



US 20030166476A1

(19) **United States**

(12) **Patent Application Publication**

Winemiller et al.

(10) **Pub. No.: US 2003/0166476 A1**

(43) **Pub. Date: Sep. 4, 2003**

(54) **LUBRICATING OIL COMPOSITIONS WITH IMPROVED FRICTION PROPERTIES**

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(21) Appl. No.: **10/354,662**
(22) Filed: **Jan. 30, 2003**

Related U.S. Application Data

(60) Provisional application No. 60/353,738, filed on Jan. 31, 2002.

Publication Classification

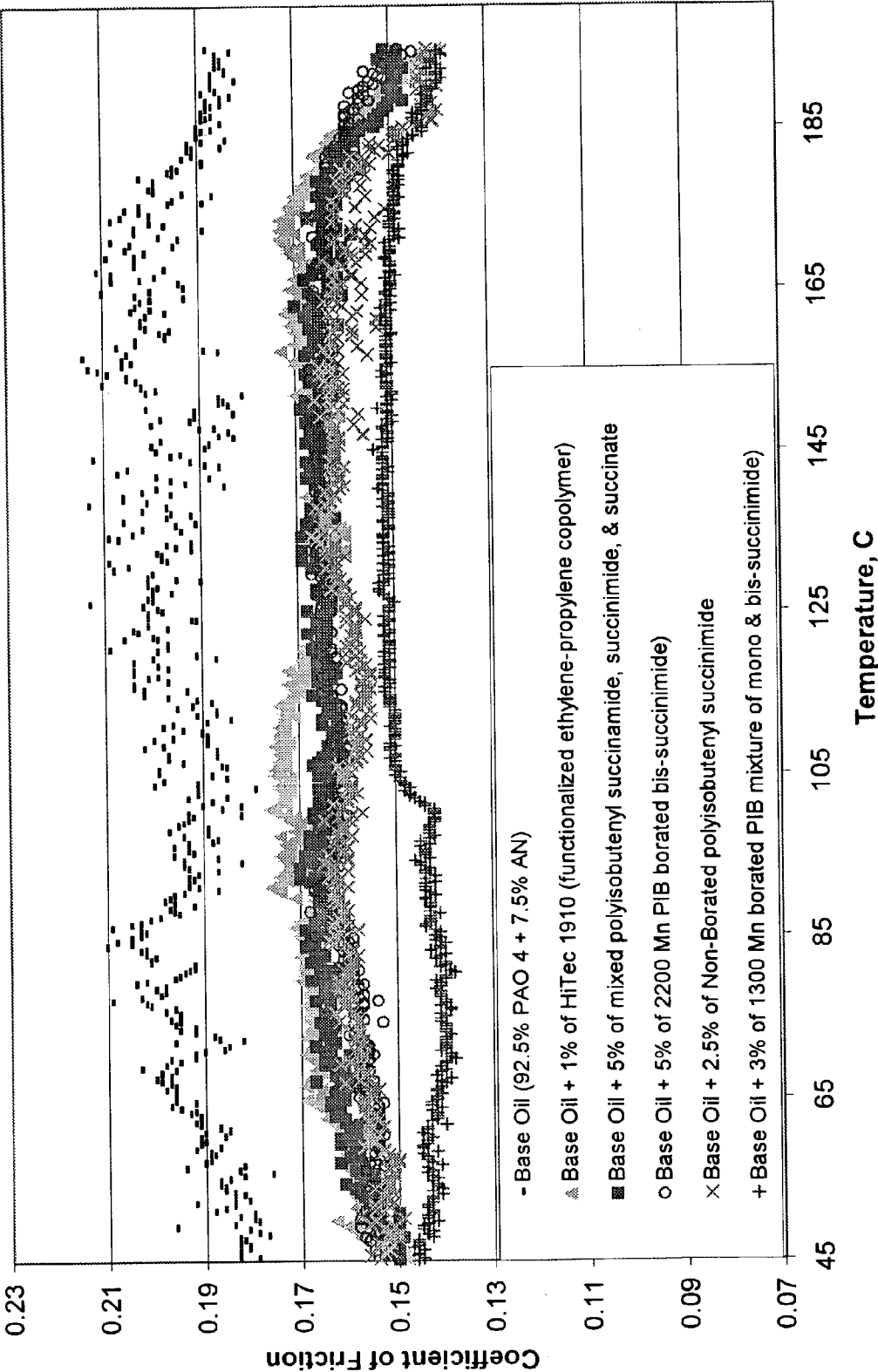
(51) **Int. Cl.⁷ C10M 139/00; C10M 141/12**

(52) **U.S. Cl. 508/192; 508/486**

(57) **ABSTRACT**

The present invention concerns friction reducers for use in lubricating oil compositions which comprise certain groups of aromatic compounds, esters, narrow mixtures of base stocks, and/or amorphous polymers such as amorphous olefin copolymers. These compositions can provide substantial reductions in the coefficient of friction and fuel economy improving benefits when admixed to lubricating oils without deleterious effects such as instability, undesirable high viscosities and deposits. In one aspect of the invention, pentaerythritol esters and optionally triol esters are added to lubricating oil compositions to provide reduced friction and improved fuel economy. In a second aspect of the invention, similar results are obtained by adding hydrocarbyl aromatics to a lubricating oil composition containing one or more of Groups II and III base stock. In a third aspect, the invention concerns a lubricating oil composition comprising an amorphous olefin copolymer and one or more of Groups II and III base stocks. In one embodiment, the third aspect also includes one or more of hydrocarbyl aromatics and polyol esters as part of the composition. In a forth aspect, moderate concentrations of hydrocarbyl aromatics are used in a lubricating oil composition comprising paraffinic base oil stocks and preferably a borated polyisobutenyl succinimide ashless dispersant.

Figure 1



LUBRICATING OIL COMPOSITIONS WITH IMPROVED FRICTION PROPERTIES

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to lubricating oil compositions suitable for use in internal combustion engines.

[0003] 2. Background

[0004] Lubricating oils for internal combustion engines contain in addition to at least one base lubricating oil, additives which enhance the performance of the lubricating oil. A variety of additives such as detergents, dispersants, friction reducers, viscosity index improvers, antioxidants, corrosion inhibitors, antiwear additives, pour point depressants, seal compatibility additives, and antifoam agents are used in lubricating oil compositions.

[0005] It is critical to maintain sufficiently high lubricating film thickness on metal surfaces in order to maintain low friction and reduce wear of metal parts at a variety of operating temperatures. It is also important to maintain cleanliness over the entire range of operating conditions while reducing wear to a minimum and to maintain a good overall lubricant performance under the most severe operating conditions. Conventional lubricant and engine oil technology relies heavily on traditional friction reducers which can be chosen from one or more classes of friction reducing compounds exemplified by alcohols, hydrocarbyl diols, hydrocarbyl triols, alkane diols or triols, esters, fatty esters, hydroxy esters, fatty acid amides such as oleamide, hydroxy alkyl hydrocarbyl amides, bis hydroxyalkyl hydrocarbyl amides such as bis(2-hydroxyethyl)oleamide, hydroxy alkyl hydrocarbyl amines, bis hydroxyalkyl hydrocarbyl amines such as bis(2-hydroxyethyl)oleyamine, borated counterparts of the above, acylated counterparts of the above, phosphorus based compositions such as trioleyl phosphites, molybdenum compounds such as inorganic molybdenum and/or organic molybdenum compounds including molybdenum dithiocarbamates, molybdenum phosphorodithioates, molybdenum complexes of amines and/or alcoholic moieties. Friction reducers often include mixtures of two or more of the above classes of components. Several of the above prior art friction reducing compositions are found to have significant and often undesirable side-effects. It is thus desirable to have several improved fuel economy components and/or systems to be able to choose from in the formulation of high quality fuel economy improving lubricants.

