esters</td>
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<td>Phthalate Esters</td>
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<tr>
<td>Dibasic Esters e.g. Adipate</td>
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<tr>
<td>Carbonate Esters</td>
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<td>3-95</td>
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<tr>
<td>Trimellitate Esters</td>
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<td>Oil Soluble Polyalkylene Glycols</td>
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<td>Polyalkylene Glycols</td>
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<td>Alkylated Naphthalenes</td>
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</tr>
<tr>
<td>Viscobase Fluids</td>
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<td>Olefin-esters (e.g. Ketjenlube)</td>
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<tr>
<td>Linear or Branched Alkylbenzenes</td>
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<tr>
<td>TME-based esters</td>
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Polyethers 0-100  3-95
2 Ethylhexanoic acid ester  0-100  3-95
PMA/PAO co-oligomers  0-100  3-95
Alkylated Diphenyl Oxide (ADPO)  0-100  3-95
Alkylated Sulfurized Diphenyl Oxide (ASDPO)  0-100  3-95
Bisphenol Sulfide Ether (BPSE)  0-100  3-95
(C16,C20) 3-phenylpropionate  0-100  3-95
Hexyl 2-(decyloxy)benzoate  0-100  3-95
Diheptyl N-octylsuccinate  0-100  3-95

Performance Additives

[0093] The lubricating composition of the present disclosure may further comprise at least one performance additive (i.e., a lubricating oil performance additive). For example, the lubricating composition may include at least one of a dispersant, an additional detergent, a corrosion inhibitor, a rust inhibitor, a metal deactivator, an additional anti-wear agent, an extreme pressure additive, an anti-seizure agent, a wax modifier, a viscosity index improver, a viscosity modifier/improver, a seal compatibility agent, an additional friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, an emulsifier, a pour point depressant, a wetting agent, a tackiness agent, a colorant, an antioxidants, an oxidation inhibitor, or a combination thereof. The presence or absence of these lubricating oil performance additives does not adversely affect the lubricating compositions of the present disclosure. For a review of many commonly used additives, see Klamann in Lubricants and Related Products, Verlag Chemie, Deerfield Beach, FL; ISBN 0 89573 177 0. Reference is also made to "Lubricant Additives" by M. W. Ranney, published by Noyes Data Corporation of Parkridge, NJ (1973) and "Lubricant Additives: Chemistry and Applications" edited by L.R. Rudnick, published by CRC Press of Boca Raton, FL (2009).

[0094] The additives useful in this disclosure do not have to be soluble in the lubricating oils. Insoluble additives in oil can be dispersed in the lubricating oils of this disclosure.

[0095] The types and quantities of performance additives used in combination with the present disclosure in lubricant compositions are not limited by the examples shown herein as illustrations.
[0096] As such, in any aspect or embodiment described herein, the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof. In any aspect or embodiment described herein, the dispersant includes succinimide-type dispersant. The dispersant may be present in an amount of ≤ about 1.5 wt.%, ≤ about 1.25 wt.%, or ≤ about 1 wt.% For example, the dispersant may be present in an amount of about 0.1 to about 1.5 wt.%, about 0.1 to about 1.25 wt.%, about 0.1 to about 1 wt.%, about 0.1 to about 0.5 wt.%, about 0.25 to about 1.5 wt.%, about 0.25 to about 1.25 wt.%, about 0.5 to about 1 wt.%, about 0.5 to about 0.75wt.%.

[0097] Unless specified otherwise, the performance additive or performance additives listed above are present in a total amount equal to or less than about 10 wt%, equal to or less than about 9.5 wt%, equal to or less than about 9 wt%, equal to or less than about 8.5 wt%, equal to or less than about 8 wt%, equal to or less than about 7.5 wt%, equal to or less than about 7 wt%, equal to or less than about 6.5 wt%, equal to or less than about 6 wt%, equal to or less than about 5.5 wt%, equal to or less than about 6 wt%, equal to or less than about 6.5 wt%, equal to or less than about 7 wt%, equal to or less than about 7.5 wt%, equal to or less than about 10 wt%, about 0.1 to about 8 wt%, about 0.1 to about 7 wt%, about 0.1 to about 6 wt%, about 0.1 to about 5 wt%, about 0.1 to about 4 wt%, about 0.1 to about 3 wt%, about 0.1 to about 2 wt%, about 0.1 to about 1 wt%, about 0.1 to about 10 wt%, about 0.1 to about 9 wt%, about 0.1 to about 8 wt%, about 0.1 to about 7 wt%, about 1 to about 6 wt%, about 1 to about 5 wt%, about 1 to about 4 wt%, about 1 to about 3 wt%, about 1 to about 2 wt%, about 1 to about 10 wt%, about 1 to about 9 wt%, about 1 to about 8 wt%, about 1 to about 7 wt%, about 1 to about 6 wt%, about 1 to about 5 wt%, about 1 to about 4 wt%, about 1 to about 3 wt%, about 1 to about 2 wt%, about 1 to about 10 wt%, about 1 to about 9 wt%, about 1 to about 8 wt%, about 1 to about 7 wt%.
Viscosity Improver(s) or Modifier(s). The viscosity improver, viscosity modifier, or Viscosity Index (VI) modifier increases the viscosity of the lubricating composition at elevated temperatures, thereby increasing film thickness, and having limited effects on the viscosity of the lubricating composition at low temperatures. In certain embodiments, the lubricating composition comprises at least one viscosity improver (e.g., 1, 2, 3, 4, 5, 6, or more viscosity improver(s)). Any viscosity improver that is known or that becomes known in the art may be utilized in the lubricating composition of the present disclosure. Exemplary viscosity improvers include high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. The molecular weight of these polymers can range from about 1,000 to about 1,500,000 (e.g., about 20,000 to about 1,200,000 or about 50,000 to about 1,000,000). In a particular embodiment, the molecular weights of these polymers can range from about 1,000 to about 1,000,000 (e.g., about 1,200 to about 500,000 or about 1,200 to about 5,000).

In certain embodiments, the viscosity improver is at least one of linear or star-shaped polymers of methacrylate, linear or star-shaped copolymers of methacrylate, butadiene, olefins, alkylated styrenes, polyisobutylene, polymethacrylate (e.g., copolymers of various chain length alkyl methacrylates), copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, or combinations thereof. For example, the viscosity improver may include styrene-isoprene or styrene-butadiene based polymers of about 50,000 to about 200,000 molecular weight.

Olefin copolymers are commercially available from Chevron Oronite Company LLC under the trade designation "PARATONE®" (such as "PARATONE® 8921" and "PARATONE® 8941"); from Afton Chemical Corporation under the trade designation "HiTEC®" (such as "HiTEC® 5850B"); and from The Lubrizol Corporation under the trade designation "Lubrizol® 7067C". Hydrogenated polyisoprene star polymers are commercially available from Infineum International Limited, e.g., under the trade designation "SV200" and "SV600". Hydrogenated
diene-styrene block copolymers are commercially available from Infineum International Limited, e.g., under the trade designation "SV 50".

The polymethacrylate or polyacrylate polymers can be linear polymers which are available from Evnoik Industries under the trade designation "Viscoplex®" (e.g., Viscoplex 6-954) or star polymers which are available from Lubrizol Corporation under the trade designation Asteric™ (e.g., Lubrizol 87708 and Lubrizol 87725).

Illustrative vinyl aromatic-containing polymers useful in the present disclosure may be derived predominantly from vinyl aromatic hydrocarbon monomer. Illustrative vinyl aromatic-containing copolymers useful in the present disclosure may be represented by the following formula:

A-B,

wherein:

A is a polymeric block derived predominantly from vinyl aromatic hydrocarbon monomer, and

B is a polymeric block derived predominantly from conjugated diene monomer.

Although their presence is not required to obtain the benefit of the composition of the present disclosure, viscosity modifiers may be used in an amount of less than about 10 weight percent (e.g. less than about 7 weight percent or less than about 4 weight percent). In certain embodiments, the viscosity improver is present in an amount less than 2 weight percent, less than about 1 weight percent, or less than about 0.5 weight percent, based on the total weight of the lubricating composition. Viscosity modifiers are generally added as concentrates, in large amounts of diluent oil.

As used herein, the viscosity modifier concentrations are given on an "as delivered" basis. The active polymer may be delivered with a diluent oil. The "as delivered" viscosity modifier may contain from about 20 weight percent to about 75 weight percent of an active polymer for polymethacrylate or polyacrylate polymers, or from about 8 weight percent to about 20 weight percent of an active polymer for olefin copolymers, hydrogenated polyisoprene star polymers, or hydrogenated diene-styrene block copolymers, in the "as delivered" polymer concentrate.

Antioxidant(s). In certain embodiments, the lubricating composition comprises at least one antioxidant (e.g., 1, 2, 3, 4, 5, 6, or more antioxidant(s)). The antioxidant(s) may be added to retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant. One skilled in the art knows a wide variety of oxidation inhibitors that are useful in lubricating oil compositions. See, Klamann in Lubricants and Related Products, op cite, and U.S. Patent Nos. 4,798,684 and 5,084,197,
for example. Any antioxidant that is known or that becomes known in the art may be utilized in the lubricating composition of the present disclosure.

[0106] Two general types of oxidation inhibitors are those that react with the initiators, peroxy radicals, and hydroperoxides to form inactive compounds, and those that decompose these materials to form less active compounds. Examples are hindered (alkylated) phenols, e.g. 6-di(tert-butyl)-4-methylphenol [2,6-di(tert-butyl)-p-cresol, DBPC], and aromatic amines, e.g. N-phenyl-\( \text{a-} \)naphthalamine. These oxidation inhibitors are used in turbine, circulation, and hydraulic oils that are intended for extended service.

[0107] The antioxidant or antioxidants may be present in an amount equal to or less than about 6 wt\%, equal to or less than about 5.75 wt\%, equal to or less than about 5.5 wt\%, equal to or less than about 5.25 wt\%, equal to or less than about 5 wt\%, equal to or less than about 4.75 wt\%, equal to or less than about 4.5 wt\%, equal to or less than about 4.25 wt\%, equal to or less than about 4 wt\%, equal to or less than about 3.75 wt\%, equal to or less than about 3.5 wt\%, equal to or less than about 3.25 wt\%, equal to or less than about 3 wt\%, equal to or less than about 2.75 wt\%, equal to or less than about 2.5 wt\%, equal to or less than about 2.25 wt\%, equal to or less than about 2 wt\%, equal to or less than about 1.75 wt\%, equal to or less than about 1.5 wt\%, equal to or less than about 1.25 wt\%, equal to or less than about 1 wt\%, equal to or less than about 0.75 wt\%, equal to or less than about 0.50 wt\%, or equal to or less than about 0.25 wt\% on an as-received basis. For example, the antioxidant or antioxidants may be present in an amount of about 0.1 wt\% to about 6 wt\%, about 0.1 wt\% to about 5 wt\%, about 0.1 wt\% to about 4 wt\%, about 0.1 wt\% to about 3 wt\%, about 0.1 wt\% to about 2 wt\%, about 0.1 wt\% to about 1.5 wt\%, about 0.1 wt\% to about 1 wt\%, about 0.1 wt\% to about 0.75 wt\%, about 0.1 wt\% to about 0.5 wt\%, about 0.1 wt\% to about 0.2 wt\% to about 6 wt\%, about 0.2 wt\% to about 5 wt\%, about 0.2 wt\% to about 4 wt\%, about 0.2 wt\% to about 3 wt\%, about 0.2 wt\% to about 2 wt\%, about 0.2 wt\% to about 1.5 wt\%, about 0.2 wt\% to about 1 wt\%, about 0.2 wt\% to about 0.75 wt\%, about 0.2 wt\% to about 0.5 wt\%, about 0.2 wt\% to about 0.3 wt\% to about 6 wt\%, about 0.3 wt\% to about 5 wt\%, about 0.3 wt\% to about 4 wt\%, about 0.3 wt\% to about 3 wt\%, about 0.3 wt\% to about 2 wt\%, about 0.3 wt\% to about 1.5 wt\%, about 0.3 wt\% to about 1 wt\%, about 0.3 wt\% to about 0.75 wt\%, about 0.3 wt\% to about 0.5 wt\%, about 0.3 wt\% to about 0.2 wt\% to about 6 wt\%, about 0.5 wt\% to about 5 wt\%, about 0.5 wt\% to about 4 wt\%, about 0.5 wt\% to about 3 wt\%, about 0.5 wt\% to about 2 wt\%, about 0.5 wt\% to about 1.5 wt\%, about 0.5 wt\% to about 1 wt\%, about 0.5 wt\% to about 0.75 wt\%, about 0.5 wt\% to about 0.5 wt\%, about 0.5 wt\% to about 0.3 wt\% to about 6 wt\%, about 1 wt\% to about 5 wt\%, about 1 wt\% to about 4 wt\%, about 1 wt\% to about 3 wt\%, about 2 wt\% to about 6
wt %, about 2 wt% to about 5 wt %, about 2 wt% to about 4 wt %, about 3 wt% to about 6 wt %, about 3 wt% to about 5 wt %, about 4 wt% to about 6 wt %, or about 5 wt% to about 6 wt % on an as-received basis. In an embodiment, the antioxidant include at least one of a food-grade phenolic antioxidant, a food-grade aminic antioxidant, or a combination thereof.

[0108] The below discussion of phenolic antioxidants is presented only by way of example, and is not limiting on the type of phenolic antioxidants that can be utilized in the lubricating composition of the present disclosure.

[0109] Useful antioxidants include hindered phenols. These phenolic antioxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. In an embodiment, the phenolic antioxidant compounds or compounds are hindered phenolics which are the ones which contain a sterically hindered hydroxyl group, such as those that are derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. In certain embodiments, the phenolic antioxidant or antioxidants are hindered phenols substituted with C6+ alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; and 2-methyl-6-t-butyl-4-dodecyl phenol. Other useful hindered monophenolic antioxidants may include for example hindered 2,6-di-alkyl-phenolic propionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used in combination with the composition of the present disclosure. Examples of ortho-coupled phenols include: 2,2'-bis(4-heptyl-6-t-butyl-phenol); 2,2'-bis(4-octyl-6-t-butyl-phenol); and 2,2'-bis(4-dodecyl-6-t-butyl-phenol). Para-coupled bisphenols include for example 4,4'-bis(2,6-di-t-butyl phenol) and 4,4'-methylene-bis(2,6-di-t-butyl phenol).

[0110] Further examples of phenol-based antioxidants include 2-t-butylphenol, 2-t-butyl-4-methylphenol, 2-t-butyl-5-methylphenol, 2,4-di-t-butylphenol, 2,4-dimethyl-6-t-butylphenol, 2-t-butyl-4-methoxyphenol, 3-t-butyl-4-methoxyphenol, 2,5-di-t-butylhydroquinone (manufactured by the Kawaguchi Kagaku Co. under trade designation "Antage DBH"), 2,6-di-t-butylphenol and 2,6-di-t-butyl-4-alkylphenols such as 2,6-di-t-butyl-4-methylphenol and 2,6-di-t-butyl-4-ethylphenol; 2,6-di-t-butyl-4-alkoxyphenols such as 2,6-di-t-butyl-4-methoxyphenol and 2,6-di-t-butyl-4-ethoxyphenol, 3,5-di-t-butyl-4-hydroxybenzylmercaptocate-1acetate, alkyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionates such as n-octyl-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionate (manufactured by the Yoshitomi Seiyaku Co. under the trade designation "Yonox SS"), n-dodecyl-3-
(3,5-di-t-butyl-4-hydroxyphenyl)propionate and 2'-ethylhexyl-3-(3,5-di-t-butyl-4-
hydroxyphenyl)propionate; 2,6-di-t-butyl-alpha-dimethylamino-p-cresol, 2,2'-methylenebis(4-alkyl-
6-t-butylphenol) compounds such as 2,2'-methylenebis(4-methyl-6-t-butylphe-
non) (manufactured by the Kawaguchi Kagaku Co. under the trade designation "Antage W-400") and 2,2'-
methylenebis(4-ethyl-6-t-butylphenol) (manufactured by the Kawaguchi Kagaku Co. under the trade
designation "Antage W-500"); bisphenols such as 4,4'-butyldenedibis(3-methyl-6-t-butyl-
phenol) (manufactured by the Kawaguchi Kagaku Co. under the trade designation "Antage W-300") and
4,4'-methylenebis(2,6-di-t-butylphenol) (manufactured by Laporte Performance Chemicals under the
trade designation "Ionox 220AH").

[0111] Other examples of phenol-based antioxidants include 4,4'-bis(2,6-di-t-butylphenol), 2,2-
(di-p-hydroxyphenyl)propane (Bisphenol A), 2,2-bis(3,5-di-t-butyl-4-hydroxyphenyl)propane, 4,4'-
cyclohexyldenedibis(2,6-di-t-butylphenol), hexamethylene glycol bis[3, (3,5-di-t-butyl-4-
hydroxyphenyl)propionate] (manufactured by the Ciba Specialty Chemicals Co. under the trade
designation "Irganox L109"), triethylene glycol bis[3-(3-t-butyl-4-hydroxy- y-5-
methylphenyl)propionate] (manufactured by the Yoshitomi Seiyaku Co. under the trade designation
"Tominox 917"), 2,2'-thio[diethyl-3-(3,5-di-t- -butyl-4-hydroxyphenyl)propionate] (manufactured by
the Ciba Specialty Chemicals Co. under the trade designation "Irganox LI 15"), 3,9-bis[1,1-
dimethyl-2-[3-(3-t-butyl-4-hydroxy-5-methylphenyl)-propionyl- xy]ethyl]2,4, 8, 10-
tetraoxaspiro[5,5]undecane (manufactured by the Sumitomo Kagaku Co. under the trade designation
"Sumilizer GA80") and 4,4'-thiobis(3-methyl-6-t-butylphenol) (manufactured by the Kawaguchi
Kagaku Co. under the trade designation "Antage RC"), 2,2'-thiobis(4,6-di-t-butylresorcinol);
polyphenols, such as tetradik[methylene-3-(3,5-di-t-butyl-4-hydroxyphenyl)propionato)methane
(manufactured by the Ciba Speciality Chemicals Co. under the trade designation "Irganox L101"),
1,1,3-tris(2-methyl-4-hydroxy-5-t-butypheny- l)butane (manufactured by the Yoshitomi Seiyaku
Co. under the trade designation "Yoshinox 930"), 1,3,5-trimethyl-2,4,6-tris(3,5-di-t-butyl-4-
hydroxybenzyl)benzene (manufactured by Ciba Speciality Chemicals under the trade designation
"Irganox 330"), bis[3,3'-bis(4'-hydroxy-3'-t-butyphenyl-1)butyric acid] glycol ester, 2-(3',5'-di-t-
butyl-4-hydroxyphenyl)-methyl- 4-(2",4"-di-t-butyl-3"-hydroxyphenyl)methyl-6-t-butylphenol and
2,6-bis(2'-hydroxy-3'-t-buty-5'-methylbenzyl)-4-methylphenol; and phenol/aldehyde condensates,
such as the condensates of p-t-butyphenol and formaldehyde and the condensates of p-t-butyphenol
and acetaldehyde.
The phenolic antioxidant or phenolic type antioxidant include sulfurized and non-sulfurized phenolic antioxidants. Phenolic antioxidants include compounds having one or more than one hydroxyl group bound to an aromatic ring which may itself be mononuclear (e.g., benzyl) or poly-nuclear (e.g., naphthyl and spiro aromatic compounds). Thus, phenol type antioxidants include phenol per se, catechol, resorcinol, hydroquinone, naphthol, etc., as well as alkyl or alkenyl and sulfurized alkyl or alkenyl derivatives thereof, and bisphenol type compounds including such bis-phenol compounds linked by alkylene bridges sulfuric bridges or oxygen bridges. Alkyl phenols may include mono- and poly-alkyl or alkenyl phenols, the alkyl or alkenyl group containing from about 3 to about 100 carbons (e.g., about 4 to about 50 carbons) and sulfurized derivatives thereof. The number of alkyl or alkenyl groups present in the aromatic ring may range from 1 up to the available unsatisfied valences of the aromatic ring remaining after counting the number of hydroxyl groups bound to the aromatic ring.

