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Chinn et al.(10) **Pub. No.: US 2008/0242564 A1**(43) **Pub. Date: Oct. 2, 2008**(54) **METHOD FOR IMPROVING THE COOLING
EFFICIENCY OF A FUNCTIONAL FLUID****Publication Classification**(76) **Inventors:** **Kevin A. Chinn**, Mount Laurel, NJ
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Annandale, NJ 08801-0900 (US)(21) **Appl. No.: 12/079,188**(22) **Filed: Mar. 25, 2008****Related U.S. Application Data**(60) **Provisional application No. 60/921,282, filed on Mar.**
30, 2007.(57) **ABSTRACT**

A method is disclosed for improving the cooling of equipment lubricated by functional fluids, such as power train fluids, by lubricating the equipment with a functional fluid comprising a wax isomerate or hydrodewaxate base stock and at least one performance additive thus permitting a reduction in the volume of lubricant used and a concomitant reduction in the size of the lubricant reservoir and related equipment.

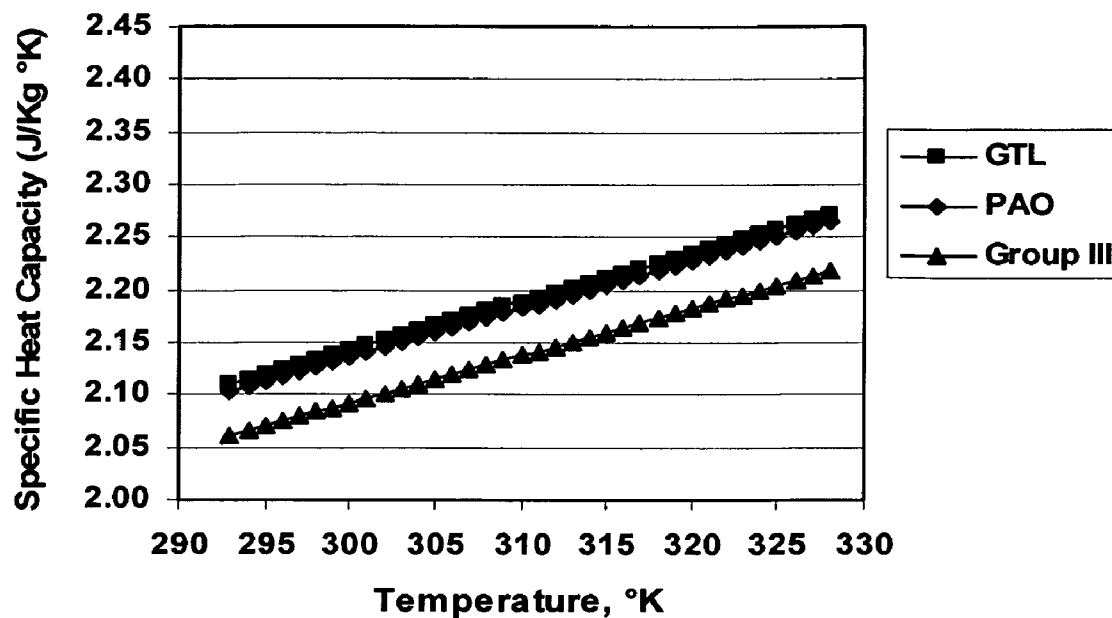
Base Stock Calculated Specific Heat Capacities

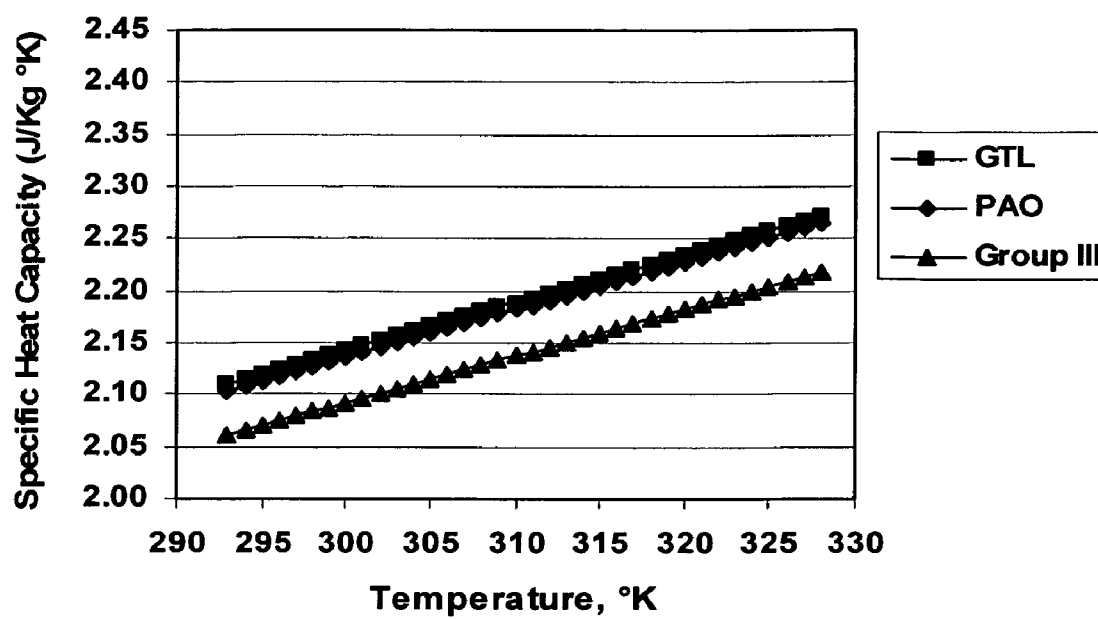
FIGURE 1**Base Stock Calculated Specific Heat Capacities**