SUMMARY OF THE INVENTION

[0006] The present invention concerns friction reducers for use in lubricating oil compositions which comprise certain groups of aromatic compounds, esters, narrow mixtures of base stocks, and/or amorphous polymers such as amorphous olefin copolymers. These compositions can provide substantial reductions in the coefficient of friction and fuel economy improving benefits when admixed to lubricating oils without deleterious effects such as instability, undesirable high viscosities and deposits.

[0007] In one aspect of the invention, pentaerythritol esters and optionally triol esters are added to lubricating oil compositions to provide reduced friction and improved fuel

economy. In a second aspect of the invention, similar results are obtained by adding hydrocarbyl aromatics to a lubricating oil composition containing one or more of Group II base stock, Group III base stock, and wax isomerate base stock. In a third aspect, the invention concerns a lubricating oil composition comprising an amorphous olefin copolymer and one or more of Group II base stock, Group III base stock, and wax isomerate base stock. In one embodiment, the third aspect also includes one or more of hydrocarbyl aromatics and polyol esters as part of the composition. In a fourth aspect, moderate concentrations of hydrocarbyl aromatics are used in a lubricating oil composition comprising paraffinic base oil stocks and preferably a borated polyisobutenyl succinimide ashless dispersant.

BRIEF DESCRIPTION OF THE DRAWING

[0008] FIG. 1 is a plot of coefficient of friction as a function of temperature for various compositions.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Engine oils contain a base lube oil and a variety of additives. These additives include detergents, dispersants, friction reducers, viscosity index improvers, antioxidants, corrosion inhibitors, antiwear additives, pour point depressants, seal compatibility additives, and antifoam agents. To be effective, these additives must be oil-soluble or oil-dispersible. By oil-soluble, it is meant that the compound is soluble in the base oil or lubricating oil composition under normal blending conditions.

[0010] The instant invention concerns certain groups of aromatic compounds, esters, mixtures of base stocks, and/or amorphous polymers such as amorphous olefin copolymers that can provide substantial reductions in the coefficient of friction and fuel economy improving benefits when admixed to lubricating oils without deleterious effects such as instability, undesirable high viscosities and deposits.

[0011] In one aspect, the present invention concerns certain pentaerythritol esters which are found to provide unexpected and significant fuel economy improving (friction reducing) benefits when formulated into lubricants containing hydrocarbyl aromatic compositions. This fuel economy improvement enhancement can be further improved with the addition of certain esters to the above-mentioned pentaerythritol esters. In particular, this additional fuel economy improvement is seen with a mixed triol ester and pentaerythritol ester system in the presence of a relatively low concentration of hydrocarbyl aromatics such as alkylated naphthalene. Useful concentrations of hydrocarbyl aromatics range from about 1% or more. We believe that about 2% to about 45% of such hydrocarbyl aromatics is often preferred, more preferably about 2% to about 30%, even more preferably about 3% to about 15%.

[0012] Desirable esters include pentaerythritol esters, derived from mono-, di-, and poly pentaerythritol polyols reacted with mixed hydrocarbyl acids (RCO_2H), and where a substantial amount of the available $-\text{OH}$ groups are converted to esters. The substituent hydrocarbyl groups, R, of the acid moiety and ester comprise from about C_6 to about C_{16} or more, with preferable ranges being about C_6 to about C_{14} , and may comprise alkyl, alkenyl, cycloalkyl, cycloalkenyl, linear, branched, and related hydrocarbyl groups, and

can optionally contain S, N, and/or O groups. Pentaerythritol esters with mixtures of substituent hydrocarbyl groups, R, are often preferred. For example, substituent hydrocarbyl groups, R, may comprise a substantial amount of C₈ and C₁₀ hydrocarbyl moieties in the proportions of about 1:4 to 4:1. In a mode, a preferred pentaerythritol ester has R groups comprising approximately about 55% C₈, about 40% C₁₀, and the remainder approximately 5% C₆ and C₁₂₊ moieties. For example, one useful pentaerythritol ester has a viscosity index of about 148, a pour point of about 3° C. and a kinematic viscosity of about 5.9 cSt at 100° C. The pentaerythritol esters can be used in lubricant compositions at concentrations of about 3% to about 30%, preferably about 4% to about 20%, and more preferably about 5% to about 15%.

[0013] Esters may also include esters of trimethylolpropane and trimethylolethane and the like.

[0014] The hydrocarbyl aromatics that can be used can be any hydrocarbyl molecule that contains at least about 5% of its weight derived from an aromatic moiety such as a benzenoid moiety or naphthenoid moiety, or their derivatives. These hydrocarbyl aromatics include alkyl benzenes, alkyl naphthalenes, alkyl diphenyl oxides, alkyl naphthols, alkyl diphenyl sulfides, alkylated bis-phenol A, alkylated thiodiphenol, and the like. The aromatic can be mono-alkylated, dialkylated, polyalkylated, and the like. The aromatic can be mono- or poly-functionalized. The hydrocarbyl groups can also be comprised of mixtures of alkyl groups, alkenyl groups, alkynyl, cycloalkyl groups, cycloalkenyl groups and other related hydrocarbyl groups. The hydrocarbyl groups can range from about C₆ up to about C₆₀ with a range of about C₈ to about C₄₀ often being preferred. A mixture of hydrocarbyl groups is often preferred. The hydrocarbyl group can optionally contain sulfur, oxygen, and/or nitrogen containing substituents. The aromatic group can also be derived from natural (petroleum) sources, provided at least about 5% of the molecule is comprised of an above-type aromatic moiety. Viscosities at 100° C. of approximately 3 cSt to about 50 cSt are preferred, with viscosities of approximately 3.4 cSt to about 20 cSt often being more preferred for the hydrocarbyl aromatic component. In one embodiment, an alkyl naphthalene where the alkyl group is primarily comprised of 1-hexadecene is used. Other alkylates of aromatics can be advantageously used. Naphthalene, for example, can be alkylated with olefins such as octene, decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like. Useful concentrations of hydrocarbyl aromatic in a lubricant oil composition can be about 2% to about 25%, preferably about 4% to about 20%, and more preferably about 4% to about 15%, depending on the application.

