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(54) Title: LOW VISCOSITY LUBRICATING OIL COMPOSITIONS WITH INCREASING FLASH POINT

Fig. 1

Blend Code	PAO 2	UCON OSP 18	Flash Point, C	KV100, cSt
-	poly(α-olefin)	polyalkyene glycol	-	-
12-97231	0	100	208	3.9
17-024583	10	90	180	3.4
17-024581	20	80	171	3.1
17-024580	30	70	169	2.8
17-024570	40	60	170	2.6
17-024569	50	50	164	2.4
17-024567	60	40	163	2.2
17-024566	70	30	162	2.0
17-024565	80	20	158	1.9
17-024561	90	10	158	1.8
16-1548	100	0	157	1.7

(57) Abstract: This disclosure relates to a lubricating oil having a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is partially esterified, and at least one second ester that is fully esterified. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV 100) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV 100) of the lubricating oil is decreased or maintained. This disclosure also relates to a method for increasing flash point, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using the lubricating oil.

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LOW VISCOSITY LUBRICATING OIL COMPOSITIONS WITH INCREASING FLASH POINT

FIELD

[0001] This disclosure relates to low viscosity, low volatility, high flash point compositions that include a mixed ester system, a lubricating oil base stock and lubricating oil containing the composition, and a method for increasing flash point, while decreasing or essentially maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil containing the composition.

BACKGROUND

[0002] Lubricants in commercial use today are prepared from a variety of natural and synthetic base stocks admixed with various additive packages and solvents depending upon their intended application. The base stocks typically include mineral oils, polyalphaolefins (PAO), gas-to-liquid base oils (GTL), silicone oils, phosphate esters, diesters, polyol esters, and the like.

[0003] A major trend for lubricants including passenger car engine oils (PCEOs) is an overall improvement in quality as higher quality base stocks become more readily available. Typically the highest quality lubricant products are formulated with base stocks such as PAOs or GTL stocks admixed with various additive packages.

[0004] For improving energy efficiency and fuel economy, base oil viscosity is very important. Substantial improved fuel economy (>2%) requires breakthrough in: (1) base oil volatility (2) durability and (3) friction. Friction losses occur between the moving components within the engine. Models developed to date indicate that fuel economy is heavily influenced by the lubricant properties at high shear. The base stock contributes a greater proportion of the total viscosity under high shear conditions than under low shear. Lowering base stock viscosity is likely to have the largest impact on future energy efficiency gains.

[0005] Lubricant-related performance characteristics such as low volatility and fuel economy are extremely advantageous attributes as measured by a variety of bench and engine tests. It is known that adding friction modifiers to a lubricant formulation imparts frictional benefits at wide range of temperatures, consequently improving the lubricant energy efficiency performance. Adding increased levels of friction modifier, however, can invite high temperature performance issues. For example, excessive wear, deposits, and varnish are undesirable consequences of high levels of friction modifier in an engine oil formulation. In addition, friction modifiers can be corrosive to certain metals and alloys used in typical engine design.

[0006] Therefore, there is need for better additive and base stock technology for lubricant compositions that will meet ever more stringent requirements of lubricant users. In particular,

there is a need for advanced additive technology and synthetic base stocks for simultaneously achieving low friction and energy efficiency while maintaining acceptable wear and deposit performance.

[0007] The present disclosure also provides many additional advantages, which shall become apparent as described below.

SUMMARY

[0008] This disclosure provides compositions that include mixed ester compounds having desirable low viscosity, low volatility and high flash point properties that are important for simultaneously achieving low friction and high energy efficiency while maintaining acceptable wear and deposit performance. Thus, the compositions of this disclosure provide a solution to achieve enhanced fuel economy and energy efficiency.

[0009] This disclosure relates in part to a composition having at least one first ester that is partially esterified, and at least one second ester that is fully esterified. The composition has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the composition is increased, the kinematic viscosity (KV_{100}) of the composition is decreased or essentially maintained.

[0010] As used herein, "partially esterified ester" would be when you react a polyol with fewer equivalents of carboxylic acid than the total number of hydroxyls present on the polyol. For example, if the polyol has 3 hydroxyl groups, and you add fewer than 3 equivalents of carboxylic acid, then the polyol will be "partially esterified" in that the reaction will be incomplete due to insufficient carboxylic acid and there will be some free hydroxyl groups.

[0011] This disclosure also relates in part to a lubricating oil having a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is partially esterified, and at least one second ester that is fully esterified. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

[0012] This disclosure further relates in part to a method for increasing flash point, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil

comprising a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is partially esterified, and at least one second ester that is fully esterified. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

[0013] This disclosure yet further relates in part to a method for increasing flash point and thermal conductivity, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil comprising a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one partially esterified ester. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445, and a thermal conductivity from about 0.1 W/m.K to about 0.2 W/m.K at 40°C as determined by ASTM D-2717. The at least one partially esterified ester is present in an amount such that, as the flash point and thermal conductivity of the lubricating oil are increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

[0014] It has been surprisingly found that, in accordance with this disclosure, lubricant compositions having a mixed ester base stock system exhibit increased flash point from about 125°C to about 225°C as determined by ASTM D-93, while maintaining or lowering kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445.

[0015] It has also been surprisingly found that, in accordance with this disclosure, lubricant compositions having a mixed ester base stock system exhibit increased thermal conductivity from about 0.1 W/m.K to about 0.2 W/m.K at 40°C as determined by ASTM D-2717, and increased flash point from about 125°C to about 225°C as determined by ASTM D-93, while maintaining or lowering kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445.

[0016] Further objects, features and advantages of the present disclosure will be understood by reference to the following drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Fig. 1 shows flash point and viscosity data for base stock mixtures containing poly alphaolefin (PAO)/poly alkyleneglycol (PAG), in accordance with Example 1.

[0018] Fig. 2 shows flash point and viscosity data for base stock mixtures containing poly alphaolefin (PAO)/tripropylene glycol dipelargonate, in accordance with Example 1.

[0019] Fig. 3 shows flash point and viscosity data for base stock mixtures containing poly alphaolefin (PAO)/2-ethylhexyl palmitate, in accordance with Example 2.

[0020] Fig. 4 shows flash point and viscosity data for base stock mixtures containing octyl octanoate (fully esterified linear monoester)/neopentyl glycol sesquipelargonate (50% esterified), in accordance with Example 3.

[0021] Fig. 5 shows flash point and viscosity data for base stock mixtures containing octyl octanoate (fully esterified linear monoester)/trimethylolpropane pelargonate (66.7% esterified), in accordance with Example 3.

[0022] Fig. 6 shows flash point and viscosity data for base stock mixtures containing trimethyl-1-hexyl trimethylhexanoate (fully esterified)/2-ethylhexyl palmitate (fully esterified), in accordance with Example 4.

[0023] Fig. 7 shows flash point and viscosity data for base stock mixtures containing trimethyl-1-hexyl trimethylhexanoate (fully esterified)/trimethylolpropane pelargonate (66.7% esterified), in accordance with Example 4.

[0024] Fig. 8 shows flash point and viscosity data for base stock mixtures containing trimethyl-1-hexyl trimethylhexanoate (fully esterified)/neopentyl glycol sesquipelargonate (50% esterified), in accordance with Example 4.

[0025] Fig. 9 shows thermal conductivity data for trimethylolpropane pelargonate, alkyl naphthalene, poly alphaolefin (PAO), and poly alkyleneglycol (PAG) base stocks, in accordance with Example 5.

DETAILED DESCRIPTION

Definitions

[0025] "About" or "approximately." 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.

[0026] "Major amount" as it relates to components included within the lubricating oils of the specification and the claims means greater than or equal to 50 wt.%, or greater than or equal to 60 wt.%, or greater than or equal to 70 wt.%, or greater than or equal to 80 wt.%, or greater than or equal to 90 wt.% based on the total weight of the lubricating oil.

[0027] "Minor amount" as it relates to components included within the lubricating oils of the specification and the claims means less than 50 wt.%, or less than or equal to 40 wt.%, or less than or equal to 30 wt.%, or greater than or equal to 20 wt.%, or less than or equal to 10 wt.%, or less than or equal to 5 wt.%, or less than or equal to 2 wt.%, or less than or equal to 1 wt.%, based on the total weight of the lubricating oil.

[0028] "Essentially free" as it relates to components included within the lubricating oils of the specification and the claims means that the particular component is at 0 weight % within the lubricating oil, or alternatively is at impurity type levels within the lubricating oil (less than 100 ppm, or less than 20 ppm, or less than 10 ppm, or less than 1 ppm).