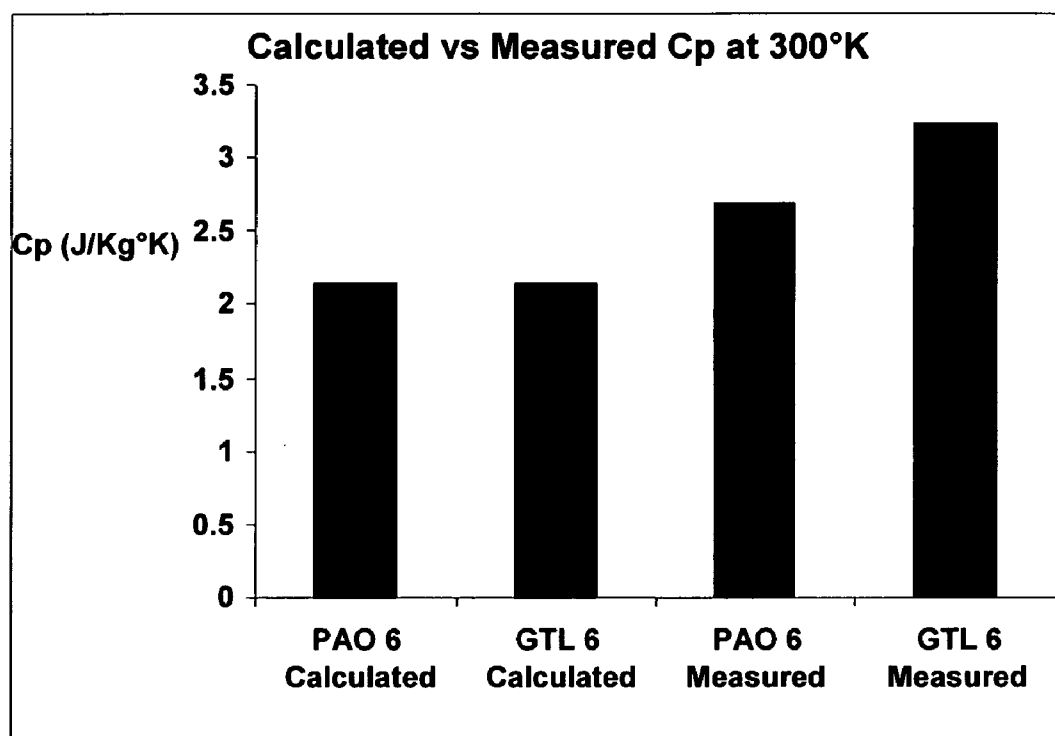
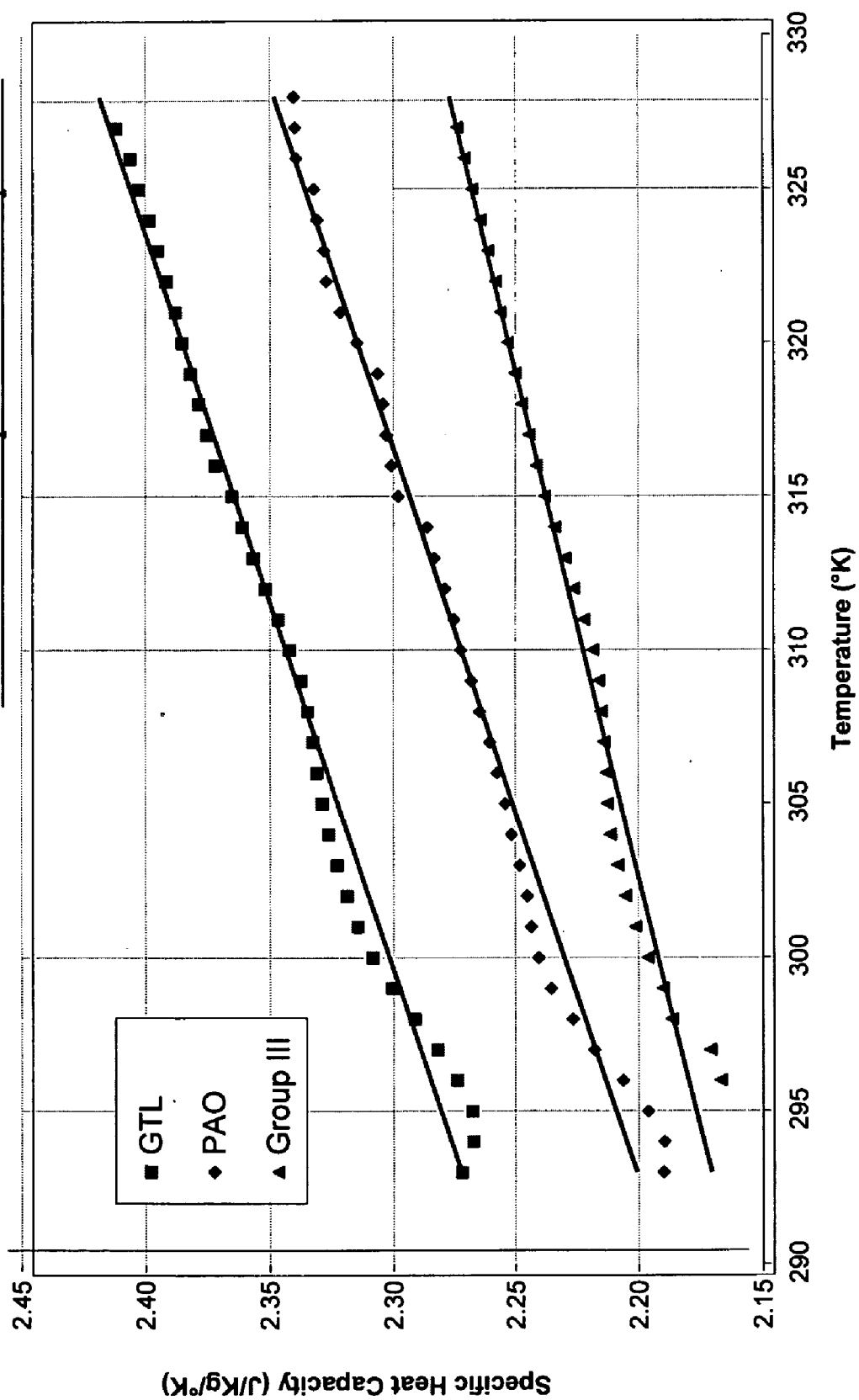
FIGURE 2

Figure 3
ATF Measured Specific Heat Capacities



METHOD FOR IMPROVING THE COOLING EFFICIENCY OF A FUNCTIONAL FLUID

[0001] This application claims the benefit of U.S. Provisional Application No. 60/921,282 filed Mar. 30, 2007.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to functional fluids, to the dissipation of heat in equipment through the use of the functional fluid, and to the improvement in the cooling properties of functional fluids.

