

LUBRICATING OIL COMPOSITION

FIELD OF THE INVENTION

5 The present invention relates to SAE 0W and SAE 5W multigrade crankcase lubricants for heavy duty diesel (HDD) engines that have less than 50 mass % of Group IV and Group V base stock, containing phosphorus-based antiwear agents in an amount introducing no greater than 1200 ppm of phosphorus into the lubricant, which lubricants meet the wear performance requirements of API CJ-4, API CI-4 and/or ACEA E7 specifications.

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BACKGROUND OF THE INVENTION

Crankcase lubricants comprise base stock and additives that delay degradation of the base stock and improve its performance. Such additives typically include dispersant, overbased and neutral salts of organic acids, corrosion inhibitors, antiwear agents, antioxidants, friction modifiers, antifoamants, and demulsifiers. These additives may be combined in a package, sometimes referred to as a detergent inhibitor (or DI) package. The additives in such a package may include functionalized polymers, but these have relatively short chains, typically having a number average molecular weight $\overline{M}_n$ of not more than 7000.

20 Multigrade lubricants perform over wide temperature ranges. Typically, they are identified by two numbers such as 10W-30 or 5W-30. The first number in the multigrade designation is associated with a safe cranking temperature (e.g., -20° C) viscosity requirement for that multigrade oil as measured by a cold cranking simulator (CCS) under high shear rates (ASTM D5293). In general, lubricants that have low CCS viscosities allow the engine to crank more easily at lower temperatures and thus improve engine startability at those ambient temperatures.

The second number in the multigrade designation is associated with a lubricant's viscosity under normal operating temperatures and is measured in terms of the kinematic viscosity (kV) at 100°C (ASTM D445). The high temperature viscosity requirement brackets minimum and maximum kinematic viscosity at 100°C.

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Viscosity at high temperatures is desirable to prevent engine wear that would result if the lubricant thinned out too much during engine operation. However the lubricant should not be too viscous because excessive viscosity may cause unnecessary viscous

drag and work to pump the lubricant which in turn can increase fuel consumption. In general, the lower a lubricants' $kV_{100^{\circ}C}$, the better the scores that lubricant achieves in fuel economy tests.

- Thus, in order to qualify for a given multigrade oil designation a particular
- 5 multigrade oil must simultaneously meet both strict low and high temperature viscosity requirements that are set by SAE specifications such as SAE J300. The current viscosity limits set in SAE J300 are as follows:

SAE VISCOSITY GRADES

SAE viscosity grade	Maximum CCS Viscosity ($10^{-3}\text{Pa.s @ } (^{\circ}\text{C})$)	$kV_{100^{\circ}C}$ (mm^2/s) minimum	$kV_{100^{\circ}C}$ (mm^2/s) maximum
0W	3250 (-30)	3.8	
5W	3500 (-25)	3.8	-
10W	3500 (-20)	4.1	-
15W	3500 (-15)	5.6	-
20W	4500 (-10)	5.6	-
25W	6000 (-5)	9.3	-
20	-	5.6	<9.3
30	-	9.3	<12.5
40	-	12.5	<16.3
50	-	16.3	<21.9
60	-	21.9	<26.1

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- In the SAE J300 scheme multigrade oils meet the requirements of both low temperature and high temperature performance. For example, an SAE 5W-30 multigrade oil has viscosity characteristics that satisfy both the 5W and the 30 viscosity grade requirements -- i.e., a maximum CCS viscosity of $3500 \times 10^{-3} \text{ Pa.s}$ at -
- 15 25°C , a minimum $kV_{100^{\circ}C}$ of $9.3 \text{ mm}^2/\text{s}$ and a maximum $kV_{100^{\circ}C}$ of $< 12.5 \text{ mm}^2/\text{s}$.

The viscosity characteristics of a lubricant depend primarily on the viscosity characteristics of the base stock and on the viscosity characteristics of the viscosity modifier. Of the other additives often found in lubricants only high molecular weight

dispersants have been thought to influence viscometrics, and their influence has been deemed small in comparison to base stock and viscosity modifier.

