

## METHOD FOR IMPROVING ENGINE FUEL EFFICIENCY

### FIELD

**[0001]** This disclosure relates to lubricating engines using formulated lubricating oils to improve engine fuel efficiency without sacrificing engine durability.

### BACKGROUND

**[0002]** Fuel efficiency requirements for passenger vehicles are becoming increasingly more stringent. New legislation in the United States and European Union within the past few years has set fuel economy and emissions targets not readily achievable with today's vehicle and lubricant technology. In order to improve lubricant fuel economy performance, reduction of viscosity is typically the best path; however, present day lubricant oils with a HTHS (ASTM D4683) viscosity of less than 2.6 cP at 150°C would not be expected to be able to provide acceptable passenger vehicle engine durability performance.

**[0003]** HTHS is the measure of a lubricant's viscosity under conditions that simulate severe engine operation. Under high temperatures and high stress conditions, viscosity index improver degradation can occur. As this happens, the viscosity of the oil decreases which may lead to increased engine wear.

**[0004]** A viscosity index improver is typically added to engine oil in order to provide appropriate viscosity at high and low temperatures and thereby widen the application temperature range. High molecular weight polymers are widely used as viscosity index improvers. The high molecular weight polymer-based viscosity index improver has the typical property of such improvers; that is, a temporary viscosity decrease due to orientation, etc., occurs during operation at high speed/high load or under other high shear conditions, and irreversible viscosity decrease occurs due to molecular weight decrease as a result of chopping of the polymer molecules when the shear conditions become severe. Also, when the viscosity of the engine oil is reduced, the engine oil film itself becomes thinner, and the opportunity for increased engine wear arises. Therefore,

for engine oils in which a viscosity index improver is added, if the viscosity is reduced by simply reducing the viscosity of the base oil, it is not possible to guarantee the oil film under high shear conditions, and engine wear can easily occur.

**[0005]** Despite the advances in lubricant oil formulation technology, there exists a need for an engine oil lubricant that effectively improves fuel economy while providing superior antiwear performance, and has the capability to do so through reduction or removal of viscosity index improvers.

### SUMMARY

**[0006]** This disclosure relates in part to a method for improving fuel efficiency, while maintaining or improving wear protection, in an engine lubricated with a lubricating oil by reducing the amount of a viscosity index improver in the lubricating oil sufficient for the lubricating oil to have a HTHS viscosity of less than 2.6 cP at 150°C.

**[0007]** This disclosure also relates in part to a method for improving fuel efficiency, while maintaining or improving wear protection, in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a HTHS viscosity of less than 2.6 cP at 150°C. The formulated oil has a composition that comprises a lubricating oil base stock as a major component, and zinc dialkyl dithio phosphate, a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents; and a viscosity index improver, as minor components. The composition contains less than 2 weight percent of the viscosity index improver, based on the total weight of the formulated oil. The composition is sufficient for the formulated oil to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA and OM646LA.

**[0008]** This disclosure further relates in part to a lubricating engine oil having a composition comprising a lubricating oil base stock as a major component, and a zinc dialkyl dithio phosphate, a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one

or more alkaline earth metal detergents, e.g., magnesium sulfonate and calcium salicylate; and a viscosity index improver, as minor components. The lubricating engine oil has a HTHS viscosity of less than 2.6 cP at 150°C. The composition contains less than 2 weight percent of the viscosity index improver, based on the total weight of the lubricating engine oil. The composition is sufficient for the lubricating engine oil to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA and OM646LA.

**[0009]** This disclosure yet further relates in part to a method for improving fuel efficiency, while maintaining or improving wear protection, in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a HTHS viscosity of less than 2.6 cP at 150°C. The formulated oil has a composition that comprises a lubricating oil base stock as a major component, and zinc dialkyl dithio phosphate, and a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, as minor components. The composition can optionally contain a viscosity index improver in an amount less than 2 weight percent, based on the total weight of the formulated oil. The composition is sufficient for the formulated oil to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA and OM646LA.

**[0010]** This disclosure also relates in part to a lubricating engine oil having a composition comprising a lubricating oil base stock as a major component, and a zinc dialkyl dithio phosphate, and a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, e.g., magnesium sulfonate and calcium salicylate, as minor components. The lubricating engine oil has a HTHS viscosity of less than 2.6 cP at 150°C. The composition can optionally contain a viscosity index improver in an amount less than 2 weight percent, based on the total weight of the formulated oil. The composition is sufficient for the formulated oil to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA and OM646LA.

[0011] In accordance with this disclosure, improvements in fuel economy are obtained without sacrificing engine durability by a reduction of HTHS viscosity to a level less than 2.6 cP through reduction or removal of viscosity modifiers. Engine wear protection is maintained even when a viscosity modifier is reduced or removed from the engine oil formulation, leading to substantially lower HTHS viscosities, e.g., 2.6 cP or lower at 150°C.

[0012] Other objects and advantages of the present disclosure will become apparent from the detailed description that follows.

#### DETAILED DESCRIPTION

[0013] All numerical values within the detailed description and the claims herein are modified by “about” or “approximately” the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

[0014] It has now been found that improved fuel efficiency can be attained, while wear protection is maintained or improved, in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a HTHS viscosity of less than 2.6 cP at 150°C. The formulated oil comprises a lubricating oil base stock as a major component, a zinc dialkyl dithio phosphate, and a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents; and a viscosity index improver, as minor components. The lubricating oils of this disclosure are particularly advantageous as passenger vehicle engine oil (PVEO) products.

[0015] The lubricating oils of this disclosure provide excellent engine protection including anti-wear performance. This benefit has been demonstrated for the lubricating oils of this disclosure in the Sequence IIIG/IIIGA (ASTM D7320), Sequence IVA (ASTM D6891), PSA TU3MS (CEC L-038-94), MB OM646LA (CEC L-099-08), and Caterpillar 1M-PC (ASTM D6618) engine tests at HTHS viscosities less than 2.6 cP (at 150°C). The lubricating oils of this disclosure provide improved fuel efficiency. A

lower HTHS viscosity engine oil generally provides superior fuel economy to a higher HTHS viscosity product. This benefit has been demonstrated for the lubricating oils of this disclosure in the MB M111 Fuel Economy (CEC L-054-96) and Sequence VID Fuel Economy (ASTM D7589) engine tests. By providing outstanding engine protection at very low HTHS viscosities, this disclosure provides improved fuel economy without sacrificing engine durability.