[0015] Alkylated aromatics such as the hydrocarbyl aromatics of the present invention may be produced by well-known Friedel-Crafts alkylation of aromatic compounds. See Friedel-Crafts and Related Reactions, Olah, G. A. (ed), Interscience Publishers, New York, 1963. For example, an aromatic compound, such as benzene or naphthalene, is alkylated by an olefin, alkyl halide or alcohol in the presence of a Friedel-Crafts catalyst. See Friedel-Crafts and Related Reactions, Vol. 2, part 1, chapters 14, 17, and 18, See Olah, G. A. (ed), Interscience Publishers, New York, 1964. Many homogeneous or heterogeneous solid catalysts are known to one skilled in the art. The choice of catalyst depends on the

reactivity of the starting materials and product quality requirements. For example, strong acids such as AlCl₃, BF₃, or HF may be used. In some cases, milder catalysts such as FeCl₃ or SnCl₄ are preferred. Other alkylation technology uses zeolites or solid super acids.

[0016] Fuel economy enhancements are seen with synergistic mixtures of (a) Group II or Group III paraffinic oil blends, including wax isomerate base oils, and (b) hydrocarbyl aromatics. In particular, the above mentioned base stocks comprising certain hydroprocessed base oils, in the presence of low concentrations of polyol based esters (such as those derived from trimethylolpropane and mixed hydrocarbyl acids), and hydrocarbyl aromatics (such as alkylated naphthalene) are found to provide unexpected and significant fuel economy improving (friction reducing) benefits when directly compared to lubricants containing relatively high quantities of about 40% of high quality synthetic fluids derived from olefin oligomers such as oligomers of 1-decene. For the comparison, both groups of base stocks have viscosities of about 4 to about 50 cSt at 100° C. and similar viscosity indices of approximately 110 to approximately 150 or greater.

[0017] In another aspect of the invention, certain amorphous olefin copolymers are found to provide unexpected and significant fuel economy improving (friction reducing) benefits when formulated into lubricants, especially those containing significant amounts of Group II or Group III base oils, including wax isomerates, having viscosity indices of about 110 to about 150 or greater. Such olefin copolymers are not predominantly crystalline. Copolymers used in this invention have molecular weights in the range of about 20,000 or higher, preferably 60,000 or higher, more preferably 100,000 or higher and even more preferably 150,000 or higher. For example, in one embodiment, amorphous ethylene-propylene copolymers comprising significant to major amounts of propylene-derived copolymers have molecular weights in the range of about 20,000 or higher. We believe that the fuel economy benefit can be further enhanced when the above amorphous olefin copolymer is used in the presence of a traditional ester and/or hydrocarbyl aromatic such as alkyl naphthalene at concentrations of about 1% to about 30% or more, preferably about 2% to about 25%, or more preferably, about 3% to about 20% in the finished formulated lubricant.

[0018] In the instant invention, use of these amorphous olefin copolymers gives surprising low-temperature pumpability performance in lubricant compositions.

[0019] In another aspect of the invention, significant fuel economy enhancements are attained with the use of moderate concentrations of hydrocarbyl aromatics, preferably in the presence of at least a minor concentration of Group II or Group III hydrocracked and/or hydrotreated base stocks, including wax isomerates. These hydrocarbyl aromatics are described above. Group II and Group III base stocks and wax isomerate base stocks are described below. We also believe that the presence of certain ashless dispersants can significantly contribute to the fuel economy enhancements observed.

[0020] For example, one preferred composition comprising about 20% hydrocarbyl aromatic, about 40% Group II paraffinic base stock, about 3 weight percent borated poly-

isobutyl succinimide ashless dispersant is found to be particularly useful. Useful ashless dispersants are described below.

[0021] Group II and/or Group III hydroprocessed or hydrocracked base stocks, including wax isomerates, or their synthetic counterparts such as polyalphaolefin lubricating oils are preferred as lubricating base stocks when used in conjunction with the components of each of the aspects of the present invention. At least about 20% of the total composition should comprise such Group II or Group III base stocks, including wax isomerates, with at least about 30% on occasion being more preferable, with at least about 50% on occasion being more preferable and more than about 80% on occasion being even more preferable. Gas-to-Liquids base stocks can also be preferentially used with the components of this invention as a portion or all of the base stocks used to formulate the finished lubricant. A mixture of all or some of such base stocks can be used to advantage and can often be preferred. We believe that the improvement and benefit is best when the components of this invention are added to lubricating systems comprised of primarily Group II and or Group III base stocks, including wax isomerates, with up to lesser quantities of alternate fluids such as the above described hydrocarbyl aromatics as exemplified by C₁₂, C₁₄, C₁₆, and/or C₁₈ alkylated naphthalenes. In some instances, hydrocarbyl aromatics products comprising substantially mono-alkylated naphthalene can be preferred.

[0022] Other components, including effective amounts of co-base stocks, and various performance additives can be advantageously used with the components of this invention. These co-base stocks include polyalphaolefin oligomeric low- and moderate- and high-viscosity oils, dibasic acid esters, polyol esters, other hydrocarbon oils such as those derived from gas to liquids type technology, supplementary hydrocarbyl aromatics and the like. These co-base stocks can also include some quantity of decene-derived trimers and tetramers, and also some quantity of Group I base stocks, provided that the above Group II and/or Group III type base stocks, including wax isomerates, predominate and make up at least about 50% of the total base stocks contained in fluids comprised of the elements of the above invention requiring a substantial portion of such stocks. The base stocks, co-base stocks and other performance additives are discussed in more detail below.

[0023] The instant invention can be used with additional lubricant components in effective amounts in lubricant compositions, such as for example polar and/or non-polar lubricant base oils, and performance additives such as for example, but not limited to, oxidation inhibitors, metallic and non-metallic dispersants, metallic and non-metallic detergents, corrosion and rust inhibitors, metal deactivators, anti-wear agents (metallic and non-metallic, phosphorus-containing and non-phosphorus, sulfur-containing and non-sulfur types), extreme pressure additives (metallic and non-metallic, phosphorus-containing and non-phosphorus, sulfur-containing and non-sulfur types), anti-seizure agents, pour point depressants, wax modifiers, viscosity modifiers, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, 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, which also gives a good discussion of

a number of the lubricant additives discussed mentioned below. Reference is also made "Lubricant Additives" by M. W. Ranney, published by Noyes Data Corporation of Parkridge, N.J. (1973).

[0024] Base Oil

[0025] A wide range of lubricating oils is known in the art. Lubricating oils that are useful in the present invention 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.

[0026] 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 stock generally have a viscosity index of between about 80 to 120 and contains greater than about 0.03% sulfur and/or 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 contain less than or equal to about 0.03% sulfur and greater than about 90% saturates. Group IV includes polyalphaolefins (PAO). Group V base stock includes base stocks not included in Groups I-IV. The table below summarizes properties of each of these five groups.

	Saturates	Sulfur	Viscosity Index
Group I	<90 &/or	>0.03% &	≥80 & <120
Group II	≥90 &	≤0.03% &	≥80 & <120
Group III	≥90 &	≤0.03% &	≥120
Group IV	Defined as polyalphaolefins (PAO)		
Group V	All other base oil stocks not included in Groups I, II, III, or IV		

[0027] 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 invention. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrotreated, or solvent extracted.

[0028] Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers, for example). Polyalphaolefin (PAO) oil base stocks are a commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C₈, C₁₀, C₁₂, C₁₄ olefins or mixtures thereof may be utilized. See U.S. Pat. Nos. 4,956,122; 4,827,064; and 4,827,073, which are incorporated herein by reference in their entirety.