[0004] 2. Related Art

[0005] Functional fluids such as power train fluids, e.g., transmission fluids, gear box oils, hydraulic fluids, require good thermal properties in order to efficiently draw heat away from the metal components in the equipment being lubricated by the functional fluid. Control of equipment heat is important in maintaining component life as well as lubricant life and effectiveness.

[0006] Functional fluid thermal properties are influenced by the choice of base stock.

[0007] Functional fluids have been made from most readily available lubricant base stocks. Over the years functional fluids have employed mineral oil and petroleum oil based lubricating oil base stocks. Such base stocks have corresponded to API Group I stocks. More recently API Group II and petroleum oil derived Group III stocks have been utilized.

[0008] With the discovery of synthetic stocks such as poly-alpha olefins, (PAO), alkylated aromatics such as alkyl benzene and alkyl naphthalene as well as synthetic esters, silicone oils, etc., such stocks have been the base stocks of choice for highly stressed functional fluids used in high performance, demanding environments.

[0009] Such stocks, however, are expensive and, therefore of more limited use, typically in premium lubricants.

[0010] U.S. Pat. No. 6,475,960 teaches an ATF made using a 100N Fischer-Tropsch wax isomerate base stock. Nothing in that patent provides any indication regarding the heat capacity of the isomerate base oil. Indeed, only the fundamental rheological characteristics are considered, e.g., kinematic viscosity, MRV, pour point, cloud point, Brookfield viscosity, cold cracking simulated (CCS) viscosity, and are compared against those properties of PAO and mineral oil.

[0011] It would be an advantage if the benefit of the premium synthetic lubricants could be brought to a more general market.

DESCRIPTION OF THE FIGURES

[0012] FIG. 1 presents the calculated specific heat capacities for GTL, PAO and Group III base stocks

[0013] FIG. 2 presents a comparison between the calculated and measured specific heat capacities for PAO 6 vs GTL 6.

[0014] FIG. 3 presents a comparison of the measured specific heat capacities for ATFs formulated with GTL-4 vs PAO 4 vs. Group III-4 base stocks.

DESCRIPTION OF THE INVENTION

[0015] The present invention is directed to a method for enhancing the cooling properties of functional fluid oils by using Gas-to-Liquid (GTL) base stock(s) and/or base oil(s),

preferably synthetic wax hydroisomerate or hydrodewaxate base stock(s) and/or base oil(s) more preferably Fischer-Tropsch wax hydroisomerate or hydrodewaxate stock(s) and/or base oil(s) as the base stock for the functional fluid, the use of such base stock(s) and/or base oil(s) resulting in an improvement in the cooling properties of the functional fluid in an amount ranging from 2.5% or more, preferably about 3 to 10%, more preferably about 3 to 20% vs. functional fluids containing PAO of equivalent kinematic viscosity and specific gravity. Because of this unexpectedly superior specific heat capacity of the GTL base stock/base oil versus PAO fluids of the same viscosity and specific gravity, it is possible to replace all or part of the base stock/base oil used in functional fluids with the GTL stock to secure some or all of the benefit associated with the GTL's higher specific heat capacity. Thus, the functional fluid can contain from about 30 to 100% of the GTL base stock, preferably about 50 to 100% of the GTL base stock, more preferably about 75 to 100% of the GTL base stock, most preferably 100% of the GTL base stock to achieve from about 2.5% or higher improvement in the cooling capacity of the functional fluid, vs functional fluids containing PAO, depending on the viscosity of the GTL base stock used. The kinematic viscosity of the GTL base stock/base oil used in the functional fluid is in the range of about 3 to 50 mm²/s at 100° C., preferably about 3.5 to 30 mm²/s at 100° C., more preferably about 4 to 20 mm²/s at 100° C. Because of the discovery that the GTL base stock/base oil has an unexpectedly superior specific heat capacity it is possible to reduce the amount of functional fluid used to lubricate any apparatus lubricated by the functional fluid and/or reduce the size of the apparatus lubricated by the functional fluid by at least about 2.5% or more, preferably about 3 to 20% vs functional fluids containing PAO.

[0016] The use of GTL base stock and/or base oil, preferably synthetic wax hydroisomerate or hydrodewaxate, more preferably Fischer-Tropsch wax hydroisomerate or hydrodewaxate as the base stock and/or base oil for the functional fluid improves the circulation rate of the oil in the equipment being lubricated, enhances the heat dissipation properties of the formulated oil and permits a reduction in the volume of lubricant employed and a decrease in equipment size due to smaller and/or lighter fluid reservoirs or smaller equipment components per se as a consequence of the improved heat dissipation properties of the lubricant.

[0017] Fischer-Tropsch wax isomerate is an isoparaffinic hydrocarbon oil. PAO is also an isoparaffin hydrocarbon oil. Because of this superficial similarity, it would have been expected that PAO and Fischer-Tropsch wax isomerate should have substantially similar specific heat capacity properties.

[0018] Indeed, when the specific heat capacity properties of Fischer-Tropsch wax isomerate and of PAO of similar kinematic viscosities and specific gravities are calculated it is determined that they are generally similar, the specific heat capacity of the Fischer-Tropsch wax isomerate being only about 0.3% higher than that of the PAO. From this there would have been no apparent advantage to using Fischer-Tropsch wax hydroisomerate or hydrodewaxate in a functional fluid for thermal property purposes as compared to PAO.

[0019] However, it has been discovered that when actually measured the specific heat capacity is unexpectedly at least about 3% higher for the Fischer-Tropsch wax hydroisomerate or hydrodewaxate than for the PAO of equivalent viscosity and specific gravity.

[0020] This unexpectedly higher specific heat capacity of Fischer-Tropsch wax hydroisomerate or hydrodewaxate base stock would permit the use of a reduced volume of functional fluid as compared to PAO based functional fluids, to achieve the same degree of heat description, considering only the effect attributable to the different base stocks.

[0021] Based on the discovery of this about 3% higher specific heat capacity of the Fischer-Tropsch wax hydroisomerate or hydrodewaxate as compared to PAO, about 3% less functional fluid could be used to achieve an equivalent level of heat description. This would permit a reduction in the size of the equipment being lubricated as a consequence of a smaller lubricant reservoir and/or reduction in size of the equipment components per se.