**[0016]** The engine lubricating oil of the present disclosure has a HTHS viscosity of less than 2.6 cP at 150°C, preferably less than 2.4 cP at 150°C, and more preferably less than 2.2 cP at 150°C.

**[0017]** The lubricating engine oils of this disclosure have a composition sufficient to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA, OM646LA and others.

#### Lubricating Oil Base Stocks

**[0018]** A wide range of lubricating base oils is known in the art. Lubricating base oils that are useful in the present disclosure are both natural oils, and synthetic oils, and unconventional oils (or mixtures thereof) can be used unrefined, refined, or rerefined (the latter is also known as reclaimed or reprocessed oil). Unrefined oils are those obtained directly from a natural or synthetic source and used without added purification. These include shale oil obtained directly from retorting operations, petroleum oil obtained directly from primary distillation, and ester oil obtained directly from an esterification process. Refined oils are similar to the oils discussed for unrefined oils except refined oils are subjected to one or more purification steps to improve at least one lubricating oil property. One skilled in the art is familiar with many purification processes. These processes include solvent extraction, secondary distillation, acid extraction, base extraction, filtration, and percolation. Rerefined oils are obtained by processes analogous to refined oils but using an oil that has been previously used as a feed stock.

**[0019]** Groups I, II, III, IV and V are broad base oil stock categories developed and defined by the American Petroleum Institute (API Publication 1509; [www.API.org](http://www.API.org)) to

create guidelines for lubricant base oils. Group I base stocks have a viscosity index of between 80 to 120 and contain greater than 0.03% sulfur and/or less than 90% saturates. Group II base stocks have a viscosity index of between 80 to 120, and contain less than or equal to 0.03% sulfur and greater than or equal to 90% saturates. Group III stocks have a viscosity index greater than 120 and contain less than or equal to 0.03 % sulfur and greater than 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stock includes base stocks not included in Groups I-IV. The table below summarizes properties of each of these five groups.

|           | Base Oil Properties                                               |            |                 |
|-----------|-------------------------------------------------------------------|------------|-----------------|
|           | Saturates                                                         | Sulfur     | Viscosity Index |
| Group I   | <90 and/or                                                        | >0.03% and | ≥80 and <120    |
| Group II  | ≥90 and                                                           | ≤0.03% and | ≥80 and <120    |
| Group III | ≥90 and                                                           | ≤0.03% and | ≥120            |
| Group IV  | Includes polyalphaolefins (PAO) and GTL products                  |            |                 |
| Group V   | All other base oil stocks not included in Groups I, II, III or IV |            |                 |

**[0020]** 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, hydrotreated, or solvent extracted.

**[0021]** Group II and/or Group III hydroprocessed or hydrocracked basestocks, including synthetic oils such as polyalphaolefins, alkyl aromatics and synthetic esters are also well known basestock oils.

**[0022]** Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymers of 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 C<sub>8</sub>, C<sub>10</sub>, C<sub>12</sub>, C<sub>14</sub> olefins or mixtures thereof may be utilized. See U.S. Patent Nos. 4,956,122; 4,827,064; and 4,827,073.

**[0023]** The number 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, typically vary from 250 to 3,000, although PAO's may be made in viscosities up to 100 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, C<sub>2</sub> to C<sub>32</sub> alphaolefins with the C<sub>8</sub> to C<sub>16</sub> alphaolefins, such as 1-octene, 1-decene, 1-dodecene and the like, being preferred. The preferred polyalphaolefins are poly-1-octene, poly-1-decene and poly-1-dodecene and mixtures thereof and mixed olefin-derived polyolefins. However, the dimers of higher olefins in the range of C<sub>14</sub> to C<sub>18</sub> may be used to provide low viscosity basestocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly trimers and tetramers of the starting olefins, with minor amounts of the higher oligomers, having a viscosity range of 1.5 to 12 cSt.

**[0024]** 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 C<sub>14</sub> to C<sub>18</sub> olefins are described in U.S. Patent No. 4,218,330.

**[0025]** The hydrocarbyl aromatics can be used as base oil or base oil component and can be any hydrocarbyl molecule that contains at least 5% of its weight 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 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 C<sub>6</sub> up to C<sub>60</sub> with a range of C<sub>8</sub> to C<sub>20</sub> often being preferred. A mixture of hydrocarbyl groups is often preferred, and up to 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 5% of the molecule is comprised of an above-type aromatic moiety. Viscosities at 100°C of approximately 3 cSt to 50 cSt are preferred, with viscosities of approximately 3.4 cSt to 20 cSt often being more preferred 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. Useful concentrations of hydrocarbyl aromatic in a lubricant oil composition can be 2% to 25%, preferably 4% to 20%, and more preferably 4% to 15%, depending on the application.

**[0026]** 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.

**[0027]** Particularly useful synthetic esters are those which are obtained by reacting one or more polyhydric alcohols, preferably the hindered polyols (such as 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 4 carbon atoms, preferably C<sub>5</sub> to C<sub>30</sub> 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.

**[0028]** 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 5 to 10 carbon atoms. These esters are widely available commercially, for example, the Mobil P-41 and P-51 esters of ExxonMobil Chemical Company).

**[0029]** Other useful fluids of lubricating viscosity include non-conventional or unconventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance lubrication characteristics.

**[0030]** 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.

**[0031]** 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, butylenes, 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); preferably 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.

**[0032]** 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 2 mm<sup>2</sup>/s to 50 mm<sup>2</sup>/s (ASTM D445). They are further characterized typically as having pour points of -5°C to -40°C or lower (ASTM D97). They are also characterized typically as having viscosity indices of 80 to 140 or greater (ASTM D2270).

**[0033]** 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 10 ppm, and more typically less than 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 phosphorous and aromatics make this materially especially suitable for the formulation of low SAP products.

**[0034]** 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.

**[0035]** 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).

**[0036]** 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) and hydrodewaxed, or hydroisomerized/cat (and/or solvent) dewaxed base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than 10 ppm, and more typically less than 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 phosphorous and aromatics make this material especially suitable for the formulation of low sulfur, sulfated ash, and phosphorus (low SAP) products.

**[0037]** 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, preferably API Group II, Group III, Group IV, and Group V oils and mixtures thereof, more preferably the Group III to

Group V base oils due to their exceptional volatility, stability, viscometric and cleanliness features. Minor quantities of Group I stock, such as the amount used to dilute additives for blending into formulated lube oil products, can be tolerated but should be kept to a minimum, i.e. amounts only associated with their use as diluent/carrier oil for additives used on an “as-received” basis. Even in regard to the Group II stocks, it is preferred that the Group II stock be in the higher quality range associated with that stock, i.e. a Group II stock having a viscosity index in the range  $100 < VI < 120$ .