For example, the phenolic antioxidant may be represented by the following formula:

\[(R)_x\text{-Ar-}(OH)_y\]

wherein:

\(\text{Ar}\) is selected from the group consisting of:

![Chemical structures](image)

wherein:
R is a C3-C1₀ alkyl or alkenyl group, a sulfur substituted alkyl or alkenyl group (e.g., a C4-C50 alkyl or alkenyl group or sulfur substituted alkyl or alkenyl group, a C3-C1₀ alkyl or sulfur substituted alkyl group, or a C4-C50 alkyl group);

Rᵩ is a Ci-Cioo alkylene or sulfur substituted alkylene group (e.g., a C2-C50 alkyene or sulfur substituted alkyene group or a C2-C2 alkyene or sulfur substituted alkyene group);

y is at least 1 to up to the available valences of Ar;

x ranges from 0 to up to the available valences of Ar-y;

z ranges from 1 to 10;

n ranges from 0 to 20;

m is 0 to 4; and

p is 0 or 1.

In certain embodiments, at least one of: R is C4-C50 alkyl group, Rᵩ is a C2-C20 alkyene or sulfur substituted alkyene group, y ranges from 1 to 3, x ranges from 0 to 3, z ranges from 1 to 4, n ranges from 0 to 5, p is 0, or a combination thereof.

In particular embodiments, the phenolic antioxidant include hindered phenolics and phenolic esters that contain a sterically hindered hydroxyl group. For example, the phenolic antioxidant can include derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. The phenolic antioxidant may include the hindered phenols substituted with Ci+ alkyl groups and the alkyene coupled derivatives of these hindered phenols, such as: 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-alkoxy phenol; and/or

\[
\begin{align*}
\text{HO} & \quad \text{t- (butyl)} \\
\text{C} & \quad \text{C} \\
\text{C} & \quad \text{O} \\
\text{C} & \quad \text{O} \\
\end{align*}
\]

\((\text{C}_3 \text{C}_{12})\)
[0116] In certain embodiments, the phenolic type antioxidant is at least one of Ethanol® 4710, Irganox® 1076, Irganox® L1035, Irganox® 1010, Irganox® L109, Irganox® L118, Irganox® L135, or a combination thereof.

[0117] The phenolic antioxidant or antioxidants may be present in an amount of about 0.05 wt% to about 3 wt%, about 0.05 wt% to about 2.5 wt%, about 0.05 wt% to about 2 wt%, about 0.05 wt% to about 1.5 wt%, about 0.05 wt% to about 1 wt%, about 0.05 wt% to about 0.75 wt%, about 0.05 wt% to about 0.5 wt%, about 0.05 wt% to about 0.3 wt%, about 0.1 wt% to about 3 wt%, about 0.1 wt% to about 2.5 wt%, about 0.1 wt% to about 2 wt%, about 0.1 wt% to about 1.5 wt%, about 0.1 wt% to about 1 wt%, about 0.1 wt% to about 0.75 wt%, about 0.1 wt% to about 0.5 wt%, about 0.1 wt% to about 0.3 wt%, about 0.5 wt% to about 3 wt%, about 0.5 wt% to about 2.5 wt%, about 0.5 wt% to about 2 wt%, about 0.5 wt% to about 1.5 wt%, about 0.5 wt% to about 1 wt%, about 1 wt% to about 3 wt%, about 1 wt% to about 2.5 wt%, about 1 wt% to about 2 wt%, about 1 wt% to about 1.75 wt%, about 1 wt% to about 1.5 wt%, about 1.5 wt% to about 3 wt%, about 1.5 wt% to about 2.5 wt%, about 1.5 wt% to about 2 wt%, about 2 wt% to about 3 wt%, about 2 wt% to about 2.5 wt%, or about 2.5 wt% to about 3 wt%, on an as-received basis.

[0118] Effective amounts of one or more catalytic antioxidants may be used. The catalytic antioxidants comprise an effective amount of a) one or more oil soluble polymetal organic compounds; and, effective amounts of b) one or more substituted N,N'-diaryl-o-phenylenediamine compounds or c) one or more hindered phenol compounds; or a combination of both b) and c).

Catalytic antioxidants are more fully described in U.S. Patent No. 8,048,833, which is incorporated herein by reference in its entirety.

[0119] Non-phenolic oxidation inhibitors that may be used in the composition of the present disclosure include aromatic amine antioxidants, which may be used either as such or in combination with phenolic antioxidants.

[0120] An exemplary aromatic amine antioxidant include alkylated and non-alkylated aromatic anilines, such as aromatic monoamines of the formula

$$R^1 R^2 R^3 N,$$

wherein:

- $R^1$ is an aliphatic, aromatic or substituted aromatic group;
- $R^2$ is an aromatic or a substituted aromatic group;
- $R^3$ is H, alkyl, aryl or $R^4 S(0)xR^5$;
- $R^4$ is an alkylene, alkenylene, or aralkylene group;
R<sup>5</sup> is a higher alkyl group, or an alkenyl, aryl, or alkaryl group; and
x is 0, 1 or 2.

[0121] The aliphatic group R<sup>1</sup> may contain from 1 to about 20 carbon atoms (e.g. from about 6 to 12 carbon atoms). The aliphatic group may be a saturated aliphatic group. In certain
embodiments, both R<sup>1</sup> and R<sup>2</sup> are aromatic or substituted aromatic groups, and the aromatic group
may be a fused ring aromatic group such as naphthyl. Aromatic groups R<sup>1</sup> and R<sup>2</sup> may be joined
together with other groups such as S.

[0122] The aminic antioxidant may be an aromatic amine antioxidant, such as an
phenyl-a-naphthyl amine (e.g., Irganox® L06) which is described by the following chemical
structure:

\[
\text{HN} \begin{array}{c}
\text{(R')n} \\
\end{array}
\begin{array}{c}
\text{phenyl} \\
\end{array}
\begin{array}{c}
\text{naphthyl} \\
\end{array}
\]  

wherein:

R<sup>2</sup> is hydrogen or a C<sub>1</sub> to C<sub>14</sub> linear or C<sub>3</sub> to C<sub>14</sub> branched alkyl group; and
n is an integer ranging from 1 to 5 (e.g. 1).

[0123] In certain embodiments, at least one of: R<sup>2</sup> is C<sub>1</sub> to C<sub>10</sub> linear or C<sub>3</sub> to C<sub>10</sub> branched alkyl
group; n is 1; or a combination thereof,

[0124] In another embodiment, R<sup>2</sup> is a linear or branched C<sub>6</sub> to C<sub>10</sub>.

[0125] In certain embodiments, the aromatic amine antioxidant can have at least 6 carbon atoms
substituted with an alkyl groups. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl,
and decyl. In an embodiments, the aliphatic groups will not contain more than about 14 carbon
atoms. Additional amine antioxidants include diphenylamines, phenyl naphthylamines,
phenothiazines, imidodibenzyls, and diphenyl phenylene diamines. In a particular embodiment, a
mixture of two or more (e.g., 2, 3, 4, 5, or more) aromatic amine antioxidants are present in the
lubricating composition. Polymeric amine antioxidants can also be used. Particular examples of
aromatic amine antioxidants useful in the composition of the present disclosure include: \( \rho,\rho' \)-
diocetylphenylamine; t-octylphenyl-alpha-naphthylamine; phenyl-alphanaphthylamine; and
p-octylphenyl-alpha-naphthylamine.
Further examples of amine-based antioxidants include dialkyldiphenylamines, such as p,p'-dioctyldiphenylamine (manufactured by the Seiko Kagaku Co. under the trade designation "Nonflex OD-3"), p,p'-di-alpha-methylbenzyl- diphenylamine and N-p-butyldiphenyl-N-p' octyldiphenylamine; monoalkyldiphenylamines, such as mono-t-butylidiphenylamine, and monooctyldiphenylamine; bis(dialkylphenyl)amines such as di(2,4-diethylyphenyl)amine and di(2-ethyl-4-nonylphenyl)amine; alkylphenyl-1-naphthylamines, such as octylphenyl-1-naphthylamine and N-t-dodecylphenyl-1-naphthylamine; arylnaphthylamines, such as 1-naphthylamine, phenyl-1-naphthylamine, phenyl-2-naphthylamine, N-hexylphenyl-2-naphthylamine and N-octylphenyl-2-naphthylamine, phenylenediamines such as N,N'-diisopropyl-p-phenylenediamine and N,N' diphenyl-p-phenylenediamine, and phenothiazines such as phenothiazine (manufactured by the Hodogaya Kagaku Co.: Phenothiazine) and 3,7-dioctyldiphenothiazine.

A sulfur-containing antioxidant may be any and every antioxidant containing sulfur, for example, including dialky thiodipropionates such as dilaury thiodipropionate and distearyl thiodipropionate, dialkyldithiocarbamic acid derivatives (excluding metal salts), bis(3,5-di-t-butyl-4-hydroxybenzyl)sulfide, mercaptobenzothiazole, reaction products of phosphorus pentoxide and olefins, and dicetyl sulfide. For example, the sulfur-containing antioxidant is a dialky thiodipropionate, such as dilaury thiodipropionate and distearyl thiodipropionate.

Additional examples of sulphur-based antioxidants include dialkysulphides, such as didodecylsulphide and dioctadecylsulphide; thiodipropionic acid esters, such as didodecyl thiodipropionate, dioctadecyl thiodipropionate, dimyristyl thiodipropionate and dodecyl-octadecyl thiodipropionate, and 2-mercaptobenzimidazole. In an embodiment, the antioxidant is a sulfurized alkyl phenols, or an alkali or alkaline earth metal salt thereof.

In certain embodiments, the lubricating composition includes at least one aminic antioxidant (e.g., 1, 2, 3, 4, 5, or more) present in an amount equal to or less than about 6 wt%, equal to or less than about 5.75 wt%, equal to or less than about 5.5 wt%, equal to or less than about 5.25 wt%, equal to or less than about 5 wt%, equal to or less than about 4.75 wt%, equal to or less than about 4.5 wt%, equal to or less than about 4.25 wt%, equal to or less than about 4 wt%, equal to or less than about 3.75 wt%, equal to or less than about 3.5 wt%, equal to or less than about 3.25 wt%, equal to or less than about 3 wt%, equal to or less than about 2.75 wt%, equal to or less than about 2.5 wt%, equal to or less than about 2.25 wt%, equal to or less than about 2 wt%, equal to or less than about 1.75 wt%, equal to or less than about 1.5 wt%, equal to or less than about 1.25 wt%, equal to or less than about 1 wt%, equal to or less than about 0.75 wt%, equal to or less than about
0.50 wt%, or equal to or less than about 0.25 wt% on an as-received basis. For example, the aminic antioxidant or antioxidants may be present in an amount of about 0.1 wt% to about 6 wt%, about 0.1 wt% to about 5 wt%, about 0.1 wt% to about 4 wt%, about 0.1 wt% to about 3 wt%, about 0.1 wt% to about 2 wt%, about 0.1 wt% to about 1.5 wt%, about 0.1 wt% to about 1 wt%, about 0.1 wt% to about 0.75 wt%, about 0.1 wt% to about 0.5 wt%, about 0.2 wt% to about 6 wt%, about 0.2 wt% to about 5 wt%, about 0.2 wt% to about 4 wt%, about 0.2 wt% to about 3 wt%, about 0.2 wt% to about 2 wt%, about 0.2 wt% to about 1.5 wt%, about 0.2 wt% to about 1 wt%, about 0.2 wt% to about 0.75 wt%, about 0.2 wt% to about 0.5 wt%, about 0.3 wt% to about 6 wt%, about 0.3 wt% to about 5 wt%, about 0.3 wt% to about 4 wt%, about 0.3 wt% to about 3 wt%, about 0.3 wt% to about 2 wt%, about 0.3 wt% to about 1.5 wt%, about 0.3 wt% to about 1 wt%, about 0.3 wt% to about 0.75 wt%, about 0.3 wt% to about 0.5 wt%, about 0.5 wt% to about 6 wt%, about 0.5 wt% to about 5 wt%, about 0.5 wt% to about 4 wt%, about 0.5 wt% to about 3 wt%, about 0.5 wt% to about 2 wt%, about 0.5 wt% to about 1.5 wt%, about 0.5 wt% to about 1 wt%, about 0.5 wt% to about 0.75 wt%, about 0.5 wt% to about 0.5 wt%, about 1 wt% to about 6 wt%, about 1 wt% to about 5 wt%, about 1 wt% to about 4 wt%, about 1 wt% to about 3 wt%, about 2 wt% to about 6 wt%, about 2 wt% to about 5 wt%, about 2 wt% to about 4 wt%, about 3 wt% to about 6 wt%, about 3 wt% to about 5 wt%, about 4 wt% to about 6 wt%, or about 5 wt% to about 6 wt% on an as-received basis.

Other oxidation inhibitors that have proven useful in lubricating compositions are chlorinated aliphatic hydrocarbons such as chlorinated wax; organic sulfides and polysulfides such as benzyl disulfide, bis(chlorobenzyl)disulfide, dibutyl tetrasulfide, sulfurized methyl ester of oleic acid, sulfurized alkylphenol, sulfurized dipentene, and sulfurized terpene; phosphosulfurized hydrocarbons such as the reaction product of a phosphorus sulfide with turpentine or methyl oleate, phosphorus esters including principally dihydrocarbon and trihydrocarbon phosphites such as dibutyl phosphite, diheptyl phosphite, dicyclohexyl phosphite, pentyphenyl phosphite, dipentylphenyl phosphite, tridecyl phosphite, distearyl phosphite, dimethyl naphthyl phosphite, oleyl 4-pentylphenyl phosphite, polypropylene (molecular weight 500)-substituted phenyl phosphite, diisobutyl-substituted phenyl phosphite; metal thio carbamates, such as zinc dioctylthiocarbamate, and barium heptylphenyl dithiocarbamate; Group II metal phosphorodithioates such as zinc dicyclohexylphosphorodithioate, zinc dioctylphosphorodithioate, barium di(heptylphenyl)phosphorodithioate, cadmium dinonylphosphorodithioate, and the reaction of
phosphorus pentasulfide with an equimolar mixture of isopropyl alcohol, 4-methyl-2-pentanol, and n-hexyl alcohol.

[0131] Another class of antioxidants which may be used in the lubricating oil compositions disclosed herein are oil soluble copper compounds. Any oil soluble suitable copper compound may be blended into the lubricating composition. Examples of suitable copper antioxidants include copper dihydrocarbyl thio- or dithio-phosphates and copper salts of carboxylic acid (naturally occurring or synthetic). Other suitable copper salts include copper dithiocarbamates, sulphonates, phenates, and acetylacetones. Basic, neutral, or acidic copper Cu(I) and or Cu(II) salts derived from alkenyl succinic acids or anhydrides are known to be particularly useful.

[0132] In an embodiment, the antioxidants includes hindered phenols, arylamines, or a combination thereof. These antioxidants may be used individually by type or in combination with one another.

[0133] Pour Point Depressant(s). In other embodiments, the lubricating composition comprises at least one pour point depressant or a lube oil flow improver. Pour point depressant may be added to lower the minimum temperature at which the fluid will flow or can be poured. Any pour point depressant or lube oil flow improved that is known or that becomes known in the art may be utilized in the lubricating composition of the present disclosure. In certain embodiments, the pour point depressant includes at least one (e.g., 1, 2, 3, 4, or more) pour point depressant or lube oil flow improver, such as at least one of alkylated naphthalenes polymethacrylates (e.g., copolymers of various chain length alkyl methacrylates), polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, terpolymers of dialkyllfumarates, vinyl esters of fatty acids, allyl vinyl ethers, or combinations thereof. U.S. Patent Nos. 1,815,022; 2,015,748; 2,191,498; 2,387,501; 2,655,479; 2,666,746; 2,721,877; 2,721,878; and 3,250,715 describe useful pour point depressants and/or the preparation thereof. The pour point depressant or depressants may be present in an amount equal to or less than about 5 wt%, for example about 0.01 to about 1.5 wt%. For example, the pour point depressant or depressants may be present in an amount equal to or less than about 5 wt%, equal to or less than about 4.75 wt%, equal to or less than about 4.5 wt%, equal to or less than about 4.25 wt%, equal to or less than about 4 wt%, equal to or less than about 3.75 wt%, equal to or less than about 3.5 wt%, equal to or less than about 3.25 wt%, equal to or less than about 3 wt%, equal to or less than about 2.75 wt%, equal to or less than about 2.5 wt%, equal to or less than about 2.25 wt%, equal to or less than about 2 wt%, equal to or less than about 1.75 wt%, equal to or less than about 1.5 wt%, equal to or less than about
1.25 wt%, equal to or less than about 1 wt%, equal to or less than about 0.75 wt%, equal to or less than about 0.50 wt%, or equal to or less than about 0.25 wt% of the lubricating composition. For example, the pour point depressant or depressants may be present in an amount of about 0.1 wt% to about 5 wt%, about 0.1 wt% to about 4 wt%, about 0.1 wt% to about 3 wt%, about 0.1 wt% to about 2 wt%, about 0.1 wt% to about 1.5 wt%, about 0.1 wt% to about 1 wt%, about 0.1 wt% to about 0.75 wt%, about 0.1 wt% to about 0.5 wt%, about 0.1 wt% to about 0.25 wt% to about 4 wt%, about 0.2 wt% to about 3 wt%, about 0.2 wt% to about 2 wt%, about 0.2 wt% to about 1.5 wt%, about 0.2 wt% to about 1 wt%, about 0.2 wt% to about 0.75 wt%, about 0.2 wt% to about 0.5 wt%, about 0.2 wt% to about 0.25 wt% to about 4 wt%, about 0.3 wt% to about 3 wt%, about 0.3 wt% to about 2 wt%, about 0.3 wt% to about 1.5 wt%, about 0.3 wt% to about 1 wt%, about 0.3 wt% to about 0.75 wt%, about 0.3 wt% to about 0.5 wt%, about 0.5 wt% to about 5 wt%, about 0.5 wt% to about 3 wt%, about 0.5 wt% to about 2 wt%, about 0.5 wt% to about 1.5 wt%, about 0.5 wt% to about 1 wt%, about 0.5 wt% to about 0.75 wt%, about 0.5 wt% to about 0.5 wt%, about 0.5 wt% to about 0.25 wt% to about 4 wt%, about 0.5 wt% to about 3 wt%, about 0.5 wt% to about 2 wt%, about 0.5 wt% to about 1.5 wt%, about 0.5 wt% to about 1 wt%, about 0.5 wt% to about 0.75 wt%, about 0.5 wt% to about 0.5 wt%, about 0.5 wt% to about 0.25 wt% to about 4 wt%, about 0.75 wt% to about 0.5 wt%, about 0.75 wt% to about 0.25 wt% to about 4 wt%, about 1 wt% to about 3 wt%, about 2 wt% to about 5 wt%, about 2 wt% to about 4 wt%, or about 3 wt% to about 5 wt% of the lubricating composition.

[0134] Seal Compatibility Agent(s). In other embodiments, the lubricating composition comprises at least one (e.g., 1, 2, 3, 4, or more) seal compatibility agent. The seal compatibility agent(s) may be added to help swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Any seal compatibility agent that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. For example, the seal compatibility agent or agents may include at least one of organic phosphates, aromatic esters, aromatic hydrocarbons, esters (e.g. butylbenzyl phthalate), polybutenyl succinic anhydride, or sulfolane-type seal swell agents (e.g. Lubrizol 730-type seal swell additives), or combinations thereof. Although their presence is not required to obtain the benefit of the present disclosure, seal compatibility additives may be present in an amount of zero to about 3 weight percent (e.g., about 0.01 to about 2 weight percent) of the lubricating composition.

[0135] Antifoam Agent(s). In other embodiments, the lubricating composition comprises at least one (e.g., 1, 2, 3, 4, or more) antifoam agent. The antifoam agent(s) may be added to retard the formation of stable foams. Any antifoam agent that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. Foam inhibitors include polymers of alkyl methacrylate especially useful poly alkyl acrylate polymers where alkyl may be understood to be
methyl, ethyl propyl, isopropyl, butyl, or iso butyl and polymers of dimethylsilicone which form materials called dimethylsiloxane polymers in the viscosity range of 100 cSt to 100,000 cSt. Silicone polymers, which have been post reacted with various carbon containing moieties, are the most widely used defoamers. Organic polymers are sometimes used as defoamers although much higher concentrations are required.

[0136] Antifoam agents are commercially available and may be used in conventional minor amounts along with other additives such as demulsifiers. Although their presence is not required to obtain the benefit of the present disclosure, the antifoam agent or agents may be present in a combined amount less than 1 weight percent (e.g. less than 0.1 weight percent) of the lubricating composition.