[0029] "Other lubricating oil additives" as used in the specification and the claims means other lubricating oil additives that are not specifically recited in the particular section of the specification or the claims. For example, other lubricating oil additives may include, but are not limited to, antioxidants, detergents, dispersants, antiwear additives, corrosion inhibitors, viscosity modifiers, metal passivators, pour point depressants, seal compatibility agents, antifoam agents, extreme pressure agents, friction modifiers and combinations thereof.

[0030] "Other mechanical component" as used in the specification and the claims means an electric vehicle component, a hybrid vehicle component, a power train, a driveline, a transmission, a gear, a gear train, a gear set, a compressor, a pump, a hydraulic system, a bearing, a bushing, a turbine, a piston, a piston ring, a cylinder liner, a cylinder, a cam, a tappet, a lifter, a gear, a valve, or a bearing including a journal, a roller, a tapered, a needle, and a ball bearing.

[0031] "Hydrocarbon" refers to a compound consisting of carbon atoms and hydrogen atoms.

[0032] "Alkane" refers to a hydrocarbon that is completely saturated. An alkane can be linear, branched, cyclic, or substituted cyclic.

[0033] "Olefin" refers to a non-aromatic hydrocarbon comprising one or more carbon-carbon double bond in the molecular structure thereof.

[0034] "Mono-olefin" refers to an olefin comprising a single carbon-carbon double bond.

[0035] "Cn" group or compound refers to a group or a compound comprising carbon atoms at total number thereof of n. Thus, "Cm-Cn" group or compound refers to a group or compound comprising carbon atoms at a total number thereof in the range from m to n. Thus, a C1-C50 alkyl group refers to an alkyl group comprising carbon atoms at a total number thereof in the range from 1 to 50.

[0036] "Carbon backbone" refers to the longest straight carbon chain in the molecule of the compound or the group in question. "Branch" refer to any substituted or unsubstituted hydrocarbyl group connected to the carbon backbone. A carbon atom on the carbon backbone connected to a

branch is called a "branched carbon."

[0037] "Epsilon-carbon" in a branched alkane refers to a carbon atom in its carbon backbone that is (i) connected to two hydrogen atoms and two carbon atoms and (ii) connected to a branched carbon via at least four (4) methylene (CH_2) groups. Quantity of epsilon carbon atoms in terms of mole percentage thereof in a alkane material based on the total moles of carbon atoms can be determined by using, e.g., ^{13}C NMR.

[0038] "Alpha-carbon" in a branched alkane refers to a carbon atom in its carbon backbone that is with a methyl end with no branch on the first 4 carbons. It is also measured in mole percentage using ^{13}C NMR.

[0039] "T/P methyl" in a branched alkane refers to a methyl end and a methyl in the 2 position. It is also measured in mole percentage using ^{13}C NMR.

[0040] "P-methyl" in a branched alkane refers to a methyl branch anywhere on the chain, except in the 2 position. It is also measured in mole percentage using ^{13}C NMR.

[0041] "SAE" refers to SAE International, formerly known as Society of Automotive Engineers, which is a professional organization that sets standards for internal combustion engine lubricating oils.

[0042] "SAE J300" refers to the viscosity grade classification system of engine lubricating oils established by SAE, which defines the limits of the classifications in rheological terms only.

[0043] "Base stock" or "base oil" interchangeably refers to an oil that can be used as a component of lubricating oils, heat transfer oils, hydraulic oils, grease products, and the like.

[0044] "Lubricating oil" or "lubricant" interchangeably refers to a substance that can be introduced between two or more surfaces to reduce the level of friction between two adjacent surfaces moving relative to each other. A lubricant base stock is a material, typically a fluid at various levels of viscosity at the operating temperature of the lubricant, used to formulate a lubricant by admixing with other components. Non-limiting examples of base stocks suitable in lubricants include API Group I, Group II, Group III, Group IV, and Group V base stocks. PAOs, particularly hydrogenated PAOs, have recently found wide use in lubricants as a Group IV base stock, and are particularly preferred. If one base stock is designated as a primary base stock in the lubricant, additional base stocks may be called a co-base stock.

[0045] All kinematic viscosity values in this disclosure are as determined pursuant to ASTM D445. Kinematic viscosity at 100°C is reported herein as KV100, and kinematic viscosity at 40°C is reported herein as KV40. Unit of all KV100 and KV40 values herein is cSt unless otherwise specified. When describing the kinematic viscosity at 100°C is "essentially" maintained, the kinematic viscosity at 100°C is expected to vary less than 0.2 cSt as measured by ASTM D445.

[0046] All viscosity index ("VI") values in this disclosure are as determined pursuant to ASTM D2270.

[0047] All Noack volatility ("NV") values in this disclosure are as determined pursuant to ASTM D5800 unless specified otherwise. Unit of all NV values is wt%, unless otherwise specified.

[0048] All pour point values in this disclosure are as determined pursuant to ASTM D5950 or D97.

[0049] All CCS viscosity ("CCSV") values in this disclosure are as determined pursuant to ASTM 5293. Unit of all CCSV values herein is millipascal second (mPa·s), which is equivalent to centipoise), unless specified otherwise. All CCSV values are measured at a temperature of interest to the lubricating oil formulation or oil composition in question. Thus, for the purpose of designing and fabricating engine oil formulations, the temperature of interest is the temperature at which the SAE J300 imposes a minimal CCSV.

[0050] All percentages in describing chemical compositions herein are by weight unless specified otherwise. "Wt.%" means percent by weight.

Lubricating Oil Compositions of This Disclosure

[0051] The compositions of this disclosure include a mixed ester base system. These compositions exhibit increasing flash point while maintaining or decreasing viscosity, which make them attractive as Group V synthetic base stocks in high performance, fuel economy lubricant applications.

[0052] The compositions of this disclosure containing the mixed ester base stocks have advantageous characteristics including low volatility, high flash point and low viscosity.

[0053] It has been found that outstanding low viscosity, low volatility and high flash point properties can be attained in an engine or a gear box lubricated with a lubricating oil by using as the lubricating oil a formulated oil in accordance with this disclosure. In particular, a lubricating oil base stock comprising a mixed ester system exhibits low viscosity, low volatility, and high flash point, which helps to prolong the useful life of lubricants and significantly improve the durability and resistance of lubricants when exposed to high temperatures. The lubricating oils of this disclosure are particularly advantageous as passenger vehicle engine oil (PVEO) or gear box oil products.

[0054] This disclosure provides high performance base stocks based on a mixed ester system. Examples include fluid mixtures of 1-20% of mid- to high hydroxyester and 80-99% fully esterified materials. In addition, combinations of 1-20% mid-to high hydroxyester and 80-99% highly branched esters are also beneficial. In certain cases, lower levels of highly branched esters from 1-20% in combination with 80-99% mid-to high hydroxyester is also beneficial.

[0055] Base stocks having a mixed ester system can be blended with lubricating oil base fluids in order to optimize lubricating properties, as described herein. In an embodiment, the base stocks having a mixed ester system can be blended with lubricating oil base fluids, to form bimodal blends.

[0056] The mixed ester base stock systems of this disclosure having low volatility, high flash point and low viscosity are of significant importance for simultaneously achieving low friction and high fuel economy while maintaining acceptable wear and deposit performance.

[0056] In an embodiment, this disclosure relates to a composition having at least one first ester that is partially esterified, and at least one second ester that is branched and is fully esterified. The composition has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the composition is increased, the kinematic viscosity (KV_{100}) of the composition is decreased or essentially maintained.

[0057] In another embodiment, this disclosure relates to a composition having at least one first ester that is branched and is fully esterified, and at least one second ester that is branched and is fully esterified. The composition has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the composition is increased, the kinematic viscosity (KV_{100}) of the composition is decreased or essentially maintained.

[0058] In still another embodiment, this disclosure relates to a lubricating oil having a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is partially esterified, and at least one second ester that is branched and is fully esterified. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

[0059] In yet another embodiment, this disclosure relates to a lubricating oil having a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is branched and is fully esterified, and at least one second ester that is branched and is fully esterified. The lubricating

oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

[0060] In another embodiment, this disclosure relates to a method for increasing flash point, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil having a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is partially esterified, and at least one second ester that is branched and is fully esterified. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

[0061] In still another embodiment, this disclosure relates to a method for increasing flash point, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil having a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component. The lubricating oil base stock has at least one first ester that is branched and is fully esterified, and at least one second ester that is branched and is fully esterified. The lubricating oil has a flash point from about 125°C to about 225°C as determined by ASTM D-93, and a kinematic viscosity (KV_{100}) from about 1 to about 5 at 100°C as determined by ASTM D-445. The at least one first ester and the at least one second ester are present in an amount such that, as the flash point of the lubricating oil is increased, the kinematic viscosity (KV_{100}) of the lubricating oil is decreased or essentially maintained.