**[0038]** The base oil constitutes the major component of the engine oil lubricant composition of the present disclosure and typically is present in an amount ranging from 50 to 99 weight percent, preferably from 70 to 95 weight percent, and more preferably from 85 to 95 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 crankcase lubricating oils for spark-ignited and compression-ignited engines. The base oil conveniently has a kinematic viscosity, according to ASTM standards, of 2.5 cSt to 12 cSt (or  $\text{mm}^2/\text{s}$ ) at  $100^\circ\text{C}$  and preferably of 2.5 cSt to 9 cSt (or  $\text{mm}^2/\text{s}$ ) at  $100^\circ\text{C}$ . Mixtures of synthetic and natural base oils may be used if desired.

#### Antiwear Additive

**[0039]** A metal alkylthiophosphate and more particularly a metal dialkyl dithio phosphate in which the metal constituent is zinc, or zinc dialkyl dithio phosphate (ZDDP) is an essential component of the lubricating oils of this disclosure. ZDDP can be primary, secondary or mixtures thereof. ZDDP compounds generally are of the formula  $\text{Zn}[\text{SP}(\text{S})(\text{OR}^1)(\text{OR}^2)]_2$  where  $\text{R}^1$  and  $\text{R}^2$  are  $\text{C}_1$ - $\text{C}_{18}$  alkyl groups, preferably  $\text{C}_2$ - $\text{C}_{12}$  alkyl groups. These alkyl groups may be straight chain or branched.

**[0040]** Preferable zinc dithiophosphates which 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”.

[0041] The ZDDP is typically used in amounts of from 0.4 weight percent to 1.2 weight percent, preferably from 0.5 weight percent to 1.0 weight percent, and more preferably from 0.6 weight percent to 0.8 weight percent, based on the total weight of the lubricating oil, although more or less can often be used advantageously. Preferably, the ZDDP is a secondary ZDDP and present in an amount of from 0.6 to 1.0 weight percent of the total weight of the lubricating oil.

#### Detergent Mixture Additive

[0042] A detergent mixture containing (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, is an essential component in the lubricating oils of this disclosure. A typical 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 is typically derived from an organic acid such as a sulfur acid, carboxylic acid, phosphorous acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal.

[0043] Salts that contain a substantially stoichiometric 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.

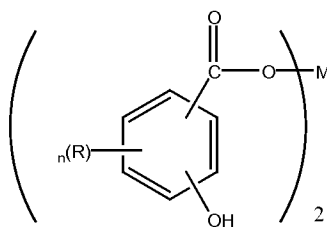
[0044] It is desirable for at least some detergent used in the detergent mixture to be overbased. Overbased detergents help neutralize acidic impurities produced by the combustion process and become entrapped in the oil. Typically, the overbased material has a ratio of metallic ion to anionic portion of the detergent of 1.05:1 to 50:1 on an equivalent basis. More preferably, the ratio is from 4:1 to 25:1. The resulting detergent is an overbased detergent that will typically have a TBN of 150 or higher, often 250 to 450 or more. Preferably, the overbasing cation is sodium, calcium, or magnesium. A mixture of detergents of differing TBN can be used in the present disclosure.

**[0045]** Preferred detergent mixtures include at least two of the alkali or alkaline earth metal salts of sulfonates, phenates, carboxylates, phosphates, and salicylates, e.g., a mixture of magnesium sulfonate and calcium salicylate.

**[0046]** Sulfonates may be prepared from sulfonic acids that are typically obtained by sulfonation of alkyl substituted aromatic hydrocarbons. Hydrocarbon examples include those obtained by alkylating benzene, toluene, xylene, naphthalene, biphenyl and their halogenated derivatives (chlorobenzene, chlorotoluene, and chloronaphthalene, for example). The alkylating agents typically have 3 to 70 carbon atoms. The alkaryl sulfonates typically contain 9 to 80 carbon or more carbon atoms, more typically from 16 to 60 carbon atoms.

**[0047]** 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)<sub>2</sub>, BaO, Ba(OH)<sub>2</sub>, MgO, Mg(OH)<sub>2</sub>, for example) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight chain or branched C<sub>1</sub>-C<sub>30</sub> alkyl groups, preferably, C<sub>4</sub>-C<sub>20</sub>. 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. 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.

**[0048]** Metal salts of carboxylic acids are also useful as detergents. 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 preferred class of detergents derived from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the formula



where R is an alkyl group having 1 to 30 carbon atoms, n is an integer from 1 to 4, and M is an alkaline earth metal. Preferred R groups are alkyl chains of at least C<sub>11</sub>, preferably C<sub>13</sub> or greater. R may be optionally substituted with substituents that do not interfere with the detergent's function. M is preferably, calcium, magnesium, or barium. More preferably, M is calcium.

**[0049]** 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.

**[0050]** Alkaline earth metal phosphates are also used as detergents and are known in the art.

**[0051]** 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.

**[0052]** Preferred detergent mixtures include at least two of calcium phenates, calcium sulfonates, calcium salicylates, magnesium phenates, magnesium sulfonates, magnesium salicylates and other related components (including borated detergents) in any combination. A preferred detergent mixture includes magnesium sulfonate and calcium salicylate.

**[0053]** The detergent mixture concentration in the lubricating oils of this disclosure can range from 1.0 to 6.0 weight percent, preferably 2.0 to 5.0 weight percent, and more

preferably from 2.0 weight percent to 4.0 weight percent, based on the total weight of the lubricating oil.

#### Other Additives

**[0054]** The formulated lubricating oil useful in the present disclosure may additionally contain one or more of the other commonly used lubricating oil performance additives including but not limited to dispersants, other detergents, corrosion inhibitors, rust inhibitors, metal deactivators, other anti-wear agents and/or extreme pressure additives, anti-seizure agents, wax modifiers, viscosity index improvers, viscosity modifiers, fluid-loss additives, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, emulsifiers, densifiers, wetting agents, gelling agents, tackiness agents, colorants, and others. 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).

**[0055]** The types and quantities of performance additives used in combination with the instant disclosure in lubricant compositions are not limited by the examples shown herein as illustrations.

#### Dispersants

**[0056]** During engine operation, oil-insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Dispersants used in the formulation of the lubricating oil may be ashless or ash-forming in nature. Preferably, the dispersant is ashless. So-called ashless dispersants 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 discussed above form ash upon combustion.