[0137] Demulsifier(s) In other embodiments, the lubricating composition comprises at least one (e.g., 1, 2, 3, 4, or more) demulsifier. The demulsifier may be added to separate emulsions (e.g., water-in-oil). Any demulsifier that is known or that becomes know may be utilized in the lubricating composition of the present disclosure. An illustrative demulsifying component is described in EP-A-330,522. This exemplary demulsifying agent is obtained by reacting an alkylene oxide with an adduct obtained by reaction of a bis-epoxide with a polyhydric alcohol. Demulsifiers are commercially available and may be used in conventional minor amounts along with other additives such as antifoam agents. Although their presence is not required to obtain the benefit of the present disclosure, the emulsifier or emulsifiers may be present a combined amount less than 1 weight percent (e.g. less than 0.1 weight percent).

[0138] In certain embodiments, the demulsifying agent includes at least one of alkoxylated phenols, phenol-formaldehyde resins, synthetic alkylaryl sulfonates (such as metallic dinonylnaphthalene sulfonates), or a combination thereof. In an embodiment, a demulsifying agent is a predominant amount of a water-soluble polyoxyalkylene glycol having a pre-selected molecular weight of any value in the range of between about 450 and about 5000 or more. In an embodiment, the water soluble polyoxyalkylene glycol demulsifier may also be one produced from alkoxylation of n-butanol with a mixture of alkylene oxides to form a random alkoxyalted product.

[0139] Polyoxyalkylene glycols useful in the present disclosure may be produced by a well-known process for preparing polyalkylene oxide having hydroxy end-groups by subjecting an alcohol or a glycol ether and one or more alkylene oxide monomers, such as ethylene oxide, butylene oxide, or propylene oxide, to form block copolymers in addition polymerization, while employing a strong base, such as potassium hydroxide as a catalyst. In such a process, the
polymerization is commonly carried out under a catalytic concentration of about 0.3 to about 1.0% by mole of potassium hydroxide to the monomer(s) and at high temperature of about 100°C to about 160°C. It is well known that the catalyst potassium hydroxide is, for the most part, bonded to the chain-end of the produced polyalkylene oxide in a form of alkoxide in the polymer solution so obtained.

The soluble polyoxyalkylene glycol emulsifier(s) useful in the compositions of the present disclosure may also be one produced from alkoxylation of n-butanol with a mixture of alkyene oxides to form a random alkoxylated product.

Corrosion Inhibitor or Anti-rust Additive. In other embodiments, the lubricating composition comprises at least one (e.g. 1, 2, 3, 4, or more) corrosion inhibitor or anti-rust additive. The corrosion inhibitor or anti-rust additive may be added to protect lubricated metal surfaces against chemical attack by water or other contaminants. A wide variety of corrosion inhibitors are commercially available, and any corrosion inhibitor or anti-rust additive that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. In an embodiment, the corrosion inhibitor can be a polar compound that wets the metal surface protecting it with a film of oil. In another embodiment, the anti-rust additive may absorb water by incorporating it in a water-in-oil emulsion so that only the oil touches the surface. In yet a further embodiment, the corrosion inhibitor chemically adheres to the metal to produce a non-reactive surface. In certain embodiments, the anti-rust additive or corrosion inhibitor is at least one zinc dithiophosphates, metal phenolates, basic metal sulfonates, a fatty acid, a fatty acid mixture, amines, or a combination thereof.

Antirust additives may include (short-chain) alkenyl succinic acids, partial esters thereof and nitrogen-containing derivatives thereof; and synthetic alkarylsulfonates, such as metal dinonylnaphthalene sulfonates. Antirust agents include, for example, monocarboxylic acids which have from 8 to 30 carbon atoms, alkyl or alkenyl succinates or partial esters thereof, hydroxy-fatty acids, which have from 12 to 30 carbon atoms and derivatives thereof, sarcosines which have from 8 to 24 carbon atoms and derivatives thereof, amino acids and derivatives thereof, naphthenic acid and derivatives thereof, lanolin fatty acid, mercapto-fatty acids, and/or paraffin oxides.

Examples of monocarboxylic acids (C8-C30), include, for example, caprylic acid, pelargonic acid, decanoic acid, undecanoic acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, behenic acid, cerotic acid, montanic acid, melissic acid, oleic acid, docosanic acid, erucic acid, eicosenic acid, beef tallow fatty acid, soy bean fatty acid, coconut oil fatty acid, linolic
acid, linoleic acid, tall oil fatty acid, 12-hydroxystearic acid, laurylsarcosinic acid, myristylsarcosinic acid, palmitylsarcosinic acid, stearylsarcosinic acid, oleylsarcosinic acid, alkylated (C8-C20) phenoxyacetic acids, lanolin fatty acid, and C8-C24 mercapto-fatty acids.

[0144] Examples of polybasic carboxylic acids include, for example, the alkenyl (C10-C18) succinic acids indicated in CAS No. 27859-58-1 and ester derivatives thereof, dimer acid, N-acyl-N-alkyloxyalkyl aspartic acid esters (U.S. Patent No. 5,275,749).

[0145] Examples of the alkylamines that function as antirust additives or as reaction products with the above carboxylates to give amides and the like are represented by primary amines, such as laurylamine, coconut-amine, n-tridecylamine, myristylamine, n-pentadecylamine, n-heptadecylamine, stearylamine, n-nonadecylamine, n-eicosylamine, n-heneicosylamine, n-docosylamine, n-tricosylamine, n-pentacosylamine, oleylamine, beef tallow-amine, hydrogenated beef tallow-amine and soy bean-amine. Examples of the secondary amines include dilaurylamine, di-coconut-amine, di-n-tridecylamine, dimyristylamine, di-n-pentadecylamine, dipalmitylamine, di-n-pentadecylamine, distearylamine, di-n-nonadecylamine, di-n-eicosylamine, di-n-heneicosylamine, di-n-docosylamine, di-n-tricosylamine, di-n-pentacosyl-amine, dioleylamine, di-beef tallow-amine, di-hydrogenated beef tallow-amine and di-soy bean-amine.

[0146] Examples of the aforementioned N-alkylpolyalkyenediamines include: ethylenediamines, such as laurylethylenediamine, coconut ethylenediamine, n-tridecylethylenediamine- , myristylethylenediamine, n-pentadecylethylenediamine, palmitylethylenediamine, n-heptadecylethylenediamine, stearylethylenediamine, n-nonadecylethylenediamine, n-eicosylethylenediamine, n-heneicosylethylenediamine, n-docosylethylenediamine, n-tricosylethylenediamine, n-pentacosylethylenediamine, oleylethylenediamine, beef tallow-ethylenediamine, hydrogenated beef tallow-ethylenediamine and soy bean-ethylenediamine; propylenediamines such as laurylpropylenediamine, coconut propylenediamine, n-tridecylpropylenediamine, myristylpropylenediamine, n-pentadecylpropylenediamine, palmitylpropylenediamine, n-heptadecylpropylenediamine, stearylpropylenediamine, n-nonadecylpropylenediamine, n-eicosylpropylenediamine, n-heneicosylpropylenediamine, n-docosylpropylenediamine, n-tricosylpropylenediamine, n-pentacosylpropylenediamine, diethylene triamine (DETA) or triethylene tetramine (TETA), oleylpropylenediamine, beef tallow-propylenediamine, hydrogenated beef tallow-propylenediamine and soy bean-propylenediamine; butylenediamines such as laurylbutylenediamine, coconut butylenediamine, n-tridecylbutylenediamine- , myristylbutylenediamine, n-pentadecylbutylenediamine,
stearylbutylenediamine, n-eicosylbutylenediamine, n-heneicosylbutylenediamine, n-docosylbutylenediamine, n-tricosylbutylenediamine, n-pentacosylbutylenediamine, oleylbutylenediamine, beef tallow-butylenediamine, hydrogenated beef tallow-butylenediamine and soybean butylenediamine; and pentylenediamines such as laurylpentylenediamine, coconut pentylenediamine, myristylpentylenediamine, palmitylpentylenediamine, stearyl pentylenediamine, oleylpentylenediamine, beef tallow-pentylenediamine, hydrogenated beef tallow-pentylenediamine and soybean pentylenediamine.

The corrosion inhibitor or anti-rust additive may be present in an amount equal to or less than about 5 wt%, for example about 0.01 to 5 wt%, on an as-received basis. For example, the corrosion inhibitor may be present in an amount equal to or less than 4 wt%, equal or less than 3 wt%, equal to or less than 2 wt%, or equal to or less than 1 wt% on an as-received basis. By way of further example, the corrosion inhibitor may be present in an amount of about 0.01 to about 5 wt%, about 0.01 to about 4 wt%, about 0.01 to about 3 wt%, about 0.01 to about 2 wt%, about 0.05 to about 5 wt%, about 0.05 to about 4 wt%, about 0.05 to about 3 wt%, about 0.05 to about 2 wt%, about 0.1 to about 5 wt%, about 0.1 to about 4 wt%, about 0.1 to about 3 wt%, about 0.1 to about 2 wt%, about 1 to about 5 wt%, about 1 to about 4 wt%, about 1 to about 3 wt%, about 2 to about 5 wt%, about 2 to about 4 wt%, or about 3 to about 5 wt%, on an as-received basis.

Metal Passivator(s), Deactivator(s) and Corrosion Inhibitor(s). This type of component includes 2,5-dimercapto-1,3,4-thiadiazoles and derivatives thereof, mercaptobenzothiazoles, alkyltriazoles and benzotriazoles. Examples of dibasic acids useful as anti-corrosion agents, other than sebacic acids, which may be used in the present disclosure, are adipic acid, azelaic acid, dodecanedioic acid, 3-methyladipic acid, 3-nitrophthalic acid, 1,10-decanedicarboxylic acid, and fumaric acid. The anti-corrosion combination is a straight or branch-chained, saturated or unsaturated monocarboxylic acid or ester thereof which may optionally be sulphurized in an amount up to 35% by weight. In an embodiment, the acid is a C4 to C22 straight chain unsaturated monocarboxylic acid. The monocarboxylic acid may be a sulphurized oleic acid. However, other suitable materials are oleic acid itself, valeric acid and erucic acid. A component of the anti-corrosion combination is a triazole as previously defined. In an embodiment, the triazole is tolyltriazole, which may be included in the compositions of the disclosure include triazoles, thiazoles and certain diamine compounds which are useful as metal deactivators or metal passivators. Examples include triazole, benzotriazole and substituted benzotriazoles, such as alkyl substituted derivatives. The alkyl substituent may contain up to 1.5 carbon atoms, e.g. up to 8
carbon atoms. The triazoles may contain other substituents on the aromatic ring such as halogens, nitro, amino, mercapto, etc. Examples of suitable compounds are benzotriazole and the tolyltriazoles, ethylbenzotriazoles, hexylbenzotriazoles, octylbenzotriazoles, chlorobenzotriazoles and nitrobenzotriazoles. In a particular embodiment, the compound is benzotriazole and/or tolyltriazole.

**Illustrative substituents include, for example,** alkyl that is straight or branched chain, for example, methyl, ethyl, n-propyl, iso-propyl, n-butyl, sec-butyl, n-pentyl, n-hexyl, n-heptyl, n-octyl, 2-ethylhexyl, n-nonyl, n-decyl, n-dodecyl, n-tetradecyl, n-hexadecyl, n-octadecyl or n-eicosyl; alkenyl that is straight or branched chain, for example, prop-2-enyl, but-2-enyl, 2-methyl-prop-2-enyl, pent-2-enyl, hexa-2,4-dienyl, dec-10-enyl or eicos-2-enyl; cycoalkyl that is, for example, cyclopentyl, cyclohexyl, cyclooctyl, cyclodecyl, adamantyl or cyclododecyl; aralkyl that is, for example, benzyl, 2-phenylethyl, benzhydryl or naphthylmethyl; aryl that is, for example, phenyl or naphthyl; heterocyclic group that is, for example, a morpholine, pyrrolidine, piperidine or a perhydroazepine ring; alkylene moieties that include, for example, methylene, ethylene, 1:2- or 1:3-propylene, 1:4-butylene, 1:6-hexylene, 1:8-octylene, 1:10-decylene and 1:12-dodecylene.

**Illustrative arylene moieties include, for example,** phenylene and naphthylene. l-(or 4)-(dimethylaminomethyl) triazole, l-(or 4)-(diethyldimethyl methyl) triazole, l-(or 4)-(di-isopropylaminomethyl) triazole, l-(or 4)-(di-n-butylaminomethyl) triazole, l-(or 4)-(di-n-hexylaminomethyl) triazole, l-(or 4)-(di-isooctylaminomethyl) triazole, l-(or 4)-(di-(2-ethylhexyl)aminomethyl) triazole, l-(or 4)-(di-n-decylaminomethyl) triazole, l-(or 4)-(di-n-dodecylaminomethyl) triazole, l-(or 4)-(di-n-octadecylaminomethyl) triazole, l-(or 4)-(di-n-eicosylaminomethyl) triazole, l-(or 4)-(di-prop-2'-enyl)aminomethyl triazole, l-(or 4)-(di-but-2'-enyl)aminomethyl triazole, l-(or 4)-(di-eicos-2'-enyl)aminomethyl triazole, l-(or 4)-(di-cyclohexylaminomethyl) triazole, l-(or 4)-(di-benzylaminomethyl) triazole, l-(or 4)-(di-phenylaminomethyl) triazole, l-(or 4)-(4'-morpholinomethyl) triazole, l-(or 4)-(1-phenylidinomethyl) triazole, l-(or 4)-(1'-piperidinomethyl) triazole, l-(or 4)-(1'-perhydridoazepinomethyl) triazole, l-(or 4)-(2',2'-dihydroxyethyl)aminomethyl triazole, l-(or 4)-(dibutoxypropyl-aminomethyl) triazole, l-(or 4)-(dibutythiopropyl-aminomethyl) triazole, l-(or 4)-(di-butyloxypropyl-aminomethyl) triazole, l-(or 4)-(1-methanomine)-N,N-bis(2-ethylhexyl)-methyl benzotriazole, N,N-bis-(l- or 4-triazolylmethyl) laurylamine, N,N-bis-(l- or 4-triazolylmethyl) oleylamine, N,N-bis-(l- or 4-triazolylmethyl) ethanolamine and N,N,N',N'-tetra(l- or 4-triazolylmethyl) ethylene diamine.
The metal deactivating agents which can be used in the lubricating composition of the present disclosure includes, for example, benzotriazole and the 4-alkylbenzotriazoles such as 4-methylbenzotriazole and 4-ethylbenzotriazole; 5-alkylbenzotriazoles such as 5-methylbenzotriazole, 5-ethylbenzotriazole; 1-alkylbenzotriazoles such as 1-dioctylaminomethyl-2,3-benzotriazole; benzotriazole derivatives such as the 1-alkyltoluatriazoles, for example, 1-dioctylaminomethyl-2,3-tolotriazole; benzimidazole and benzimidazole derivatives such as 2-(alkyldithio)-benzimidazoles, for example, such as 2-(octyldithio)-benzimidazole, 2-(decyldithio)benzimidazole and 2-(dodecylthi dithio)-benzimidazole; 2-(alkyldithio)-toluimidazoles such as 2-(octyldithio)-toluimidazole, 2-(decyldithio)-toluimidazole and 2-(dodecylthi dithio)-toluimidazole; indazole and indazole derivatives of toluimidazoles such as 4-alkylindazole, 5-alkylindazole; benzothiazole, 2-mercaptobenzothiazole derivatives (manufactured by the Chiyoda Kagaku Co. under the trade designation "Thiolite B-3100") and 2-(alkyldithio)benzothiazoles such as 2-(hexyldithio)benzothiazole and 2-(octyldithio)benzothiazole; 2-(alkyl-dithio)toluthiazoles such as 2-(benzylldithio)toluthiazole and 2-(octyldithio)toluthiazole, 2-(N,N-dialkylldithiocarbamyl)benzothiazoles such as 2-(N,N-diethyldithiocarbamyl)benzothiazole, 2-(N,N-dibutylldithiocarbamyl)- benzotriazole and 2,N,N-dihexyl-dithiocarbamylbenzotriazole; benzothiazole derivatives of 2-(N,N-dialkylldithiocarbamyl)toluthiazoles such as 2-(N,N-diethylldithiocarbamyl)toluthiazole, 2-(N,N-dibutylldithiocarbamyl)toluthiazole and 2-(dodecylthi dithio)benzothiazole; 2-(alkylldithio)benzoxazoles such as 2-(octyldithio)benzoxazo le, 2-(decyldithio)benzoxazole and 2-(dodecylthi dithio)benzoxazole; benzoxazole derivatives of 2-(alkyldithio)toloxyzoles such as 2-(octyldithio)toloxyzole, 2-(de cyldithio)toloxyzole, 2-(dodecylthi dithio)toloxyzole; 2,5-bis(alkyldithio)-1,3,4-thiadiazoles such as 2,5-bis(heptyldithio)-1,3,4-thiadiazole, 2,5-bis-(nonylldithio)-1,3,4-thiadiazole, 2,5-bis(dodecylthi dithio)-1,3,4-thiadiazole and 2,5-bis-(octadecylthi dithio)-1,3,4-thiadiazole; 2,5-bis(N,N-dialkyl-dithiocarbamyl)-1,3,4-thiadiazoles such as 2,5-bis(N,N-diethylldithiocarbamyl)-1,3,4-thiadiazole, 2,5-bis(N,N-dibutylldithiocarbamyl)-1,3,4-thiadiazole and 2,5-bis(N,N-dioctylldithiocarbamyl)-1,3,4-thiadiazole; thia diazole derivatives of 2,N,N-dialkylldithiocarbamyl-5-mercapto-1,3,4-thiadiazoles such as 2,N,N-dibutylldithiocarbamyl-5-mercapto-1,3,4-thiadiazole and 2,N,N-dioctyl-dithiocarbamyl-5-mercapto-1,3,4-thiadiazole; or concentrates and/or mixtures thereof.
Although their presence is not required to obtain the benefit of the present disclosure, the metal deactivator(s) and corrosion inhibitor(s) may be present from zero to about 1% by weight (e.g. from 0.01% to about 0.5% by weight) of the total lubricating composition.

Additional Antiwear additive^) or inhibitors In certain embodiments, the lubricating composition comprises at least one antiwear additive or wear inhibitor. Any antiwear additive that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. In certain embodiments, the wear inhibitor is at least one of a food-grade sulfur containing compound, a food-grade phosphorus containing compound, or a combination thereof. The antiwear additive may be an alkyldithiophosphate(s), aryl phosphate(s) and/or phosphite(s). The antiwear additive(s) may be essentially free of metals, or they may contain metal salts.

In certain embodiments, the antiwear additive is a phosphoric ester or salt thereof. A phosphate ester or salt may be a monohydrocarbyl, dihydrocarbyl or a trihydrocarbyl phosphate, wherein each hydrocarbyl group is saturated. In an embodiment, each hydrocarbyl group independently contains from about 8 to about 30, or from about 12 up to about 28, or from about 14 up to about 24, or from about 14 up to about 18 carbons atoms. In an embodiment, the hydrocarbyl groups are alkyl groups. Examples of hydrocarbyl groups include at least one of tridecyl, tetradecyl, pentadecyl, hexadecyl, heptadecyl, octadecyl groups, and mixtures thereof.

A phosphate ester or salt is a phosphorus acid ester prepared by reacting at least one (e.g., 1, 2, 3, 4, or more) phosphorus acid or anhydride with a saturated alcohol. The phosphorus acid or anhydride can be an inorganic phosphorus reagent, such as phosphorus pentoxide, phosphorus trioxide, phosphorus tetroxide, phosphorous acid, phosphoric acid, phosphorus halide, lower phosphorus esters, or a phosphorus sulfide, including phosphorus pentasulfide, and the like. Lower phosphorus acid esters may contain from 1 to about 7 carbon atoms in each ester group. Alcohols used to prepare the phosphorus acid esters or salts. Examples of commercially available alcohols and alcohol mixtures include Alfol 1218 (a mixture of synthetic, primary, straight-chain alcohols containing 12 to 18 carbon atoms); Alfol 20+ alcohols (mixtures of C18 - C28 primary alcohols having mostly C20 alcohols as determined by GLC (gas-liquid-chromatography)); and Alfol22+ alcohols (C18 - C28 primary alcohols containing primarily C22 alcohols). Alfol alcohols are available from, e.g., Continental Oil Company. Another example of a commercially available alcohol mixture is Adol 60 (about 75% by weight of a straight chain C22 primary alcohol, about 15% of a C20 primary alcohol, and about 8% of C18 and C24 alcohols). The Adol alcohols are marketed by Ashland Chemical.
The antiwear additive may include at least one (e.g., a mixture of) monohydric fatty alcohol. For example, a mixture of monohydric fatty alcohols derived from naturally occurring triglycerides and ranging in chain length from C8 to C18 may be utilized as an antiwear additive. A variety of monohydric fatty alcohol mixtures are available from Procter & Gamble Company. These mixtures contain various amounts of fatty alcohols containing 12, 14, 16, or 18 carbon atoms. For example, CO-1214 is a fatty alcohol mixture containing 0.5% of C10 alcohol, 66.0% of C12 alcohol, 26.0% of C14 alcohol and 6.5% of C16 alcohol.