[0022] 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 feedstocks 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 feedstocks. 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/ followed by cat and/or solvent dewaxed synthesized wax or waxy hydrocarbons; (3) hydrodewaxed, or hydroisomerized/ followed by 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.

[0023] GTL base stock(s) and/or base oil(s) derived from GTL materials, especially, hydrodewaxed, or hydroisomerized/ followed by cat and/or solvent dewaxed wax or waxy feed preferably F-T material derived base stock(s) and/or base oil(s), are characterized typically as having kinematic viscosities at 100° C. of from about 2 mm²/s to about 50 mm²/s, preferably from about 3 mm²/s to about 50 mm²/s, more preferably from about 3.5 mm²/s to about 30 mm²/s (ASTM D445). They are further characterized typically as having pour points of about -5° C. to about -40° C. or lower. (ASTM D97) They are also characterized typically as having viscosity indices of about 80 to 140 or greater (ASTM D2270).

[0024] 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 material especially suitable for the formulation of low SAP products.

[0025] 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.

[0026] In a preferred embodiment, the GTL material, from which the GTL base stock(s) and/or base oil(s) is/are derived is an F-T material (i.e., hydrocarbons, waxy hydrocarbons, wax).

[0027] Examples of typical additives include, but are not limited to, oxidation inhibitors, antioxidants, dispersants, detergents, corrosion inhibitors, rust inhibitors, metal deactivators, anti-wear agents, extreme pressure additives, anti-seizure agents, wax modifiers, other viscosity index improvers, other viscosity modifiers, fluid-loss additives, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, emulsifiers, densifiers, wetting agents, gelling agents, tackiness agents, colorants, and others. For a review of many commonly used additives, see Klamann in *Lubricants and Related Products*, Verlag Chemie, Deerfield Beach, Fla.; ISBN 0-89573-177-0. Reference is also made to "Lubricant Additives" by M. W. Ranney, published by Noyes Data Corporation of Parkridge, N.J. (1973).

[0028] Finished lubricants comprise the lubricant base stock or base oil, plus at least one performance additive.

[0029] The types and quantities of performance additives used in combination with the instant invention in lubricant compositions are not limited by the examples shown herein as illustrations.

Antiwear and EP Additives

[0030] Many lubricating oils require the presence of antiwear and/or extreme pressure (EP) additives in order to provide adequate antiwear protection. Increasingly specifications for, e.g., engine oil performance have exhibited a trend for improved antiwear properties of the oil. Antiwear and extreme EP additives perform this role by reducing friction and wear of metal parts.

[0031] While there are many different types of antiwear additives, for several decades the principal antiwear additive for internal combustion engine crankcase oils is a metal alkylthiophosphate and more particularly a metal dialkylthiophosphate in which the primary metal constituent is zinc, or zinc dialkylthiophosphate (ZDDP). ZDDP compounds generally are of the formula $Zn[SP(S)(OR^1)(OR^2)]_2$ where R¹ and R² are C₁-C₁₈ alkyl groups, preferably C₂-C₁₂ alkyl groups. These alkyl groups may be straight chain or branched. The ZDDP is typically used in amounts of from about 0.4 to 1.4 wt % of the total lube oil composition, although more or less can often be used advantageously.

[0032] However, it is found that the phosphorus from these additives has a deleterious effect on the catalyst in catalytic converters and also on oxygen sensors in automobiles. One

way to minimize this effect is to replace some or all of the ZDDP with phosphorus-free antiwear additives.

[0033] A variety of non-phosphorous additives are also used as antiwear additives. Sulfurized olefins are useful as antiwear and EP additives. Sulfur-containing olefins can be prepared by sulfurization or various organic materials including aliphatic, arylaliphatic or alicyclic olefinic hydrocarbons containing from about 3 to 30 carbon atoms, preferably 3-20 carbon atoms. The olefinic compounds contain at least one non-aromatic double bond. Such compounds are defined by the formula



where each of R^3 — R^6 are independently hydrogen or a hydrocarbon radical. Preferred hydrocarbon radicals are alkyl or alkenyl radicals. Any two of R^3 — R^6 may be connected so as to form a cyclic ring. Additional information concerning sulfurized olefins and their preparation can be found in U.S. Pat. No. 4,941,984, incorporated by reference herein in its entirety.

[0034] The use of polysulfides of thiophosphorus acids and thiophosphorus acid esters as lubricant additives is disclosed in U.S. Pat. Nos. 2,443,264; 2,471,115; 2,526,497; and 2,591,577. Addition of phosphorothionyl disulfides as an antiwear, antioxidant, and EP additive is disclosed in U.S. Pat. No. 3,770,854. Use of alkylthiocarbamoyl compounds (bis(dibutyl)thiocarbamoyl, for example) in combination with a molybdenum compound (oxymolybdenum diisopropylphosphorodithioate sulfide, for example) and a phosphorous ester (dibutyl hydrogen phosphite, for example) as antiwear additives in lubricants is disclosed in U.S. Pat. No. 4,501,678. U.S. Pat. No. 4,758,362 discloses use of a carbamate additive to provide improved antiwear and extreme pressure properties. The use of thiocarbamate as an antiwear additive is disclosed in U.S. Pat. No. 5,693,598. Thiocarbamate/molybdenum complexes such as moly-sulfur alkyl dithiocarbamate trimer complex ($R=C_8-C_{18}$ alkyl) are also useful antiwear agents. The use or addition of such materials should be kept to a minimum if the object is to produce low SAP formulations.

[0035] Esters of glycerol may be used as antiwear agents. For example, mono-, di-, and tri-oleates, mono-palmitates and mono-myristates may be used.

[0036] ZDDP is combined with other compositions that provide antiwear properties. U.S. Pat. No. 5,034,141 discloses that a combination of a thiodixanthogen compound (octylthiodixanthogen, for example) and a metal thiophosphate (ZDDP, for example) can improve antiwear properties. U.S. Pat. No. 5,034,142 discloses that use of a metal alkoxyalkylxanthate (nickel ethoxyethylxanthate, for example) and a dixanthogen (diethoxyethyl dixanthogen, for example) in combination with ZDDP improves antiwear properties.