**[0057]** Suitable dispersants typically contain a polar group attached to a relatively high molecular weight hydrocarbon chain. The polar group typically contains at least one element of nitrogen, oxygen, or phosphorus. Typical hydrocarbon chains contain 50 to 400 carbon atoms.

**[0058]** Chemically, many dispersants may be characterized as phenates, sulfonates, sulfurized phenates, salicylates, naphthenates, stearates, carbamates, thiocarbamates, phosphorus derivatives. A particularly useful class of dispersants are the alkenylsuccinic derivatives, typically produced by the reaction of a long chain hydrocarbyl substituted succinic compound, usually 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; 3,215,707; 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; 3,725,480; 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.

**[0059]** 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 preferably having at least 50 carbon atoms in the hydrocarbon substituent, with at least one equivalent of an alkylene amine are particularly useful.

**[0060]** 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 1:1 to 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.

**[0061]** Succinate esters are 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.

**[0062]** Succinate ester amides are 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.

**[0063]** The molecular weight of the hydrocarbyl substituted succinic anhydrides used in the preceding paragraphs will typically range between 800 and 2,500. 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 generally having from 0.1 to 5 moles of boron per mole of dispersant reaction product.

**[0064]** 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 range from 800 to 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.

**[0065]** Typical high molecular weight aliphatic acid modified Mannich condensation products useful in this disclosure can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or HN(R)<sub>2</sub> group-containing reactants.

[0066] 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.

[0067] Preferred dispersants include borated and 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 500 to 5000 or a mixture of such hydrocarbylene groups. Other preferred dispersants include succinic acid-esters and amides, alkylphenol-polyamine-coupled Mannich adducts, their capped derivatives, and other related components. Such additives may be used in an amount of 0.1 to 20 weight percent, preferably 0.5 to 8 weight percent.

#### Antioxidants

[0068] Antioxidants 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.

[0069] 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. Typical phenolic antioxidant compounds are the hindered phenolics which are the ones which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with C<sub>6</sub>+ 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

mono-phenolic antioxidants may include for example hindered 2,6-di-alkyl-phenolic proprionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used in combination with the instant 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).

**[0070]** Non-phenolic oxidation inhibitors which may be used include aromatic amine antioxidants and these may be used either as such or in combination with phenolics. Typical examples of non-phenolic antioxidants include: alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula  $R^8R^9R^{10}N$  where  $R^8$  is an aliphatic, aromatic or substituted aromatic group,  $R^9$  is an aromatic or a substituted aromatic group, and  $R^{10}$  is H, alkyl, aryl or  $R^{11}S(O)_xR^{12}$  where  $R^{11}$  is an alkylene, alkenylene, or aralkylene group,  $R^{12}$  is a higher alkyl group, or an alkenyl, aryl, or alkaryl group, and x is 0, 1 or 2. The aliphatic group  $R^8$  may contain from 1 to 20 carbon atoms, and preferably contains from 6 to 12 carbon atoms. The aliphatic group is a saturated aliphatic group. Preferably, both  $R^8$  and  $R^9$  are aromatic or substituted aromatic groups, and the aromatic group may be a fused ring aromatic group such as naphthyl. Aromatic groups  $R^8$  and  $R^9$  may be joined together with other groups such as S.

**[0071]** Typical aromatic amines antioxidants have alkyl substituent groups of at least 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than 14 carbon atoms. The general types of amine antioxidants useful in the present compositions include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more aromatic amines are also useful. Polymeric amine antioxidants can also be used. Particular examples of aromatic amine antioxidants useful in the present disclosure include: p,p'-dioctyldiphenylamine; t-octylphenyl-alpha-naphthylamine; phenyl-alphanaphthylamine; and p-octylphenyl-alpha-naphthylamine.

[0072] Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants.

[0073] Preferred antioxidants include hindered phenols, arylamines. These antioxidants may be used individually by type or in combination with one another. Such additives may be used in an amount of 0.01 to 5 weight percent, preferably 0.01 to 1.5 weight percent, more preferably zero to less than 1.5 weight percent, most preferably zero.

#### Pour Point Depressants (PPDs)

[0074] Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present disclosure if desired. These pour point depressant may be added to lubricating compositions of the present disclosure to lower the minimum temperature at which the fluid will flow or can be poured. Examples of suitable pour point depressants include polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffin waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty acids and allyl vinyl ethers. 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. Such additives may be used in an amount of 0.01 to 5 weight percent, preferably 0.01 to 1.5 weight percent.

#### Seal Compatibility Agents

[0075] Seal compatibility agents help to swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Suitable seal compatibility agents for lubricating oils include organic phosphates, aromatic esters, aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride. Such additives may be used in an amount of 0.01 to 3 weight percent, preferably 0.01 to 2 weight percent.

### Anti-Foam Agents

[0076] Anti-foam agents may advantageously be added to lubricant compositions. These agents retard the formation of stable foams. Silicones and organic polymers are typical anti-foam agents. For example, polysiloxanes, such as silicon oil or polydimethyl siloxane, provide antifoam properties. Anti-foam agents are commercially available and may be used in conventional minor amounts along with other additives such as demulsifiers; usually the amount of these additives combined is less than 1 weight percent and often less than 0.1 weight percent.

### Friction Modifiers

[0077] 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. Friction modifiers may include metal-containing compounds or materials as well as ashless compounds or materials, or mixtures thereof. Metal-containing friction modifiers may include metal salts or metalligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have low-ash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivative of alcohols, polyols, glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles, triazoles, and other polar molecular functional groups containing effective amounts of O, N, S, or P, individually or in combination. In particular, Mo-containing compounds can be particularly effective such as for example Mo-dithiocarbamates, Mo(DTC), Mo-dithiophosphates, Mo(DTP), Mo-amines, Mo (Am), Mo-alcoholates,

Mo-alcohol-amides, etc. See U.S. Patent Nos. 5,824,627, 6,232,276, 6,153,564, 6,143,701, 6,110,878, 5,837,657, 6,010,987, 5,906,968, 6,734,150, 6,730,638, 6,689,725, 6,569,820; WO 99/66013; WO 99/47629; and WO 98/26030.

**[0078]** Ashless friction modifiers may also include lubricant materials that contain effective amounts of polar groups, for example, hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hydrocarbyl groups containing effective amounts of O, N, S, or P, individually or in combination. Other friction modifiers that may be particularly effective include, for example, salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long-chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, and the like. In some instances fatty organic acids, fatty amines, and sulfurized fatty acids may be used as suitable friction modifiers.