Another group of commercially available alcohol mixtures include the "Neodol" products available from Shell Chemical Co. For example, Neodol 23 is a mixture of C12 and C13 alcohols; Neodol 25 is a mixture of C12 to C15 alcohols; and Neodol 45 is a mixture of C14 to C15 linear alcohols. The phosphate contains from about 14 to about 18 carbon atoms in each hydrocarbyl group. The hydrocarbyl groups of the phosphate may be derived from a mixture of fatty alcohols having from about 14 up to about 18 carbon atoms. The hydrocarbyl phosphate may also be derived from a fatty vicinal diol. Fatty vicinal diols include, but not limited to, those available from Ashland Oil under the general trade designation Adol 114 and Adol 158. The former is derived from a straight chain alpha olefin fraction of C11 - C14, and the latter is derived from a C15 - C18 fraction.

Phosphate salts may be prepared by reacting an acidic phosphate ester with an amine compound or a metallic base to form an amine or a metal salt. The amines may be monoamines or polyamines. Useful amines include those amines disclosed in U.S. Patent No. 4,234,435.

Illustrative monoamines may contain a hydrocarbyl group, which contains from 1 to about 30 carbon atoms, or from 1 to about 12, or from 1 to about 6. Examples of primary monoamines useful in the present disclosure include methylamine, ethylamine, propylamine, butylamine, cyclopentylamine, cyclohexylamine, octylamine, dodecylamine, allylamine, cocoamine, stearylamine, and laurylamine. Examples of secondary monoamines include dimethylamine, diethylamine, dipropylamine, dibutylamine, dicyclopentylamine, dicyclohexylamine, methylbutylamine, ethylhexylamine, etc.

An amine may be a fatty (C8 - C30) amine which includes n-octylamine, n-decylamine, n-dodecylamine, n-tetradecylamine, n-hexadecylamine, n-octadecylamine, oleylamine, etc. Also useful fatty amines include commercially available fatty amines, such as "Armeen" amines (products available from Akzo Chemicals, Chicago, 111), e.g. Armeen C, Armeen O, Armeen OL, Armeen T, Armeen HT, Armeen S and Armeen SD, wherein the letter designation relates to the fatty group, such as coco, oleyl, tallow, or stearyl groups.
Other useful amines include primary ether amines, such as those represented by the formula:

\[ R'(OR')_x NH_2, \]

wherein:
- \( R' \) is a divalent alkylen group having about 2 to about 6 carbon atoms;
- \( x \) is a number from one to about 150, or from about one to about five, or one; and
- \( R'' \) is a hydrocarbyl group of about 5 to about 150 carbon atoms.

An exemplary or illustrative ether amine is available under the name SURFAM® amines produced and marketed by Mars Chemical Company, Atlanta, Ga. Additional exemplary ether amines include those identified as SURFAM P14B (decyloxypropylamine), SURFAM P16A (linear C16), and SURFAM P17B (tridecyloxypropylamine). The carbon chain lengths (i.e., C14, etc.) of the SURFAM ether amines described above and used hereinafter are approximate and include the oxygen ether linkage.

A further illustrative amine is a tertiary-aliphatic primary amine. For example, the aliphatic group, such as an alkyl group, contains from about 4 to about 30, or from about 6 to about 24, or from about 8 to about 22 carbon atoms. Usually the tertiary alkyl primary amines are monoamines the alkyl group is a hydrocarbyl group containing from one to about 27 carbon atoms. Such amines are illustrated by tert-butylamine, tert-hexylamine, 1-methyl-1- amino-cyclohexane, tert-octylamine, tert-decylamine, tert-dodecylamine, tert-tetradecylamine, tert-hexadecylamine, tert-octadecylamine, tert-tetacosanylaminate, tert-octacosanamylamine, and combinations thereof. Mixtures of tertiary aliphatic amines may also be used in preparing the phosphate salt. Illustrative of amine mixtures of this type are "Primene 81R", which is a mixture of C11-C14 tertiary alkyl primary amines, and "Primene JMT", which is a similar mixture of C18-C22 tertiary alkyl primary amines (both are available from Rohm and Haas Company). The tertiary aliphatic primary amines and methods for their preparation are known to those of ordinary skill in the art.

Another illustrative amine is a heterocyclic polycrime. The heterocyclic polyamines include aziridines, azetidines, azolidines, tetra- and dihydropyridines, pyrroles, indoles, piperidines, imidazoles, di- and tetra-hydroimidazoles, piperazines, isoindoles, purines, morpholines, thiomorpholines, N-aminoalkylmorpholines, N-aminoalkylthiomorpholines, N-aminoalkylpipersazines, N,N' -diaminoalkylpipersazines, azepines, azocines, azonines, azecines and tetra-, di- and perhydro derivatives of each of the above, and mixtures of two or more (e.g., 2, 3, 4, 5, 6, or more) of these heterocyclic amines. In certain embodiments, the heterocyclic amines are saturated 5- and
6-membered heterocyclic amines containing only nitrogen, oxygen and/or sulfur in the hetero ring, especially the piperidines, piperazines, thiomorpholines, morpholines, pyrrolidines, and the like. Piperidine, aminooalkyl substituted piperidines, piperazine, aminooalkyl substituted piperazines, morpholine, aminooalkyl substituted morpholines, pyrrolidine, and aminoalkyl-substituted pyrrolidines, are especially preferred. Usually the aminoalkyl substituents are substituted on a nitrogen atom forming part of the hetero ring. Specific examples of such heterocyclic amines include N-aminopropylmorpholine, N-aminoethylpiperazine, and N,N'-diaminoethylpiperazine. Hydroxy heterocyclic polyamines are also useful. Examples include N-(2-hydroxyethyl)cyclohexylamine, 3-hydroxycyclopentylamine, parahydroxyaniline, N-hydroxyethylpiperazine, and the like.

[0165] The metal salts of the phosphorus acid esters may be prepared by the reaction of a metal base with the acidic phosphorus ester. The metal base may be any metal compound capable of forming a metal salt. Examples of metal bases include metal oxides, hydroxides, carbonates, sulfates, borates, or the like. The metals of the metal base include Group IA, IIA, IB through VIIB, and VIII metals (CAS version of the Periodic Table of the Elements). These metals include the alkali metals, alkaline earth metals and transition metals. In an embodiment, the metal is a Group IIA metal, such as calcium or magnesium, Group IIB metal, such as zinc, or a Group VIIIB metal, such as manganese. In particular embodiments, the metal is magnesium, calcium, manganese or zinc. Examples of metal compounds which may be reacted with the phosphorus acid include zinc hydroxide, zinc oxide, copper hydroxide, copper oxide, etc.

[0166] The lubricating composition of the present disclosure also may include a fatty imidazoline or a reaction product of a fatty carboxylic acid and at least one polyamine. The fatty imidazoline has fatty substituents containing from 8 to about 30, or from about 12 to about 24 carbon atoms. The substituent may be saturated or unsaturated, for example, heptadeceneyl derived oleyl groups. In a particular embodiment, the substituents are saturated. In one aspect, the fatty imidazoline may be prepared by reacting a fatty carboxylic acid with a polyalkylenepolyamine. The fatty carboxylic acids are can be mixtures of straight and branched chain fatty carboxylic acids containing about 8 to about 30 carbon atoms, or from about 12 to about 24, or from about 16 to about 18. Carboxylic acids include the polycarboxylic acids or carboxylic acids or anhydrides having from 2 to about 4 carbonyl groups, (e.g. 2 carbonyl groups). The polycarboxylic acids include succinic acids and anhydrides and Diels-Alder reaction products of unsaturated monocarboxylic acids with unsaturated carboxylic acids (such as acrylic, methacrylic, maleic,
fumaric, crotonic and itaconic acids). In particular embodiments, the fatty carboxylic acids are fatty monocarboxylic acids, having from about 8 to about 30, (e.g. about 12 to about 24 carbon atoms), such as octanoic, oleic, stearic, linoleic, dodecanoic, and tall oil acids. In an embodiment, the fatty carboxylic acid is stearic acid. The fatty carboxylic acid or acids are reacted with at least one polyamine. The polyamines may be aliphatic, cycloaliphatic, heterocyclic or aromatic. Examples of the polyamines include alkylene polyamines and heterocyclic polyamines.

The antiwear additive according to the present disclosure has very high effectiveness when used in low concentrations and is free of chlorine. For the neutralization of the phosphoric esters, the latter are taken and the corresponding amine slowly added with stirring. The resulting heat of neutralization is removed by cooling. The antiwear additive according to the present disclosure can be incorporated into the respective base liquid with the aid of fatty substances (e.g., tall oil fatty acid, oleic acid, etc.) as solubilizers. The base liquids used are napthenic or paraffinic base oils, synthetic oils (e.g., polyglycols, mixed polyglycols), polyolefins, carboxylic esters, etc.

In further embodiments, the lubricating compositions of the present disclosure can contain at least one phosphorus containing antiwear additive. Examples of such additives are amine phosphate antiwear additives such as that known under the trade name IRGALUBE 349 and/or triphenyl phosphorothionate antiwear additives, such as that known under the trade name IRGALUBE TPPT. Such amine phosphates may be present in an amount of from about 0.01 to about 2% (e.g. about 0.2 to about 1.5%) by weight of the lubricant composition, while such phosphorothionates are suitably present in an amount of from about 0.01 to about 3% (e.g., about 0.5 to about 1.5%) by weight of the lubricating composition. A mixture of an amine phosphate and phosphorothionate may be employed.

Neutral organic phosphates may be present in an amount from zero to about 4% (e.g., about 0.1 to about 2.5%) by weight of the lubricating composition. The above amine phosphates can be mixed together to form a single component capable of delivering antiwear performance. The neutral organic phosphate is also a conventional ingredient of lubricating oils.

Phosphates for use in the present disclosure include phosphates, acid phosphates, phosphites, and acid phosphites. The phosphates include triaryl phosphates, trialkyl phosphates, trialkylaryl phosphates, triarylalkyl phosphates, trialkenyl phosphates, or combinations thereof. As specific examples of these, referred to are triphenyl phosphate, tricresyl phosphate, benzyldiphenyl phosphate, ethylidiphenyl phosphate, tributyl phosphate, ethylidibutyl phosphate, cresylidiphenyl phosphate, dicresylphenyl phosphate, ethylphenyldiphenyl phosphate, diethylphenylphenyl

[0171] The acid phosphates include, for example, 2-ethylhexyl acid phosphate, ethyl acid phosphate, butyl acid phosphate, oleyl acid phosphate, tetracosyl acid phosphate, isodecyl acid phosphate, lauryl acid phosphate, tridecyl acid phosphate, stearyl acid phosphate, isostearyl acid phosphate, or combinations thereof.

[0172] The phosphites include, for example, triethyl phosphite, tributyl phosphite, triphenyl phosphite, tricresyl phosphite, tri(nonylphenyl) phosphite, tri(2-ethylhexyl) phosphite, tridecyl phosphite, trilauryl phosphite, triisooctyl phosphite, diphenylisodecyl phosphite, tristearyl phosphite, trioleyl phosphite, or combinations thereof.

[0173] The acid phosphites include, for example, dibutyl hydrogenphosphite, dilauryl hydrogenphosphite, dioleyl hydrogenphosphite, distearyl hydrogenphosphite, diphenyl hydrogenphosphite, or combinations thereof.

[0174] Amines that form amine salts with such phosphates include, for example, mono-substituted amines, di-substituted amines and tri-substituted amines. Examples of the mono-substituted amines include butylamine, pentylamine, hexylamine, cyclohexylamine, octylamine, laurylamine, stearylamine, oleylamine and benzylamine; and those of the di-substituted amines include dibutylamine, dipentylamine, dihexylamine, dicyclohexylamine, dioctylamine, dilaurylamine, distearylamine, dioleylamine, dibenzylamine, stearyl monoethanolamine, decyl monoethanolamine, hexyl monopropanolamine, benzyl monoethanolamine, phenyl monoethanolamine, and tolyl monopropanolamine. Examples of tri-substituted amines include tributylamine, tripentylamine, trihexylamine, tricyclohexylamine, trioctylamine, trilaurylamine, tristearylamine, trioctylamine, tribenzylamine, dioleyl monoethanolamine, dilauryl monopropanolamine, dioctyl monoethanolamine, dihexyl monopropanolamine, dibutyl monopropanolamine, oleyl diethanolamine, stearyl dipropanolamine, lauryl diethanolamine, octyl dipropanolamine, butyl diethanolamine, benzyl diethanolamine, phenyl diethanolamine, tolyl dipropanolamine, xylyl diethanolamine, triethanolamine, and tripropanolamine. Phosphates or their amine salts are added to the base oil in an amount from zero to about 5% by weight, (e.g. from about 0.1 to about 2% by weight) relative to the total weight of the lubricating composition.
Illustrative carboxylic acids to be reacted with amines include, for example, aliphatic carboxylic acids, dicarboxylic acids (dibasic acids), aromatic carboxylic acids, or combinations thereof. The aliphatic carboxylic acids have from 8 to 30 carbon atoms, and may be saturated or unsaturated, and linear or branched. Specific examples of the aliphatic carboxylic acids include pelargonic acid, lauric acid, tridecanoic acid, myristic acid, palmitic acid, stearic acid, isostearic acid, eicosanoic acid, behenic acid, triacontanoic acid, caproic acid, undecylenic acid, oleic acid, linolenic acid, erucic acid, linoleic acid, or combinations thereof. Specific examples of the dicarboxylic acids include octadecylsuccinic acid, octadecenylsuccinic acid, adipic acid, azelaic acid, sebacic acid, or combinations thereof. One example of the aromatic carboxylic acids is salicylic acid. Illustrative amines to be reacted with carboxylic acids include, for example, polyalkylene-polyamines, such as diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenexexamine, hexaethyleneheptamine, heptaethyleneoctamine, dipropylenetriamine, tetrathylene hexamethylenetetramine, hexethyleneheptamine, or combinations thereof; and alkanolamines, such as monoethanolamine and diethanolamine. Of these, preferred are a combination of isostearic acid, tetraethylenepentamine, or combinations thereof; and a combination of oleic acid and diethanolamine. Reaction products of carboxylic acids and amines may be added to the base oil in an amount of from zero to about 5% by weight (e.g. from about 0.03 to about 3% by weight) relative to the total weight of the lubricating composition.

Other illustrative antiwear additives include phosphites, thiophosphites, phosphates, and thiophosphates, including mixed materials having, for instance, one or two sulfur atoms, i.e., monothio- or dithio compounds. As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group primarily composed of carbon and hydrogen atoms and is attached to the remainder of the molecule through a carbon atom and does not exclude the presence of other atoms or groups in a proportion insufficient to detract from the molecule having a predominantly hydrocarbon character. In general, no more than two, preferably no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; typically, there will be no non-hydrocarbon substituents in the hydrocarbyl group. A more detailed definition of the terms "hydrocarbyl substituent" or "hydrocarbyl group," is described in US Patent 6,583,092.

Specific examples of some phosphites and thiophosphites within the scope of the disclosure include phosphorous acid, mono-, di- or tri-thiophosphorous acid, mono-, di- or tri-propyl phosphite or mono-, di- or tri-thiophosphite; mono-, di- or tri-butyl phosphite or mono-, di- or tri-
thiophosphite; mono-, di- or tri-amyl phosphite or mono-, di- or tri-thiophosphite; mono-, di- or tri-hexyl phosphite; or mono-, di- or tri-thiophosphite; mono-, di- or tri-phenyl phosphite; or mono-, di- or tri-thiophosphite; mono-, di- or tri-phenyl phosphite; or mono-, di- or tri-thiophosphite; mono-, di- or tri-cresyl phosphite; or mono-, di- or tri-thiophosphite; dibutyl phenyl phosphite; or mono-, di- or tri-phosphate; amyl dicresyl phosphate; or mono-, di- or tri-thiophosphite, and any of the above with substituted groups, such as chlorophenyl or chlorobutyl.

Specific examples of the phosphates and thiophosphates within the scope of the disclosure include phosphoric acid, mono-, di-, or tri-thiophosphoric acid, mono-, di-, or tri-propyl phosphate or mono-, di-, or tri-thiophosphate; mono-, di-, or tri-butyl phosphate or mono-, di-, or tri-thiophosphate; mono-, di-, or tri-amyl phosphate or mono-, di-, or tri-thiophosphate; mono-, di-, or tri-hexyl phosphate or mono-, di-, or tri-thiophosphate; mono-, di-, or tri-phenyl phosphate or mono-, di-, or tri-thiophosphate; mono-, di-, or tri-phosphate; dibutyl phenyl phosphate or mono-, di-, or tri-hexyl phosphate or mono-, di-, or tri-thiophosphate; dibutyl phenyl phosphate or mono-, di-, or tri-phosphate, amyl dicresyl phosphate or mono-, di-, or tri-thiophosphate, and any of the above with substituted groups, such as chlorophenyl or chlorobutyl.

These phosphorus compounds may be prepared by well-known reactions. For example, the reaction of an alcohol or a phenol with phosphorus trichloride or by a transesterification reaction. Alcohols and phenols can be reacted with phosphorus pentoxide to provide a mixture of an alkyl or aryl phosphoric acid and a dialkyl or diaryl phosphoric acid. Alkyl phosphates can also be prepared by the oxidation of the corresponding phosphites. Thiophosphates can be prepared by the reaction of phosphites with elemental sulfur. In any case, the reaction can be conducted with moderate heating. Moreover, various phosphorus esters can be prepared by reaction using other phosphorus esters as starting materials. Thus, medium chain (C9 to C22) phosphorus esters have been prepared by reaction of dimethylphosphite with a mixture of medium-chain alcohols by means of a thermal transesterification or an acid- or base-catalyzed transesterification. See, for example, U.S. Patent No. 4,652,416. Most such materials are also commercially available; for instance, triphenyl phosphite is available from Albright and Wilson as Duraphos TPPT™; di-n-butyl hydrogen phosphite from Albright and Wilson as Duraphos DBHP™; and triphenylthiophosphate from Ciba Specialty Chemicals as Irgalube TPPT™.

Examples of esters of the dialkylphosphorodithioic acids include esters obtained by reaction of the dialkyl phosphorodithioic acid with an alpha, beta-unsaturated carboxylic acid (e.g., methyl acrylate) and, optionally an alkylene oxide such as propylene oxide.
One or more of the above-identified metal dithiophosphates may be used from about zero to about 2% by weight (e.g., from about 0.1 to about 1% by weight) based on the weight of the total composition.

The hydrocarbyl in the dithiophosphate may be alkyl, cycloalkyl, aralkyl or alkaryl groups, or a substantially hydrocarbon group of similar structure. Illustrative alkyl groups include isopropyl, isobutyl, n-butyl, sec-butyl, the various amyl groups, n-hexyl, methylisobutyl, heptyl, 2-ethylhexyl, diisobutyl, isoctyl, nonyl, behenyl, decyl, dodecyl, tridecyl, etc. Illustrative lower alkylphenyl groups include butylphenyl, amylphenyl, heptylphenyl, etc. Cycloalkyl groups likewise are useful and these include chiefly cyclohexyl and the lower alkyl-cyclohexyl radicals. Many substituted hydrocarbon groups may also be used, e.g., chloropentyl, dichlorophenyl, and dichlorodecyl.

The phosphorodithioic acids from which the metal salts useful in this disclosure are prepared are well known. Examples of dihydrocarbonylphosphorodithioic acids and metal salts, and processes for preparing such acids and salts are found in, for example U.S. Patent Nos. 4,263,150; 4,289,635; 4,308,154; and 4,417,990. These patents are hereby incorporated by reference.

The phosphorodithioic acids may be prepared by the reaction of a phosphorus sulfide with an alcohol or phenol or mixtures of alcohols. An exemplary reaction involves four moles of the alcohol or phenol and one mole of phosphorus pentasulfide, and may be carried out within the temperature range from about 50°C to about 200°C. Thus, the preparation of 0,0-di-n-hexyl phosphorodithioic acid involves the reaction of a mole of phosphorus pentasulfide with four moles of n-hexyl alcohol at about 100°C for about two hours. Hydrogen sulfide is liberated and the residue is the desired acid. The preparation of the metal salts of these acids may be effected by reaction with metal compounds as well known in the art.