[0029] The number average molecular weights of the PAOs, which are known materials and generally available on a major commercial scale from suppliers such as Exxon-Mobil Chemical Company, Chevron-Phillips, BP-Amoco, and others, typically vary from about 250 to about 3,000, although PAO's may be made in viscosities up to about 100 cSt (100° C.). The PAOs are typically comprised of relatively low molecular weight hydrogenated polymers or oligomers of alphaolefins which include, but are not limited to, C₂ to about C₃₂ alphaolefins with the C₈ to about C₁₆ alphaolefins, such as 1-octene, 1-decene, 1-dodecene and the like, being preferred. The preferred polyalphaolefins are poly-1-octene, poly-1-decene and poly-1-dodecene and mixtures thereof and mixed olefin-derived polyolefins. However, the dimers of higher olefins in the range of C₁₄ to C₁₈ may be used to provide low viscosity basestocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly trimers and tetramers of the starting olefins, with minor amounts of the higher oligomers, having a viscosity range of 1.5 to 12 cSt.

[0030] The PAO fluids may be conveniently made by the polymerization of an alphaolefin in the presence of a polymerization catalyst such as the Friedel-Crafts catalysts including, for example, aluminum trichloride, boron trifluoride or complexes of boron trifluoride with water, alcohols such as ethanol, propanol or butanol, carboxylic acids or esters such as ethyl acetate or ethyl propionate. For example the methods disclosed by U.S. Pat. No. 4,149,178 or U.S. Pat. No. 3,382,291 may be conveniently used herein. Other descriptions of PAO synthesis are found in the following U.S. Pat. Nos. 3,742,082; 3,769,363; 3,876,720; 4,239,930; 4,367,352; 4,413,156; 4,434,408; 4,910,355; 4,956,122; and 5,068,487. The dimers of the C₁₄ to C₁₈ olefins are described in U.S. Pat. No. 4,218,330. All of the aforementioned patents are incorporated by reference herein in their entirety.

[0031] Other useful synthetic lubricating base stocks oils may also be utilized, for example those described in the seminal work "Synthetic Lubricants", Gunderson and Hart, Reinhold Publ. Corp., New York 1962, which is incorporated in its entirety.

[0032] In alkylated aromatic stocks, the alkyl substituents are typically alkyl groups of about 8 to 25 carbon atoms, usually from 10 to 18 carbon atoms and up to three such substituents may be present, as described for the alkyl benzenes in ACS Petroleum Chemistry Preprint 1053-1058, "Poly n-Alkylbenzene Compounds: A Class of Thermally Stable and Wide Liquid Range Fluids", Eapen et al, Phila. 1984. Tri-alkyl benzenes may be produced by the cyclodimerization of 1-alkynes of 8 to 12 carbon atoms as described in U.S. Pat. No. 5,055,626. Other alkylbenzenes are described in European Patent Application No. 168534

and U.S. Pat. No. 4,658,072. Alkylbenzenes are used as lubricant basestocks, especially for low-temperature applications (arctic vehicle service and refrigeration oils) and in papermaking oils. They are commercially available from producers of linear alkylbenzenes (LABs) such as Vista Chem. Co, Huntsman Chemical Co., Chevron Chemical Co., and Nippon Oil Co. The linear alkylbenzenes typically have good low pour points and low temperature viscosities and VI values greater than 100 together with good solvency for additives. Other alkylated aromatics which may be used when desirable are described, for example, in "Synthetic Lubricants and High Performance Functional Fluids", Dressler, H., chap 5, (R. L. Shubkin (Ed.)), Marcel Dekker, N.Y. 1993.

[0033] Other useful lubricant oil base stocks include wax isomerate base stocks and base oils, comprising hydroisomerized waxy stocks (e.g. waxy stocks such as gas oils, slack waxes, fuels hydrocracker bottoms, etc.), hydroisomerized Fischer-Tropsch waxes, Gas-to-Liquids (GTL) base stocks and base oils, and other wax isomerate hydroisomerized base stocks and base oils, or mixtures thereof. Fischer-Tropsch waxes, the high boiling point residues of Fischer-Tropsch synthesis, are highly paraffinic hydrocarbons with very low sulfur content. The hydroprocessing used for the production of such base stocks may use an amorphous hydrocracking/hydroisomerization catalyst, such as one of the specialized lube hydrocracking (LHDC) catalysts or a crystalline hydrocracking/hydroisomerization catalyst, preferably a zeolitic catalyst. For is example, one useful catalyst is ZSM-48 as described in U.S. Pat. No. 5,075,269, the disclosure of which is incorporated herein by reference in its entirety. Processes for making hydrocracked/hydroisomerized distillates and hydrocracked/hydroisomerized waxes are described, for example, in U.S. Pat. Nos. 2,817,693; 4,975,177; 4,921,594 and 4,897,178 as well as in British Patent Nos. 1,429,494; 1,350,257; 1,440,230 and 1,390,359. Each of the aforementioned patents is incorporated herein in their entirety. Particularly favorable processes are described in European Patent Application Nos. 464546 and 464547, also incorporated herein by reference. Processes using Fischer-Tropsch wax feeds are described in U.S. Pat. Nos. 4,594,172 and 4,943,672, the disclosure of which is incorporated herein by reference in their entirety. Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and other wax-derived hydroisomerized (wax isomerate) base oils be advantageously used in the instant invention, and may have useful kinematic viscosities at 100° C. of about 3 cSt to about 50 cSt, preferably about 3 cSt to about 30 cSt, more preferably about 3.5 cSt to about 25 cSt, as exemplified by GTL 4 with kinematic viscosity of about 4.0 cSt at 100° C. and a viscosity index of about 141. These Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and other wax-derived hydroisomerized base oils may have useful pour points of about -20° C. or lower, and under some conditions may have advantageous pour points of about -25° C. or lower, with useful pour points of about -30° C. to about -40° C. or lower. Useful compositions of Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, and wax-derived hydroisomerized base oils are recited in U.S. Pat. Nos. 6,080,301; 6,090,989, and 6,165,949 for example, and are incorporated herein in their entirety by reference.

[0034] Gas-to-Liquids (GTL) base oils, Fischer-Tropsch wax derived base oils, have a beneficial kinematic viscosity

advantage over conventional Group II and Group III base oils, which may be very advantageously used with the instant invention. Gas-to-Liquids (GTL) base oils can have significantly higher kinematic viscosities, up to about 20-50 cSt at 100° C., whereas by comparison commercial Group II base oils can have kinematic viscosities, up to about 15 cSt at 100° C., and commercial Group III base oils can have kinematic viscosities, up to about 10 cSt at 100° C. The higher kinematic viscosity range of Gas-to-Liquids (GTL) base oils, compared to the more limited kinematic viscosity range of Group II and Group III base oils, in combination with the instant invention can provide additional beneficial advantages in formulating lubricant compositions. Also, the exceptionally low sulfur content of Gas-to-Liquids (GTL) base oils, and other wax-derived hydroisomerized base oils, in combination with the low sulfur content of suitable olefin oligomers and/or alkyl aromatics base oils, and in combination with the instant invention can provide additional advantages in lubricant compositions where very low overall sulfur content can beneficially impact lubricant performance.