**[0079]** Useful concentrations of friction modifiers may range from 0.01 weight percent to 10-15 weight percent or more, often with a preferred range of 0.1 weight percent to 5 weight percent. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from 10 ppm to 3000 ppm or more, and often with a preferred range of 20-2000 ppm, and in some instances a more preferred range of 30-1000 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.

#### Viscosity Index Improvers

**[0080]** Viscosity index improvers (also known as VI improvers, viscosity modifiers, and viscosity improvers) can be included in the lubricant compositions of this disclosure. Preferably, the method of this disclosure obtains improvements in fuel economy without sacrificing durability by a reduction of high-temperature high-shear (HTHS) viscosity to a level lower than 2.6 cP through reduction or removal of viscosity index improvers or modifiers.

**[0081]** Viscosity index improvers provide lubricants with high and low temperature operability. These additives impart shear stability at elevated temperatures and acceptable viscosity at low temperatures.

**[0082]** Suitable viscosity index improvers include high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. Typical molecular weights of these polymers are between 10,000 to 1,500,000, more typically 20,000 to 1,200,000, and even more typically between 50,000 and 1,000,000.

**[0083]** Examples of suitable viscosity index improvers are linear or star-shaped polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity index improver. Another suitable viscosity index improver is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity index improvers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of 50,000 to 200,000 molecular weight.

**[0084]** 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". Polyisoprene polymers are commercially available from Infineum International Limited, e.g. under the trade designation "SV200"; diene-styrene copolymers are commercially available from Infineum International Limited, e.g. under the trade designation "SV 260".

**[0085]** In an embodiment of this disclosure, the viscosity index improvers may be used in an amount of less than 2.0 weight percent, preferably less than 1.0 weight

percent, and more preferably less than 0.5 weight percent, based on the total weight of the formulated oil or lubricating engine oil.

**[0086]** In another embodiment of this disclosure, the viscosity index improvers may be used in an amount of from 0.0 to 2.0 weight percent, preferably 0.0 to 1.0 weight percent, and more preferably 0.0 to 0.5 weight percent, based on the total weight of the formulated oil or lubricating engine oil.

**[0087]** 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. Typical amounts of such additives useful in the present disclosure are shown in Table 1 below.

**[0088]** 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 diluent. Accordingly, the weight amounts in the table below, as well as other amounts mentioned in this specification, 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 1  
Typical Amounts of Other Lubricating Oil Components

| Compound                                          | Approximate<br>wt% (Useful) | Approximate<br>wt% (Preferred) |
|---------------------------------------------------|-----------------------------|--------------------------------|
| Dispersant                                        | 0.1-20                      | 0.1-8                          |
| Friction Modifier                                 | 0.01-5                      | 0.01-1.5                       |
| Antioxidant                                       | 0.1-5                       | 0.1-1.5                        |
| Pour Point Depressant<br>(PPD)                    | 0.0-5                       | 0.01-1.5                       |
| Anti-foam Agent                                   | 0.001-3                     | 0.001-0.15                     |
| Viscosity Index Improver<br>(solid polymer basis) | 0.0-2                       | 0.0-1                          |

[0089] 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.

[0090] The following non-limiting examples are provided to illustrate the disclosure.

### **EXAMPLES**

[0091] Representative formulations are given in Table 2.

TABLE 2

| <u>Formulation</u>                                                                             | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.<br/>Ex. A</u> |
|------------------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|------------------------|
| Viscosity Grade                                                                                | 0W           | 0W           | 0W           | 5W           | 0W-20                  |
| Component, wt%                                                                                 |              |              |              |              |                        |
| Salicylate and Sulfonate Detergent Mixture                                                     | 2.73         | 2.73         | 3.52         | *            | 2.73                   |
| ZDDP                                                                                           | 0.734        | 0.734        | .75          | *            | 0.734                  |
| Viscosity Index Improver                                                                       | 0.0          | 0.468        | .12          | 0            | 0.702                  |
| Other Additives (dispersant, antioxidant, defoamant, PPD, seal swell agent, friction modifier) | Balance      | Balance      | Balance      | *            | Balance                |
| Base Oil                                                                                       | 88.886       | 88.42        | 87.46        | 88.9         | 88.184                 |
| Formulated Oil KV@100C, cSt                                                                    | 5.7          | 7.7          | 6.0          | 6.1          | 8.8                    |

\*10.8 weight % of Lubrizol 20018 commercially available GF-4 additive package.

| <u>Formulation</u>                                                                             | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------------------------------------------------------------------------|------------------------------|------------------------------|------------------------------|
| Viscosity Grade                                                                                | 0W-20                        | 5W-20                        | 0W                           |
| Component, wt%                                                                                 |                              |                              |                              |
| Salicylate and Sulfonate Detergent Mixture                                                     | 3.52                         | *                            | 2.73                         |
| ZDDP                                                                                           | 0.75                         | *                            | 0.734                        |
| Viscosity index improver                                                                       | 0.561                        | 0.315                        | 0.78                         |
| Other Additives (dispersant, antioxidant, defoamant, PPD, seal swell agent, friction modifier) | Balance                      | *                            | Balance                      |
| Base oil                                                                                       | 87.019                       | 88.585                       | 88.106                       |
| Formulated Oil KV@100C, cSt                                                                    | 8.6                          | 8.5                          | 9.9                          |

\*10.8 weight % of Lubrizol 20018 commercially available GF-4 additive package.

**[0092]** Among the features of the compositions of the disclosure is that there has been demonstrated both unexpected combination of wear and fuel efficiency performance. For instance, fuel economy can be improved by at least 0.4% as measured in the M111 FE engine test and while the wear performance is improved relative to the comparison oils.

**[0093]** Performance evaluation of the formulations is given in Tables 3–11. The following engine tests were performed to measure wear and fuel economy of the engine oil lubricant composition of the present disclosure: TU3M (CEC L-038-94), M111FE (CEC L-054-96), Sequence IIIG (ASTM D7320), Sequence IVA (ASTM D6891), Sequence VID (ASTM D7589), OM646LA (CEC L-099-08), Caterpillar 1M-PC (ASTM D6618) and Sequence VIII (ASTM D6709); all of which are incorporated herein by reference. HTHS viscosity was measured using ASTM D4683 which is incorporated herein by reference.