The metal salts of dihydrocarbonyldithiophosphates, which are useful in the present disclosure, include those salts containing Group I metals, Group II metals, aluminum, lead, tin, molybdenum, manganese, cobalt, and nickel. The Group II metals, aluminum, tin, iron, cobalt, lead, molybdenum, manganese, nickel and copper are among the preferred metals. Zinc and copper are especially useful metals. Examples of metal compounds which may be reacted with the acid include lithium oxide, lithium hydroxide, sodium hydroxide, sodium carbonate, potassium hydroxide, potassium carbonate, silver oxide, magnesium oxide, magnesium hydroxide, calcium oxide, zinc hydroxide, strontium hydroxide, cadmium oxide, cadmium hydroxide, barium oxide, aluminum
oxide, iron carbonate, copper hydroxide, lead hydroxide, tin butylate, cobalt hydroxide, nickel hydroxide, nickel carbonate, and the like.

[0186] In some instances, the incorporation of certain ingredients such as small amounts of the metal acetate or acetic acid in conjunction with the metal reactant will facilitate the reaction and result in an improved product. For example, the use of up to about 5% of zinc acetate in combination with the required amount of zinc oxide facilitates the formation of a zinc phosphorodithioate with potentially improved performance properties.

[0187] Especially useful metal phosphorodithioates can be prepared from phosphorodithioic acids, which in turn are prepared by the reaction of phosphorus pentasulfide with mixtures of alcohols. In addition, the use of such mixtures enables the utilization of less expensive alcohols, which individually may not yield oil-soluble phosphorodithioic acids. Thus, a mixture of isopropyl and hexylalcohols can be used to produce a very effective, oil-soluble metal phosphorodithioate. For the same reason mixtures of phosphorodithioic acids can be reacted with the metal compounds to form less expensive, oil-soluble salts.

[0188] The mixtures of alcohols may be mixtures of different primary alcohols, mixtures of different secondary alcohols, or mixtures of primary and secondary alcohols. Examples of useful mixtures include: n-butanol and n-octanol; n-pentanol and 2-ethyl-1-hexanol; isobutanol and n-hexanol; isobutanol and isopropanol; isopropanol and 2-methyl-4-pentanol; isopropanol and sec-butyl alcohol; isopropanol and isoctyl alcohol; and the like.

[0189] Organic triesters of phosphorus acids are also employed in lubricants. Exemplary esters include triarylphosphates, trialkyl phosphates, neutral alkyaryl phosphates, alkoxyalkyl phosphates, triaryl phosphite, trialkylphosphite, neutral alkyl aryl phosphites, neutral phosphonate esters and neutral phosphine oxide esters. In one embodiment, the long chain dialkyl phosphonate esters are used. For example, the dimethyl-, diethyl-, and/or dipropyl-oleyl phosphonates can be used. Neutral acids of phosphorus acids are the triesters rather than an acid (HO-P) or a salt of an acid.

[0190] Any C4 to C8 alkyl or higher phosphate ester may be employed in the disclosure. For example, tributyl phosphate (TBP) and tri isoocatal phosphate (TOF) can be used. The specific triphosphate ester or combination of esters can easily be selected by one skilled in the art to adjust the density, viscosity, etc., of the formulated fluid. Mixed esters, such as dibutyl octyl phosphate or the like may be employed rather than a mixture of two or more trialkyl phosphates.

[0191] A trialkyl phosphate is often useful to adjust the specific gravity of the formulation, but it is desirable that the specific trialkyl phosphate be a liquid at low temperatures. Consequently, a
mixed ester containing at least one partially alkylated with a C3 to C4 alkyl group is very desirable, for example, 4-isopropylphenyl diphenyl phosphate or 3-butylphenyl diphenyl phosphate. Even more desirable is a triaryl phosphate produced by partially alkylating phenol with butylene or propylene to form a mixed phenol which is then reacted with phosphorus oxychloride as taught in U.S. Patent No. 3,576,923.

Any mixed triaryl phosphate (TAP) esters may be used as cresyl diphenyl phosphate, tricresyl phosphate, mixed xylyl cresyl phosphates, lower alkylphenyl/phenyl phosphates, such as mixed isopropylphenyl/phenyl phosphates, t-butylphenyl phenyl phosphates. These esters are used extensively as plasticizers, functional fluids, gasoline additives, flame-retardant additives and the like.

A metal alkylthiophosphate and more particularly a metal dialkyl dithio phosphate in which the metal constituent is zinc, or zinc dialkyl dithio phosphate (ZDDP) can be a useful component of the lubricating oils of this disclosure. ZDDP can be derived from primary alcohols, secondary alcohols or mixtures thereof. ZDDP compounds are of the formula:

\[ \text{Zn}[(\text{OR})_2\text{S}]_2 \]

wherein R1 and R2 are C1 - C18 alkyl groups (e.g. C2 - C12 alkyl groups).

These alkyl groups may be straight chain or branched. Alcohols used in the ZDDP can be propanol, 2-propanol, butanol, secondary butanol, pentanols, hexanols such as 4-methyl-2-pentanol, n-hexanol, n-octanol, 2-ethyl hexanol, alkylated phenols, and the like. Mixtures of secondary alcohols or of primary and secondary alcohol can be utilized. Alkyl aryl groups may also be used.

Exemplary zinc dithiophosphates that are commercially available include secondary zinc dithiophosphates, such as those available from for example, The Lubrizol Corporation under the trade designations "LZ 677A", "LZ 1095" and "LZ 1371", from for example Chevron Oronite under the trade designation "OLOA 262", and from for example Afton Chemical under the trade designation "HITEC 7169".

ZDDP may be used in amounts of from about zero to about 3 weight percent (e.g. from about 0.05 weight percent to about 2 weight percent, from about 0.1 weight percent to about 1.5 weight percent, or from about 0.1 weight percent to about 1 weight percent) based on the total weight of the lubricating composition, although more or less can often be used advantageously. A secondary ZDDP may be present in an amount of from zero to about 1 weight percent of the total weight of the lubricating composition.
Extreme Pressure Agent(s). In other embodiments, the lubricating composition comprises at least one extreme pressure agent. Any extreme pressure agent that is known or that becomes know may be utilized in the lubricating composition of the present disclosure. In certain embodiments, the extreme pressure agent includes at least two (e.g., 2, 3, 4, or more) extreme pressure agents.

The extreme pressure agents can be at least one sulfur-based extreme pressure agents, such as sulfides, sulfoxides, sulfones, thiophosphinates, thiocarbonates, sulfurized fats and oils, sulfurized olefins, the like, or combinations thereof; at least one phosphorus-based extreme pressure agents, such as phosphoric acid esters (e.g., tricresyl phosphate (TCP) and the like), phosphorous acid esters, phosphoric acid ester amine salts, phosphorous acid ester amine salts, the like, or combinations thereof; halogen-based extreme pressure agents, such as chlorinated hydrocarbons, the like, or combinations thereof; organo metallic extreme pressure agents, such as thiophosphoric acid salts (e.g., zinc dithiophosphate (ZnDTP) and the like), thiocarbamic acid salts, or combinations thereof; and the like.

The phosphoric acid ester, thiophosphoric acid ester, and amine salts thereof functions to enhance the lubricating performances, and can be selected from known compounds conventionally employed as extreme pressure agents. For example, phosphoric acid esters, a thiophosphoric acid ester, or an amine salt thereof which has an alkyl group, an alkenyl group, an alkylaryl group, or an aralkyl group, any of which contains approximately 3 to 30 carbon atoms, may be employed.

Examples of the phosphoric acid esters include aliphatic phosphoric acid esters such as triisopropyl phosphate, tributyl phosphate, ethyl dibutyl phosphate, trihexyl phosphate, tri-2-ethylhexyl phosphate, trilauryl phosphate, tristearyl phosphate, and trioleyl phosphate; and aromatic phosphoric acid esters such as benzyl phenyl phosphate, allyl diphenyl phosphate, triphenyl phosphate, tricresyl phosphate, ethyl diphenyl phosphate, cresyl diphenyl phosphate, dicresyl phenyl phosphate, ethylphenyl diphenyl phosphate, diethylphenyl phenyl phosphate, propylphenyl diphenyl phosphate, dipropylphenyl phenyl phosphate, triethylphenyl phosphate, tripropylphenyl phosphate, butylphenyl diphenyl phosphate, dibutylphenyl phenyl phosphate, and tributylphenyl phosphate. In an embodiment, the phosphoric acid ester is a trialkylyphenyl phosphate.

Examples of the thiophosphoric acid esters include aliphatic thiophosphoric acid esters such as triisopropyl thiophosphate, tributyl thiophosphate, ethyl dibutyl thiophosphate, trihexyl thiophosphate, tri-2-ethylhexyl thiophosphate, trilauryl thiophosphate, tristearyl thiophosphate, and trioleyl thiophosphate; and aromatic thiophosphoric acid esters such as benzyl phenyl thiophosphate,
allyl diphenyl thiophosphate, triphenyl thiophosphate, tricresyl thiophosphate, ethyl diphenyl thiophosphate, cresyl diphenyl thiophosphate, dicresyl phenyl thiophosphate, ethylphenyl diphenyl thiophosphate, diethylphenyl phenyl thiophosphate, propylphenyl diphenyl thiophosphate, dipropylphenyl phenyl thiophosphate, triethylphenyl phenyl thiophosphate, and tributylphenyl phenyl thiophosphate. In an embodiment, the thiophosphoric acid ester is a trialkylphenyl thiophosphate.

Also employable are amine salts of the above-mentioned phosphates and thiophosphates. Amine salts of acidic alkyl or aryl esters of the phosphoric acid and thiophosphoric acid are also employable. In an embodiment, the amine salt is an amine salt of trialkylphenyl phosphate or an amine salt of alkyl phosphate.

One or any combination of the compounds selected from the group consisting of a phosphoric acid ester, a thiophosphoric acid ester, and an amine salt thereof may be used.

The phosphorus acid ester and/or its amine salt function to enhance the lubricating performance of the composition, and can be selected from known compounds conventionally employed as extreme pressure agents. For example, the extreme pressure agent can be a phosphorus acid ester or an amine salt thereof, which has an alkyl group, an alkenyl group, an alkylaryl group, or an aralkyl group, any of which contains approximately 3 to 30 carbon atoms.

Examples of phosphorus acid esters that may be used includes aliphatic phosphorus acid esters, such as triisopropyl phosphite, tributyl phosphite, ethyl dibutyl phosphite, trihexyl phosphite, tri-2-ethylhexyl phosphite, trilauryl phosphite, tristearyl phosphite, and trioleyl phosphite; and aromatic phosphorus acid esters such as benzyl phenyl phosphite, allyl diphenylphosphite, triphenyl phosphite, tricresyl phosphite, ethyl diphenyl phosphite, tributyl phosphite, ethyl dibutyl phosphite, cresyl diphenyl phosphite, dicresyl phenyl phosphite, ethylphenyl diphenyl phosphite, diethylphenyl phenyl phosphite, propylphenyl diphenyl phosphite, dipropylphenyl phenyl phosphite, triethylphenyl phosphite, tripropylphenyl phosphite, butylphenyl diphenyl phosphite, dibutylphenyl phenyl phosphite, and tributylphenyl phosphite. Also favorably employed are dilauryl phosphite, dioleyl phosphite, dialkyl phosphites, and diphenyl phosphite. In certain embodiments, the phosphorus acid ester is a dialkyl phosphite or a trialkyl phosphite.

The phosphate salt may be derived from a polyamine, such as alkoxylated diamines, fatty polyamine diamines, alkenepolyamines, hydroxy containing polyamines, condensed polyamines arylpolyamines, and heterocyclic polyamines. Examples of these amines include Ethoduomeen T/13
and T/20, which are ethylene oxide condensation products of N-tallowtrimethylenediamine containing 3 and 10 moles of ethylene oxide per mole of diamine, respectively.

[0207] In another embodiment, the polyamine is a fatty diamine. The fatty diamine may include mono- or dialkyl, symmetrical or asymmetrical ethylene diamines, propane diamines (1,2 or 1,3), and polyamine analogs of the above. Suitable commercial fatty polyamines are Duomeen C (N-coco-1,3-diaminopropylamine), Duomeen S (N-soya-1,3-diaminopropylamine), Duomeen T (N-tallow-1,3-diaminopropylamine), and Duomeen O (N-oleyl-1,3-diaminopropylamine). "Duomeens" are commercially available from Armak Chemical Co., Chicago, Ill.

[0208] Such alkylenepolyamines include methylenepolyamines, ethylenepolyamines, butylenepolyamines, propylenepolyamines, pentylenepolyamines, etc. The higher homologs and related heterocyclic amines, such as piperazines and N-amino alkyl-substituted piperazines, are also included. Specific examples of such polyamines are ethylenediamine, triethylenetetramine, tris-(2-aminoethyl)amine, propylenediamine, trimethylenediamine, tripopylenetetramine, tetraethylenepentamine, hexaethylenepentamine, pentaethylenepentamine, etc. Higher homologs obtained by condensing two or more of the above-noted alkylenepolyamines are similarly useful as are mixtures of two or more of the aforedescribed polyamines.


[0210] Other useful types of polyamine mixtures are those resulting from stripping of the above-described polyamine mixtures to leave, as residue, what is often termed "polyamine bottoms". The alkylenepolyamine bottoms can be characterized as having less than 2%, usually less than 1% (by weight) material boiling below about 200°C. An exemplary sample of such ethylene polyamine bottoms obtained from the Dow Chemical Company of Freeport, Tex. designated "E-100". These alkylenepolyamine bottoms include cyclic condensation products, such as piperazine, and higher analogs of diethylenetriamine, triethylenetetramine and the like. These alkylenepolyamine bottoms can be reacted solely with the acylating agent or they can be used with other amines, polyamines, or mixtures thereof. Another useful polyamine is a condensation reaction between at least one hydroxy compound with at least one polyamine reactant containing at least one primary or secondary amino group. In an embodiment, the hydroxy compounds are alcohols and amines. The polyhydric
alcohols are described below. In one embodiment, the hydroxy compounds are polyhydric amines. Polyhydric amines include any of the above-described monoamines reacted with an alkylene oxide (e.g., ethylene oxide, propylene oxide, butylene oxide, etc.) having from two to about 20 carbon atoms, or from two to about four. Examples of polyhydric amines include tri-(hydroxypropyl)amine, tris-(hydroxymethyl)amino methane, 2-amino-2-methyl-1,3-propanediol, N,N,N',N'-tetrakis(2-hydroxypropyl)ethylenediamine, and N,N,N',N'-tetrakis(2-hydroxyethyl)ethylenediamine. In an embodiment, the polyhydric amine is tris(hydroxymethyl)aminomethane (THAM).

Polyamines which react with the polyhydric alcohol or amine to form the condensation products or condensed amines, are described above. In an embodiment, the polyamine include at least one of triethylenetetramine (TETA), tetraethylenepentamine (TEPA), pentaethylenetetramine (PEHA), and mixtures of polyamines, such as the above-described "amine bottoms".

In some embodiments, the extreme pressure additive or additives includes sulphur-based extreme pressure additives, such as dialkyl sulphides, dibenzyl sulphide, dialkyl polysulphides, dibenzyl disulphide, alkyl mercaptans, dibenzothiophene, 2,2'-dithiobis(benzothiazole), or combinations thereof; phosphorus-based extreme pressure additives, such as trialkyl phosphates, triaryl phosphates, trialkyl phosphonates, trialkyl phosphites, triaryl phosphites, dialkylhydrazine phosphites, or combinations thereof; and/or phosphorus- and sulphur-based extreme pressure additives, such as zinc dialkyldithiophosphates, dialkylthiophosphoric acid, trialkyl thiophosphate esters, acidic thiophosphate esters, trialkyl trithiophosphates, or combinations thereof. Extreme pressure additives can be used individually or in the form of mixtures, conveniently in an amount within the range from zero to about 2% by weight of the lubricating composition.

Dispersant(s). In other embodiments, the lubricating composition comprises at least one dispersant. During machine operation, oil-insoluble oxidation byproducts are produced. The dispersant may be added to help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Any dispersant that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. In certain embodiments, the dispersant includes at least two (e.g., 2, 3, 4, or more) dispersants.

In some embodiments, the dispersants is ashless or ash-forming in nature. In an embodiment, the dispersant is an ashless. So called ashless are organic materials that form substantially no ash upon combustion. For example, non-metal-containing or borated metal-free dispersants are considered ashless. In contrast, metal-containing detergents form ash upon combustion.
Suitable dispersants may contain a polar group attached to a relatively high molecular weight hydrocarbon chain (e.g., about 50 to about 400 carbon atoms). In certain embodiments, the polar group contains at least one element of nitrogen, oxygen, or phosphorus.

A particularly useful class of dispersants are the (poly)alkenylsuccinic derivatives, which may be produced by the reaction of a long chain hydrocarbyl substituted succinic compound, e.g. a hydrocarbyl substituted succinic anhydride, with a polyhydroxy or polyamino compound. The long chain hydrocarbyl group constituting the oleophilic portion of the molecule, which confers solubility in the oil, is normally a polyisobutylene group. Many examples of this type of dispersant are well known commercially and in the literature. Exemplary U.S. patents describing such dispersants are U.S. Patent Nos. 3,172,892; 3,2145,707; 3,219,666; 3,316,177; 3,341,542; 3,444,170; 3,454,607; 3,541,012; 3,630,904; 3,632,511; 3,787,374 and 4,234,435. Other types of dispersant are described in U.S. Patent Nos. 3,036,003; 3,200,107; 3,254,025; 3,275,554; 3,438,757; 3,454,555; 3,565,804; 3,413,347; 3,697,574; 3,725,277; 3,726,480; 3,726,882; 4,454,059; 3,329,658; 3,449,250; 3,519,565; 3,666,730; 3,687,849; 3,702,300; 4,100,082; 5,705,458. A further description of dispersants may be found, for example, in European Patent Application No. 471 071, to which reference is made for this purpose.

Hydrocarbyl-substituted succinic acid and hydrocarbyl-substituted succinic anhydride derivatives are useful dispersants. In particular, succinimide, succinate esters, or succinate ester amides prepared by the reaction of a hydrocarbon-substituted succinic acid compound (e.g., a hydrocarbon-substituted succinic acid compound having at least 50 carbon atoms in the hydrocarbon substituent) with at least one equivalent of an alkylene amine are particularly useful.

Succinimides are formed by the condensation reaction between hydrocarbyl substituted succinic anhydrides and amines. Molar ratios can vary depending on the polyamine. For example, the molar ratio of hydrocarbyl substituted succinic anhydride to TEPA can vary from about 1:1 to about 5:1. Representative examples are shown in U.S. Patent Nos. 3,087,936; 3,172,892; 3,219,666; 3,272,746; 3,322,670; and 3,652,616, 3,948,800; and Canada Patent No. 1,094,044.

Succinate esters may be formed by the condensation reaction between hydrocarbyl substituted succinic anhydrides and alcohols or polyols. Molar ratios can vary depending on the alcohol or polyol used. For example, the condensation product of a hydrocarbyl substituted succinic anhydride and pentaerythritol is a useful dispersant.

Succinate ester amides may be formed by condensation reaction between hydrocarbyl substituted succinic anhydrides and alkanol amines. For example, suitable alkanol amines include...
ethoxylated polyalkylpolyamines, propoxylated polyalkylpolyamines and polyalkenylpolyamines, such as polyethylene polyamines. One example is propoxylated hexamethylenediamine. Representative examples are shown in U.S. Patent No. 4,426,305.

[0221] The molecular weight of the hydrocarbyl substituted succinic anhydrides used in the preceding paragraphs can range between about 800 and about 2,500 or more. The above products can be post-reacted with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids, such as oleic acid. The above products can also be post reacted with boron compounds, such as boric acid, borate esters or highly borated dispersants, to form borated dispersants, which may have from about 0.1 to about 5 moles of boron per mole of dispersant reaction product.

[0222] Mannich base dispersants are made from the reaction of alkylphenols, formaldehyde, and amines. See U.S. Patent No. 4,767,551, which is incorporated herein by reference. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Molecular weights of the alkylphenols may range from about 800 to about 2,500. Representative examples are shown in U.S. Patent Nos. 3,697,574; 3,703,536; 3,704,308; 3,751,365; 3,756,953; 3,798,165; and 3,803,039.

[0223] High molecular weight aliphatic acid modified Mannich condensation products useful in this disclosure can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or HNR2 group-containing reactants, wherein each R is independently selected from hydrogen, C1-C18 alkyl, aryl, alkenyl, alkaryl group.