[0035] Alkylene oxide polymers and interpolymers and their derivatives containing modified terminal hydroxyl groups obtained by, for example, esterification or etherification are useful synthetic lubricating oils. By way of example, these oils may be obtained by polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers (methyl-polyisopropylene glycol ether having an average molecular weight of about 1000, diphenyl ether of polyethylene glycol having a molecular weight of about 500-1000, and the diethyl ether of polypropylene glycol having a molecular weight of about 1000 to 1500, for example) or mono- and polycarboxylic esters thereof (the acidic acid esters, mixed C₃₋₈ fatty acid esters, or the C₁₃Oxo acid diester of tetraethylene glycol, for example).

[0036] Esters comprise a useful base stock. Additive solvency and seal compatibility characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid, alkyl succinic acid, alkenyl succinic acid, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.

[0037] 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 alkanolic acids containing at least about 4 carbon atoms (preferably C₅ to C₃₀ acids such as saturated straight chain fatty acids including caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, and behenic acid, or the corresponding

branched chain fatty acids or unsaturated fatty acids such as oleic acid, or mixtures of any of these materials).

[0038] Suitable synthetic ester components include the esters of trimethylol propane, trimethylol butane, trimethylol ethane, pentaerythritol and/or dipentaerythritol with one or more monocarboxylic acids containing from about 5 to about 10 carbon atoms. These esters are widely available commercially, for example, the Mobil P-41 and P-51 esters ExxonMobil Chemical Company).

[0039] Silicon-based oils are another class of useful synthetic lubricating oils. These oils include polyalkyl-, polyaryl-, polyalkoxy-, and polyaryloxy-siloxane oils and silicate oils. Examples of suitable silicon-based oils include tetraethyl silicate, tetraisopropyl silicate, tetra-(2-ethylhexyl)silicate, tetra-(4-methylhexyl)silicate, tetra-(p-tert-butylphenyl) silicate, hexyl-(4-methyl-2-pentoxo) disiloxane, poly(methyl) siloxanes, and poly-(methyl-2-mehtylphenyl) siloxanes.

[0040] Another class of synthetic lubricating oil is esters of phosphorous-containing acids. These include, for example, tricresyl phosphate, trioctyl phosphate, diethyl ester of decanephosphonic acid. Another class of oils includes polymeric tetrahydrofurans and the like.

[0041] Besides unique additive effects of hydrocarbyl aromatics and high molecular weight olefin oligomers of this invention, we believe that highly refined, low sulfur Group II/III base oils (such as hydroprocessed oils, HDP) and wax isomerate base oil may be used in place or in addition to Group IV and V base oils as the base stocks used in combination with the components of this invention to provide the above-documented superior performance characteristics.

[0042] 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.

[0043] Antiwear and EP Additives

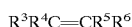
[0044] Internal combustion engine lubricating oils require the presence of antiwear and/or extreme pressure (EP) additives in order to provide adequate antiwear protection for the engine. Increasingly specifications for engine oil performance have exhibited a trend for improved antiwear properties of the oil. Antiwear and extreme EP additives perform this role by reducing friction and wear of metal parts.

[0045] 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 dialkylldithio-phosphate in which the primary metal constituent is zinc, or zinc dialkylldithio-phosphate (ZDDP). ZDDP compounds generally are of the formula Zn[SP(S)(OR¹)(OR²)]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 weight percent of the total lube oil composition, although more or less can often be used advantageously.

[0046] 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.

[0047] 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



[0048] 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.

[0049] The use of polysulfides of thiophosphorous acids and thiophosphorous 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. Each of the aforementioned patents is incorporated by reference herein in its entirety.

[0050] Esters of glycerol may be used as antiwear agents. For example, mono-, di, and tri-oleates, mono-palmitates and mono-myristates may be used.

[0051] 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. Each of the aforementioned patents is incorporated herein by reference in its entirety.

[0052] Preferred antiwear additives include phosphorus and sulfur compounds such as zinc dithiophosphates and/or sulfur, nitrogen, boron, molybdenum phosphorodithioates, molybdenum dithiocarbamates and various organo-molybdenum 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 weight percent, preferably about 0.01 to 4 weight percent.

[0053] Viscosity Index Improvers

[0054] Viscosity index improvers (also known as VI improvers, viscosity modifiers, and viscosity improvers) provide lubricants with high and low temperature operability. These additives impart shear stability at elevated temperatures and acceptable viscosity at low temperatures.

[0055] Suitable viscosity index improvers include high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. Typical molecular weights of these polymers are between about 10,000 to 1,000,000, more typically about 20,000 to 500,00, and even more typically between about 50,000 and 200,000.

[0056] Examples of suitable viscosity index 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.

[0057] Viscosity index improvers may be used in an amount of about 0.01 to 8 weight percent, preferably about 0.01 to 4 weight percent.

[0058] Antioxidants

[0059] 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, each of which is incorporated by reference herein in its entirety.

[0060] Useful antioxidants include hindered phenols. These phenolic antioxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. Typical phenolic antioxidant compounds are the hindered phenolics which are the ones which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with C_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(6-t-butyl-4-heptyl phenol); 2,2'-bis(6-t-butyl-4-octyl phenol); and 2,2'-bis(6-t-butyl-4-dodecyl phenol). Para coupled bis phenols include for example 4,4'-bis(2,6-di-t-butyl phenol) and 4,4'-methylene-bis(2,6-di-t-butyl phenol).

[0061] 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 $R^{11}S(O)_x$ 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.

[0062] 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 naphthyl-amines, 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-alpha-naphthylamine; phenyl-alphanaphthylamine; and p-octylphenyl-alpha-naphthylamine.

[0063] Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants. Low sulfur peroxide decomposers are useful as antioxidants.

[0064] 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 dithiocarbamates, 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.

[0065] Preferred antioxidants include hindered phenols, arylamines, low sulfur peroxide decomposers and other related components. 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 weight percent, preferably about 0.01 to 1.5 weight percent.

[0066] Detergents

[0067] Detergents are commonly used in lubricating compositions. A typical detergent is an anionic material that

contains a long chain oleophilic portion of the molecule and a smaller anionic or oleophobic 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 counter ion is typically an alkaline earth or alkali metal.

[0068] 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.

[0069] 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.

[0070] Preferred detergents include the alkali or alkaline earth metal salts of sulfates, phenates, carboxylates, phosphates, and salicylates.

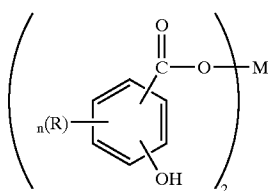
[0071] Sulfonates may be prepared from sulfonic acids that are typically obtained by sulfonation of alkyl substituted aromatic hydrocarbons. Hydrocarbon examples include those obtained by alkylating benzene, toluene, xylene, naphthalene, biphenyl and their halogenated derivatives (chlorobenzene, chlorotoluene, and chloronaphthalene, for example). The alkylating agents typically have 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.

[0072] Klamann in *Lubricants and Related Products*, op cit discloses a number of overbased metal salts of various sulfonic acids which are useful as detergents and 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 which are useful as dispersants/detergents.

[0073] 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, 1-ethyldecylphenol, 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.