Mixed Ester Base Stocks

[0062] The base lubricating oil compositions of this disclosure can be comprised of mixed ester systems. Suitable mixed ester base systems include, for example, fully esterified esters, partially esterified esters, branched fully esterified esters, and branched partially esterified esters.

[0063] In an embodiment, the partially esterified esters comprise a partially esterified polyol ester of a monocarboxylic acid.

[0064] The partially esterified esters can be derived by reacting one or more polyhydric alcohols with one or more monocarboxylic acids. The one or more polyhydric alcohols can be branched or unbranched and include, for example, neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, or tetrapentaerythritol. The one or more monocarboxylic acids can be branched or unbranched and include, for example, acetic acid, propionic acid, butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid, decanoic acid, undecanoic acid, dodecanoic acid, tridecanoic acid, tetradecanoic acid, pentadecanoic acid, 3-methylbutanoic acid, 2-methylbutanoic acid, 2-ethylhexanoic acid, 2,4-dimethylpentanoic acid, 3,3,5-trimethylhexanoic acid, benzoic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, behenic acid, or oleic acid.

[0065] Illustrative partially esterified esters include, for example, partially esterified neopentyl glycol sesquipelargonate, partially esterified trimethylolpropane pelargonate, partially esterified neopentyl glycol ester, partially esterified 2-methyl-2-propyl-1,3-propanediol ester, partially esterified trimethylol ethane ester, partially esterified trimethylol propane ester, partially esterified pentaerythritol ester, partially esterified dipentaerythritol ester, partially esterified tripentaerythritol ester, partially esterified tetrapentaerythritol ester, or mixtures thereof. The partially esterified esters can be branched or unbranched.

[0066] Reaction conditions for the reaction of the one or more polyhydric alcohols with the one or more monocarboxylic acids, such as temperature, pressure and contact time, may also vary greatly and any suitable combination of such conditions may be employed herein. The reaction temperature may range between about 25°C to about 250°C, and preferably between about 30°C to about 200°C, and more preferably between about 60°C to about 150°C. Normally the reaction is carried out under ambient pressure and the contact time may vary from a matter of seconds or minutes to a few hours or greater. The reactants can be added to the reaction mixture or combined in any order. The stir time employed can range from about 0.5 to about 48 hours, preferably from about 1 to 36 hours, and more preferably from about 2 to 24 hours.

[0067] The fully esterified esters can be derived by reacting one or more monoalkanoic acids with one or more monoalkanols. The one or more monoalkanoic acids can be branched or unbranched and include, for example, butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid, decanoic acid, undeanoic acid, dodecanoic acid, tridecanoic acid, tetradecanoic acid, pentadecanoic acid, hexadecanoic acid, and their isomers. The one or more monalkanols can be branched or unbranched and include, for example, butyl alcohol, pentyl

alcohol, hexyl alcohol, heptyl alcohol, octyl alcohol, nonyl alcohol, decyl alcohol, dodecyl alcohol, tridecyl alcohol, tetradecyl alcohol, pentadecyl alcohol, hexadecyl alcohol, and their isomers.

[0068] Illustrative fully esterified esters include, for example, dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, tripropylene glycol dipelargonate, 2-ethylhexyl palmitate, octyl octanoate, trimethyl-1-hexyl trimethylhexanoate, or mixtures thereof. The fully esterified esters can be branched or unbranched.

[0069] Reaction conditions for the reaction of the one or more monoalkanoic acids with the one or more monoalkanols, such as temperature, pressure and contact time, may also vary greatly and any suitable combination of such conditions may be employed herein. The reaction temperature may range between about 25°C to about 250°C, and preferably between about 30°C to about 200°C, and more preferably between about 60°C to about 150°C. Normally the reaction is carried out under ambient pressure and the contact time may vary from a matter of seconds or minutes to a few hours or greater. The reactants can be added to the reaction mixture or combined in any order. The stir time employed can range from about 0.5 to about 48 hours, preferably from about 1 to 36 hours, and more preferably from about 2 to 24 hours.

[0070] The fully esterified esters and partially esterified esters useful in this disclosure can exhibit a wide range of amount of esterification, for example, esterification amount of at least 100%, or at least about 90%, or at least about 80%, or at least about 70%, or at least about 60%, or at least about 50%, or at least about 40%, or at least about 30%, or at least about 20%, or at least about 10%.

[0071] As used herein, low to mid-hydroxyesters include those esters having at least about 50% esterification, and high-hydroxyesters include those esters having less than about 50% esterification (e.g., 33% esterification).

[0072] Illustrative high performance mixed ester base stock systems include, for example, mixtures of 1-20% of mid- to high hydroxyester and 80-99% fully esterified materials. In addition, combinations of 1-20% mid-to high hydroxyester and 80-99% highly branched esters are also beneficial. In certain cases, lower levels of highly branched esters from 1-20% in combination with 80-99% mid-to high hydroxyester is also beneficial.

[0073] The mixed ester base stock systems of this disclosure conveniently have a kinematic viscosity, according to ASTM standards, of about 1 cSt to about 5 cSt (or mm^2 /s) at 100°C and preferably of about 1.25 cSt to about 4.75 cSt (or mm^2 /s) at 100°C, often more preferably from about 1.3 cSt to about 4.5 cSt at 100°C, even more preferably from 1.5 to 3.0 cSt at 100°C.

[0074] Mixtures of mixed ester base stocks may be used if desired. Bi-modal, tri-modal, and additional combinations of mixtures of mixed ester base stocks and optional Group I, II, III, IV, and/or V base stocks may be used if desired. With mixtures of mixed ester base stocks and Group I, II, III, IV, and/or V base stocks, the mixed ester base stock is present is an amount ranging from about 5 to about 99 weight percent or from about 10 to about 95 weight percent, preferably from about 50 to about 99 weight percent or from about 70 to about 95 weight percent, and more preferably from about 85 to about 95 weight percent, based on the total weight of the composition. Preferably, with mixtures of mixed ester base stocks and Group I, II, III, IV, and/or V base stocks, the mixed ester base stock is present is an amount ranging from about 50 to about 99 weight percent or from about 55 to about 95 weight percent, preferably from about 60 to about 99 weight percent or from about 70 to about 95 weight percent, and more preferably from about 85 to about 95 weight percent, based on the total weight of the composition.

[0075] The mixed ester base stock system typically is present in an amount ranging from about 5 to about 99 weight percent or from about 10 to about 95 weight percent, preferably from about 50 to about 99 weight percent or from about 70 to about 95 weight percent, and more preferably from about 85 to about 95 weight percent, based on the total weight of the composition.

[0076] Preferably, the mixed ester base stock system constitutes the major component of the engine, or other mechanical component, oil lubricant composition of the present disclosure and typically is present in an amount ranging from greater than about 50 to about 99 weight percent or from about 55 to about 95 weight percent, preferably from about 60 to about 99 weight percent or from about 70 to about 95 weight percent, and more preferably from about 85 to about 95 weight percent, based on the total weight of the composition.

[0077] Examples of techniques that can be employed to characterize the compositions formed by the process described above include, but are not limited to, analytical gas chromatography, nuclear magnetic resonance, thermogravimetric analysis (TGA), inductively coupled plasma mass spectrometry, differential scanning calorimetry (DSC), volatility and viscosity measurements.

[0078] Examples of techniques that can be employed to characterize the compositions formed by the process described above include, but are not limited to, analytical gas chromatography, nuclear magnetic resonance, thermogravimetric analysis (TGA), inductively coupled plasma mass spectrometry, differential scanning calorimetry (DSC), volatility and viscosity measurements.

[0079] This disclosure provides lubricating oils useful as engine oils and in other applications characterized by an increasing flash point while maintaining or decreasing viscosity. The lubricating oils are based on high quality base stocks including a major portion of a mixed ester base stock system with a hydrocarbon base fluid such as a PAO or GTL as described herein. The

lubricating oil base stock can be any oil boiling in the lube oil boiling range, typically between about 100 to 450ºC. In the present specification and claims, the terms base oil(s) and base stock(s) are used interchangeably.

Lubricating Oil Base Stocks

[0080] A wide range of lubricating oils is known in the art. Lubricating oils that are useful in the present disclosure are both natural oils and synthetic oils. Natural and synthetic 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 the 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.