The viscosity characteristic of a base stock on which a lubricating oil is based is typically expressed by the neutral number of the oil (e.g., S150N) with a higher neutral number being associated with a higher viscosity at a given temperature. This number is defined as the viscosity of the base stock at 40°C measured in Saybolt Universal Seconds. Blending base stocks is one way of modifying the viscosity properties of the resulting lubricating oil. For example a lubricant formulated entirely with S100N will have both a lower kV 100 and a lower CCS than a lubricant formulated entirely with a S150N base stock. A base stock comprised of a blend of S100N and S150N will have a CCS in between those of the straight cuts. The average base stock neutral number (ave. BSNN) of a blend of straight cuts may be determined according to the following formula:

$$\log(\text{ave. BSNN}) = \left[\text{BSR}_1 \times \log \frac{\text{BSNN}_1}{100} \right] + \left[\text{BSR}_2 \times \log \frac{\text{BSNN}_2}{100} \right] + \dots + \left[\text{BSR}_n \times \log \frac{\text{BSNN}_n}{100} \right] \text{ where}$$

BSR_n = base stock ratio for base stock n

$$= (\text{wt. \% base stock } n / \text{wt. \% total base stock in oil}) \times 100\%$$

BSNN_n = base stock neutral number for base stock n

Merely blending base stocks of different viscosity characteristics may not enable the formulator to meet the low and high temperature viscosity requirements of some multigrade oils. The formulator's primary tool for achieving this goal is an additive conventionally referred to as a viscosity modifier or viscosity index (V.I.) improver. Usually, to reach the minimum high temperature viscosity required, it is necessary to add significant amounts of viscosity modifier. However, the use of an increased amount of viscosity modifier results in increased low temperature lubricant viscosity. The ever increasing need to formulate crankcase lubricants that deliver improved performance in fuel economy tests is driving the industry to HDD engine lubricants in the lower viscosity grades, such as 0W20, 0W30, 5W20 and 5W30.

Concurrent with the demand for lower viscosity, high fuel economy lubricants, there has been a continued effort to reduce the content of sulfated ash, phosphorus and sulfur in the crankcase lubricant due to both environmental concerns and to insure

compatibility with pollution control devices used in combination with modern engines (e.g., three-way catalytic converters and particulate traps). A particularly effective class of antioxidant-antiwear additives available to lubricant formulators is metal salts of dialkyldithiophosphates, particularly zinc salts thereof, commonly referred to as ZDDP. While such additives provide excellent performance, ZDDP contributes each of sulfated ash, phosphorus and sulfur to lubricants.

The most recent specifications for heavy duty diesel (HDD) engine crankcase lubricants in each of Europe (ACEA E7) and the United States (API CJ-4) require reductions in allowable levels of sulfated ash, phosphorus and sulfur relative to the prior standard, thus limiting the amount of ZDDP that can be used. At the same time, modern lubricants are required to provide improved wear protection. Where reduced amounts of ZDDP are employed, alternative means of providing engine wear protection must be identified, preferably means that do not cause introduction of additional sulfated ash, phosphorus and/or sulfur into the lubricant. Alternative means of providing wear protection are particularly critical in low viscosity lubricants formulated with lower viscosity base stocks which, as noted above, are less capable of contributing to antiwear performance at high temperature.

To provide low viscosity, low phosphorus lubricating oil compositions capable of meeting API CJ-4; API CI-4 and/or ACEA E7 performance standards, lubricant manufacturers have formulated fully synthetic, lubricants and lubricants containing significant proportions of synthetic base stocks defined as Group IV base stocks (polyalphaolefin or PAO base stocks) and/ or Group V base stocks, such as ester base stocks. Compared to Group I, Group II and Group III base stocks, Group IV and Group V base stocks have a high viscosity index (VI), which means that the kinematic viscosity of the base stock varies less with temperature. Thus, by using a low viscosity, high VI PAO, for example, a lubricant can be provided having a low CCS viscosity and high kV100. However, Group IV and Group V base stocks are expensive relative to Group I, Group II and Group III mineral oil base stocks.

Therefore, it would be advantageous to provide a means for blending low viscosity SAE 0W and SAE 5W multigrade crankcase lubricants for heavy duty diesel (HDD) engines having reduced amounts, such less than 30 mass %, of Group IV and/or Group V base stock, and phosphorus-based antiwear agents in amounts introducing no greater than 1200 ppm of phosphorus into the lubricant, which

lubricants meet the wear performance requirements of API CJ-4; API CI-4; and/or ACEA E7 specifications.