[0074] 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



[0075] 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.

[0076] 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.

[0077] Alkaline earth metal phosphates are also used as detergents.

[0078] 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. 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 weight percent, preferably, about 0.1 to 0.4 weight percent.

[0079] Dispersant

[0080] During engine operation, oil insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposit 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.

[0081] 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 phosphorous. Typical hydrocarbon chains contain 50 to 400 carbon atoms.

[0082] 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; 3,214,570; 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. Each of the aforementioned patents is incorporated herein in its entirety by reference.

[0083] 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.

[0084] 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, which are incorporated herein in their entirety by reference.

[0085] 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.

[0086] 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, incorporated herein by reference.

[0087] 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 is product.

[0088] 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. Representative 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, which are incorporated herein in their entirety by reference.

[0089] 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.

[0090] 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.

[0091] 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.

[0092] 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 $\text{H}_2\text{N-(Z-NH-)}_n\text{H}$, 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-, pentapropylene 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 dichloro alkanes having 2 to 6 carbon atoms and the chlorines on different carbons are suitable alkylene polyamine reactants.

[0093] 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 (b-hydroxybutyraldehyde). Formaldehyde or a formaldehyde-yielding reactant is preferred.

[0094] 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.

[0095] 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, preferably from about 1000 to 3000, more preferably from about 1000 to 2000, and even more preferably from about 1000 to 1600 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 weight percent, preferably about 0.1 to 8 weight percent.

[0096] Pour Point Depressants

[0097] Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present invention if desired. 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 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. Each of these references is incorporated herein in its entirety. Such additives may be used in an amount of is about 0.01 to 5 weight percent, preferably about 0.01 to 1.5 weight percent.

[0098] Corrosion Inhibitors

[0099] Corrosion inhibitors are used to reduce the degradation of metallic parts that are in contact with the lubricating oil composition. Suitable corrosion inhibitors include thiadizoles. 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 weight percent, preferably about 0.01 to 1.5 weight percent.

[0100] Seal Compatibility Additives

[0101] 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 weight percent, preferably about 0.01 to 2 weight percent.

[0102] Anti-Foam Agents

[0103] 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.

[0104] Inhibitors and Antirust Additives

[0105] 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 cite.

[0106] 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 weight percent, preferably about 0.01 to 1.5 weight percent.

[0107] Friction Modifiers

[0108] A friction modifier is any material or materials that can alter the coefficient of friction of 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 coefficient of friction of lubricant base oils, formulated lubricant compositions, or functional fluids, 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.

[0109] Ashless friction modifiers may have also include lubricant materials that contain effective amounts of polar groups, for example hydroxyl-containing hydrocaryl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hyrdocarbyl 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.

[0110] 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 modifiers(s) with alternate surface active material(s), are also desirable.

[0111] Typical Additive Amounts

[0112] 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 the table below.

[0113] 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 patent, are directed to the amount of active ingredient (that is the non-solvent or non-diluent portion of the ingredient). The weight percents indicated below are based on the total weight of the lubricating oil composition.

TABLE 1

Typical Amounts of Various Lubricant Oil Components		
Compound	Approximate Weight Percent (Useful)	Approximate Weight Percent (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 Index Improver	0.0-40	0.01-30, more preferably 0.01-15
Antioxidant	0.01-5	0.01-1.5
Corrosion Inhibitor	0.01-5	0.01-1.5
Anti-wear Additive	0.01-6	0.01-4
Pour Point Depressant	0.0-5	0.01-1.5
Anti-foam Agent	0.001-3	0.001-0.15
Base Oil	Balance	Balance

[0114] Experimental

[0115] Unless otherwise specified, kinematic viscosity at 40° C. or 100° C. is determined according to ASTM test method D 445, viscosity index is determined by ASTM test method D 2270, pour point is determined by ASTM test method D 97, and TBN by ASTM test method number D 2896.

[0116] The hydrocarbyl aromatic in the following examples is alkylated naphthalene (primarily mono-alkylated) having a kinematic viscosity of approximately 4.6 cSt at 100° C. The primarily mono-alkylated naphthalene is prepared by the alkylation of naphthalene with an olefin primarily comprised of 1-hexadecene.

[0117] In the Examples, the components listed below are used in the lubricant compositions:

[0119] A series of industry-sanctioned Sequence VIB fuel economy engine tests (ASTM Research Report D02-1469) were performed to determine the effect of compositional changes upon fuel economy of the test lubricants. The fuel economy improvement (FEI) limits for the various SAE viscosity grades is given in ASTM D 4485. Referring to Table 3, Comparative Example 3.1 serves as the reference engine test formulation and establishes the base-line FEI value used in comparison to that of the inventive Examples. The percent difference (positive or negative) for FEI between Comparative Example 3.1 and the standard D 4485 limit is first calculated. Similarly, the percent differences (positive or negative) for FEI between the various candidate oils and the standard D4485 limit is then calculated. The percent advantage of the candidate FEI value over the Comparative Example 3.1 FEI value is then calculated. The

TABLE 2

		Typical Base Stock Properties							
		GpIII 4	Hydro- treated A	Hydro- treated B	Hydro- carbyl Aromatic	PA O 4	PA O 6	PE derived ester	TMP derived ester
D 445	Kinematic Viscosity at 40 C., cSt	15.6	36.2	22.65	29.3	18	31	29.8	18.4
D 445	Kinematic Viscosity at 100 C., cSt	3.8	6	4.55	4.7	4	6	5.94	4.2
D 2272	Viscosity Index	138	114	116	75	120	138	149	136
D 1500	ASTM Color	0		15.0	1.0	0	0		
D 2007	Saturates, wt %	na	96	97	na	100	100	0	0
D 2662	Sulfur, ppm	0	40	60	150	0	0	0	0
	API Group	III	II	II	V	IV	IV	V	V

[0118] All examples shown herein illustrate the instant invention but do not limit the composition for this invention.

percent advantage results for each of the candidate oils are summarized in Table 3 below.

TABLE 3

Results from fuel economy tests for test oils containing pentaerythritol esters.						
Examples	3.1	3.2	3.3	3.4	3.5	3.6
SAE Oil Viscosity	5W-30	10W-30	10W-30	10W-30	5W-30	5W-30
Performance Additives to deliver approximately 2% active borated succinimide type dispersant based on total composition	16.1	15.8	15.8	15.7	16.7	16.0
Hydrotreated Base Oil A	0	0	0	20.0	0	0
Hydrotreated Base Oil B	0	0	40.0	20.0	0	0
GpIII 4	0	0	0	0	0	0
4 cS PAO	40.9	45.5	27.3	30.7	63.3	69.8
6 cS PAO	25.0	19.0	0	0	0	0
Pentaerythritol derived ester	0	15.0	12.0	9.4	11.0	8.6
Trimethylolpropane derived ester	2.0	0	0	0	2.0	0
Hydrocarbyl Aromatic	16.0	4.7	4.9	4.2	7.0	5.6

TABLE 3-continued

Results from fuel economy tests for test oils containing pentaerythritol esters.						
Examples	3.1	3.2	3.3	3.4	3.5	3.6
Performance						
Phase I FEI %	1.1	1.3	1.2	1.0	1.5	1.6
Overall Enhancement relative to SAE viscosity grade	Base	78.0	66.0	44.0	25.0	31.0

[0120] It is unexpectedly found that the addition of from about 8-9 to about 15% of the above-described pentaerythritol ester (PE ester) provided significant and surprising fuel economy enhancements. The admixture of 9.4% of such PE ester to a SAE 10W-30 automotive engine oil exhibited a surprising 44% fuel economy enhancement. The admixture of 12% of such PE ester to a SAE 10W-30 automotive engine oil exhibited a surprising 65% fuel economy enhancement. The admixture of 15% of such PE ester to a SAE 10W-30 automotive engine oil exhibited a surprising 77% fuel economy enhancement. It is found that increasing concentrations of such PE ester resulted in greater fuel economy enhancements. Each of these test oils contained a hydrocarbyl aromatic base oil, and it is believed that the presence of such hydrocarbyl aromatic may have contributed to the favorable results obtained.