[0081] Groups I, II, III, IV and V are broad categories of base oil stocks developed and defined by the American Petroleum Institute (API Publication 1509; www.API.org) to create guidelines for lubricant base oils. Group I base stocks generally have a viscosity index of between about 80 to 120 and contain greater than about 0.03% sulfur and less than about 90% saturates. Group II base stocks generally have a viscosity index of between about 80 to 120, and contain less than or equal to about 0.03% sulfur and greater than or equal to about 90% saturates. Group III stock generally has a viscosity index greater than about 120 and contains less than or equal to about 0.03% sulfur and greater than about 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stocks include 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) products		
Group V	All other base oil stocks not included in Groups I, II, III or IV		

[0082] 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 in the present disclosure. 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, hydrorefined, or solvent extracted.

[0083] Group II and/or Group III hydroprocessed or hydrocracked base stocks, as well as synthetic oils such as polyalphaolefins, alkyl aromatics and synthetic esters, i.e. Group IV and Group V oils are also well known base stock oils.

[0084] Synthetic oils include hydrocarbon oil such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers, for example). Polyalphaolefin (PAO) oil base stocks, the Group IV API base stocks, are a commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C_8, C_{10}, C_{12}, C_{14} olefins or mixtures thereof may be utilized. See U.S. Patent Nos. 4,956,122; 4,827,064; and 4,827,073, which are incorporated herein by reference in their entirety. Group IV oils, that is, the PAO base stocks have viscosity indices preferably greater than 130, more preferably greater than 135, still more preferably greater than 140.

[0085] Esters in a minor amount may be useful in the lubricating oils of this disclosure. 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, 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.

[0086] 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 about 4 carbon atoms, preferably C_5 to C_{30} acids such as saturated straight chain fatty acids including caprylic acid, capric acids, 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.

[0087] Esters should be used in an amount such that the improved wear and corrosion resistance provided by the lubricating oils of this disclosure are not adversely affected.

[0088] Non-conventional or unconventional base stocks and/or base oils include one or a mixture of base stock(s) and/or base oil(s) derived from: (1) one or more Gas-to-Liquids (GTL) materials, as well as (2) hydrodewaxed, or hydroisomerized/cat (and/or solvent) dewaxed base stock(s) and/or base oils derived from synthetic wax, natural wax or waxy feeds, mineral and/or non-mineral oil waxy feed stocks such as gas oils, slack waxes (derived from the solvent dewaxing of natural oils, mineral oils or synthetic oils; e.g., Fischer-Tropsch feed stocks), natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, foots oil or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials recovered from coal liquefaction or shale oil, linear or branched hydrocarbyl compounds with carbon number of about 20 or greater, preferably about 30 or greater and mixtures of such base stocks and/or base oils.

[0089] 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.

[0090] GTL base stock(s) and/or base oil(s) derived from GTL materials, especially, hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxed wax or waxy feed, preferably F-T material derived base stock(s) and/or base oil(s), are characterized typically as having kinematic viscosities at 100°C of from about 2 mm^2/s to about 50 mm^2/s (ASTM D445). They are further characterized typically as having pour points of -5°C to about -40°C or lower (ASTM D97). They are also characterized typically as having viscosity indices of about 80 to about 140 or greater (ASTM D2270).

[0091] In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffins. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than about 10 ppm, and more typically less than about 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this materially especially suitable for the formulation of low SAP products.

[0092] 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.

[0093] 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).

[0094] 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, Group V and Group VI oils and mixtures thereof, preferably API Group II, Group III, Group IV, Group V and Group VI oils and mixtures thereof, more preferably the Group III to Group VI 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 $100 < VI < 120$.

[0095] 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 about 10 ppm, and more typically less than about 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this material especially suitable for the formulation of low sulfur, sulfated ash, and phosphorus (low SAP) products.

[0096] The base stock component of the present lubricating oils will typically be from 50 to 99 weight percent of the total composition (all proportions and percentages set out in this specification are by weight unless the contrary is stated) and more usually in the range of 80 to 99 weight percent.

Other Additives

[0097] 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, other 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 Chemistry and Applications" edited by Leslie R. Rudnick, Marcel Dekker, Inc. New York, 2003 ISBN: 0-8247-0857-1.

[0098] 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.

Viscosity Improvers

[0099] Viscosity improvers (also known as Viscosity Index modifiers, and VI improvers) increase the viscosity of the oil composition at elevated temperatures which increases film thickness, while having limited effect on viscosity at low temperatures.

[00100] Suitable viscosity 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 about 10,000 to 1,000,000, more typically about 20,000 to 500,000, and even more typically between about 50,000 and 200,000.

[00101] Examples of suitable viscosity improvers are 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.

[00102] The amount of viscosity modifier may range from zero to 8 wt%, preferably zero to 4 wt%, more preferably zero to 2 wt% based on active ingredient and depending on the specific viscosity modifier used.

Antioxidants

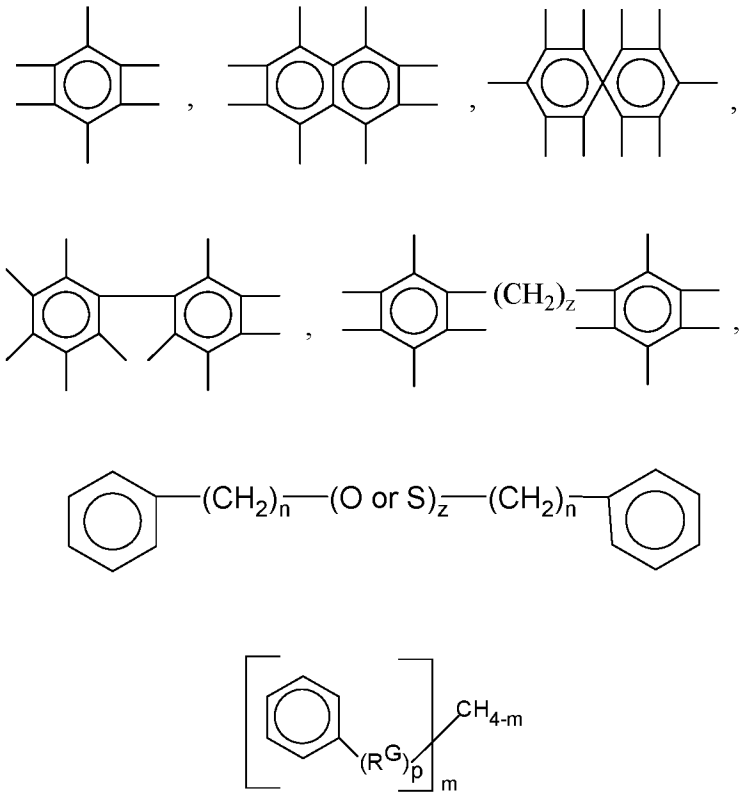
[00103] Typical antioxidants include phenolic antioxidants, aminic antioxidants and oil-soluble copper complexes.

[00104] The phenolic antioxidants include sulfurized and non-sulfurized phenolic antioxidants. The terms “phenolic type” or “phenolic antioxidant” used herein includes compounds having one or more than one hydroxyl group bound to an aromatic ring which may itself be mononuclear, e.g., benzyl, or poly-nuclear, e.g., naphthyl and spiro aromatic compounds. Thus “phenol type” includes phenol per se, catechol, resorcinol, hydroquinone, naphthol, etc., as well as alkyl or alkenyl and sulfurized alkyl or alkenyl derivatives thereof, and bisphenol type compounds including such bi-phenol compounds linked by alkylene bridges sulfuric bridges or oxygen bridges. Alkyl phenols include mono- and poly-alkyl or alkenyl phenols, the alkyl or alkenyl group containing from about 3-100 carbons, preferably 4 to 50 carbons and sulfurized derivatives thereof, the number of alkyl or alkenyl groups present in the aromatic ring ranging from 1 to up to the available unsatisfied valences of the aromatic ring remaining after counting the number of hydroxyl groups bound to the aromatic ring.