Surprisingly, it has been found that SAE 0W and SAE 5W multigrade crankcase lubricants for heavy duty diesel (HDD) engines having less than 30 mass %, of Group IV and/or Group V base stock, and phosphorus-based antiwear agents in amounts introducing no greater than 1200 ppm of phosphorus into the lubricant, can meet the performance requirements, including the wear performance requirements of the API CJ-4; API CI-4; and/or ACEA E7 specifications when formulated with a minor amount of a non-hydrogenated olefin polymer and at least 40 ppm of boron.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the invention, there is provided a SAE 0W and SAE 5W multigrade crankcase lubricating oil composition for heavy duty diesel (HDD) engines meeting the performance requirements of at least one of the API CJ-4; API CI-4; and/or ACEA E7 specifications, having a sulfated ash content of no greater than 1.0 mass %, such as from about 0.7 to 1.0 mass %, a sulfur content of no greater than 0.4 mass %, and a phosphorus content of no greater than 0.12 mass % (1200 ppm), such as from about 0.08 to 0.12 mass %; which lubricating oil composition comprises a major amount of oil of lubricating viscosity including less than about 30 mass %, preferably less than 10 mass %, based on the total mass of oil of lubricating viscosity, of Group IV and/or Group V base stock, at least 0.3 mass %, such as 0.3 to 5 mass %, of a non-hydrogenated olefin polymer; and greater than about 40 ppm, such as 40 to 600 ppm, of boron.

In accordance with a second aspect of the invention, there is provided a lubricating oil composition, as described in the first aspect, having a TBN of from about 7 to about 15,

In accordance with a third aspect of the invention, there is provided a lubricating oil composition, as described in the first or second aspect, comprising a magnesium detergent in an amount providing said composition with at least 0.09 mass % (900 ppm), preferably at least 0.10 mass % (1000 ppm), more preferably at least 0.115 mass % (1150 ppm) of magnesium.

In accordance with a fourth aspect of the invention, there is provided a lubricating oil composition, as described in the first, second or third aspect, further comprising a nitrogen-containing dispersant in an amount providing the lubricating oil composition with at least 0.08 mass% of nitrogen.

5 In accordance with a fifth aspect of the invention, there is provided a lubricating oil composition, as described in the first through fourth aspects, comprising at least 0.5 mass %, such as at least 0.6 mass %, preferably at least 0.8 mass%, more preferably at least 1.0 mass % of at least one ashless antioxidant selected from sulfur-free hindered phenol antioxidants, aminic antioxidants, and
10 combinations thereof.

In accordance with a sixth aspect of the invention, there is provided a heavy duty diesel (HDD) engine, lubricated with a lubricating oil composition as described in any of the first through fifth aspects.

In accordance with a seventh aspect of the invention, there is provided a
15 method for improving the fuel economy and wear performance of a heavy duty diesel (HDD) engine, which method comprises the steps of lubricating the engine with a lubricating oil composition as described in any of the first through fifth aspects, and operating the lubricated engine.

In accordance with a eighth aspect of the invention, there is provided the use
20 of a lubricating oil composition as described in any of the first through fifth aspects to improve the fuel economy and wear performance of a heavy duty diesel (HDD) engine.

Other and further objects, advantages and features of the present invention will be understood by reference to the following specification.

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DETAILED DESCRIPTION OF THE INVENTION

The oil of lubricating viscosity useful in the practice of the invention may range in viscosity from about 2 mm²/sec (centistokes) to about 40 mm²/sec, especially from about 3 mm²/sec to about 20 mm²/sec, most preferably from about 9 mm²/sec to
30 about 17 mm²/sec, measured at 100°C.

Natural oils include animal oils and vegetable oils (e.g., castor oil, lard oil); liquid petroleum oils and hydrorefined, solvent-treated or acid-treated mineral oils of

the paraffinic, naphthenic and mixed paraffinic-naphthenic types. Oils of lubricating viscosity derived from coal or shale also serve as useful base oils.

Synthetic lubricating oils include hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and interpolymerized olefins (e.g.,
5 polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes)); alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)benzenes); polyphenyls (e.g., biphenyls, terphenyls, alkylated polyphenols); and alkylated diphenyl ethers and alkylated diphenyl sulfides and
10 derivative, analogs and homologs thereof.

Alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification, etc., constitute another class of known synthetic lubricating oils. These are exemplified by polyoxyalkylene polymers prepared by polymerization of ethylene oxide or propylene
15 oxide, and the alkyl and aryl ethers of polyoxyalkylene polymers (e.g., methylpolyiso-propylene glycol ether having a molecular weight of 1000 or diphenyl ether of poly-ethylene glycol having a molecular weight of 1000 to 1500); and mono- and polycarboxylic esters thereof, for example, the acetic acid esters, mixed C₃-C₈ fatty acid esters and C₁₃ Oxo acid diester of tetraethylene glycol.

20 Another suitable class of synthetic lubricating oils comprises the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids and alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkylmalonic acids, alkenyl malonic acids) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol,
25 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol). Specific examples of such esters includes dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, and the complex ester formed by reacting one mole of sebacic
30 acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid.

Esters useful as synthetic oils also include those made from C₅ to C₁₂ monocarboxylic acids and polyols and polyol esters such as neopentyl glycol, trimethylolpropane, pentaerythritol, dipentaerythritol and tripentaerythritol.

Silicon-based oils such as the polyalkyl-, polyaryl-, polyalkoxy- or polyaryloxysilicone oils and silicate oils comprise another useful class of synthetic lubricants; such oils include tetraethyl silicate, tetraisopropyl silicate, tetra-(2-ethylhexyl)silicate, tetra-(4-methyl-2-ethylhexyl)silicate, tetra-(p-tert-butyl-phenyl) silicate, hexa-(4-methyl-2-ethylhexyl)disiloxane, poly(methyl)siloxanes and poly(methylphenyl)siloxanes. Other synthetic lubricating oils include liquid esters of phosphorous-containing acids (e.g., tricresyl phosphate, trioctyl phosphate, diethyl ester of decylphosphonic acid) and polymeric tetrahydrofurans.

Other examples of base oil are gas-to-liquid ("GTL") base oils, i.e. the base oil may be oil derived from Fischer-Tropsch-synthesized hydrocarbons made from synthesis gas containing hydrogen and carbon monoxide using a Fischer-Tropsch catalyst. These hydrocarbons typically require further processing in order to be useful as base oil. For example, they may, by methods known in the art, be hydroisomerized; hydrocracked and hydroisomerized; dewaxed; or hydroisomerized and dewaxed.

Definitions for the base stocks and base oils in this invention are the same as those found in the American Petroleum Institute (API) publication "Engine Oil Licensing and Certification System", Industry Services Department, Fourteenth Edition, December 1996, Addendum 1, December 1998. Said publication categorizes base stocks as follows:

- a) Group I base stocks contain less than 90 percent saturates and/or greater than 0.03 percent sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table 1.
- b) Group II base stocks contain greater than or equal to 90 percent saturates and less than or equal to 0.03 percent sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table 1.
- c) Group III base stocks contain greater than or equal to 90 percent saturates and less than or equal to 0.03 percent sulfur and have a viscosity index greater than or equal to 120 using the test methods specified in Table 1.
- d) Group IV base stocks are polyalphaolefins (PAO).
- e) Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

Table 1 - Analytical Methods for Base Stock

Property	Test Method
Saturates	ASTM D 2007
Viscosity Index	ASTM D 2270
Sulfur	ASTM D 2622; ASTM D 4294; ASTM D 4927; ASTM D 3120

Oil of lubricating viscosity useful in the practice of the present invention may comprise a Group I, Group II, Group III, base stocks or base oil blends of the
5 aforementioned base stocks. The oil of lubricating viscosity may also comprise a base oil blend of one or more Group I, Group II, and/or Group III, base stocks and less than 30 mass %, based on the total mass of oil of lubricating viscosity, of one or more Group IV and/or Group V base stocks. Preferably, the oil of lubricating viscosity is mixture of one or more Group II and/or Group III base stock and an amount of less
10 than 30 mass %, preferably less than 10 mass %, based on the total mass % of oil of lubricating viscosity, of one or more Group IV or Group V base stocks. Particularly preferred are Group III base stocks and base stock blends, and blends of one or more Group III base stocks and 0 to 10 mass %, based on the total mass of oil of lubricating viscosity, of one or more Group IV base stocks. The base stock, or base stock blend
15 preferably has a saturate content of at least 65%, more preferably at least 75%, such as at least 85%.