[0121] It is unexpectedly found that the addition of about 8% or greater of the above-described pentaerythritol ester (PE ester) optionally coupled with the addition of 2% trimethylolpropane ester provided even more significant and more surprising fuel economy enhancements of at least 25% in Sequence VIB engine testing. These test oils contain hydrocarbyl aromatics, and it is believed that the presence of such hydrocarbyl aromatics may have contributed to the favorable results obtained.

[0122] As shown by Examples 3.2, 3.3, and 3.4 of Table 3, fuel economy enhancements of up to 78% are found with such combinations. The benefit may reach a maximum with the use of about 0% to about 20% hydrocarbyl aromatic, about 20% to about 60% Group II type paraffinic base stock and about 0.5% to about 5% by weight, of the neat borated polyisobutenyl succinimide ashless dispersant (0.33 wt % to 3.3 wt % active ingredient) where the polyisobutenyl mono and bis succinimide is made by the reaction of polyisobutenyl succinic anhydride with an approximate M_n of 1300 for the PIB group with amines. Preferred amounts may be from about 4% to about 15% hydrocarbyl aromatic, about 30% to about 50% Group II type paraffinic base stocks and about 1% to about 4% borated polyisobutenyl succinimide ashless dispersant as received by weight that correspond with HFRR testing of dispersants in FIG. 1. The neat borated polyisobutenyl succinimide ashless dispersant is approximately two-thirds active ingredient and provides about 2% active ingredient when added to the oil blends.

[0123] One of ordinary skill in the art would easily note that these findings may be extended to any paraffinic base stock. The inventors note that this discovery may also employ Group III base stocks, and preferably Gas-to-Liquids or Fischer-Tropsch base stocks. Thus, as a non-limiting illustrative sample, the inventors also note that a mixture of about 70 wt % Group III base stock, about 8 to

9 wt % Pentaerythritol derived ester and about 5 to 6 wt % Hydrocarbyl Aromatics, with the remainder being a Performance Additive package will also achieve the same surprising Fuel Economy increases.

[0124] A series of industry-sanctioned Sequence VIB fuel economy engine tests is performed to determine the effect of compositional changes upon fuel economy of the test lubricants. Referring to Table 4, Comparative Example 4.1 is used as the reference engine test formulation to establish the base-line FEI value used in subsequent calculations as described above.

TABLE 4

Results from fuel economy tests for Group II/Group III-type paraffinic oil blends and hydrocarbyl aromatics				
Examples	4.1	4.2	4.3	4.4
SAE Oil Viscosity	5W-30	5W-30	5W-30	5W-30
Performance Additives to deliver approximately 2% active borated succinimide type dispersant based on total composition	15.9	16.1	15.7	15.7
Hydrotreated Base Oil B	37.5	0	44.0	44.0
GpIII 4	0	0	0	0
4 cS PAO	37.6	40.9	32.8	33.2
6 cS PAO	0	25.0	0	0
Trimethylolpropane derived ester	2.0	2.0	2.0	2.0
Hydrocarbyl Aromatic	7.0	16.0	5.5	5.1
Performance				
Phase I FEI %	1.1	1.1	1.5	1.6
Overall Enhancement relative to SAE viscosity grade	Base	Base	26	30

[0125] It is surprisingly found that when relatively high concentrations of Group II/Group III type paraffinic base stock is included in lube compositions in the presence of both hydrocarbyl aromatic and polyol esters, such as those derived from trimethylolpropane, significant FEI enhancements are unexpectedly found in Sequence VIB engine testing. With the use of approximately 44% such paraffinic base oil, approximately 2% trimethylol-propane ester, and approximately 5% alkylated naphthalene as the hydrocarbyl aromatic, a fuel economy enhancement of 30% is observed. With the use of approximately 44% such paraffinic base oils, approximately 2% trimethylol-propane ester, and approximately 5.5% alkylated naphthalene as the hydrocarbyl aromatic, an equally surprising fuel economy enhancement of 26% is found. The benefit may reach a maximum with the use of about 3% to 30% hydrocarbyl aromatic, about 40% to about 90% paraffinic base oil and about 1% to about 20%

trimethylolpropane ester with preferred amounts being about 4% to about 20% hydrocarbyl aromatic, about 40% or greater of paraffinic base oils and about 2% to about 10% trimethylolpropane ester. These engine tests clearly demonstrate the advantages of such fuel economy improving formulations.

[0126] We believe that the fuel economy benefit can be further enhanced when the above Group II/III type paraffinic stocks are used in the presence of about 1% to about 10% or more of any traditional polyol ester and/or hydrocarbyl aromatic such as alkyl naphthalene and/or other co-base oils in the finished formulated lubricant.

[0127] One of ordinary skill in the art would easily note that these findings may be extended to any paraffinic base stock. The inventors note that this discovery may also employ Group III base stocks, and preferably Gas-to-Liquids or Fischer-Tropsch base stocks. Thus, as a non-limiting illustrative sample, the inventors also note that a mixture of about 40 wt % Group III base stock, about 30 to 35% PAO, about 2 wt % Trimethylolpropane and about 4 to 6 wt % Hydrocarbyl Aromatics, with the remainder being a Performance Additive package will also achieve the same surprising Fuel Economy increases.

[0128] Certain amorphous olefin copolymers are found to provide unexpected and significant fuel economy improving (friction reducing) benefits when formulated into lubricants, especially those containing significant amounts of Group II or Group III base oils having viscosity indices of about 110 to about 150 or greater. A series of industry-sanctioned Sequence VIB fuel economy engine tests is performed to determine the effect of compositional changes upon fuel economy of the test lubricants. Comparative Example 5.1 is used as the reference engine test formulation to establish the base-line FEI value used in subsequent calculations as described above.

[0129] It is surprisingly found that the addition of 5% of an amorphous olefin copolymer to a formulated oil blended with mixed Group II/Group III and polyalpha olefin base stocks derived from decene-type olefins, that the fuel economy enhancement in Sequence VIB engine testing is a surprising 26% to 38% enhancement. These results clearly show the unexpected fuel economy improving benefits of such formulations comprising amorphous olefin copolymers at about 1% to about 20% where about 2% to about 15% is preferred and about 3% to about 10% is most preferred.