[0037] Preferred antiwear additives include phosphorus and sulfur compounds such as zinc dithiophosphates and/or sulfur, nitrogen, boron, molybdenum phosphorodithioates, molybdenum dithiocarbamates and various organomolybdenum derivatives including heterocyclics, for example dimercaptiothiadiazoles, mercaptobenzothiadiazoles, triazines, and the like, alicyclics, amines, alcohols, esters, diols, triols, fatty amides and the like can also be used. Such additives may be used in an amount of about 0.01 to 6 wt %, preferably about 0.01 to 4 wt %. ZDDP-like compounds provide limited hydroperoxide decomposition capability, significantly below that exhibited by compounds disclosed and claimed in this patent and can therefore be eliminated from the formulation

or, if retained, kept at a minimal concentration to facilitate production of low SAPS formulations.

Viscosity Improvers

[0038] Viscosity improvers (also known as Viscosity Index modifiers, and VI improvers) provide lubricants with high and low temperature operability. These additives increase the viscosity of the oil composition at elevated temperatures which increases film thickness, while having limited effect on viscosity at low temperatures.

[0039] 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.

[0040] 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.

[0041] 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

[0042] Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant. One skilled in the art knows a wide variety of oxidation inhibitors that are useful in lubricating oil compositions. See, Klamann in *Lubricants and Related Products*, op cite, and U.S. Pat. Nos. 4,798,684 and 5,084,197, for example.

[0043] Useful antioxidants include hindered phenols. These phenolic anti-oxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. Typical phenolic antioxidant compounds are the hindered phenolics which are the ones which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with C_6 +alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; and 2-methyl-6-t-butyl-4-dodecyl phenol. Other useful hindered mono-phenolic antioxidants may include for example hindered 2,6-di-alkyl-phenolic propionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used in combination with the

instant invention. Examples of ortho-coupled phenols include: 2,2'-bis(4-heptyl-6-t-butyl-phenol); 2,2'-bis(4-octyl-6-t-butyl-phenol); and 2,2'-bis(4-dodecyl-6-t-butyl-phenol). Para-coupled bisphenols include for example 4,4'-bis(2,6-di-t-butyl phenol) and 4,4'-methylene-bis(2,6-di-t-butyl phenol).

[0044] Non-phenolic oxidation inhibitors which may be used include aromatic amine antioxidants and these may be used either as such or in combination with phenolics. Typical examples of non-phenolic antioxidants include: alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula $R^8R^9R^{10}N$ where R^8 is an aliphatic, aromatic or substituted aromatic group, R^9 is an aromatic or a substituted aromatic group, and R^{10} is H, alkyl, aryl or $R^{11}S(O)_xR^{12}$ where R^{11} is an alkylene, alkenylene, or aralkylene group, R^{12} is a higher alkyl group, or an alkenyl, aryl, or alkaryl group, and x is 0, 1 or 2. The aliphatic group R^8 may contain from 1 to 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.

[0045] Typical aromatic amines antioxidants 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 amine antioxidants useful in the present compositions include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more aromatic amines are also useful. Polymeric amine antioxidants can also be used. Particular examples of aromatic amine antioxidants useful in the present invention include: p,p'-dioctyldiphenylamine; t-octylphenyl- α -naphthylamine; phenyl- α -naphthylamine; and p-octylphenyl- α -naphthylamine.

[0046] Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants.

[0047] Another class of antioxidant used in lubricating oil compositions is 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.

[0048] Preferred antioxidants include hindered phenols, arylamines. These antioxidants may be used individually by type or in combination with one another. Such additives may be used in an amount of about 0.01 to 5 wt %, preferably about 0.01 to 1.5 wt %, more preferably zero to less than 1.5 wt %, most preferably zero.

Detergents

[0049] Detergents are commonly used in lubricating compositions. A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent is typically derived from an organic acid such as a sulfur acid, carboxylic acid,

phosphorous acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal.

[0050] Salts that contain a substantially stoichiometric amount of the metal are described as neutral salts and have a total base number (TBN, as measured by ASTM D2896) of from 0 to 80. Many compositions are overbased, containing large amounts of a metal base that is achieved by reacting an excess of a metal compound (a metal hydroxide or oxide, for example) with an acidic gas (such as carbon dioxide). Useful detergents can be neutral, mildly overbased, or highly overbased.

[0051] It is desirable for at least some detergent to be overbased. Overbased detergents help neutralize acidic impurities produced by the combustion process and become entrapped in the oil. Typically, the overbased material has a ratio of metallic ion to anionic portion of the detergent of about 1.05:1 to 50:1 on an equivalent basis. More preferably, the ratio is from about 4:1 to about 25:1. The resulting detergent is an overbased detergent that will typically have a TBN of about 150 or higher, often about 250 to 450 or more. Preferably, the overbasing cation is sodium, calcium, or magnesium. A mixture of detergents of differing TBN can be used in the present invention.

[0052] Preferred detergents include the alkali or alkaline earth metal salts of sulfonates, phenates, carboxylates, phosphates, and salicylates.

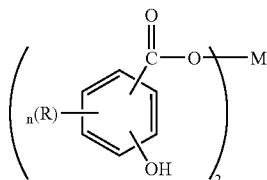
[0053] Sulfonates may be prepared from sulfonic acids that are typically obtained by sulfonation of alkyl substituted aromatic hydrocarbons. Hydro-carbon examples include those obtained by alkylating benzene, toluene, xylene, naphthalene, biphenyl and their halogenated derivatives (chlorobenzene, chlorotoluene, and chloronaphthalene, for example). The alkylating agents typically have about 3 to 70 carbon atoms. The alkaryl sulfonates typically contain about 9 to about 80 carbon or more carbon atoms, more typically from about 16 to 60 carbon atoms.

[0054] Klamann in *Lubricants and Related Products*, op cit discloses a number of overbased metal salts of various sulfonic acids which are useful as detergents dispersants in lubricants. The book entitled "Lubricant Additives", C. V. Smallheer and R. K. Smith, published by the Lezius-Hiles Co. of Cleveland, Ohio (1967), similarly discloses a number of overbased sulfonates that are useful as dispersants/detergents.