TABLE 3

| Description                  |                                                      | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|------------------------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                      | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade              |                                                      | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                     |              |              |              |              |                              |
| TU3M                         | <u>Valve Train</u><br><u>Scuffing</u><br><u>Wear</u> |              |              |              |              |                              |
|                              | Average cam<br>wear, $\mu\text{m}$                   | 3.6          | -            | 7.0          | 3.0          | 6.4                          |
|                              | Maximum<br>cam wear,<br>$\mu\text{m}$                | 4.5          | -            | 9.5          | 5.0          | 9.9                          |
|                              | Pad rating<br>(average of<br>8), merits              | 8.3          | -            | 8.8          | 8.9          | 8.6                          |

| Description                  |                                                      | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp. Ex.</u><br><u>D</u> |
|------------------------------|------------------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                      | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                                      | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                     |                              |                              |                              |
| TU3M                         | <u>Valve Train</u><br><u>Scuffing</u><br><u>Wear</u> |                              |                              |                              |
|                              | Average cam<br>wear, $\mu\text{m}$                   | 4.8                          | -                            | -                            |
|                              | Maximum<br>cam wear,<br>$\mu\text{m}$                | 10.9                         | -                            | -                            |
|                              | Pad rating<br>(average of<br>8), merits              | 8.6                          | -                            | -                            |

[0094] The parameters listed in Table 3 above, and methods for determining same, are more fully described in CEC L-038-94.

TABLE 4

| Description                  |                                              | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|----------------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                              | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade              |                                              | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                             |              |              |              |              |                              |
| M111<br>FE                   | <u>Fuel</u><br><u>Economy</u>                |              |              |              |              |                              |
|                              | Fuel<br>economy<br>improvement<br>vs. RL 191 | 3.77/4.01    | 3.91/3.69    | -            | -            | -                            |

| Description                  |                                              | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------|----------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                              | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                              | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                             |                              |                              |                              |
| M111<br>FE                   | <u>Fuel</u><br><u>Economy</u>                |                              |                              |                              |
|                              | Fuel<br>economy<br>improvement<br>vs. RL 191 | -                            | -                            | 3.22/3.31                    |

[0095] The parameters listed in Table 4 above, and methods for determining same, are more fully described in CEC-L-054-96.

TABLE 5

| Description                  |                                                      | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|------------------------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                      | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade              |                                                      | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                     |              |              |              |              |                              |
| Sequence III G               | <u>Wear and Oil</u><br><u>Thickness</u>              |              |              |              |              |                              |
|                              | Kinematic<br>viscosity<br>increase at<br>40°C, %     | 52.5         | -            | 51.4         | 126.0        | 50.0                         |
|                              | Average<br>weighted<br>piston<br>deposits,<br>merits | 6.43         | -            | 5.17         | 3.77         | 4.45                         |
|                              | Hot stuck<br>rings                                   | None         | -            | None         | None         | None                         |
|                              | Average cam<br>and lifter<br>wear, $\mu\text{m}$     | 15,8         | -            | 25.4         | 17.6         | 14.9                         |

| Description                  |                                                      | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------|------------------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                      | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                                      | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                     |                              |                              |                              |
| Sequenc<br>e IIIG            | <u>Wear and Oil</u><br><u>Thickness</u>              |                              |                              |                              |
|                              | Kinematic<br>viscosity<br>increase at<br>40°C, %     | 41.4                         | 121.8                        | -                            |
|                              | Average<br>weighted<br>piston<br>deposits,<br>merits | 5.4                          | 3.76                         | -                            |
|                              | Hot stuck<br>rings                                   | None                         | None                         | -                            |
|                              | Average cam<br>and lifter<br>wear, µm                | 59                           | 38.2                         | -                            |

**[0096]** The parameters listed in Table 5 above, and methods for determining same, are more fully described in ASTM D7320.

TABLE 6

| Description                  |                                                         | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|---------------------------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                         | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade              |                                                         | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                        |              |              |              |              |                              |
| Sequence<br>IVA              | <u>Valvetrain</u><br><u>Wear</u>                        |              |              |              |              |                              |
|                              | Average cam<br>wear (7 point<br>average), $\mu\text{m}$ | 11           | -            | -            | -            | 12                           |

| Description                  |                                                               | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------|---------------------------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                               | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                                               | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                              |                              |                              |                              |
| Sequence<br>IVA              | <u>Valvetrain</u><br><u>Wear</u>                              |                              |                              |                              |
|                              | Average<br>cam wear (7<br>point<br>average),<br>$\mu\text{m}$ | -                            | -                            | -                            |

[0097] The parameters listed in Table 6 above, and methods for determining same, are more fully described in ASTM D6891.

TABLE 7

| Description                           |                                      | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|---------------------------------------|--------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C               |                                      | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade                       |                                      | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u>          | <u>Parameter</u>                     |              |              |              |              |                              |
| Sequence<br>VID<br>(modified<br>test) | <u>Fuel</u><br><u>Economy</u>        |              |              |              |              |                              |
|                                       | FEI, SUM                             | 2.30         | 2.18         | -            | -            | -                            |
|                                       | FEI 2 after<br>100 hours<br>aging, % | 1.10         | .85          | -            | -            | -                            |
|                                       | FEI 1 after<br>16 hours<br>aging, %  | 1.20         | 1.33         | -            | -            | -                            |

| Description                           |                                      | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|---------------------------------------|--------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C               |                                      | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade                       |                                      | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u>          | <u>Parameter</u>                     |                              |                              |                              |
| Sequence<br>VID<br>(modified<br>test) | <u>Fuel</u><br><u>Economy</u>        |                              |                              |                              |
|                                       | FEI, SUM                             | -                            | -                            | 2.06                         |
|                                       | FEI 2 after<br>100 hours<br>aging, % | -                            | -                            | 0.99                         |
|                                       | FEI 1 after<br>16 hours<br>aging, %  | -                            | -                            | 1.07                         |

[0098] The parameters listed in Table 7 above, and methods for determining same, are more fully described in ASTM D7589. In this case a slightly modified version of ASTM D7589 was run; two additional samples were taken during the test compared to the ASTM method.