[0224] Hydrocarbyl substituted amine ashless dispersant additives are well known to one skilled in the art; see, for example, U.S. Patent Nos. 3,275,554; 3,438,757; 3,565,804; 3,755,433; 3,822,209; and 5,084,197.

[0225] In certain embodiments, the dispersants include borated and/or non-borated succinimides, including those derivatives from mono-succinimides, bis-succinimides, and/or mixtures of mono- and bis-succinimides, wherein the hydrocarbyl succinimide is derived from a hydrocarbylene group such as polyisobutylene having a Mn of from about 500 to about 5000, or from about 1000 to about 3000, or about 1000 to about 2000, or a mixture of such hydrocarbylene groups, often with high terminal vinyl groups. Other dispersants include succinic acid-esters and amides, alkylphenol-polyamine-coupled Mannich adducts, their capped derivatives, and other related components.

[0226] Polymethacrylate or polyacrylate derivatives are another class of dispersants. These dispersants may be prepared by reacting a nitrogen containing monomer and a methacrylic or acrylic acid esters containing about 5 to about 25 carbon atoms in the ester group. Representative examples
are shown in U.S. Patent Nos. 2,100,993, and 6,323,164. Polymethacrylate and polyacrylate dispersants may be used as multifunctional viscosity modifiers. The lower molecular weight versions can be used as lubricant dispersants or fuel detergents.

Illustrative dispersants useful in this disclosure include those derived from polyalkenyl-substituted mono- or dicarboxylic acid, anhydride or ester, wherein the polyalkenyl moiety has an average molecular weight of at least about 900 and from greater than 1.3 to 1.7 (e.g. from greater than 1.3 to 1.6 or from greater than 1.3 to 1.5) functional groups (mono- or dicarboxylic acid producing moieties) per polyalkenyl moiety (a medium functionality dispersant). Functionality (F) can be determined according to the following formula:

\[ F = \frac{(\text{SAP} \times \text{Mn})}{((12,200 \times \text{A.I.})-(\text{SAP} \times 98))}, \]

wherein:

- SAP is the saponification number (i.e., the number of milligrams of KOH consumed in the complete neutralization of the acid groups in one gram of the succinic-containing reaction product, as determined according to ASTM D94);
- Mn is the number average molecular weight of the starting olefin polymer; and
- A.I. is the percent active ingredient of the succinic-containing reaction product (the remainder being unreacted olefin polymer, succinic anhydride and diluent).

The polyalkenyl moiety of the dispersant may have a number average molecular weight of at least about 900 or suitably at least about 1500, such as between about 1800 and about 3000 (e.g. between about 2000 and about 2800, from about 2100 to about 2500, or from about 2200 to about 2400). The molecular weight of a dispersant is generally expressed in terms of the molecular weight of the polyalkenyl moiety. This is because the precise molecular weight range of the dispersant depends on numerous parameters including the type of polymer used to derive the dispersant, the number of functional groups, and the type of nucleophilic group employed.

Polymer molecular weight, specifically Mn, can be determined by various known techniques. One convenient method is gel permeation chromatography (GPC), which additionally provides molecular weight distribution information (see W. W. Yau, J. J. Kirkland and D. D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979). Another useful method for determining molecular weight, particularly for lower molecular weight polymers, is vapor pressure osmometry (e.g., ASTMD3592).

In an embodiment, the polyalkenyl moiety in a dispersant has a narrow molecular weight distribution (MWD), also referred to as polydispersity, as determined by the ratio of weight average
molecular weight (Mw) to number average molecular weight (Mn). Polymers having a Mw/Mn of less than 2.2 (e.g. less than 2.0) are most desirable. Suitable polymers have a polydispersity of from about 1.5 to 2.1 (e.g. from about 1.6 to about 1.8).

Suitable polyalkenes employed in the formation of the dispersants include homopolymers, interpolymers or lower molecular weight hydrocarbons. One family of such polymers comprise polymers of ethylene and/or at least one C3 to C26 alpha-olefin having the formula:

$$H_2C = CHR^6,$$

wherein R^6 is a straight or branched chain alkyl radical comprising 1 to 26 carbon atoms and wherein the polymer contains carbon-to-carbon unsaturation, and a high degree of terminal ethenylidene unsaturation. In an embodiment, such polymers comprise interpolymers of ethylene and at least one alpha-olefin of the above formula, wherein R^6 is alkyl of from 1 to 18 carbon atoms (e.g. from 1 to 8 carbon atoms or from 1 to 2 carbon atoms).

Another useful class of polymers is polymers prepared by cationic polymerization of monomers such as isobutene and styrene. For example, the polymer(s) can be polyisobutenes obtained by polymerization of a C4 refinery stream having a butene content of 35 to 75% by wt., and an isobutene content of 30 to 60% by wt. Petroleum feedstreams, such as Raffinate II, can be a source of monomer for making poly-n-butene. These feedstocks are disclosed in the art such as in U.S. Pat. No. 4,952,739. Certain embodiments utilize polyisobutylene prepared from a pure isobutylene stream or a Raffinate I stream to prepare reactive isobutylene polymers with terminal vinylidene olefins. Polyisobutene polymers that may be employed may be based on a polymer chain of from about 1500 to about 3000.

In yet further embodiments, the dispersant(s) are non-polymeric (e.g., mono- or bis-succinimides). Such dispersants can be prepared by conventional processes, such as those disclosed in U.S. Patent Application Publication No. 2008/0020950, the disclosure of which is incorporated herein by reference.

The dispersant(s) can be borated by conventional means, as generally disclosed in U.S. Patent Nos. 3,087,936, 3,254,025 and 5,430,105.

Dispersants may be used in an amount of zero to about 10 weight percent or about 0.01 to about 8 weight percent (e.g. about 0.1 to about 5 weight percent or about 0.5 to about 3 weight percent). Or such dispersants may be used in an amount of zero to about 8 weight percent (e.g. about 0.01 to about 5 weight percent or about 0.1 to about 3 weight percent). On an active
ingredient basis, such additives may be used in an amount of zero to about 10 weight percent (e.g. about 0.3 to about 3 weight percent). The hydrocarbon portion of the dispersant atoms can range from about C60 to about C1000, or from about C70 to about C300, or from about C70 to about C200. These dispersants may contain both neutral and basic nitrogen, and mixtures thereof. Dispersants can be end-capped by borates and/or cyclic carbonates. Nitrogen content in the finished oil can vary from about zero to about 2000 ppm by weight (e.g. from about 100 ppm by weight to about 1200 ppm by weight). Basic nitrogen can vary from about zero to about 1000 ppm by weight (e.g. from about 100 ppm by weight to about 600 ppm by weight).

Dispersants as described herein are beneficially useful with the compositions of the present disclosure. Further, in one embodiment, preparation of the compositions of the present disclosure using one or more (e.g. 1, 2, 3, 4, or more) dispersants is achieved by combining ingredients of the present disclosure, plus optional base stocks and lubricant additives, in a mixture at a temperature above the melting point of such ingredients, particularly that of the one or more M-carboxylates (M = H, metal, two or more metals, mixtures thereof).

As used herein, the dispersant concentrations are given on an "as delivered" basis. The active dispersant may be delivered with a process oil. The "as delivered" dispersant may contain from about 20 weight percent to about 80 weight percent, or from about 40 weight percent to about 60 weight percent, of active dispersant in the "as delivered" dispersant product.

Additional Detergent(s). In other embodiments, the lubricating composition comprises at least one detergent. The detergent may be added to protect lubricated metal surfaces against chemical attack by water or other contaminants. Any detergent that is known or that becomes known may be utilized in the lubricating composition of the present disclosure. In certain embodiments, the detergent includes at least two (e.g., 2, 3, 4, or more) detergents.

Illustrative detergents useful in this disclosure include, for example, alkali metal detergents, alkaline earth metal detergents, or mixtures of one or more alkali metal detergents and one or more alkaline earth metal detergents. In an embodiment, the detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent may be derived from an organic acid, such as a sulfur-containing acid, carboxylic acid (e.g., salicylic acid), phosphorus-containing acid, phenol, or mixtures thereof. The counterion may be an alkaline earth or alkali metal. The detergent can be overbased as described herein.
In other embodiments, the detergent is a metal salt of an organic or inorganic acid, a metal salt of a phenol, or mixtures thereof. The metal may be selected from an alkali metal, an alkaline earth metal, and mixtures thereof. The organic or inorganic acid may be selected from an aliphatic organic or inorganic acid, a cycloaliphatic organic or inorganic acid, an aromatic organic or inorganic acid, and mixtures thereof.

In certain embodiments, the metal is selected from an alkali metal, an alkaline earth metal, and mixtures thereof. In another embodiment, the metal is selected from calcium (Ca), magnesium (Mg), and mixtures thereof.

The organic acid or inorganic acid may be selected from a sulfur-containing acid, a carboxylic acid, a phosphorus-containing acid, and mixtures thereof.

In a particular embodiment, the metal salt of an organic or inorganic acid or the metal salt of a phenol comprises at least one of calcium phenate, calcium sulfonate, calcium salicylate, magnesium phenate, magnesium sulfonate, magnesium salicylate, an overbased detergent, or mixtures thereof.

Salts that contain a substantially stochiometric amount of the metal are described as neutral salts and have a total base number (TBN, as measured by ASTM D2896) of from 0 to 80. Many compositions are overbased, containing large amounts of a metal base that is achieved by reacting an excess of a metal compound (a metal hydroxide or oxide, for example) with an acidic gas (such as carbon dioxide). Useful detergents can be neutral, mildly overbased, or highly overbased. These detergents can be used in mixtures of neutral, overbased, highly overbased calcium salicylate, sulfonates, phenates and/or magnesium salicylate, sulfonates, phenates. The TBN ranges can vary from low, medium to high TBN products, including as low as 0 to as high as 600. In an embodiment, the TBN delivered by the detergent is between 1 and 20 (e.g. between 1 and 12). Mixtures of low, medium, high TBN can be used, along with mixtures of calcium and magnesium metal based detergents, and including sulfonates, phenates, salicylates, and carboxylates. A detergent mixture with a metal ratio of 1, in conjunction with a detergent with a metal ratio of 2, and as high as a detergent with a metal ratio of 5, can be used. Borated detergents can also be used.

Alkaline earth phenates are another useful class of detergent. These detergents can be made by reacting alkaline earth metal hydroxide or oxide (CaO, Ca(OH)₂, BaO, Ba(OH)₂, MgO, Mg(OH)₂, for example) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight chain or branched C1 - C30 alkyl groups (e.g. C4 - C20 alkyl groups) or mixtures thereof. Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl
phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched and can be used from about 0.5 to about 6 weight percent. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (including elemental sulfur, sulfur halides, such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

In some embodiments, the detergent is a metal salts of carboxylic acids. These carboxylic acid detergents may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing free water from the reaction product. These compounds may be overbased to produce the desired TBN level. Detergents made from salicylic acid are one class of detergents derived from carboxylic acids. Useful salicylates include long chain alkyl salicylates.

One useful family of compositions is of the formula:

\[
\left( \right. \begin{array}{c}
\text{C}
\end{array}
\left. \right) \text{M}^2
\]

wherein:

- \( R \) is an alkyl group having about 1 to about 30 carbon atoms, \( n \) is an integer from 1 to 4, and
- \( M \) is an alkaline earth metal.

In certain embodiments, the \( R \) group or groups are alkyl chains of at least CI 1 (e.g. at least CI 3). \( R \) may be optionally substituted with substituents that do not interfere with the detergent’s function. In an embodiment, the \( M \) is calcium, magnesium, barium, or mixtures thereof. In a particular embodiment, the \( M \) is calcium.

Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Patent No. 3,595,791). The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent, such as water or alcohol.

Alkaline earth metal phosphates are also used as detergents and are known in the art.

Detergents may be simple detergents or what is known as hybrid or complex detergents. The latter detergents can provide the properties of two detergents without the need to blend separate materials. See U.S. Patent No. 6,034,039.
In an embodiment, the detergent or detergents (e.g., 1, 2, 3, 4, or more detergents) includes calcium sulfonates, magnesium sulfonates, calcium salicylates, magnesium salicylates, calcium phenates, magnesium phenates, and other related components (including borated detergents), or mixtures thereof. For example, a mixture of detergents may include magnesium sulfonate and calcium salicylate, magnesium sulfonate and calcium sulfonate, magnesium sulfonate and calcium phenate, calcium phenate and calcium salicylate, calcium phenate and calcium sulfonate, calcium phenate and magnesium salicylate, or calcium phenate and magnesium phenate. Overbased detergents may also be utilized in the lubricating composition of the present disclosure.

Detergent concentration in the lubricating oils of this disclosure can range from zero to about 6.0 weight percent (e.g. zero to 5.0 weight percent or from about 0.01 weight percent to about 3.0 weight percent) based on the total weight of the lubricating oil.

As used herein, the detergent concentrations are given on an "as delivered" basis. The active detergent may delivered with a process oil. The "as delivered" detergent can contain from about 20 weight percent to about 100 weight percent, or from about 40 weight percent to about 60 weight percent, of active detergent in the "as delivered" detergent product.

Friction Modifier(s). In other embodiments, the lubricating composition comprises at least one (e.g., 1, 2, 3, 4, or more) friction modifier. A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material(s). Friction modifiers, also known as friction reducers, or lubricity agents or oiliness agents, and other such agents that change the ability of base oils, formulated lubricant compositions, or functional fluids, to modify the coefficient of friction of a lubricated surface may be effectively used in combination with the base oils or lubricant compositions of the present disclosure if desired. Friction modifiers that lower the coefficient of friction are particularly advantageous in combination with the base oils and lube compositions of this disclosure. Any friction modifier that is known or that becomes know may be utilized in the lubricating composition of the present disclosure.

Friction modifiers may include, for example, organometallic compounds or materials, or mixtures thereof. Illustrative organometallic friction modifiers useful in the lubricating turbine oil formulations of this disclosure include, for example, molybdenum amine, molybdenum diamine, an organotungstenate, a molybdenum dithiocarbamate, molybdenum dithiophosphates, molybdenum amine complexes, molybdenum carboxylates, and the like, and mixtures thereof. In an embodiment, tungsten-based compounds are utilized.
[0256] Other illustrative friction modifiers useful in the lubricating formulations of the present disclosure include, for example, alkoxylated fatty acid esters, alkanolamides, polyol fatty acid esters, borated glycerol fatty acid esters, fatty alcohol ethers, and mixtures thereof.

[0257] Illustrative alkoxylated fatty acid esters include, for example, polyoxyethylene stearate, fatty acid polyglycol ester, and the like. These can include polyoxypropylene stearate, polyoxybutylene stearate, polyoxyethylene isostearate, polyoxypropylene isostearate, polyoxyethylene palmitate, and the like.

[0258] Illustrative alkanolamides include, for example, lauric acid diethylalkanolamid, palmic acid diethylalkanolamide, and the like. These can include oleic acid diethylalkanolamide, stearic acid diethylalkanolamide, oleic acid diethylalkanolamide, polyethoxylated hydrocarbylamides, polypropoxylated hydrocarbylamides, and the like.

[0259] Illustrative polyol fatty acid esters include, for example, glycerol mono-oleate, saturated mono-, di-, and tri-glyceride esters, glycerol mono-stearate, and the like. These can include polyol esters, hydroxyl-containing polyol esters, and the like.

[0260] Illustrative borated glycerol fatty acid esters include, for example, borated glycerol mono-oleate, borated saturated mono-, di-, and tri-glyceride esters, borated glycerol mono-stearate, and the like. In addition to glycerol polyols, these can include trimethylolpropane, pentaerythritol, sorbitan, and the like. These esters can be polyol monocarboxylate esters, polyol dicarboxylate esters, and on occasion polyoltricarboxylate esters. In certain embodiments, the friction modifier is glycerol mono-oleates, glycerol dioleates, glycerol trioleates, glycerol monostearates, glycerol distearates, and glycerol tristearates and the corresponding glycerol monopalmitates, glycerol dipalmitates, glycerol tripalmitates, or the respective isostearates, linoleates, and the like, or combinations thereof. In an embodiment, the friction modifier is a glycerol esters or mixtures containing any of these. Ethoxylated, propoxylated, butoxylated fatty acid esters of polyols, especially using glycerol as underlying polyol can be utilized.

[0261] Illustrative fatty alcohol ethers include, for example, stearyl ether, myristyl ether, and the like. Alcohols, including those that have carbon numbers from C3 to C50, can be ethoxylated, propoxylated, or butoxylated to form the corresponding fatty alkyl ethers. The underlying alcohol portion can be, e.g., stearyl, myristyl, C11 - C13 hydrocarbon, oleyl, isosteryl, and the like.

[0262] Other friction modifiers could be optionally included in addition to the fatty phosphites and fatty imidazolines. A useful list of such other friction modifier additives is included in U.S. Patent No. 4,792,410. U.S. Patent No. 5,10,488 discloses metal salts of fatty acids and especially
zinc salts, useful as friction modifiers. Fatty acids are also useful friction modifiers. A list of other suitable friction modifiers includes at least one of: (i) fatty phosphonates; (ii) fatty acid amides; (iii) fatty epoxides; (iv) borated fatty epoxides; (v) fatty amines; (vi) glycerol esters; (vii) borated glycerol esters; (viii) alkoxylated fatty amines; (ix) borated alkoxylated fatty amines; (x) metal salts of fatty acids; (xi) sulfurized olefins; (xii) condensation products of carboxylic acids or equivalents and polyalkylene-polyamines; (xiii) metal salts of alkyl salicylates; (xiv) amine salts of alkylphosphoric acids; (xv) fatty esters; (xvi) condensation products of carboxylic acids; or equivalents with polyols and mixtures thereof.

Representatives of each of these types of friction modifiers are known and are commercially available. For instance, (i) includes components of the formulas:

\[(RO)2\text{P(OR)}\text{R(OR)}\text{PHO},\]
\[(RO)(HO)\text{P(OR)}\text{R(OR)}\text{PHO},\]
\[\text{and } P(OR)(OR)(OR),\]

wherein, in these structures, the each "R" is conventionally referred to as an alkyl group, but may also be hydrogen. It is, of course, possible that the alkyl group is actually alkenyl and thus the terms "alkyl" and "alkylated," as used herein, will embrace other than saturated alkyl groups within the component. The component should have sufficient hydrocarbyl groups to render it substantially oleophilic. In some embodiments, the hydrocarbyl groups are substantially un-branched. Many suitable such components are available commercially and may be synthesized as described in U.S. Patent No. 4,752,416. In some embodiments, the component contains 8 to 24 carbon atoms in each of the R groups. In other embodiments, the component may be a fatty phosphite containing 12 to 22 carbon atoms in each of the fatty radicals, or 16 to 20 carbon atoms. In one embodiment the fatty phosphite can be formed from oleyl groups, thus having 18 carbon atoms in each fatty radical.

The (iv) borated fatty epoxides are known from Canadian Patent No. 1,188,704. These oil-soluble boron-containing compositions are prepared by reacting, at a temperature from 80°C to 250°C, boric acid or boron trioxide with at least one fatty epoxide having the formula:

\[
\begin{array}{c}
O \\
/ \\
R^7R^8\text{C—CR}^9R^{10}
\end{array}
\]

wherein each of R^7, R^8, R^9 and R^{10} is independently hydrogen or an aliphatic radical, or any two thereof together with the epoxy carbon atom or atoms to which they are attached, form a cyclic radical. In an embodiment, the fatty epoxide contains at least 8 carbon atoms.
The borated fatty epoxides can be characterized by the method for their preparation which involves the reaction of two materials. Reagent A can be boron trioxide or any of the various forms of boric acid including metaboric acid (HBO2), orthoboric acid (H3BO3) and tetraboric acid (H2B4O7). In an embodiment, Reagent A is boric acid, such as orthoboric acid. Reagent B can be at least one fatty epoxide having the above formula. In the formula, each of the R groups is most often hydrogen or an aliphatic radical with at least one being a hydrocarbyl or aliphatic radical containing at least 6 carbon atoms. The molar ratio of reagent A to reagent B may be about 1:0.25 to about 1:4 (e.g. about 1:1 to about 1:3 or about 1:2). The borated fatty epoxides can be prepared by merely blending the two reagents and heating them at temperature of about 80°C to about 250°C, such as about 100°C to about 200°C, for a period of time sufficient for reaction to take place. If desired, the reaction may be effected in the presence of a substantially inert, normally liquid organic diluent. During the reaction, water is evolved and may be removed by distillation.

The (iii) non-borated fatty epoxides, corresponding to Reagent B above, are also useful as friction modifiers.