[00105] Generally, therefore, the phenolic anti-oxidant may be represented by the general formula:

$$(R)_X—Ar—(OH)_y$$

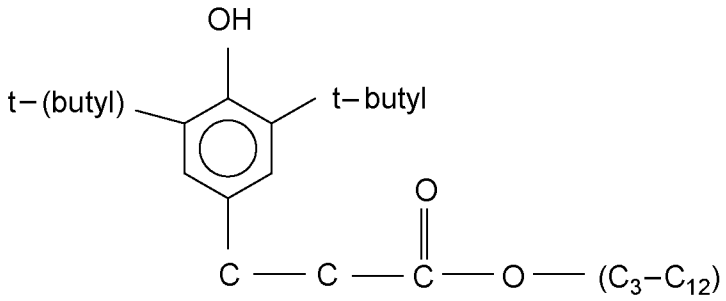
where Ar is selected from the group consisting of:



wherein R is a C_3-C_{100} alkyl or alkenyl group, a sulfur substituted alkyl or alkenyl group, preferably a C_4-C_{50} alkyl or alkenyl group or sulfur substituted alkyl or alkenyl group, more preferably C_3-C_{100} alkyl or sulfur substituted alkyl group, most preferably a C_4-C_{50} alkyl group, R^G is a C_1-C_{100} alkylene or sulfur substituted alkylene group, preferably a C_2-C_{50} alkylene or sulfur substituted alkylene group, more preferably a C_2-C_2 alkylene or sulfur substituted alkylene group, y is at least 1 to up to the available valences of Ar, x ranges from 0 to up to the available valances of Ar-y, z ranges from 1 to 10, n ranges from 0 to 20, and m is 0 to 4 and p is 0 or 1, preferably y ranges from 1 to 3, x ranges from 0 to 3, z ranges from 1 to 4 and n ranges from 0 to 5, and p is 0.

[00106] Preferred phenolic anti-oxidant compounds are the hindered phenolics and phenolic esters 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 anti-oxidants include the hindered phenols substituted with C_1+ 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;

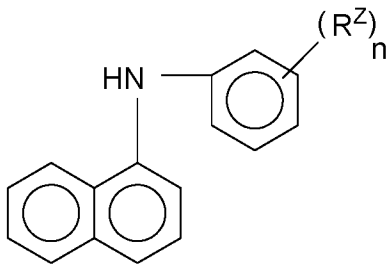
2-methyl-6-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4 methyl phenol; 2,6-di-t-butyl-4-ethyl phenol; and 2,6-di-t-butyl 4 alkoxy phenol; and



[00107] Phenolic type anti-oxidants are well known in the lubricating industry and commercial examples such as Ethanox® 4710, Irganox® 1076, Irganox® L1035, Irganox® 1010, Irganox® L109, Irganox® L118, Irganox® L135 and the like are familiar to those skilled in the art. The above is presented only by way of exemplification, not limitation on the type of phenolic anti-oxidants which can be used.

[00108] The phenolic anti-oxidant can be employed in an amount in the range of about 0.1 to 3 wt%, preferably about 1 to 3 wt%, more preferably 1.5 to 3 wt% on an active ingredient basis.

[00109] Aromatic amine anti-oxidants include phenyl-α-naphthyl amine which is described by the following molecular structure:



wherein R^z is hydrogen or a C_1 to C_{14} linear or C_3 to C_{14} branched alkyl group, preferably C_1 to C_{10} linear or C_3 to C_{10} branched alkyl group, more preferably linear or branched C_6 to C_8 and n is an integer ranging from 1 to 5 preferably 1. A particular example is Irganox L06.

[00110] Other aromatic amine anti-oxidants include other 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 about 20 carbon atoms, and preferably contains from about 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.

[00111] Typical aromatic amines anti-oxidants have alkyl substituent groups of at least about 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than about 14 carbon atoms. The general types of such other additional amine anti-oxidants which may be present include diphenylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more of such other additional aromatic amines may also be present. Polymeric amine antioxidants can also be used.

[00112] Another class of anti-oxidant used in lubricating oil compositions and which may also be present are oil-soluble copper compounds. Any oil-soluble suitable copper compound may be blended into the lubricating oil. Examples of suitable copper antioxidants include copper dihydrocarbyl thio- or dithio-phosphates and copper salts of carboxylic acid (naturally occurring or synthetic). Other suitable copper salts include copper dithiacarbamates, sulphonates, phenates, and acetylacetonates. Basic, neutral, or acidic copper Cu(I) and or Cu(II) salts derived from alkenyl succinic acids or anhydrides are known to be particularly useful.

[00113] Such antioxidants may be used individually or as mixtures of one or more types of anti-oxidants, the total amount employed being an amount of about 0.50 to 5 wt%, preferably about 0.75 to 3 wt% (on an as-received basis).

Detergents

[00114] In addition to the alkali or alkaline earth metal salicylate detergent which is an essential component in the present disclosure, other detergents may also be present. While such other detergents can be present, it is preferred that the amount employed be such as to not interfere with the synergistic effect attributable to the presence of the salicylate. Therefore, most preferably such other detergents are not employed.

[00115] If such additional detergents are present, they can include alkali and alkaline earth metal phenates, sulfonates, carboxylates, phosphonates and mixtures thereof. These supplemental detergents can have total base number (TBN) ranging from neutral to highly overbased, i.e. TBN of 0 to over 500, preferably 2 to 400, more preferably 5 to 300, and they can be present either individually or in combination with each other in an amount in the range of from 0 to 10 wt%, preferably 0.5 to 5 wt% (active ingredient) based on the total weight of the formulated lubricating oil. As previously stated, however, it is preferred that such other detergent not be present in the formulation. Such additional other detergents include by way of example and not limitation

calcium phenates, calcium sulfonates, magnesium phenates, magnesium sulfonates and other related components (including borated detergents).

Friction Modifiers

[00116] 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.

[00117] Illustrative friction modifiers may include, for example, organometallic compounds or materials, or mixtures thereof. Illustrative organometallic friction modifiers useful in the lubricating engine oil formulations of this disclosure include, for example, molybdenum amine, molybdenum diamine, an organotungstenate, a molybdenum dithiocarbamate, molybdenum dithiophosphates, molybdenum amine complexes, molybdenum carboxylates, and the like, and mixtures thereof. Similar tungsten based compounds may be preferable.

[00118] Other illustrative friction modifiers useful in the lubricating engine oil formulations of this disclosure include, for example, alkoxylated fatty acid esters, alkanolamides, polyol fatty acid esters, borated glycerol fatty acid esters, fatty alcohol ethers, and mixtures thereof.

[00119] Illustrative alkoxylated fatty acid esters include, for example, polyoxyethylene stearate, fatty acid polyglycol ester, and the like. These can include polyoxypropylene stearate, polyoxybutylene stearate, polyoxyethylene isosterate, polyoxypropylene isostearate, polyoxyethylene palmitate, and the like.

[00120] Illustrative alkanolamides include, for example, lauric acid diethylalkanolamide, palmic acid diethylalkanolamide, and the like. These can include oleic acid diethyalkanolamide, stearic acid diethylalkanolamide, oleic acid diethylalkanolamide, polyethoxylated hydrocarbylamides, polypropoxylated hydrocarbylamides, and the like.

[00121] Illustrative polyol fatty acid esters include, for example, glycerol mono-oleate, saturated mono-, di-, and tri-glyceride esters, glycerol mono-stearate, and the like. These can include polyol esters, hydroxyl-containing polyol esters, and the like.

[00122] Illustrative borated glycerol fatty acid esters include, for example, borated glycerol mono-oleate, borated saturated mono-, di-, and tri-glyceride esters, borated glycerol mono-sterate, and the like. In addition to glycerol polyols, these can include trimethylolpropane, pentaerythritol,

sorbitan, and the like. These esters can be polyol monocarboxylate esters, polyol dicarboxylate esters, and on occasion polyoltricarboxylate esters. Preferred can be the glycerol mono-oleates, glycerol dioleates, glycerol trioleates, glycerol monostearates, glycerol distearates, and glycerol tristearates and the corresponding glycerol monopalmitates, glycerol dipalmitates, and glycerol tripalmitates, and the respective isostearates, linoleates, and the like. On occasion the glycerol esters can be preferred as well as mixtures containing any of these. Ethoxylated, propoxylated, butoxylated fatty acid esters of polyols, especially using glycerol as underlying polyol can be preferred.

[00123] Illustrative fatty alcohol ethers include, for example, stearyl ether, myristyl ether, and the like. Alcohols, including those that have carbon numbers from C3 to C5, can be ethoxylated, propoxylate, or butoxylated to form the corresponding fatty alkyl ethers. The underlying alcohol portion can preferably be stearyl, myristyl, C11 – C13 hydrocarbon, oleyl, isosteryl, and the like.

[00124] Useful concentrations of friction modifiers may range from 0.01 weight percent to 5 weight percent, or about 0.1 weight percent to about 2.5 weight percent, or about 0.1 weight percent to about 1.5 weight percent, or about 0.1 weight percent to about 1 weight percent. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from 25 ppm to 2000 ppm or more, and often with a preferred range of 50-1500 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.

Dispersants

[00125] During engine operation, oil-insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Dispersants 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.

[00126] 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.