[0055] Alkaline earth phenates are another useful class of detergent. These detergents can be made by reacting alkaline earth metal hydroxide or oxide (CaO , $Ca(OH)_2$, BaO , $Ba(OH)_2$, MgO , $Mg(OH)_2$, for example) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight chain or branched C_1 - C_{30} alkyl groups, preferably, C_4 - C_{20} . Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (including elemental sulfur, sulfur halides such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

[0056] Metal salts of carboxylic acids are also useful as detergents. These carboxylic acid detergents may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing free water from the reaction product.

These compounds may be overbased to produce the desired TBN level. Detergents made from salicylic acid are one preferred class of detergents derived from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the formula



where R is a hydrogen atom or an alkyl group having 1 to about 30 carbon atoms, n is an integer from 1 to 4, and M is an alkaline earth metal. Preferred R groups are alkyl chains of at least C₁₁, preferably C₁₃ or greater. R may be optionally substituted with substituents that do not interfere with the detergent's function. M is preferably, calcium, magnesium, or barium. More preferably, M is calcium.

[0057] Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction. See U.S. Pat. No. 3,595,791, which is incorporated herein by reference in its entirety, for additional information on synthesis of these compounds. The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent such as water or alcohol.

[0058] Alkaline earth metal phosphates are also used as detergents.

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

[0060] Preferred detergents include calcium phenates, calcium sulfonates, calcium salicylates, magnesium phenates, magnesium sulfonates, magnesium salicylates and other related components (including borated detergents). Typically, the total detergent concentration is about 0.01 to about 6.0 wt %, preferably, about 0.1 to 0.4 wt %.

Dispersant

[0061] 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.

[0062] 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.

[0063] Chemically, many dispersants may be characterized as phenates, sulfonates, sulfurized phenates, salicylates, naphthenates, stearates, carbamates, thiocarbamates, phosphorus derivatives. A particularly useful class of dispersants

are the alkenylsuccinic derivatives, typically produced by the reaction of a long chain 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 U.S. patents describing such dispersants are U.S. Pat. Nos. 3,172,892; 3,2145,707; 3,219,666; 3,316,177; 3,341,542; 3,444,170; 3,454,607; 3,541,012; 3,630,904; 3,632,511; 3,787,374 and 4,234,435. Other types of dispersant are described in U.S. Pat. Nos. 3,036,003; 3,200,107; 3,254,025; 3,275,554; 3,438,757; 3,454,555; 3,565,804; 3,413,347; 3,697,574; 3,725,277; 3,725,480; 3,726,882; 4,454,059; 3,329,658; 3,449,250; 3,519,565; 3,666,730; 3,687,849; 3,702,300; 4,100,082; 5,705,458. A further description of dispersants may be found, for example, in European Patent Application No. 471 071, to which reference is made for this purpose.

[0064] 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.

[0065] Succinimides are formed by the condensation reaction between alkenyl succinic anhydrides and amines. Molar ratios can vary depending on the polyamine. For example, the molar ratio of alkenyl succinic anhydride to TEPA can vary from about 1:1 to about 5:1. Representative examples are shown in U.S. Pat. Nos. 3,087,936; 3,172,892; 3,219,666; 3,272,746; 3,322,670; and 3,652,616, 3,948,800; and Canada Pat. No. 1,094,044.

[0066] 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.

[0067] 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. Representative examples are shown in U.S. Pat. No. 4,426,305.

[0068] The molecular weight of the alkenyl succinic anhydrides used in the preceding paragraphs will typically range between 800 and 2,500. The above products can be post-reacted with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids such as oleic acid, 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.

[0069] Mannich base dispersants are made from the reaction of alkylphenols, formaldehyde, and amines. See U.S. Pat. No. 4,767,551, which is incorporated herein by reference. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Molecular weights of the alkylphenols range from 800 to 2,500. Repre-

sentative examples are shown in U.S. Pat. Nos. 3,697,574; 3,703,536; 3,704,308; 3,751,365; 3,756,953; 3,798,165; and 3,803,039.

[0070] Typical high molecular weight aliphatic acid modified Mannich condensation products useful in this invention can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or HN(R)_2 group-containing reactants.

[0071] 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.

[0072] 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.

[0073] Examples of alkylene polyamide 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 $\text{H}_2\text{N}-(\text{Z}-\text{NH}-)_n\text{H}$, 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-, penta-propylene tri-, tetra-, penta- and hexamines 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 chlorines on different carbons are suitable alkylene polyamine reactants.

[0074] Aldehyde reactants useful in the preparation of the high molecular products useful in this invention 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.

[0075] Hydrocarbyl substituted amine ashless dispersant additives are well known to one skilled in the art; see, for example, U.S. Pat. Nos. 3,275,554; 3,438,757; 3,565,804; 3,755,433, 3,822,209, and 5,084,197, which are incorporated herein in their entirety by reference.

[0076] 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 %.

Pour Point Depressants

[0077] Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present invention if desired to help meet performance targets. These pour point depressant may be added to lubricating compositions of the present invention 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. U.S. Pat. Nos. 1,815,022; 2,015,748; 2,191,498; 2,387,501; 2,655, 479; 2,666,746; 2,721,877; 2,721,878; and 3,250,715 describe useful pour point depressants and/or the preparation thereof. Such additives may be omitted totally or may be used in a minor amount of about 0.001 to 0.1 wt % on an as-received basis.

Corrosion Inhibitors

[0078] Corrosion inhibitors are used to reduce the degradation of metallic parts that are in contact with the lubricating oil composition. Suitable corrosion inhibitors include thiadiazoles. See, for example, U.S. Pat. Nos. 2,719,125; 2,719,126; and 3,087,932, which are incorporated herein by reference in their entirety. Such additives may be used in an amount of about 0.01 to 5 wt %, preferably about 0.01 to 1.5 wt %.

Seal Compatibility Additives

[0079] Seal compatibility agents help to swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Suitable seal compatibility agents for lubricating oils include organic phosphates, aromatic esters, aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride. Such additives may be used in an amount of about 0.01 to 3 wt %, preferably about 0.01 to 2 wt %.

Anti-Foam Agents

[0080] 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 and often less than 0.1 percent.

Inhibitors and Antirust Additives

[0081] Antirust additives (or corrosion inhibitors) are additives that protect lubricated metal surfaces against chemical attack by water or other contaminants. A wide variety of these are commercially available; they are referred to in Klamann in *Lubricants and Related Products*, op cit.