Most preferably, the base stock, or base stock blend, has a saturate content of greater than 90%. Preferably, the oil or oil blend will have a sulfur content of less than 1 mass %, preferably less than 0.6 mass %, most preferably less than 0.4 mass %,
20 such as less than 0.3 mass %.

Preferably the volatility of the base stock or base stock blend, as measured by the Noack test (ASTM D5800), is less than or equal to 30 mass %, such as less than about 25 mass%, preferably less than or equal to 20 mass %, more preferably less than or equal to 15 mass %, most preferably less than or equal 13 mass %. Preferably,
25 the viscosity index (VI) of the base stock or base stock blend is at least 85, preferably at least 100, most preferably from about 105 to 140.

A certain amount of oil of lubricating viscosity may be introduced into the lubricating oil composition as a diluent for the various additives and are commonly Group I base stocks. The preferred mass percentages, saturates contents, Noack and

VI described above are for the base stock or base stock blends used to formulate the lubricating oil composition, excluding any oil that may be introduced as an additive diluent.

The non-hydrogenated olefin (co)polymer useful in the practice of the present invention is preferably a polymer or copolymer of one or more acyclic olefin monomers. Generally, the non-hydrogenated olefin (co)polymers useful in the invention have, or have on average, about one double bond per polymer chain.

The (co)polymer may be prepared by polymerizing alpha-olefin monomer, or mixtures of alpha-olefin monomers, or mixtures comprising ethylene and at least one C₃ to C₂₈ alpha-olefin monomer, in the presence of a catalyst system comprising at least one metallocene (*e.g.*, a cyclopentadienyl-transition metal compound) and an alumoxane compound. Using this process, a polymer in which 95 % or more of the polymer chains possess terminal ethenylidene-type unsaturation can be provided. The percentage of polymer chains exhibiting terminal ethenylidene unsaturation may be determined by FTIR spectroscopic analysis, titration, or C¹³ NMR. Interpolymers of this latter type may be characterized by the formula POLY-C(R¹)=CH₂ wherein R¹ is C₁ to C₂₆ alkyl, preferably C₁ to C₁₈ alkyl, more preferably C₁ to C₈ alkyl, and most preferably C₁ to C₂ alkyl, (*e.g.*, methyl or ethyl) and wherein POLY represents the polymer chain. The chain length of the R¹ alkyl group will vary depending on the comonomer(s) selected for use in the polymerization. A minor amount of the polymer chains can contain terminal ethenyl, *i.e.* vinyl, unsaturation, *i.e.* POLY-CH=CH₂, and a portion of the polymers can contain internal monounsaturations, *e.g.*, POLY-CH=CH(R¹), wherein R¹ is as defined above. These terminally unsaturated interpolymers may be prepared by known metallocene chemistry and may also be prepared as described in U.S. Patent Nos. 5,498,809; 5,663,130; 5,705,577; 5,814,715; 6,022,929 and 6,030,930.

Another useful class of (co)polymers is (co)polymers prepared by cationic polymerization of isobutene, styrene, and the like. Common (co)polymers from this class include polyisobutenes obtained by polymerization of a C₄ refinery stream having a butene content of about 35 to about 75 mass %, and an isobutene content of about 30 to about 60% by wt., in the presence of a Lewis acid catalyst, such as aluminum trichloride or boron trifluoride, with aluminium trichloride preferred. A preferred source of monomer for making poly-n-butenes is petroleum feedstreams

such as Raffinate II. These feedstocks are disclosed in the art such as in U.S. Patent No. 4,952,739. Polyisobutylene is a most preferred polymer of the present invention because it is readily available by cationic polymerization from butene streams (*e.g.*, using AlCl_3 or BF_3 catalysts). Such polyisobutylenes generally contain residual
5 unsaturation in amounts of about one ethylenic double bond per polymer chain, positioned along the chain. A preferred embodiment utilizes polyisobutylene prepared from a pure isobutylene stream or a Raffinate I stream to prepare reactive isobutylene polymers with terminal vinylidene olefins. Preferably, these polymers, referred to as highly reactive polyisobutylene (HR-PIB), have a terminal vinylidene
10 content of at least 65%, *e.g.*, 70%, more preferably at least 80%, most preferably, at least 85%. The preparation of such polymers is described, for example, in U.S. Patent No. 4,152,499. HR-PIB is known and is commercially available, for example, under the tradenames GlissopalTM (from BASF) and UltravisTM (from BP-Amoco).