[00127] A particularly useful class of dispersants are the alkenylsuccinic derivatives, typically produced by the reaction of a long chain substituted alkenyl succinic compound, usually a

substituted succinic anhydride, with a polyhydroxy or polyamino compound. The long chain 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 patents describing such dispersants are U.S. Patent Nos. 3,172,892; 3,219,666; 3,316,177 and 4,234,435. Other types of dispersants are described in U.S. Patent Nos. 3,036,003; and 5,705,458.

[00128] Hydrocarbyl-substituted succinic acid compounds are popular 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.

[00129] Succinimides are formed by the condensation reaction between alkenyl succinic anhydrides and amines. Molar ratios can vary depending on the amine or polyamine. For example, the molar ratio of alkenyl succinic anhydride to TEPA can vary from about 1:1 to about 5:1.

[00130] Succinate esters are formed by the condensation reaction between alkenyl succinic anhydrides and alcohols or polyols. Molar ratios can vary depending on the alcohol or polyol used. For example, the condensation product of an alkenyl succinic anhydride and pentaerythritol is a useful dispersant.

[00131] Succinate ester amides are formed by condensation reaction between alkenyl 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.

[00132] The molecular weight of the alkenyl succinic anhydrides 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, and boron compounds such as borate esters or highly borated dispersants. The dispersants can be borated with from about 0.1 to about 5 moles of boron per mole of dispersant reaction product.

[00133] Mannich base dispersants are made from the reaction of alkylphenols, formaldehyde, and amines. 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.

[00134] Typical high molecular weight aliphatic acid modified Mannich condensation products can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or $HN(R)_2$ group-containing reactants.

[00135] Examples of high molecular weight alkyl-substituted hydroxyaromatic compounds are polypropylphenol, polybutylphenol, and other polyalkylphenols. These polyalkylphenols can be

obtained by the alkylation, in the presence of an alkylating catalyst, such as BF_3, of phenol with high molecular weight polypropylene, polybutylene, and other polyalkylene compounds to give alkyl substituents on the benzene ring of phenol having an average 600-100,000 molecular weight.

[00136] Examples of $HN(R)_2$ group-containing reactants are alkylene polyamines, principally polyethylene polyamines. Other representative organic compounds containing at least one $HN(R)_2$ group suitable for use in the preparation of Mannich condensation products are well known and include the mono- and di-amino alkanes and their substituted analogs, e.g., ethylamine and diethanol amine; aromatic diamines, e.g., phenylene diamine, diamino naphthalenes; heterocyclic amines, e.g., morpholine, pyrrole, pyrrolidine, imidazole, imidazolidine, and piperidine; melamine and their substituted analogs.

[00137] Examples of alkylene polyamine reactants include ethylenediamine, diethylene triamine, triethylene tetraamine, tetraethylene pentaamine, pentaethylene hexamine, hexaethylene heptaamine, heptaethylene octaamine, octaethylene nonaamine, nonaethylene decamine, and decaethylene undecamine and mixture of such amines having nitrogen contents corresponding to the alkylene polyamines, in the formula $H_2N\text{-}(Z\text{-}NH\text{-})_nH$, mentioned before, Z is a divalent ethylene and n is 1 to 10 of the foregoing formula. Corresponding propylene polyamines such as propylene diamine and di-, tri-, tetra-, pentapropylene tri-, tetra-, penta- and hexaamines are also suitable reactants. The alkylene polyamines are usually obtained by the reaction of ammonia and dihalo alkanes, such as dichloro alkanes. Thus the alkylene polyamines obtained from the reaction of 2 to 11 moles of ammonia with 1 to 10 moles of dichloroalkanes having 2 to 6 carbon atoms and the chlo

[00138] Aldehyde reactants useful in the preparation of the high molecular products useful in this disclosure include the aliphatic aldehydes such as formaldehyde (also as paraformaldehyde and formalin), acetaldehyde and aldol (β-hydroxybutyraldehyde). Formaldehyde or a formaldehyde-yielding reactant is preferred.

[00139] 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 about 500 to about 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 about 0.1 to 20 wt%, preferably about 0.1 to 8 wt%, more preferably about 1 to 6 wt% (on an as-received basis) based on the weight of the total lubricant.

Pour Point Depressants

[00140] Conventional pour point depressants (also known as lube oil flow improvers) may also be present. Pour point depressant may be added to lower the minimum temperature at which the fluid will flow or can be poured. Examples of suitable pour point depressants include alkylated naphthalenes 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. Such additives may be used in amount of about 0.0 to 0.5 wt%, preferably about 0 to 0.3 wt%, more preferably about 0.001 to 0.1 wt% on an as-received basis.

Corrosion Inhibitors/Metal Deactivators

[00141] Corrosion inhibitors are used to reduce the degradation of metallic parts that are in contact with the lubricating oil composition. Suitable corrosion inhibitors include aryl thiazines, alkyl substituted dimercapto thiodiazoles thiadiazoles and mixtures thereof. Such additives may be used in an amount of about 0.01 to 5 wt%, preferably about 0.01 to 1.5 wt%, more preferably about 0.01 to 0.2 wt%, still more preferably about 0.01 to 0.1 wt% (on an as-received basis) based on the total weight of the lubricating oil composition.

Seal Compatibility Additives

[00142] 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 and sulfolane-type seal swell agents such as Lubrizol 730-type seal swell additives. Such additives may be used in an amount of about 0.01 to 3 wt%, preferably about 0.01 to 2 wt% on an as-received basis.

Anti-Foam Agents

[00143] 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 percent, preferably 0.001 to about 0.5 wt%, more preferably about 0.001 to about 0.2 wt%, still more preferably about 0.0001 to 0.15 wt% (on an as-received basis) based on the total weight of the lubricating oil composition.

Inhibitors and Antirust Additives

[00144] Anti-rust additives (or corrosion inhibitors) are additives that protect lubricated metal surfaces against chemical attack by water or other contaminants. One type of anti-rust additive is a polar compound that wets the metal surface preferentially, protecting it with a film of oil. Another type of anti-rust additive absorbs water by incorporating it in a water-in-oil emulsion so that only the oil touches the surface. Yet another type of anti-rust additive chemically adheres to the metal to produce a non-reactive surface. Examples of suitable additives include zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines. Such additives may be used in an amount of about 0.01 to 5 wt%, preferably about 0.01 to 1.5 wt% on an as-received basis.

[00145] In addition to the ZDDP anti-wear additives which are essential components of the present disclosure, other anti-wear additives can be present, including zinc dithiocarbamates, molybdenum dialkyldithiophosphates, molybdenum dithiocarbamates, other organo molybdenum-nitrogen complexes, sulfurized olefins, etc.

[00146] The term "organo molybdenum-nitrogen complexes" embraces the organo molybdenum-nitrogen complexes described in U.S. Patent 4,889,647. The complexes are reaction products of a fatty oil, dithanolamine and a molybdenum source. Specific chemical structures have not been assigned to the complexes. U.S. Patent 4,889,647 reports an infrared spectrum for a typical reaction product of that disclosure; the spectrum identifies an ester carbonyl band at 1740 cm^{-1} and an amide carbonyl band at 1620 cm^{-1}. The fatty oils are glyceryl esters of higher fatty acids containing at least 12 carbon atoms up to 22 carbon atoms or more. The molybdenum source is an oxygen-containing compound such as ammonium molybdates, molybdenum oxides and mixtures.

[00147] Other organo molybdenum complexes which can be used in the present disclosure are tri-nuclear molybdenum-sulfur compounds described in EP 1 040 115 and WO 99/31113 and the molybdenum complexes described in U.S. Patent 4,978,464.

[00148] In the above detailed description, the specific embodiments of this disclosure have been described in connection with its preferred embodiments. However, to the extent that the above description is specific to a particular embodiment or a particular use of this disclosure, this is intended to be illustrative only and merely provides a concise description of the exemplary embodiments. Accordingly, the disclosure is not limited to the specific embodiments described above, but rather, the disclosure includes all alternatives, modifications, and equivalents falling within the true scope of the appended claims. Various modifications and variations of this disclosure will be obvious to a worker skilled in the art and it is to be understood that such modifications and variations are to be included within the purview of this application and the spirit and scope of the claims.

EXAMPLES

[00149] Typical base stock mixtures have a logarithmic viscosity relationship as well as a logarithmic volatility relationship. It is known that higher base stock viscosity correlates to lower volatility, lower vapor pressure and higher flash point. In accordance with this disclosure, it is advantageous to have base stock mixtures that deviate from this traditional relationship such that low volatility/high flash point are achieved with low viscosity. In particular, the base stocks of this disclosure that exhibit properties such as high flash point and low viscosity are extremely advantageous for improved fuel economy, minimizing power loss due to friction and ensuring safe operation of high power engines operating at high temperature.