[0082] One type of antirust additive is a polar compound that wets the metal surface preferentially, protecting it with a film of oil. Another type of antirust additive absorbs water by incorporating it in a water-in-oil emulsion so that only the oil touches the metal surface. Yet another type of antirust 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 %.

Friction Modifiers

[0083] 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 invention if desired. Friction modifiers that lower the coefficient of friction are particularly advantageous in combination with the base oils and lube compositions of this invention. Friction modifiers may include metal-containing compounds or materials as well as ashless compounds or materials, or mixtures thereof. Metal-containing friction modifiers may include metal salts or metal-ligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have low-ash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivative of alcohols, polyols, glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles, triazoles, and other polar molecular functional groups containing effective amounts of O, N, S, or P, individually or in combination. In particular, Mo-containing compounds can be particularly effective such as for example Mo-dithiocarbamates, Mo(DTC), Mo-dithiophosphates, Mo(DTP), Mo-amines, Mo (Am), Mo-alcoholates, Mo-alcohol-amides, etc. See U.S. Pat. No. 5,824,627; U.S. Pat. No. 6,232,276; U.S. Pat. No. 6,153,564; U.S. Pat. No. 6,143,701; U.S. Pat. No. 6,110,878; U.S. Pat. No. 5,837,657; U.S. Pat. No. 6,010,987; U.S. Pat. No. 5,906,968; U.S. Pat. No. 6,734,150; U.S. Pat. No. 6,730,638; U.S. Pat. No. 6,689,725; U.S. Pat. No. 6,569,820; WO 99/66013; WO 99/47629; WO 98/26030.

[0084] Ashless friction modifiers may have also include lubricant materials that contain effective amounts of polar groups, for example, hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hydrocarbyl groups containing effective amounts of O, N, S, or P, individually or in combination. Other friction modifiers that may be particularly effective include, for example, salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long-chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, and the like. In some instances fatty organic acids, fatty amines, and sulfurized fatty acids may be used as suitable friction modifiers.

[0085] Useful concentrations of friction modifiers may range from about 0.01 wt % to 10-15 wt % or more, often with a preferred range of about 0.1 wt % to 5 wt %. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from about 10 ppm to 3000 ppm or more, and often with a preferred range of about 20-2000 ppm, and in some instances a more preferred range of about 30-1000 ppm. Friction modifiers of all types may be used

alone or in mixtures with the materials of this invention. Often mixtures of two or more friction modifiers, or mixtures of friction modifier(s) with alternate surface active material(s), are also desirable.

Typical Additive Amounts

[0086] When lubricating oil compositions contain one or more of the additives discussed above, the additive(s) are blended into the composition in an amount sufficient for it to perform its intended function. Typical amounts of such additives useful in the present invention are shown in Table 1 below.

[0087] Note that many of the additives are shipped from the manufacturer and used with a certain amount of base oil solvent in the formulation. Accordingly, the weight amounts in the table below, as well as other amounts mentioned in this text unless otherwise indicated, are directed to the amount of active ingredient (that is the non-solvent portion of the ingredient). The wt % indicated below are based on the total weight of the lubricating oil composition.

TABLE 1

Typical Amounts of Various Lubricant Oil Components		
Compound	Approximate Wt % (Useful)	Approximate Wt % (Preferred)
Detergent	0.01-6	0.01-4
Dispersant	0.1-20	0.1-8
Friction Reducer	0.01-5	0.01-1.5
Viscosity Improver	0.0-8	0.1 to 4, more preferably 0.1 to 2
Antioxidant	0.0-5	0.1-1.5
Corrosion Inhibitor	0.01-5	0.01-1.5
Anti-wear Additive	0.01-6	0.01-4
Pour Point Depressant	0-0.1 (as received)	0-0.05 (as received)
Anti-foam Agent	0.001-3	0.001-0.15
Base Oil	Balance	Balance

[0088] In the following examples the specific heat capacity was measured by ASTM E1269 (DSC), while the specific heat capacity was calculated by ASTM D2890. The calculation is presented below:

$$C_p = [0.06811 - 0.308G + (0.000815 - 0.000306G) T] / (0.055K + 0.35)$$

where:

[0089] C_p = specific heat capacity, Btu/lb.° F.,

[0090] G = specific gravity,

[0091] T = temperature ° F., and

[0092] K = Watson characterization factor determined by using the nomogram of the specific gravity and average boiling point (FIG. 2, ASTM D2890).

EXAMPLE 1

[0093] The specific heat capacities of GTL -4, PAO -4 and Group III -4 base stocks at various temperature were calculated by the ASTM D2890 method. The results in Btu/lb.° F. were converted to J/Kg.° K. by multiplying the results obtained by the conversion factor 4.186800. The results show no significant difference between the GTL base stock and the PAO. The specific heat capacity results for the other Group III were slightly lower as would be expected based on the higher specific gravity of the Group III stock.

TABLE 1

Calculated Specific Heat Capacity of the Base Stocks						
Temperature (° K)	Temperature (° F.)	Specific Heat Capacity (J/Kg · ° K)			GTL Benefit (%)	
		PAO-4	GTL-4	Group III-4	vs. PAO	vs. Group III
300	80.24	2.136	2.143	2.092	0.31	2.36
305	89.24	2.159	2.166	2.115	0.31	2.35
310	98.24	2.182	2.189	2.137	0.31	2.35
315	197.24	2.205	2.212	2.160	0.31	2.35
320	116.24	2.228	2.234	2.182	0.31	2.35
325	125.24	2.250	2.257	2.205	0.31	2.34

[0094] The data of Table 1 is presented graphically in FIG. 1.

[0095] A comparison was also made on PAO and GTL base stocks having a kinematic viscosity at 100° C. of 6 mm²/s. The calculated Cp and measured Cp were determined at 300° K. and are presented in Table 2 and FIG. 2.

TABLE 2

Base Stock	Calculated Cp J/Kg · ° K	Measured Cp J/Kg · ° K
GTL 6	2.144	3.23
PAO 6	2.136	2.68

The specific gravity for GTL 6 and PAO 6 used in the calculations in Example 1 are 0.8220 and 0.8260 respectively. GTL -6 shows an about +20.5% benefit over the PAO -6 base stock.