In another embodiment, the non-hydrogenated olefin (co)polymer, for
15 example, polyisobutylene, has at most 10, such as 5 to 10, %, of the polymer chains possessing a terminal double bond (or terminal ethenylidene-type or terminal vinylidene unsaturation). Such a polymer is considered not highly reactive; an example of a commercially available polymer is under tradename NapvisTM (from BP-Amoco), and usually obtained by polymerization with aluminium trichloride as
20 catalyst.

Preferably the (co)polymer is derived from polymerisation of one or more olefins having 2 to 10, such as 3 to 8, carbon atoms. An especially preferred olefin is butene, advantageously isobutene.

The number average molecular weight of the non-hydrogenated olefin
25 (co)polymer useful in the present invention is preferably in the range of from about 450 to about 2300, such as from about 450 to about 1300, preferably from about 450 to about 950. The molecular weight can be determined by several known techniques. A convenient method for such determination is by gel permeation chromatography (GPC), which additionally provides molecular weight distribution information (see
30 W.W. Yau, J.J. Kirkland and D.D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979). Further, it is preferred that the kinematic viscosity of the non-hydrogenated olefin polymer at 100°C, as measured according to ASTM D445, is at least 9 or 15, such as 100 or 150 to 3000,

advantageously 200 to 2500 or 2700 mm^2s^{-1} . In one embodiment of the present invention, a polyisobutylene polymer having a number average molecular weight of 450 to 2300, and a kinematic viscosity at 100°C of from about 200 to 2400 mm^2s^{-1} was found to provide particularly beneficial properties. Lubricating oil compositions
5 of the present invention can contain the non-hydrogenated olefin polymer in an amount of at least 0.3 mass %, such as from about 0.3 to about 5.0 mass %, particularly from about 0.5 to about 3.0 mass %, preferably from about 1.0 to about 2.5 mass %. Preferably, lubricating oil compositions of the present invention contain less than about 35 mass %, preferably less than about 15 mass %, based on the
10 combined total mass of oil of lubricating viscosity and non-hydrogenated olefin polymer, of a combination of Group IV and/or Group V base stock and non-hydrogenated olefin polymer.

Lubricating oil compositions of the present invention contain greater than about 40 ppm, such as 40 to 600 ppm, preferably from about 50 to 200 ppm, more preferably from
15 about 50 to 100 ppm of boron. The boron can be introduced into the lubricating oil composition by a borated dispersant, a borated detergent, or other boron-containing additive, or a mixture thereof, or by addition of elemental boron or other boron compound.

Metal-containing or ash-forming detergents function as both detergents to
20 reduce or remove deposits and as acid neutralizers or rust inhibitors, thereby reducing wear and corrosion and extending engine life. Detergents generally comprise a polar head with a long hydrophobic tail. The polar head comprises a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal in which case they are usually described as normal or neutral salts, and have
25 a total base number or TBN (as can be measured by ASTM D2896) of from 0 to less than 150, such as 0 to about 80 or 100. A large amount of a metal base may be incorporated by reacting excess metal compound (e.g., an oxide or hydroxide) with an acidic gas (e.g., carbon dioxide). The resulting overbased detergent comprises neutralized detergent as the outer layer of a metal base (e.g. carbonate) micelle. Such
30 overbased detergents have a TBN of 150 or greater, and typically will have a TBN of from 250 to 450 or more.

Detergents that may be used include oil-soluble neutral and overbased sulfonates, phenates, sulfurized phenates, thiophosphonates, salicylates, and

naphthenates and other oil-soluble carboxylates of a metal, particularly the alkali or alkaline earth metals, e.g., barium, sodium, potassium, lithium, calcium, and magnesium. The most commonly used metals are calcium and magnesium, which may both be present in detergents used in a lubricant, and mixtures of calcium and/or
5 magnesium with sodium. Combinations of detergents, whether overbased or neutral or both, may be used.