Example 1

[00150] Comparative examples illustrating traditional flash point and viscosity relationships are shown in Figs. 1 and 2. As shown in Figs. 1 and 2, base stock mixtures containing poly alphaolefin (PAO)/poly alkyleneglycol (PAG) and poly alphaolefin (PAO)/tripropylene glycol dipelargonate exhibit no unexpected increase in flash point at low viscosity. Flash point was determined by ASTM D-93. Kinematic viscosity (KV_{100}) was determined by ASTM D-445.

[00151] Fig. 1 shows flash point and viscosity data for base stock mixtures containing poly alphaolefin (PAO)/poly alkyleneglycol (PAG). The mixtures exhibit traditional flash point and viscosity relationships, that is a higher base stock viscosity correlates to lower volatility, lower vapor pressure and higher flash point.

[00152] Fig. 2 shows flash point and viscosity data for base stock mixtures containing poly alphaolefin (PAO)/tripropylene glycol dipelargonate. The mixtures exhibit traditional flash point and viscosity relationships, that is a higher base stock viscosity correlates to lower volatility, lower vapor pressure and higher flash point.

Example 2

[00153] As shown in Fig. 3, base stock mixtures containing poly alphaolefin (PAO)/2-ethylhexyl palmitate exhibit traditional flash point relationships. However, the viscosity relationship of the mixture containing 60% ester is lower than expected. Flash point was determined by ASTM D-93. Kinematic viscosity (KV_{100}) was determined by ASTM D-445.

[00154] Fig. 3 shows flash point and viscosity data for base stock mixtures containing poly alphaolefin (PAO)/2-ethylhexyl palmitate. The mixtures exhibit traditional flash point relationships, but an unexpected viscosity relationship.

Example 3

[00155] As shown in Figs. 4 and 5, when linear monoesters (fully esterified) are mixed with mid to high-hydroxyesters (66.7 and 50% esterified), the viscosity relationship remains consistent with

a traditional logarithmic correlation, however the flash point is elevated unexpectedly. Flash point was determined by ASTM D-93. Kinematic viscosity (KV_{100}) was determined by ASTM D-445.

[00156] Fig. 4 shows flash point and viscosity data for base stock mixtures containing octyl octanoate (fully esterified linear monoester)/neopentyl glycol sesquipelargonate (50% esterified). The mixtures exhibit traditional viscosity relationships, but an unexpected flash point relationship. In these blends, it is preferred to have 0 to 20% neopentyl glycol sesquipelargonate (50% esterified).

[00157] Fig. 5 shows flash point and viscosity data for base stock mixtures containing octyl octanoate (fully esterified linear monoester)/trimethylolpropane pelargonate (66.7% esterified). The mixtures exhibit traditional viscosity relationships, but an unexpected flash point relationship. In these blends, it is preferred to have 0 to 15% trimethylolpropane pelargonate (66.7% esterified).

Example 4

[00158] As shown in Figs. 6 and 7, when branched esters (fully esterified) are mixed together or with mid-to high-hydroxyesters (66.7% and 50% esterified), flash point unexpectedly increases and viscosity unexpectedly decreases resulting in low volatility, low viscosity systems. Flash point was determined by ASTM D-93. Kinematic viscosity (KV_{100}) was determined by ASTM D-445.

[00159] Fig. 6 shows flash point and viscosity data for base stock mixtures containing trimethyl-1-hexyl trimethylhexanoate (fully esterified)/2-ethylhexyl palmitate (fully esterified). The mixtures exhibit an unexpected viscosity relationship and flash point relationship. In these blends, it is preferred to have 0 to 40% 2-ethylhexyl palmitate (fully esterified)

[00160] Fig. 7 shows flash point and viscosity data for base stock mixtures containing trimethyl-1-hexyl trimethylhexanoate (fully esterified)/trimethylolpropane pelargonate (66.7% esterified). The mixtures exhibit an unexpected viscosity relationship and flash point relationship. In these blends, it is preferred to have 0 to 20% trimethylolpropane pelargonate (66.7% esterified).

[00161] Fig. 8 shows flash point and viscosity data for base stock mixtures containing trimethyl-1-hexyl trimethylhexanoate (fully esterified)/neopentyl glycol sesquipelargonate (50% esterified). The mixtures exhibit an unexpected viscosity relationship and flash point relationship. In these blends, it is preferred to have 0 to 40% neopentyl glycol sesquipelargonate (50% esterified).

Example 5

[00162] In addition to imparting increased flash point and constant or diminished viscosity, the use of partially hydroxylated esters leads to an improvement in the thermal conductivity of the formulation. For example, trimethylolpropane pelargonate exhibits significantly higher thermal conductivity than other base oils of comparable viscosity. The combination of increased flash

point and improved thermal conductivity at constant or decreased viscosity is very desirable from both a safety as well as a performance standpoint.

[00163] Fig. 9 shows thermal conductivity data for trimethylolpropane pelargonate, alkyl naphthalene, poly alphaolefin (PAO), and poly alkyleneglycol (PAG) base stocks. Thermal conductivity was determined by ASTM D-7896. Flash point was determined by ASTM D-93. Kinematic viscosity (KV_{100}) was determined by ASTM D-445.

[00164] 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.

[00165] 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.

[00166] 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.

CLAIMS:

1. A composition comprising: at least one first ester that is partially esterified; and at least one second ester that is fully esterified; wherein the composition has a flash point from 125°C to 225°C as determined by ASTM D-93; wherein the composition has a kinematic viscosity (KV_{100}) from 1 to 5 at 100°C as determined by ASTM D-445; and wherein the at least one first ester and the at least one second ester are present in an amount such that, as the flash point of said composition is increased, the kinematic viscosity (KV_{100}) of said composition is decreased or maintained.

2. The composition of claim 1 wherein the at least one first ester is present in an amount from 1 to 40 weight percent, based on the total weight of the composition; and the at least one second ester is present in an amount from 60 to 99 weight percent, based on the total weight of the composition.

3. The composition of claims 1 and 2 wherein the at least one first ester has a high hydroxyl content, and wherein the hydroxyl content is from 0.1 to 1 free hydroxyl group per molecule.

4. The composition of claims 1-3 wherein the at least one first ester comprises at least one partially esterified polyol ester of a monocarboxylic acid.

5. The composition of claims 1-4 wherein the at least one first ester is derived by reacting one or more polyhydric alcohols with one or more monocarboxylic acids; wherein the one or more polyhydric alcohols comprise neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, or tetrapentaerythritol; and wherein the one or more monocarboxylic acids comprise acetic acid, propionic acid, butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid, decanoic acid, undecanoic acid, dodecanoic acid, tridecanoic acid, tetradecanoic acid, pentadecanoic acid, 3-methylbutanoic acid, 2-methylbutanoic acid, 2-ethylhexanoic acid, 2,4-dimethylpentanoic acid, 3,3,5-trimethylhexanoic acid, benzoic acid, caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, behenic acid, or oleic acid.

6. The composition of claims 1-5 wherein the at least one first ester comprises partially esterified neopentyl glycol sesquipelargonate, partially esterified trimethylolpropane pelargonate, partially esterified neopentyl glycol ester, partially esterified 2-methyl-2-propyl-1,3-propanediol ester, partially esterified trimethylol ethane ester, partially esterified trimethylol propane ester, partially esterified pentaerythritol ester, partially esterified dipentaerythritol ester, partially esterified tripentaerythritol ester, or partially esterified tetrapentaerythritol ester.

7. The composition of claims 1-6 wherein the at least one second ester is derived by reacting one or more monoalkanoic acids with one or more monoalkanols; where the one or more monoalkanoic acids comprise butanoic acid, pentanoic acid, hexanoic acid, heptanoic acid, octanoic acid, nonanoic acid, decanoic acid, undeanoic acid, dodecanoic acid, tridecanoic acid, tetradecanoic acid, pentadecanoic acid, hexadecanoic acid, and their isomers; and wherein the one or more monalkanols comprise butyl alcohol, pentyl alcohol, hexyl alcohol, heptyl alcohol, octyl alcohol, nonyl alcohol, decyl alcohol, dodecyl alcohol, tridecyl alcohol, tetradecyl alcohol, pentadecyl alcohol, hexadecyl alcohol, and their isomers.