TABLE 5

Results from fuel economy tests for amorphous OCP type oil blends and hydrocarbyl aromatics			
Examples	5.1	5.2	5.3
SAE Oil Viscosity	5W-30	5W-30	5W-30
Performance Additives to deliver approximately 2% active borated succinimide type dispersant based on total composition			
Amorphous OCP	0	5.0	5.0
Hydrotreated Base Oil B	0	31.0	31.0
GpIII 4	0	0	0
4 cS PAO	40.9	39.6	39.7
6 cS PAO	25.0	0	0

TABLE 5-continued

Results from fuel economy tests for amorphous OCP type oil blends and hydrocarbyl aromatics			
Examples	5.1	5.2	5.3
Trimethylolpropane derived ester	2.0	2.0	2.0
Hydrocarbyl Aromatic Performance	16.0	7.0	7.0
Phase I FEI %	1.1	1.7	1.5
Overall Enhancement relative to SAE viscosity grade	Base	38	26

[0130] The inventors have found that the fuel economy benefit can be further enhanced when the above amorphous olefin copolymer is used in the presence of about 1% to about 10% or more of any traditional polyol ester and/or hydrocarbyl aromatic such as alkyl naphthalene and/or other co-base oils in the finished formulated lubricant.

[0131] One of ordinary skill in the art would easily note that these findings may be extended to any paraffinic base stock. The inventors note that this discovery may also employ Group III base stocks, and preferably Gas-to-Liquids or Fischer-Tropsch base stocks. Thus, as a non-limiting illustrative sample, the inventors also note that a mixture of about 30 wt % Group III base stock, about 40 wt % PAO, about 2 wt % Trimethylolpropane and about 4 to 10 wt % Hydrocarbyl Aromatics, with the remainder being a Performance Additive package will also achieve the same surprising Fuel Economy increases.

[0132] Sequence VIB engine testing shows that significant fuel economy enhancements can be attained with the use of moderate concentrations of hydrocarbyl aromatics, preferably in the presence of at least a minor concentration of Group II or Group III, or hydrocracked and/or hydrotreated base stocks, including wax isomerate base oils. The presence of certain ashless dispersants also can significantly contribute to the fuel economy enhancements observed. A series of industry-sanctioned Sequence VIB fuel economy engine tests is performed to determine the effect of compositional changes upon fuel economy of the test lubricants. Comparative Example 6.1 is used as the reference engine test formulation to establish the base-line FEI value used in subsequent calculations as described above.

[0133] It is surprisingly found that fuel economy enhancements can be attained with the use of certain paraffinic base stocks in the presence of moderate concentrations of hydrocarbyl aromatics, preferably in the presence of certain borated polyisobutenyl succinimide ashless dispersants. As shown by Examples 6.2, 6.3 and 6.4 of Table 6, fuel economy enhancements of up to 77% are found with such combinations. The benefit may reach a maximum with the use of about 0% to about 20% hydrocarbyl aromatic, about 20% to about 60% Group II type paraffinic base stocks and about 0.5% to about 5% by weight, as received, of a borated polyisobutenyl succinimide ashless dispersant. Preferred amounts may be from about 4% to about 15% hydrocarbyl aromatic, about 30% to about 50% Group II type paraffinic base stocks and about 1% to about 4% borated polyisobutenyl succinimide ashless dispersant as received by weight that correspond with HFRR testing of dispersants in FIG. 1.

The Sequence VIB fuel economy engine test results clearly show the unexpected advantages obtainable by using the components of this invention.

[0134] Table 6. Results from fuel economy tests hydrocracked/hydrotreated stocks used with synergistic amounts of hydrocarbyl aromatics as fuel economy improving compositions.

Examples	6.1	6.2	6.3	6.4
SAE Oil Viscosity	5W-30	10W-30	10W-30	10W-30
Performance Additive Package containing 3% borated succinimide type dispersant	15.9	15.5	15.6	15.5
Hydrotreated Base Oil A	0	0	35.0	35.0
Hydrotreated Base Oil B	37.5	0	5.0	0
GpIII 4	0	0	0	0
4 cS PAO	37.6	4.0	22.4	7.5
6 cS PAO	0	23.5	0	25.0
8 cS PAO	0	15.0	0	0
Trimethylolpropane derived ester	2.0	2.0	2.0	2.0
Hydrocarbyl Aromatic	7.0	40.0	20.0	15.0
Performance				
Phase I FEI %	1.1	1.0	1.3	0.9
Overall Enhancement relative to SAE viscosity grade	Base	78	66	44

[0135] One of ordinary skill in the art would easily note that these findings may be extended to any paraffinic base stock. The inventors note that this discovery may also employ Group III base stocks, and preferably Gas-to-Liquids or Fischer-Tropsch base stocks. Thus, as a non-limiting illustrative sample, the inventors also note that a mixture of about 30 wt % Group III base stock, about 30 to 40% PAO, about 2 wt % Trimethylolpropane and about 5 to 40 wt % Hydrocarbyl Aromatics, with the remainder being a Performance Additive package will also achieve the same surprising Fuel Economy increases.

[0136] All U.S. patents, non-U.S. patents and applications, and non-patent references cited in this application are hereby incorporated in their entirety by reference.

What is claimed is:

1. A method of improving fuel economy of an internal combustion engine by lubricating the engine with a lubricant composition selected from the group of lubricants consisting of:

- (i) a lubricant composition comprising (a) a mixture of about 3 wt % to about 30 wt % pentaerythritol esters in a base stock wherein said lubricating composition contains more than about 18 wt % saturates; (b) 0 to 2 wt % of at least one triol, ester; (c) 0 to about 3.3 wt % of a borated hydrocarbyl succinimide (active ingredient) and wherein the percentages are based upon the total lubricating composition;
- (ii) a lubricant composition comprising (a) about at least 20 wt % of one or more base stocks selected from the group consisting of Group II base stocks, Group III base stocks, and wax isomerates; (b) about at least 4 wt % of a hydrocarbyl aromatic; (c) 0 to 3.3 wt % of a borated hydrocarbyl succinimide (active ingredient), and wherein the percentages are based upon the total lubricating composition; and,
- (iii) a lubricant composition comprising (a) one or more base stocks selected from the group consisting of Group II base stock, Group III base stocks and wax isomerates; (b) an amorphous olefin copolymer; and (c) 0 to 3.3 wt % of a borated hydrocarbyl succinimide.

2. The method of claim 1 wherein lubricant (i) contains at least 20 wt % of a base stock containing at least 90% saturates.

3. The method of claim 1 wherein a lubricant (i) comprises a GTL base stock.

4. The method of claim 1 wherein lubricant (iii) comprises at least one member selected from the group consisting of esters, hydrocarbyl aromatics and mixtures thereof.

5. The method of claim 4 wherein said member comprises about 1 wt % to about 30 wt % of the lubricating compositions.

6. The method of claim 1 wherein the hydrocarbyl group of said borated hydrocarbyl succinimide has an M_n from about 1000 to about 5000.

7. The method of claim 6 wherein said borated hydrocarbyl succinimide is a borated polyisobutenyl succinimide.

8. The method of claim 7 wherein said borated polyisobutenyl succinimide contains both mono and bis succinimide.

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