Borated amines are generally known from U.S. Patent No. 4,622,158. Borated amine friction modifiers (including (ix) borated alkoxylated fatty amines) can be prepared by the reaction of a boron compound, as described above, with the corresponding amines. The amine can be a simple fatty amine or hydroxy containing tertiary amines. The borated amines can be prepared by adding the boron reactant, as described above, to an amine reactant and heating the resulting mixture at about 50°C to about 300°C (e.g. about 100°C to about 250°C or about 130°C to about 180°C) with stirring. The reaction is continued until by-product water ceases to evolve from the reaction mixture indicating completion of the reaction.

Among the amines useful in preparing the borated amines are commercial alkoxylated fatty amines known by the trademark "ETHOMEEN™" and available from Akzo Nobel. Representative examples of these ETHOMEEN™ materials is ETHOMEEN™ C/12 (bis[2-hydroxyethyl]-coco-amine); ETHOMEEN™ C/20 (polyoxyethylene®JOcocoamine); ETHOMEEN™ S/12 (bis[2-hydroxyethyl]-soyamine); ETHOMEEN™ T/12 (bis[2-hydroxyethyl]-tallow-amine); ETHOMEEN™ T/15 (polyoxyethylene-[5]tallowamine); ETHOMEEN™ 0/12 (bis[2-hydroxyethyl]oleyl-amine); ETHOMEEN™ 18/12 (bis[2—hydroxyethyl]-octadecylamine); and ETHOMEEN™ 18/25 (polyoxyethylene[15]octadecylamine). Fatty amines and ethoxylated fatty amines are also described in U.S. Patent No. 4,741,848. Dihydroxyethyl tallowamine (commercially sold as ENT-12™) is included in these types of amines.
The (viii) alkoxylated fatty amines, and (v) fatty amines themselves (such as oleylamine and dihydroxyethyl tallowamine) may be useful as friction modifiers in this disclosure. Such amines are commercially available.

Both borated and unborated fatty acid esters of glycerol can be used as friction modifiers. The (vii) borated fatty acid esters of glycerol are prepared by borating a fatty acid ester of glycerol with boric acid with removal of the water of reaction. In an embodiment, there is sufficient boron present such that each boron will react with from 1.5 to 2.5 hydroxyl groups present in the reaction mixture. The reaction may be carried out at a temperature in the range of about 60°C to about 135°C, in the absence or presence of any suitable organic solvent, such as methanol, benzene, xylenes, toluene, or oil.

The (vi) fatty acid esters of glycerol themselves can be prepared by a variety of methods well known in the art. Many of these esters, such as glycerol monooleate and glycerol tallowate, are manufactured on a commercial scale. In a particular embodiment, the esters are oil-soluble and prepared from C8 to C22 fatty acids or mixtures thereof, such as are found in natural products and as are described in greater detail below. In an embodiment, fatty acid monoesters of glycerol used, although, mixtures of mono- and diesters may be used. For example, commercial glycerol monooleate may contain a mixture of 45% to 55% by weight monoester and 55% to 45% diester.

Fatty acids can be used in preparing the above glycerol esters; they can also be used in preparing their (x) metal salts, (ii) amides, and (xii) imidazolines, any of which can also be used as friction modifiers. In an embodiment, the fatty acids are those containing 10 to 24 carbon atoms, such as those containing 12 to 18 carbon atoms. The acids can be branched or straight-chain, saturated or unsaturated. In some embodiments, the acids are straight-chain acids. In other embodiments, the acids are branched. Suitable acids include decanoic, oleic, stearic, isostearic, palmitic, myristic, palmitoleic, linoleic, lauric, and linolenic acids, and the acids from the natural products tallow, palm oil, olive oil, peanut oil, corn oil, coconut oil and Neat's foot oil. In certain embodiments, the acid is oleic acid. In other embodiments, the metal salts include zinc and calcium salts. Examples are overbased calcium salts and basic oleic acid-zinc salt complexes, such as zinc oleate, which can be represented by the formula ZnOlateeOi. In an embodiment, the amides are those prepared by condensation with ammonia or with primary or secondary amines such as ethylamine and diethanolamine. Fatty imidazolines are the cyclic condensation product of an acid with a diamine or polyamine, such as a polyethylene polyamine. The imidazolines may be represented by the structure:
wherein: R is an alkyl group; and R is hydrogen or a hydrocarbyl group or a substituted hydrocarbyl group, including —(CH2CH2NH)ₙ— groups, wherein n is an integer from 1 to 4. In an embodiment, the friction modifier is the condensation product of a ClO to C24 fatty acid with a polyalkylene polyamine, and in particular, the product of isostearic acid with tetaethylenepentamine.

[0273] The condensation products of carboxylic acids and polyalkyleneamines (xiii) may be imidazolines or amides. They may be derived from any of the carboxylic acids described above and any of the polyamines described herein.

[0274] Sulfurized olefins (xi) are well known commercial materials used as friction modifiers. A particularly sulfurized olefin utilized herein is one which is prepared in accordance with the detailed teachings of U.S. Patent Nos. 4,957,651 and 4,959,168. Described therein is a co-sulfurized mixture of 2 or more reactants selected from the group consisting of (1) at least one fatty acid ester of a polyhydric alcohol, (2) at least one fatty acid, (3) at least one olefin, and (4) at least one fatty acid ester of a monohydric alcohol. Reactant (3), the olefin component, comprises at least one olefin. This olefin may be an aliphatic olefin, which usually will contain 4 to 40 carbon atoms, e.g. from 8 to 36 carbon atoms. For example, terminal olefins, or alpha-olefins, including those having from 12 to 20 carbon atoms, may be utilized. Mixtures of these olefins are commercially available, and such mixtures are contemplated for use in this disclosure. The co-sulfurized mixture of two or more of the reactants, is prepared by reacting the mixture of appropriate reactants with a source of sulfur. The mixture to be sulfurized can contain about 10 to about 90 parts of Reactant (1), or about 0.1 to about 15 parts by weight of Reactant (2); or about 10 to about 90 parts (e.g. about 15 to about 60 parts or about 25 to about 35 parts) by weight of Reactant (3), or about 10 to about 90 parts by weight of reactant (4). The mixture, in the present disclosure, includes Reactant (3) and at least one other member of the group of reactants identified as Reactants (1), (2) and (4). The sulfurization reaction may be effected at an elevated temperature with agitation and optionally in an inert atmosphere and in the presence of an inert solvent. The sulfurizing agents useful in the process of the present disclosure include elemental sulfur, which may be hydrogen sulfide, sulfur halide plus
sodium sulfide, and a mixture of hydrogen sulfide and sulfur or sulfur dioxide. For example, about 0.5 to about 3 moles of sulfur are employed per mole of olefinic bonds. Sulfurized olefins may also include sulfurized oils, such as vegetable oil, lard oil, oleic acid and olefin mixtures.

Metal salts of alkyl salicylates (xiii) include calcium and other salts of long chain (e.g. C12 to C16) alkyl-substituted salicylic acids.

Amine salts of alkylphosphoric acids (xiv) include salts of oleyl and other long chain esters of phosphoric acid, with amines as described below. Useful amines in this regard are tertiary-aliphatic primary amines, sold under the tradename Primene™.

In some embodiments, the friction modifier is a fatty acid or fatty oil, a metal salt of a fatty acid, a fatty amide, a sulfurized fatty oil or fatty acid, an alkyl phosphate, an alkyl phosphate amine salt; a condensation product of a carboxylic acid and a polyamine, a borated fatty epoxide, a fatty imidazoline, or combinations thereof.

In other embodiments, the friction modifier may be the condensation product of isostearic acid and tetraethylene pentamine, the condensation product of isostearic acid and 1-[tris(hydroxymethyl)]methylamine, borated polytetradecyloxirane, zinc oleate, hydroxylethyl-2-heptadeceny]l imidazoline, dioleyl hydrogen phosphate, C14 - C18 alkyl phosphate or the amine salt thereof, sulfurized vegetable oil, sulfurized lard oil, sulfurized oleic acid, sulfurized olefins, oleyl amide, glycerol monooleate, soybean oil, or mixtures thereof.

In still other embodiments, the friction modifier may be glycerol monooleate, oleylamide, the reaction product of isostearic acid and 2-amino-2-hydroxymethyl 1,1,3-propanediol, sorbitan monooleate, 9-octadecenoic acid, isostearyl amide, isostearyl monooleate or combinations thereof.

Although their presence is not required to obtain the benefit of the present disclosure, friction modifiers may be present in an amount from zero to about 2 wt% (e.g., about 0.01 wt% to about 1.5 wt%) of the lubricating composition. These ranges may apply to the amounts of individual friction modifier present in the composition or to the total friction modifier component in the compositions, which may include a mixture of two or more friction modifiers.

Many friction modifiers tend to also act as emulsifiers. This is often due to the fact that friction modifiers often have non-polar fatty tails and polar head groups.

The lubricating composition of the present disclosure exhibit desired properties, e.g., wear control, in the presence or absence of a friction modifier.

Although their presence is not required to obtain the benefit of this disclosure, the friction modifier or friction modifiers may be present in an amount of about 0.01 weight percent to about 5
weight percent (e.g. about 0.1 weight percent to about 2.5 weight percent, or about 0.1 weight
percent to about 1.5 weight percent, or about 0.1 weight percent to about 1 weight percent).
Concentrations of molybdenum-containing materials are often described in terms of Mo metal
concentration. Advantageous concentrations of Mo may range from about 25 ppm to about 700 ppm
or more (e.g. about 50 to about 200 ppm). Friction modifiers of all types may be used alone or in
mixtures with the materials of this disclosure. Often mixtures of two or more friction modifiers, or
mixtures of friction modifier(s) with alternate surface active material(s), are also desirable.

[0284] Molybdenum-Containing Compounds (Friction Reducers). Illustrative molybdenum-
containing friction reducers useful in the disclosure include, for example, an oil-soluble
decomposable organo molybdenum compound, such as Molyvan™ 855 which is an oil soluble
secondary diarylamine defined as substantially free of active phosphorus and active sulfur. The
Molyvan™ 855 is described in Vanderbilt's Material Data and Safety Sheet as a organomolybdenum
compound having a density of 1.04 and viscosity at 100°C of 47.12 cSt. The organo molybdenum
compounds may be useful because of their superior solubility and effectiveness.

[0285] Another illustrative molybdenum-containing compound is Molyvan™ L, which is
sulfonated oxymolybdenum dialkylthiophosphate described in U.S. Patent No. 5,055,174 hereby
incorporated by reference.

[0286] Molyvan™ A made by R. T. Vanderbilt Company, Inc., New York, N.Y., USA, is also
an illustrative molybdenum-containing compound, which contains about 28.8 wt. % Mo, 31.6 wt. %
C, 5.4 wt. % H, and 25.9 wt. % S. Also useful are Molyvan™ 855, Molyvan™ 822, Molyvan™
856, and Molyvan™ 807.

[0287] Also useful is Sakura Lube™ 500, which is more soluble Mo dithiocarbamate containing
lubricant additive obtained from Asahi Denki Corporation and comprised of about 20.2 wt. % Mo,
43.8 wt. % C, 7.4 wt. % H, and 22.4 wt. % S. Sakura Lube™ 300, a low sulfur molybdenum
dithiophosphate having a molybdenum to sulfur ratio of 1:1.07, is a molybdenum-containing
compound useful in this disclosure.

[0288] Also useful is Molyvan™ 807, a mixture of about 50 wt. % molybdenum
ditrifiedycldithyocarbonate, and about 50 wt. % of an aromatic oil having a specific gravity of about
38.4 SUS and containing about 4.6 wt. % molybdenum, also manufactured by R. T. Vanderbilt and
marketed as an antioxidant and antiwear additive.
[0289] Other sources are molybdenum Mo(Co)6, and molybdenum octoate, MoO(C7Hi5C02)2 containing about 8 wt-% Mo marketed by Aldrich Chemical Company, Milwaukee, Wis. and molybdenum naphthenethioctoate marketed by Shephard Chemical Company, Cincinnati, Ohio.

[0290] Inorganic molybdenum compounds, such as molybdenum sulfide and molybdenum oxide, are substantially less preferred than the organic compounds as described in Molyvan™ 855, Molyvan™ 822, Molyvan™ 856, and Molyvan™ 807.

[0291] Illustrative molybdenum-containing compounds useful in this disclosure are disclosed, for example, in U.S. Patent Application Publication No. 2003/01 19682, which is incorporated herein by reference.

[0292] Organo molybdenum-nitrogen complexes may also be included in the formulations of the present disclosure. The term "organo molybdenum nitrogen complexes" embraces the organo molybdenum nitrogen complexes described in U.S. Patent No. 4,889,647. The complexes are reaction products of a fatty oil, dithanolamine and a molybdenum source. Specific chemical structures have not been assigned to the complexes. U.S. Patent No. 4,889,647 reports an infrared spectrum for an exemplary reaction product of that disclosure; the spectrum identifies an ester carbonyl band at 1740 cm⁻¹ and an amide carbonyl band at 1620 cm⁻¹. The fatty oils are glyceryl esters of higher fatty acids containing at least 12 carbon atoms up to 22 carbon atoms or more. The molybdenum source is an oxygen-containing compound such as ammonium molybdates, molybdenum oxides and mixtures.

[0293] Other organo molybdenum complexes which can be used in the present disclosure are tri nuclear molybdenum sulfur compounds described in EP 1 040 115 and WO 99/3 1113, and the molybdenum complexes described in U.S. Patent No. 4,978,464.

[0294] Although their presence is not required to obtain the benefit of the present disclosure, molybdenum-containing additives may be used in an amount of from zero to about 5.0 percent by mass of the lubricating composition. For example, the dosage may be up to about 3,000 ppm by mass, such as from about 100 ppm to about 2,500 ppm by mass, from about 300 to about 2,000 ppm by mass, or from about 300 to about 1,500 ppm by mass of molybdenum.

[0295] **Borated Ester Compounds.** Illustrative boron-containing compounds useful in the disclosure include, for example, a borate ester, a boric acid, other boron compounds, such as a boron oxide. The boron compound is hydrolytically stable and is utilized for improved antiwear, and performs as a rust and corrosion inhibitor for copper bearings and other metal engine components. The borated ester compound acts as an inhibitor for corrosion of metal to prevent corrosion of either
ferrous or non-ferrous metals (e.g. copper, bronze, brass, titanium, aluminum and the like) or both, present in concentrations in which they are effective in inhibiting corrosion.

[0296] Patents describing techniques for making basic salts of sulfonic, carboxylic acids and mixtures thereof include U.S. Patent Nos. 5,354,485; 2,501,731; 2,616,911; 2,777,874; 3,384,585; 3,320,162; 3,488,284; and 3,629,109. The disclosures of these patents are incorporated herein by reference. Methods of preparing borated overbased compositions are found in U.S. Patent Nos. 4,744,920; 4,792,410; and PCT publication WO 88/03144. The disclosures of these references are incorporated herein by reference. The oil-soluble neutral or basic salts of alkali or alkaline earth metals salts may also be reacted with a boron compound.

[0297] An illustrative borate ester utilized in this disclosure is manufactured by Exxon-Mobil USA under the product designation of ("MCP 1286") and MOBIL ADC700. Test data show the viscosity at 100°C using the D-445 method is 2.9 cSt; the viscosity at 40°C using the D-445 method is 11.9; the flash point using the D-93 method is 146; the pour point using the D-97 method is -69; and the percent boron as determined by the ICP method is 5.3%. The borated ester (Vanlube™ 289), which is marketed as an antiwear/antiscuff additive and friction reducer, is an exemplary borate ester useful in the disclosure.

[0298] An illustrative borate ester useful in this disclosure is the reaction product obtained by reacting about 1 mole fatty oil, about 1.0 to 2.5 moles diethanolamine followed by subsequent reaction with boric acid to yield about 0.1 to 3 percent boron by mass. It is believed that the reaction products may include one or both of the following two primary components, with the further listed components being possible components when the reaction is pushed toward full hydration:
where $R_1 = H$ or $C_nH_y$ where $x = 1$ to 60, and $y = 3$ to 121.
wherein Y represents a fatty oil residue. In an embodiment, the fatty oils are glyceryl esters of higher fatty acids containing at least 12 carbon atoms (e.g. 22 carbon atoms or more). Such esters are commonly known as vegetable and animal oils. Vegetable oils that may be used include oils derived from coconut, corn, cottonseed, linseed, peanut, soybean and sunflower seed. Similarly, animal fatty oils such as tallow may be used.

[0299] The source of boron is boric acid or materials that afford boron and are capable of reacting with the intermediate reaction product of fatty oil and diethanolamine to form a borate ester composition.

[0300] While the above organoborate ester composition is specifically discussed above, it should be understood that other organoborate ester compositions should also function with similar effect in the present disclosure, such as those set forth in U.S. Patent Application Publication No. 2003/01 19682, which is incorporated herein by reference. In addition, dispersions of borate salts, such as potassium borate, may also be useful.

[0301] Other illustrative organoborate compositions useful in this disclosure are disclosed, for example, in U.S. Patent Application Publication No. 2008/0261838, which is incorporated herein by reference.

[0302] In addition, other illustrative organoborate compositions useful in this disclosure are disclosed, for example, U.S. Patent No. 4,478,732, U.S. Patent No. 4,406,802, U.S. Patent No. 4,568,472 on borated mixed hydroxyl esters, alkoxylated amides, and amines; U.S. Patent No. 4,298,486 on borated hydroxyethyl imidazolines; U.S. Patent No. 4,328,113 on borated alkyl amines and alkyl diamines; U.S. Patent No. 4,370,248 on borated hydroxyl-containing esters, including GMO; U.S. Patent No. 4,374,032 on borated hydroxyl-containing hydrocarbonyl oxazolines; U.S. Patent No. 4,376,712 on borated sorbitan esters; U.S. Patent No. 4,382,006 on borated ethoxylated amines; U.S. Patent No. 4,389,322 on ethoxylated amines and their borates; U.S. Patent No. 4,472,289 on hydrocarbonyl vicinal diols and alcohols and ester mixtures and their borates; U.S. Patent No. 4,522,734 on borates of hydrolyzed hydrocarbonyl epoxides; U.S. Patent No. 4,537,692 on etherdiamine borates; U.S. Patent No. 4,541,941 on mixtures containing vicinal diols and hydroxyl substituted esters and their borates; U.S. Patent No. 4,594,171 on borated mixtures of various hydroxyl and/or nitrogen containing borates; and U.S. Patent No. 4,692,257 on various borated alcohols/diols, all of which are incorporated herein by reference.

[0303] Although their presence is not required to obtain the benefit of this disclosure, boron-containing compounds may be present in an amount of from zero to about 10.0% percent (e.g. from
about 0.01% to about 5% or from about 0.1% to about 3.0%) by weight of the lubricating composition. An effective elemental boron range of up to about 1000 ppm or less than about 1% elemental boron. Thus, in an embodiment, a concentration of elemental boron is from about 100 to about 1000 ppm (e.g. from about 100 to about 300 ppm).

[0304] When lubricating oil compositions contain one or more of the additives discussed above, the additive(s) are blended into the composition in an amount sufficient for it to perform its intended function. Exemplary amounts of such additives useful in the present disclosure are shown in Table 3 below.

[0305] It is noted that many of the additives are shipped from the additive manufacturer as a concentrate, containing one or more additives together, with a certain amount of base oil diluents. Accordingly, the weight amounts in Table 3 below, as well as other amounts mentioned herein, are directed to the amount of active ingredient (that is the non-diluent portion of the ingredient). The weight percent (wt%) indicated below is based on the total weight of the lubricating oil composition.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Approximate wt% (Useful)</th>
<th>Approximate wt% (Exemplary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersant</td>
<td>0-20</td>
<td>0-3</td>
</tr>
<tr>
<td>Detergent</td>
<td>0-20</td>
<td>0-3</td>
</tr>
<tr>
<td>Friction Modifier</td>
<td>0-5</td>
<td>0-1.5</td>
</tr>
<tr>
<td>Antioxidant</td>
<td>0.1-5</td>
<td>0.1-3</td>
</tr>
<tr>
<td>Pour Point Depressant (PPD)</td>
<td>0.0-5</td>
<td>0.01-1.5</td>
</tr>
<tr>
<td>Antifoam Agent</td>
<td>0.0001-3</td>
<td>0.001-0.3</td>
</tr>
<tr>
<td>Demulsifier</td>
<td>0.001-3</td>
<td>0.001-0.15</td>
</tr>
<tr>
<td>Viscosity Modifier (solid polymer basis)</td>
<td>0.1-2</td>
<td>0.1-1</td>
</tr>
<tr>
<td>Antiwear</td>
<td>0.2-3</td>
<td>0.5-1.5</td>
</tr>
<tr>
<td>Inhibitor and Antirust</td>
<td>0.01-5</td>
<td>0.01-2</td>
</tr>
</tbody>
</table>

[0306] The foregoing additives are all commercially available materials. These additives may be added independently but are usually precombined in packages which can be obtained from suppliers of lubricant oil additives. Additive packages with a variety of ingredients, proportions and characteristics are available and selection of the appropriate package will take the requisite use of the
ultimate composition into account.