EXAMPLE 2

[0096] ATF fluids were formulated with antioxidants, anti-wear additives, an ashless dispersant, a friction modifier and a VI improver.

TABLE 3

Fluid	GTL GTL, wt %	Group III Group III wt %	PAO PAO, wt %
GTL 3.6 (-27° C. pour point)	64.8	0	0
GTL 6 (-18° C. pour point)	16.0	0	0
PAO 4	0	0	80.0
Group III 4	0	80.8	0
Specific Gravity, 60° F./60° F.	0.8145	0.8338	0.819
Mean Average Boiling Point, ° F.	814.8	801.0	835.7
Watson Factor from Nomogram	13.2	13.0	13.2
Adpack, wt %	19.2	19.2	19.2
Total	100.0	100.0	100.0
<u>Properties</u>			
KV @ 40° C., cSt	32	40	35
KV @ 100° C., cSt	7.5	8.3	7.7
VI	212	191	197
Brookfield @ -40° C., cSt	5,030	15,660	6,740
Brookfield @ -30° C., cSt	1,910	3,810	1,830
Brookfield @ -20° C., cSt	780	1,250	820
Brookfield @ -10° C., cSt	360	440	380
Pour Point, ° C.	-54	-51	-54

The GTL base stocks used in Table 3 was obtained from Fischer-Tropsch gas conversion process wax which was then

hydroisomerized/hydrodewaxed to pour point indicated in Table 3. The GTL base stock has saturates content greater than 90%, sulfur content lower than 0.03% and a viscosity index (VI) greater than 120. The Group III base stock was obtained by catalytic dewaxing of fuels hydrocracker bottoms. The Group III has also a saturates content greater than 90%, a sulfur content less than 0.03% and a VI greater than 120.

[0097] The specific heat capacity properties of ATF fluids containing the GTL, PAO and Group III base stocks were determined by Differential Scanning Calorimetry (DSC). Higher specific heat capacity translates to a powertrain fluid that efficiently distributes heat away from the metal components. The results are presented in Table 4 below and FIG. 3.

TABLE 4

Measured Specific Heat Capacities						
ATF fluid base stock	300° K	305° K	310° K	315° K	320° K	325° K
PAO-4	2.241	2.254	2.273	2.298	2.315	2.332
GTL-4	2.308	2.329	2.342	2.365	2.385	2.403
Group III-4	2.196	2.212	2.219	2.238	2.253	2.268

Benefit

[0098]

Measured		
Temperature (° K)	GTL vs. Group III	GTL vs. PAO
300	+5.1%	+3.0%
305	+5.3%	+3.3%
310	+5.5%	+3.0%
315	+5.7%	+2.9%
320	+5.8%	+3.0%
325	+5.9%	+3.0%

[0099] The specific heat capacity decreases with increasing specific gravity. The specific gravity of the GTL -4 base stock (0.8145@60° F./60° F.) was similar to the specific gravity of the PAO -4 base stock (0.819@60° F./60° F.) leading to substantially equivalent calculated specific heat capacities for GTL and PAO base stocks. The specific gravity of the other Group III -4 base stock was directionally higher (0.8338@60° F./60° F.) which led to a lower specific heat

capacity to that of GTL and PAO base stocks. However, the measurement by DSC of the ATF fluids gave unexpectedly higher specific heat capacity for the ATF with the GTL base stock than the ATF fluids formulated with either the PAO or the Other Group III base stocks.

Based on the first law of thermodynamics use can be made of the formula

$$dU=Q-\delta w$$

[0100] where $Q=mC_p \delta t$

[0101] giving $dU=mC_p \delta t+\delta w$

wherein

U=Internal energy of the system

Q=Heat flow in or out of the system

m=mass of lubricant

δt =change in temperature

C_p =specific heat capacity

δw =is the work done (energy/heat loss)

to calculate the change in mass (m) associated with the higher heat capacity of the GTL base oils used.

If C_p is increased by e.g. 3% (e.g., a factor of 1.03), then the mass (m) can be correspondingly reduced by its reciprocal (i.e. 1/1.03) and the term in the equation remain unchanged. Based on this, the amount of fluid used, i.e., the mass of the fluid used, or the size of the equipment employed can be reduced by at least about 2.5% or more preferably about 3 to 20% vs functional fluids containing PAO.

What is claimed is:

1. A method for enhancing the cooling properties of functional fluid oil containing a base oil by at least 2.5% or more as compared to a functional fluid comprising PAO by using as all or a part of the base oil a Gas-to-liquid (GTL) base stock and/or base oil.

2. The method of claim 1 wherein the enhancement of cooling properties ranges from about 3 to 20% compared to PAO.

3. The method of claim 1 or 2 wherein the GTL base stock and/or base oil constitutes about 30 to 100% of the base stock of the functional fluid.

4. The method of claim 1 or 2 wherein the GTL base stock and/or base oil has a kinematic viscosity at 100° C. in the range of about 3 to 50 mm²/s.

5. A method for reducing the amount of functional fluid containing a base oil or base stock used in an apparatus by at least about 2.5% or more as compared to the amount of functional fluid used when the functional fluid is a PAO based functional fluid by employing a Gas-to-liquids base stock and/or base oil as from about 30 to 100% of the base oil.

6. A method for reducing the size of an apparatus lubricated with a functional fluid containing a base stock or base oil by at least about 2.5% or more as compared to the size of the apparatus when using a PAO based functional fluid by employing a Gas-to-liquids base stock and/or base oil as from about 30 to 100% of the base oil or base stock in the functional fluid.

7. The method of claim 5 wherein the amount of functional fluid used to lubricate the apparatus is reduced by about 3 to 20%.

8. The method of claim 6 wherein the size of the apparatus lubricated by the functional fluid is reduced by about 3 to 20%.

9. The method of claim 5 or 7 wherein the functional fluid comprises about 30 to 100% GTL as base stock and/or base oil.

10. The method of claim 5 or 7 wherein the GTL base stock and/or base oil has a kinematic viscosity at 100° C. in the range of about 3 to 50 mm²/s.

11. The method of claim 6 or 8 wherein the functional fluid comprises about 30 to 100% GTL as base stock and/or base oil.

12. The method of claim 6 or 8 wherein the GTL base stock and/or base oil has a kinematic viscosity at 100° C. in the range of about 3 to 50 mm²/s.

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