8. The composition of claims 1-7 wherein the at least one second ester is derived by reacting one or more dibasic acids with one or more monoalkanols; wherein the one or more dibasic acids comprise phthalic acid, succinic acid, sebacic acid, fumaric acid, adipic acid, azelaic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, or alkenyl malonic acid; and wherein the one or more monoalkanols comprise pentyl alcohol, hexyl alcohol, heptyl alcohol, octyl alcohol, nonyl alcohol, decyl alcohol, dodecyl alcohol, tridecyl alcohol, tetradecyl alcohol, pentadecyl alcohol, hexadecyl alcohol, and their isomers.

9. The composition of claims 1-8 wherein the at least one second ester comprises dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, tripropylene glycol dipelargonate, 2-ethylhexyl palmitate, octyl octanoate, or trimethyl-1-hexyl trimethylhexanoate.

10. The composition of claims 1-9 which has a flash point from 130°C to 220°C as determined by ASTM D-93, a viscosity (Kv_{100}) from 1 to 4 at 100°C as determined by ASTM D-445, and a Noack volatility of no greater than 50 percent as determined by ASTM D-5800.

11. The composition of claims 1-10 which is a lubricating oil base stock.

12. A lubricating oil comprising a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component; wherein the lubricating oil base stock comprises: at least one first ester that is partially esterified; and at least one second ester that is fully esterified; wherein the lubricating oil has a flash point from 125°C to 225°C as determined by ASTM D-93; wherein the lubricating oil has a kinematic viscosity (KV_{100}) from 1 to 5 at 100°C as determined by ASTM D-445; and wherein the at least one first ester and the at least one second ester are present in an amount such that, as the flash point of said lubricating oil is increased, the kinematic viscosity (KV_{100}) of said lubricating oil is decreased or maintained.

13. The lubricating oil of claim 12 wherein the at least one first ester is present in an amount from 1 to 40 weight percent, based on the total weight of the lubricating oil; and the at least one

second ester is present in an amount from 60 to 99 weight percent, based on the total weight of the lubricating oil.

14. A method for increasing flash point, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil comprising a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component; wherein the lubricating oil base stock comprises: at least one first ester that is partially esterified; and at least one second ester that is fully esterified; wherein the lubricating oil has a flash point from 125°C to 225°C as determined by ASTM D-93; wherein the lubricating oil has a kinematic viscosity (KV_{100}) from 1 to 5 at 100°C as determined by ASTM D-445; and wherein the at least one first ester and the at least one second ester are present in an amount such that, as the flash point of said lubricating oil is increased, the kinematic viscosity (KV_{100}) of said lubricating oil is decreased or maintained.

15. A method for increasing flash point and thermal conductivity, while decreasing or maintaining viscosity, of a lubricating oil in an engine or other mechanical component lubricated with the lubricating oil by using as the lubricating oil a formulated oil comprising a lubricating oil base stock as a major component, and one or more lubricating oil additives as a minor component; wherein the lubricating oil base stock comprises: at least one partially esterified ester; wherein the lubricating oil has a flash point from 125°C to 225°C as determined by ASTM D-93; wherein the lubricating oil has a kinematic viscosity (KV_{100}) from 1 to 5 at 100°C as determined by ASTM D-445; and wherein the lubricating oil has a thermal conductivity from 0.1 W/m.K to 0.2 W/m.K as determined by ASTM D-2717; wherein the at least one partially esterified ester is present in an amount such that, as the flash point and thermal conductivity of said lubricating oil are increased, the kinematic viscosity (KV_{100}) of said lubricating oil is decreased or maintained.

Fig. 1

Blend Code	PAO 2	UCON OSP 18	Flash Point, C	KV100, cSt
-	poly(α-olefin)	polyalkyene glycol	-	-
12-97231	0	100	208	3.9
17-024583	10	90	180	3.4
17-024581	20	80	171	3.1
17-024580	30	70	169	2.8
17-024570	40	60	170	2.6
17-024569	50	50	164	2.4
17-024567	60	40	163	2.2
17-024566	70	30	162	2.0
17-024565	80	20	158	1.9
17-024561	90	10	158	1.8
16-1548	100	0	157	1.7

Fig. 2

Blend Code	poly(α-olefin) 2 cSt	tripropylene glycol dipelargonate	Flash Point, C	KV100, cSt
EC-0001068	0	100	240	2.8
17- 28526	20	80	167	2.4
17- 28528	40	60	163	2.2
17- 28530	60	40	158	1.9
17- 28532	80	20	161	1.8
16-1548	100	0	157	1.7

Fig. 3

Blend Code	poly(α-olefin) 2 cSt	2-ethyhexyl palimitate	Flash Point, C	KV100, cSt
EC-0001028	0	100	245	2.6
17- 28525	20	80	181	2.4
17-28532	40	60	161	1.8
17- 28627	60	40	165	2.0
17- 28626	80	20	158	1.8
16-1548	100	0	157	1.7

Fig. 4

Blend Code	Octyl octanoate	Neopentyl glycol sesquipelargonate - 50% esterified	Flash Point, C	KV100, cSt
EC-0000673 / 15-79904	0	100	174	2.5
17-050243	10	90	168	2.3
17-050244	20	80	167	2.2
17-050245	40	60	162	1.9
17-050246	60	40	162	1.6
17-050337	80	20	154	1.5
17-050338	85	15	164	1.4
17-050339	90	10	152	1.4
EC-0000712 / 16-49580	100	0	152	1.3

Fig. 5

Blend Code	Octyl octanoate	trimethylolpropane pelargonate-66.7% esterified	Flash Point, C	KV100, cSt
EC-0000666 / 15-74329	0	100	174	5.0
17-050046	10	90	173	4.2
17-050047	20	80	172	3.5
17-050050	40	60	164	2.7
17-050051	60	40	158	2.1
17-050198	80	20	168	1.8
17-050199	85	15	155	1.6
17-050201	90	10	156	1.5
EC-0000712 / 16-49580	100	0	152	1.3

Fig. 6

Blend Code	trimethyl-1-hexyl trimethylhexanoate	2-ethyhexyl palimitate	Flash Point, C	KV100, cSt
EC-0001028	0	100	245	2.6
17- 32268	10	90	180	2.5
17- 32269	20	80	165	2.1
17- 32270	30	70	160	2.3
17- 32271	40	60	160	2.2
17- 32272	50	50	153	2.1
17- 32273	60	40	154	2.0
17- 32277	70	30	148	1.9
17- 32282	80	20	148	1.8
17- 32284	82	18	152	1.8
17- 32285	85	15	144	1.5
17- 32287	88	12	143	1.8
17- 32288	90	10	146	1.7
16-72652 / EC-0000387	100	0	146	1.8

Fig. 7

Blend Code	trimethyl-1-hexyl trimethylhexanoate	trimethylolpropane pelargonate 66.7% esterified	Flash Point, C	KV100, cSt
15-74329	0	100	174	5.0
17-75349	10	90	167	4.4
17-75348	20	80	158	3.9
17-75347	40	60	155	3.1
17-75346	60	40	149	2.5
17-75263	80	20	151	2.0
17-75262	85	15	149	1.9
17-75261	90	10	149	1.8
16-72652	100	0	146	1.8

Fig. 8

Blend Code	trimethyl-1-hexyl trimethylhexanoate	neopentyl glycol sesquipelargonate - 50% esterified	Flash Point, C	KV100, cSt
EC-0000673 / 15-79904	0	100	174	2.5
17-79408	10	90	168	2.4
17-79409	20	80	168	2.3
17-79429	40	60	153	2.1
17-79430	60	40	153	1.9
17- 79677	80	20	150	1.8
17- 79678	85	15	149	1.8
17- 79679	90	10	149	1.7
16-72652	100	0	146	1.8

Fig. 9

	Thermal Conductivity (W/m.K)			
	15-074329	11-132910	11-113861	17-082165
	Lubricit 6911-DF	**AN5**	**PAO4**	**PAG**
40° **C**	0.154	0.140	0.145	0.140
100°**C**	0.142	0.131	0.138	0.130
140°**C**	0.134	0.125		0.124
KV40, cSt	28.1	28	18.4	10.66
KV100, cSt	4.95	4.76	4.1	2.73

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/067190

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10M105/32
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C10M C10N

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	example 5; table 1	2,7-10, 13

Y	US 2011/190183 A1 (MIYAMOTO HIROYA [JP] ET AL) 4 August 2011 (2011-08-04) examples 1, 2	2,7-10, 13

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A	WO 2015/153021 A2 (EXXONMOBIL RES & ENG CO [US]) 8 October 2015 (2015-10-08) claim 1; examples 8, 9	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 April 2020	07/05/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Klaes, Daphne

INTERNATIONAL SEARCH REPORT

Information on patent family members

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