METHOD OF MAKING OF THE PRESENT DISCLOSURE

[0307] Another aspect of the present disclosure provides a method of making a hydraulic oil composition with at least one of improved hydrolytic stability, improved thermo-oxidative stability, decreased metal corrosion (such as, yellow metal corrosion), or a combination thereof. The method comprises mixing: at least one lubricating base oil; an overbased detergent in an amount no greater than about 3 wt.%; and a thermally stable ZDDP in an amount from about 0.01 wt.% to about 5 wt.%.  

[0308] In any aspect or embodiment described herein, at least one of: (i) the overbased detergent is present in an amount of from about 0.001 wt.% to about 1.5 wt.%; (ii) the thermally stable ZDDP is present in an amount from about 0.05 wt.% to about 2 wt.%; or (iii) a combination thereof.

[0309] In any aspect or embodiment described herein, at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

[0310] A further aspect of the disclosure provides a hydraulic oil composition produced according to the method(s) of the present disclosure.

[0311] An additional aspect of the disclosure provides a method for lubricating a hydraulic pump and/or motor requiring a hydraulic oil composition. The method comprises: supplying the hydraulic motor with a hydraulic oil composition of the present disclosure, such as a hydraulic oil composition comprising: at least one lubricating base oil; an effective amount of an overbased detergent; and an effective amount of a thermally stable ZDDP.
In any aspect or embodiment described herein, at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 5 wt.%; or (iii) a combination thereof.

In any aspect or embodiment described herein, at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seize agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

In any aspect or embodiment described herein, the lubricating base oil or oils are Group II oil.

In any aspect or embodiment described herein, the method results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in the hydraulic motor relative to a method using a hydraulic oil composition that does not include the effective amount of the overbased detergent and/or the thermally stable ZDDP.

Industrial Applications

The methods and lubricating composition of the present disclosure may be suitable industrial fluids, hydraulic fluids, turbine oils, circulating oils, or combinations thereof. In any aspect or embodiments described herein, the lubricating composition of the present disclosure is suitable for various mechanical devices including industrial systems, hydraulic systems or turbines. In any aspect or embodiments described herein, the lubricating composition of the present disclosure is suitable for a hydraulic system.

In any aspect and embodiment described herein, the methods and compositions of the present disclosure are used in a hydraulic pump. In any aspect or embodiments described herein,
the pump is a hydraulic piston pump, such as a vane pump. In any aspect or embodiment described herein, the pump is a hydraulic hybrid piston and vane pump.

[0318] In certain embodiments, the lubricating composition or hydraulic fluid/oil of the disclosure contains at least one Group II oil, at least one overbased detergent, and at least of thermally stable ZDDP.

EXAMPLES

[0319] The present disclosure is further illustrated by the following examples which should not be construed as limiting. The data below demonstrates that the lubricating composition of the present disclosure provides the surprising and unexpected improvement in hydrolytic stability and thermos-oxidative stability of the composition, while having decreased levels of corrosion (such as yellow metal corrosion), rust, wear and deposits, as compared to comparative lubricant compositions. Those skilled in the art will recognize that the present disclosure may be practiced with variations on the disclosed structures, materials, compositions and methods, and such variations are regarded as within the ambit of the disclosure.

[0320] Example Formulations

[0321] Comparative Examples (C.E.) A-E and K, and Exemplary Examples (E.E.) F-J, L, and M are shown in Table 4 (see Fig. 1).

[0322] Hydrolytic Stability Testing (ASTM D2619)

[0323] The hydrolytic stability test evaluates the tendency of an oil to resist hydrolysis in the presence of water and copper components. Hydrolytically unstable hydraulic fluids can cause hydraulic system malfunctions due to corrosion, valve sticking, or change in viscosity of the fluid.

[0324] The hydrolytic stability test was performed as follows: a mixture of 75 g oil, 25 g water and a copper specimen was heated in a closed coke bottle for 48 hours at 93°C. At end of incubation, weight change of copper specimen was measured, and the acid number change of oil and acidity of water layer was determined. The weight change, acid number change and acidity data is shown in Table 4.


[0326] The viscosity of the exemplary and comparative compositions was examined utilizing ASTM D445. The kinematic viscosity of each composition is shown in Table 4.

[0327] Discussion
Comparative Examples A-D had difficulty meeting the weight change of copper strip requirement for hydraulic OEM specificiations, e.g. Eaton, Parker Hannifin, Bosch Rexroth, which is measured by ASTM D2619. As shown by Comparative Examples E and K, the additional of thermally stable ZDDP alone was not able to meet the copper strip requirements for yellow metal corrosion. Unexpectedly, as shown in Exemplary Examples F-J, L, and M, acceptable weight change of copper strip was obtained through the addition of overbased detergent additive technology in addition to the thermally stable ZDDP.

Decomposition of less thermally stable ZDDP and other performance additives can contribute to deterioration of lubricating oils properties, varnish, yellow metal corrosion, deposits and poor oil life. The compositions of the present disclosure combine additives to extend hydraulic oil drain intervals with the unexpected benefit of yellow metal corrosion control through the use of overbased detergents in combination with thermally stable ZDDP.

SPECIFIC EMBODIMENTS

An aspect of the present disclosure provides a hydraulic oil composition comprising: one or more lubricating base oil; an effective amount of at least one overbased detergent; and an effective amount of at least one thermally stable zinc dialkyl dithiophosphate (ZDDP).

In any aspect or embodiment described herein, at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or (iii) a combination thereof.

In any aspect or embodiment described herein, at least one of: (i) the effective amount of the overbased detergent is from about 0.001 wt.% to about 1.5 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.05 wt.% to about 2 wt.%; or (iii) a combination thereof.

In any aspect or embodiment described herein, at least one of: (i) the effective amount of the overbased detergent is from about 0.01 wt.% to about 0.75 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.1 wt.% to about 1 wt.%; or (iii) a combination thereof.

In any aspect or embodiment described herein, at least one of: (i) the overbased detergent includes at least one of calcium, magnesium, sodium, barium, or a combination thereof; (ii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; or (iii) a combination thereof.

In any aspect or embodiment described herein, the overbased detergent includes at least one of overbased sulfurized calcium phenate detergent, overbased magnesium sulfonate detergent,
overbased calcium phenate detergent, overbased calcium sulfonate detergent, or a combination thereof.

[0336] In any aspect or embodiment described herein, the thermally stable ZDDP includes at least one of a primary ZDDP, a branched primary ZDDP, or a combination thereof.

[0337] In any aspect or embodiment described herein, the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil (e.g., at least one of Group II light neutral oil, Group II heavy neutral oil, or a combination thereof), a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof.

[0338] In any aspect or embodiment described herein, the lubricating base oil or oils include at least one Group II oil.

[0339] In any aspect or embodiment described herein, the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof.

[0340] In any aspect or embodiment described herein, the dispersant includes succinimide-type dispersant.

[0341] In any aspect or embodiments described herein, the hydraulic oil composition results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in a hydraulic motor relative to a hydraulic oil composition that does not include the effective amount of a overbased detergent and/or the effective amount of a thermally stable ZDDP.

[0342] Another aspect of the present disclosure provides a method of making a hydraulic oil composition with at least one of improved hydrolytic stability, improved thermo-oxidative stability, decreased metal corrosion (such as, yellow metal corrosion), or a combination thereof. The method comprises mixing: at least one lubricating base oil; at least one overbased detergent in an amount no greater than about 3 wt.%; and at least one thermally stable ZDDP in an amount from about 0.01 wt.% to about 3 wt.%. 
In any aspect or embodiment described herein, at least one of: (i) the overbased detergent is present in an amount of from about 0.001 wt.% to about 1.5 wt.%; (ii) the thermally stable ZDDP is present in an amount from about 0.05 wt.% to about 2 wt.%; or (iii) a combination thereof.

In any aspect or embodiment described herein, at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

A further aspect of the disclosure provides a hydraulic oil composition produced according to the method(s) of the present disclosure.

An additional aspect of the disclosure provides a method for lubricating a hydraulic motor requiring a hydraulic oil composition. The method comprises: supplying the hydraulic motor with a hydraulic oil composition of the present disclosure, such as a hydraulic oil composition comprising: at least one lubricating base oil; an effective amount of at least one overbased detergent; and an effective amount of at least one thermally stable ZDDP.

In any aspect or embodiment described herein, at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or (iii) a combination thereof.

In any aspect or embodiment described herein, at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least
one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof

[0349] In any aspect or embodiment described herein, the lubricating base oil or oils are Group II oil.

[0350] In any aspect or embodiment described herein, the method results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in the hydraulic motor relative to a method using a hydraulic oil composition that does not include the effective amount of the overbased detergent and/or the thermally stable ZDDP.

PCT/EP Clauses:

[0351] 1. A hydraulic oil composition comprising: one or more lubricating base oil; an effective amount of at least one overbased detergent; and an effective amount of at least one thermally stable zinc dialkyl dithiophosphate (ZDDP).

[0352] 2. The composition of clause 1, wherein at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or (iii) a combination thereof.

[0353] 3. The composition of clauses 1-2, wherein at least one of: (i) the effective amount of the overbased detergent is from about 0.001 wt.% to about 1.5 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.05 wt.% to about 2 wt.%; or (iii) a combination thereof.

[0354] 4. The composition of clauses 1-3, wherein at least one of: (i) the effective amount of the overbased detergent is from about 0.01 wt.% to about 0.75 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.1 wt.% to about 1 wt.%; or (iii) a combination thereof.

[0355] 5. The composition of clauses 1-4, wherein at least one of: (i) the overbased detergent includes at least one of calcium, magnesium, sodium, barium, or a combination thereof; (ii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; or (iii) a combination thereof.

[0356] 6. The composition of clauses 1-5, wherein the overbased detergent includes at least one of overbased sulfurized calcium phenate detergent, overbased magnesium sulfonate detergent,
overbased calcium phenate detergent, overbased calcium sulfonate detergent, or a combination thereof.

[0357] 7. The composition of clauses 1-6, wherein the thermally stable ZDDP includes at least one of a primary ZDDP, a branched primary ZDDP, or a combination thereof.

[0358] 8. The composition of clauses 1-7, wherein the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil (e.g., at least one of Group II light neutral oil, Group II heavy neutral oil, or a combination thereof), a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof.

[0359] 9. The composition of clauses 1-8, wherein the lubricating base oil or oils include at least one Group II oil.

[0360] 10. The composition of clauses 1-9, wherein the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seize agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof.

[0361] 11. The composition of clauses 10, wherein the dispersant includes succinimide-type dispersant.

[0362] 12. The composition of clauses 1-11, wherein the hydraulic oil composition results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in a hydraulic motor relative to a hydraulic oil composition that does not include the effective amount of a overbased detergent and/or the effective amount of a thermally stable ZDDP.

[0363] 13. A method of making a hydraulic oil composition with at least one of improved hydrolytic stability, improved thermo-oxidative stability, decreased metal corrosion (such as, yellow metal corrosion), or a combination thereof comprising mixing at least one lubricating base oil; at least one overbased detergent in an amount no greater than about 3 wt.%; and at least one thermally stable ZDDP in an amount from about 0.01 wt.% to about 3 wt.%. 
14. The method of clause 13, wherein at least one of: (i) the overbased detergent is present in an amount of from about 0.001 wt.% to about 1.5 wt.%; (ii) the thermally stable ZDDP is present in an amount from about 0.05 wt.% to about 2 wt.%; or (iii) a combination thereof.

15. The method of clauses 13-14, wherein at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

16. A method for lubricating a hydraulic motor requiring a hydraulic oil composition comprising: supplying the hydraulic motor with a hydraulic oil composition comprising at least one lubricating base oil; an effective amount of at least one overbased detergent; and an effective amount of at least one thermally stable ZDDP.

17. The method of clause 16, wherein the at least one of: (i) the effective amount of the overbased detergent is no greater than about 3 wt.%; (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or (iii) a combination thereof.

18. The method of clauses 16-17, wherein at least one of: (i) the thermally stable ZDDP is a primary thermally stable ZDDP; (ii) the overbased detergent includes calcium, magnesium, sodium or barium; (iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; (iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof; (v) the composition further comprises at least one of a dispersant, an additional antitrust agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity
improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or (vi) a combination thereof.

19. The method of clauses 16-18, wherein the lubricating base oil or oils are Group II oil.

20. The method of clauses 16-19, wherein the method results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in the hydraulic motor relative to a method using a hydraulic oil composition that does not include the effective amount of the overbased detergent and/or the thermally stable ZDDP.

EQUIVALENTS

Each documents referred to herein is incorporated herein by reference. Except in the Examples, or where otherwise explicitly indicated, all numerical quantities in this description specifying amounts of materials, reaction conditions, molecular weights, number of carbon atoms, and the like, are to be understood as modified by the word "about". Unless otherwise indicated all percent values on weight percents and all ppm values are on a weight to weight basis. Unless otherwise indicated, each chemical or composition referred to herein should be interpreted as being a commercial grade material which may contain the isomers, by-products, derivatives, and other such materials which are normally understood to be present in the commercial grade. However, the amount of each chemical component is presented exclusive of any solvent or diluent, which may be customarily present in the commercial material, unless otherwise indicated. It is to be understood that the upper and lower amount, range, and ratio limits set forth herein may be independently combined. Similarly, the ranges and amounts for each element of the disclosure can be used together with ranges or amounts for any of the other elements.

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments and methods described herein. Such equivalents are intended to be encompassed by the scope of the following claims.

It is understood that the detailed examples and embodiments described herein are given by way of example for illustrative purposes only, and are in no way considered to be limiting to the disclosure. Various modifications or changes in light thereof will be suggested to persons skilled in the art and are included within the spirit and purview of this application and are considered within the scope of the appended claims. For example, the relative quantities of
the ingredients may be varied to optimize the desired effects, additional ingredients may be added, and/or similar ingredients may be substituted for one or more of the ingredients described. Additional advantageous features and functionalities associated with the systems, methods, and processes of the present disclosure will be apparent from the appended claims. Moreover, those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments of the disclosure described herein. Such equivalents are intended to be encompassed by the following claims.
CLAIMS:
1. A hydraulic oil composition comprising:
   one or more lubricating base oil;
   an effective amount of at least one overbased detergent; and
   an effective amount of at least one thermally stable zinc dialkyl dithiophosphate (ZDDP).
2. The composition of claim 1, wherein at least one of:
   (i) the effective amount of the overbased detergent is no greater than about 3 wt.%;
   (ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or
   (iii) a combination thereof.
3. The composition of claims 1-2, wherein at least one of:
   (i) the effective amount of the overbased detergent is from about 0.001 wt.% to about 1.5 wt.%;
   (ii) the effective amount of the thermally stable ZDDP ranges from about 0.05 wt.% to about 2 wt.%; or
   (iii) a combination thereof.
4. The composition of claims 1-3, wherein at least one of:
   (i) the effective amount of the overbased detergent is from about 0.01 wt.% to about 0.75 wt.%;
   (ii) the effective amount of the thermally stable ZDDP ranges from about 0.1 wt.% to about 1 wt.%; or
   (iii) a combination thereof.
5. The composition of claims 1-4, wherein at least one of:
   (i) the overbased detergent includes at least one of calcium, magnesium, sodium, barium, or a combination thereof;
   (ii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof; or
   (iii) a combination thereof.
6. The composition of claims 1-5, wherein the overbased detergent includes at least one of overbased sulfurized calcium phenate detergent, overbased magnesium sulfonate detergent, overbased calcium phenate detergent, overbased calcium sulfonate detergent, or a combination thereof.
7. The composition of claims 1-6, wherein the thermally stable ZDDP includes at least one of a primary ZDDP, a branched primary ZDDP, or a combination thereof.
8. The composition of claims 1-7, wherein the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil (e.g., at least one of Group II light neutral oil, Group II heavy neutral oil, or a combination thereof), a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof.

9. The composition of claims 1-8, wherein the lubricating base oil or oils include at least one Group II oil.

10. The composition of claims 1-9, wherein the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof.

11. The composition of claim 10, wherein the dispersant includes succinimide-type dispersant.

12. The composition of claims 1-11, wherein the hydraulic oil composition results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in a hydraulic motor relative to a hydraulic oil composition that does not include the effective amount of a overbased detergent and/or the effective amount of a thermally stable ZDDP.

13. A method of making a hydraulic oil composition with at least one of improved hydrolytic stability, improved thermo-oxidative stability, decreased metal corrosion (such as, yellow metal corrosion), or a combination thereof comprising mixing at least one lubricating base oil; at least one overbased detergent in an amount no greater than about 3 wt.%; and at least one thermally stable ZDDP in an amount from about 0.01 wt.% to about 3 wt.%. 

14. The method of claim 13, wherein at least one of:

   (i) the overbased detergent is present in an amount of from about 0.001 wt.% to about 1.5 wt.%;

   (ii) the thermally stable ZDDP is present in an amount from about 0.05 wt.% to about 2 wt.%;

   or

   (iii) a combination thereof.

15. The method of claims 13-14, wherein at least one of:

   (i) the thermally stable ZDDP is a primary thermally stable ZDDP;
(ii) the overbased detergent includes calcium, magnesium, sodium or barium;

(iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof;

(iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof;

(v) the composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or

(vi) a combination thereof

16. A method for lubricating a hydraulic motor requiring a hydraulic oil composition comprising:

supplying the hydraulic motor with a hydraulic oil composition comprising at least one lubricating base oil;

an effective amount of at least one overbased detergent; and

an effective amount of at least one thermally stable ZDDP.

17. The method of claim 16, wherein the at least one of:

(i) the effective amount of the overbased detergent is no greater than about 3 wt.%;

(ii) the effective amount of the thermally stable ZDDP ranges from about 0.01 wt.% to about 3 wt.%; or

(iii) a combination thereof.

18. The method of claims 16-17, wherein at least one of:

(i) the thermally stable ZDDP is a primary thermally stable ZDDP;

(ii) the overbased detergent includes calcium, magnesium, sodium or barium;

(iii) the overbased detergent is at least one of an overbased sulfonate, an overbased phenate, an overbased salicylate, or a combination thereof;

(iv) the lubricating base oil or oils comprise at least one of: a Group I oil, a Group II oil, a Group III oil, a Group IV oil, a Group V oil, a gas-to-liquid oil, a polyalphaolefin, or combinations thereof;
(v) The composition further comprises at least one of a dispersant, an additional antiwear agent, a corrosion inhibitor, a rust inhibitor, an additional detergent, an anti-seizure agent, an antifoam agent or defoamant, a wax modifier, a metal deactivator/passivator, an extreme pressure additive, an antioxidant, a viscosity index improver, a viscosity improver/modifier, a seal compatibility agent, a pour point depressant, a friction modifier, a lubricity agent, an anti-staining agent, a dye or colorant/chromophoric agent, a demulsifier, a wetting agent, an oxidation inhibitor, a tackiness agent, a colorant, a detergent stabilizer, or combinations thereof; or

(vi) a combination thereof

19. The method of claims 16-18, wherein the lubricating base oil or oils are Group II oil.

20. The method of claims 16-19, wherein the method results in improved hydrolytic stability, improved thermo-oxidative stability, and/or decreased metal corrosion (such as, yellow metal corrosion) in the hydraulic motor relative to a method using a hydraulic oil composition that does not include the effective amount of the overbased detergent and/or the thermally stable ZDDP.
Table 4. Formulation and characteristics of Exemplary Examples and Comparative Examples

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INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. C10M137/10 C10M159/20 C10M163/00

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

CIOM CIOM

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>EP 0 382 242 A1 (COSMO OI L CO LTD [JP] ; NISSAN MOTOR [JP] ) 16 August 1990 (1990-08-16) page 7, line 19 - line 23; claim 1; examples comp. ex. 1-3; tables 1, 2</td>
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Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"A" document member of the same patent family

Date of the actual completion of the international search

27 November 2018

Date of mailing of the international search report

03/12/2018

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax. (+31-70) 340-3016

Authorized officer

Kal uza, Nora
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