TABLE 8

| Description                  |                                                                | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|----------------------------------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                                | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade              |                                                                | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                               |              |              |              |              |                              |
| OM646<br>LA                  | <u>Wear</u>                                                    |              |              |              |              |                              |
|                              | Main bearing wear, $\mu\text{m}$                               | 0.2          | -            | -            | -            | 0.2                          |
|                              | Conrod bearing wear, $\mu\text{m}$                             | 0.0          |              |              |              | 0.2                          |
|                              | Axial piston ring wear, (1 <sup>st</sup> ring), $\mu\text{m}$  | 11.0         |              |              |              | 8.6                          |
|                              | Axial piston ring wear, (2 <sup>nd</sup> ring), $\mu\text{m}$  | 0.4          |              |              |              | 0.8                          |
|                              | Axial piston ring wear, (3 <sup>rd</sup> ring), $\mu\text{m}$  | 1.7          |              |              |              | 1.2                          |
|                              | Radial piston ring wear, (1 <sup>st</sup> ring), $\mu\text{m}$ | 9.5          |              |              |              | 6.8                          |
|                              | Radial piston ring wear, (2 <sup>nd</sup> ring), $\mu\text{m}$ | 2.4          |              |              |              | 7.9                          |
|                              | Radial piston ring wear, (3 <sup>rd</sup> ring), $\mu\text{m}$ | 4.0          |              |              |              | 6.7                          |
|                              | Cam wear outlet (ave. max wear 8 cams), $\mu\text{m}$          | 67.4         |              |              |              | 89.7                         |

|  |                                                      |      |  |  |  |      |
|--|------------------------------------------------------|------|--|--|--|------|
|  | Cam wear inlet (ave. max wear 8 cams), $\mu\text{m}$ | 74.0 |  |  |  | 71.4 |
|  | Cylinder wear (ave. 4 cylinders), $\mu\text{m}$      | 2.8  |  |  |  | 2.9  |
|  | Timing chain elongation, %                           | 0.2  |  |  |  | 0.2  |
|  | Bore polishing (max.), %                             | 0.0  |  |  |  | 1.3  |
|  | Tappet wear inlet                                    | 5.4  |  |  |  | 8.9  |
|  | Tappet wear outlet                                   | 8.0  |  |  |  | 9.7  |
|  | Ring sticking (max.)                                 | none |  |  |  | None |
|  | Oil consumption, g                                   | 6245 |  |  |  | 6185 |
|  | Viscosity increase @100°C, %                         | 60.3 |  |  |  | 30.5 |
|  | Soot, %                                              | 5.6  |  |  |  | 5.1  |
|  | Piston cleanliness, merits                           | 15.5 |  |  |  | 10.2 |
|  | Average engine, sludge, merits                       | 9.03 |  |  |  | 9.2  |

| Description                  |                                                                | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------|----------------------------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                                | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                                                | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                               |                              |                              |                              |
| OM646<br>LA                  | <u>Wear</u>                                                    | -                            | -                            | -                            |
|                              | Main bearing wear, $\mu\text{m}$                               |                              |                              |                              |
|                              | Conrod bearing wear, $\mu\text{m}$                             |                              |                              |                              |
|                              | Axial piston ring wear, (1 <sup>st</sup> ring), $\mu\text{m}$  |                              |                              |                              |
|                              | Axial piston ring wear, (2 <sup>nd</sup> ring), $\mu\text{m}$  |                              |                              |                              |
|                              | Axial piston ring wear, (3 <sup>rd</sup> ring), $\mu\text{m}$  |                              |                              |                              |
|                              | Radial piston ring wear, (1 <sup>st</sup> ring), $\mu\text{m}$ |                              |                              |                              |
|                              | Radial piston ring wear, (2 <sup>nd</sup> ring), $\mu\text{m}$ |                              |                              |                              |
|                              | Radial piston ring wear, (3 <sup>rd</sup> ring), $\mu\text{m}$ |                              |                              |                              |
|                              | Cam wear outlet (ave. max wear 8 cams), $\mu\text{m}$          |                              |                              |                              |
|                              | Cam wear inlet (ave. max wear 8 cams), $\mu\text{m}$           |                              |                              |                              |
|                              | Cylinder wear (ave. 4 cylinders), $\mu\text{m}$                |                              |                              |                              |

|  |                                |  |  |  |
|--|--------------------------------|--|--|--|
|  | Timing chain elongation, %     |  |  |  |
|  | Bore polishing (max.), %       |  |  |  |
|  | Tappet wear inlet              |  |  |  |
|  | Tappet wear outlet             |  |  |  |
|  | Ring sticking (max.)           |  |  |  |
|  | Oil consumption, g             |  |  |  |
|  | Viscosity increase @100°C, %   |  |  |  |
|  | Soot, %                        |  |  |  |
|  | Piston cleanliness, merits     |  |  |  |
|  | Average engine, sludge, merits |  |  |  |

[0099] The parameters listed in Table 8 above, and methods for determining same, are more fully described in CEC L-099-08.

TABLE 9

| Description                  |                                                    | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Ex. 4</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|----------------------------------------------------|--------------|--------------|--------------|--------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                    | 2.0          | 2.3          | 2.1          | 2.2          | 2.6                          |
| Viscosity Grade              |                                                    | 0W           | 0W           | 0W           | 5W           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                   |              |              |              |              |                              |
| Caterpillar 1M-PC            | <u>Diesel</u><br><u>Deposit and</u><br><u>Wear</u> |              |              |              |              |                              |
|                              | Top groove fill, %                                 | 37           | -            | -            | -            | 50                           |
|                              | Weighted total demerits                            | 138.0        | -            | -            | -            | 145.1                        |
|                              | Piston, ring and liner scuffing                    | None         | -            | -            | -            | None                         |
|                              | Piston ring sticking                               | none         | -            | -            | -            | none                         |

| Description                  |                                                    | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------|----------------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                    | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                                    | 0W-20                        | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                   |                              |                              |                              |
| Caterpillar 1M-PC            | <u>Diesel</u><br><u>Deposit and</u><br><u>Wear</u> |                              |                              |                              |
|                              | Top groove fill, %                                 | -                            | -                            | -                            |
|                              | Weighted total demerits                            | -                            | -                            | -                            |
|                              | Piston, ring and liner scuffing                    | -                            | -                            | -                            |
|                              | Piston ring sticking                               | -                            | -                            | -                            |

[00100] The parameters listed in Table 9 above, and methods for determining same, are more fully described in ASTM D6618.

TABLE 10

| Description                  |                                                   | <u>Ex. 1</u> | <u>Ex. 2</u> | <u>Ex. 3</u> | <u>Comp.</u><br><u>Ex. A</u> | <u>Comp.</u><br><u>Ex. A</u> |
|------------------------------|---------------------------------------------------|--------------|--------------|--------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                   | 2.0          | 2.3          | 2.1          | 2.2                          | 2.6                          |
| Viscosity Grade              |                                                   | 0W           | 0W           | 0W           | 0W                           | 0W-20                        |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                  |              |              |              |                              |                              |
| Sequenc<br>e VIII            | <u>Bearing</u><br><u>Corrosion</u>                |              |              |              |                              |                              |
|                              | Bearing<br>weight loss,<br>mg                     | 4.6          | -            | 11.9         | 3.0                          | -                            |
|                              | 10 hour<br>stripped<br>viscosity at<br>100°C, cSt | 5.69         | -            | 6.13         | 6.12                         | -                            |

| Description                  |                                                   | <u>Comp.</u><br><u>Ex. B</u> | <u>Comp.</u><br><u>Ex. C</u> | <u>Comp.</u><br><u>Ex. D</u> |
|------------------------------|---------------------------------------------------|------------------------------|------------------------------|------------------------------|
| HTHS,<br>cP at<br>150°C      |                                                   | 2.6                          | 2.6                          | 2.6                          |
| Viscosity Grade              |                                                   | 0W-205W                      | 5W-20                        | 0W                           |
| <u>Engine</u><br><u>Test</u> | <u>Parameter</u>                                  |                              |                              |                              |
| Sequenc<br>e VIII            | <u>Bearing</u><br><u>Corrosion</u>                |                              |                              |                              |
|                              | Bearing<br>weight loss,<br>mg                     | -                            | 21.6                         | -                            |
|                              | 10 hour<br>stripped<br>viscosity at<br>100°C, cSt | -                            | 8.08                         | -                            |

**[00101]** The parameters listed in Table 10 above, and methods for determining same, are more fully described in ASTM D6709.

**[00102]** As can be seen from the foregoing Tables, the composition of the disclosure provided improved or equivalent antiwear properties while providing a substantial improvement in fuel economy when compared to the other oils identified. In the foregoing Tables, the blanks for engine test properties indicate that no data was available for that particular test.

CLAIMS:

1. A method for improving fuel efficiency, while maintaining or improving wear protection, in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a HTHS viscosity of less than 2.6 cP at 150°C, said formulated oil having a composition comprising a lubricating oil base stock as a major component, and a zinc dialkyl dithio phosphate, a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents; and a viscosity index improver, as minor components; wherein said composition contains less than 2 weight percent of the viscosity index improver, based on the total weight of the formulated oil; and wherein said composition is sufficient for the formulated oil to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA and OM646LA.

2. The method of clause 1 wherein the base oil comprises a Group I, Group II, Group III, Group IV or Group V base oil.

3. The method of clause 1 wherein the lubricating oil base stock comprises a poly alpha olefin (PAO) or gas-to-liquid (GTL) oil base stock; the mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, are selected from metallic salicylates and sulfonates, wherein the metallic salicylates and sulfonates are selected from calcium and magnesium; and the ZDDP is a secondary dialkyl dithio phosphate.

4. The method of clauses 1-3 wherein said composition contains less than 1 weight percent of the viscosity index improver, based on the total weight of the formulated oil.

5. The method of clauses 1-3 wherein the oil base stock is present in an amount of from 70 weight percent to 95 weight percent, the zinc dialkyl dithio phosphate (ZDDP) is present in an amount of from 0.4 weight percent to 1.2 weight percent, and

the mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, is present in an amount of from 1.0 weight percent to 6.0 weight percent, based on the total weight of the formulated oil.

6. The method of clauses 1-5 wherein the formulated oil has a HTHS viscosity of less than 2.4 cP at 150°C.

7. The method of clauses 1-6 wherein the lubricating oil is a passenger vehicle engine oil (PVEO).

8. A lubricating engine oil having a composition comprising a lubricating oil base stock as a major component, and a zinc dialkyl dithio phosphate, a mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents; and a viscosity index improver, as minor components; wherein said lubricating oil has a HTHS viscosity of less than 2.6 cP at 150°C; wherein said composition contains less than 2 weight percent of the viscosity index improver, based on the total weight of the lubricating engine oil; and wherein said composition is sufficient for the lubricating engine oil to pass wear protection requirements of one or more engine tests selected from TU3M, Sequence IIIG, Sequence IVA and OM646LA.

9. The lubricating engine oil of clause 8 wherein the oil base stock comprises a Group I, Group II, Group III, Group IV or Group V base oil.

10. The lubricating engine oil of clause 8 wherein the lubricating oil base stock comprises a poly alpha olefin (PAO) or gas-to-liquid (GTL) oil base stock; the mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, are selected from metallic salicylates and sulfonates, wherein the metallic salicylates and sulfonates are selected from calcium and magnesium; and the ZDDP is a secondary dialkyl dithio phosphate.

11. The lubricating engine oil of clauses 8-10 wherein said composition contains less than 1 weight percent of the polymeric viscosity index improver, based on the total weight of the lubricating engine oil.

12. The lubricating engine oil of clauses 8-10 wherein the oil base stock is present in an amount of from 70 weight percent to 95 weight percent, the zinc dialkyl dithio phosphate (ZDDP) is present in an amount of from 0.4 weight percent to 1.2 weight percent, and the mixture of (i) at least two alkali metal detergents, (ii) at least two alkaline earth metal detergents, or (iii) one or more alkali metal detergents and one or more alkaline earth metal detergents, is present in an amount of from 1.0 weight percent to 6.0 weight percent, based on the total weight of the lubricating engine oil.

13. The lubricating engine oil of clauses 8-12 wherein the ZDDP is a secondary dialkyl dithio phosphate.

14. The lubricating engine oil of clauses 8-13 which has a HTHS viscosity of less than 2.4 cP at 150°C.

15. The lubricating engine oil of clauses 8-14 comprising a passenger vehicle engine oil (PVEO).

16. All patents and patent applications, test procedures (such as ASTM methods, UL methods, and the like), and other documents cited herein are fully incorporated by reference to the extent such disclosure is not inconsistent with this disclosure and for all jurisdictions in which such incorporation is permitted.

17. When numerical lower limits and numerical upper limits are listed herein, ranges from any lower limit to any upper limit are contemplated. While the illustrative embodiments of the disclosure have been described with particularity, it will be understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the spirit and scope of the disclosure. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the examples and descriptions set forth herein but rather that the claims be construed as

encompassing all the features of patentable novelty which reside in the present disclosure, including all features which would be treated as equivalents thereof by those skilled in the art to which the disclosure pertains.

18. The present disclosure has been described above with reference to numerous embodiments and specific examples. Many variations will suggest themselves to those skilled in this art in light of the above detailed description. All such obvious variations are within the full intended scope of the appended claims.