Sulfonates may be prepared from sulfonic acids which are typically obtained by the sulfonation of alkyl substituted aromatic hydrocarbons such as those obtained from the fractionation of petroleum or by the alkylation of aromatic hydrocarbons.
10 Examples included those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen derivatives such as chlorobenzene, chlorotoluene and chloronaphthalene. The alkylation may be carried out in the presence of a catalyst with alkylating agents having from about 3 to more than 70 carbon atoms. The alkaryl sulfonates usually contain from about 9 to about 80 or
15 more carbon atoms, preferably from about 16 to about 60 carbon atoms per alkyl substituted aromatic moiety.

The oil soluble sulfonates or alkaryl sulfonic acids may be neutralized with oxides, hydroxides, alkoxides, carbonates, carboxylate, sulfides, hydrosulfides, nitrates, borates and ethers of the metal. The amount of metal compound is chosen
20 having regard to the desired TBN of the final product but typically ranges from about 100 to 220 mass % (preferably at least 125 mass %) of that stoichiometrically required.

Metal salts of phenols and sulfurized phenols are prepared by reaction with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased
25 products may be obtained by methods well known in the art. Sulfurized phenols may be prepared by reacting a phenol with sulfur or a sulfur containing compound such as hydrogen sulfide, sulfur monohalide or sulfur dihalide, to form products which are generally mixtures of compounds in which 2 or more phenols are bridged by sulfur containing bridges.

30 Carboxylate detergents, e.g., salicylates, can be prepared by reacting an aromatic carboxylic acid with an appropriate metal compound such as an oxide or hydroxide and neutral or overbased products may be obtained by methods well known in the art. The aromatic moiety of the aromatic carboxylic acid can contain hetero

atoms, such as nitrogen and oxygen. Preferably, the moiety contains only carbon atoms; more preferably the moiety contains six or more carbon atoms; for example benzene is a preferred moiety. The aromatic carboxylic acid may contain one or more aromatic moieties, such as one or more benzene rings, either fused or connected via
5 alkylene bridges. The carboxylic moiety may be attached directly or indirectly to the aromatic moiety. Preferably the carboxylic acid group is attached directly to a carbon atom on the aromatic moiety, such as a carbon atom on the benzene ring. More preferably, the aromatic moiety also contains a second functional group, such as a hydroxy group or a sulfonate group, which can be attached directly or indirectly to a
10 carbon atom on the aromatic moiety.

Preferred examples of aromatic carboxylic acids are salicylic acids and sulfurized derivatives thereof, such as hydrocarbyl substituted salicylic acid and derivatives thereof. Processes for sulfurizing, for example a hydrocarbyl - substituted salicylic acid, are known to those skilled in the art. Salicylic acids are typically
15 prepared by carboxylation, for example, by the Kolbe - Schmitt process, of phenoxides, and in that case, will generally be obtained, normally in a diluent, in admixture with uncarboxylated phenol.

Preferred substituents in oil - soluble salicylic acids are alkyl substituents. In alkyl - substituted salicylic acids, the alkyl groups advantageously contain 5 to 100,
20 preferably 9 to 30, especially 14 to 20, carbon atoms. Where there is more than one alkyl group, the average number of carbon atoms in all of the alkyl groups is preferably at least 9 to ensure adequate oil solubility.

Detergents generally useful in the formulation of lubricating oil compositions also include "hybrid" detergents formed with mixed surfactant systems, e.g.,
25 phenate/salicylates, sulfonate/phenates, sulfonate/salicylates, sulfonates/phenates/salicylates, as described, for example, in U.S. Patent Nos. 6,153,565; 6,281,179; 6,429,178; and 6,429,178.

Borated detergents and methods for borating detergents are well known and described, for example, in U.S. Patent Nos. 3,929,650; 3,480,548; and 4,792,410.
30 Borated detergents can be used to provide the lubricating oil compositions of the present invention with all, or a portion, of the requisite amount of boron.

Lubricating oil compositions of the present invention preferably contain a magnesium detergent, more preferably an overbased magnesium detergent, in an

amount providing the lubricating oil composition with at least 0.09 mass % (900 ppm), preferably at least 0.10 mass % (1000 ppm), more preferably at least 0.115 mass % (1150 ppm) of elemental magnesium. Preferably, the overbased magnesium detergent will have, or have on average, a TBN of at least about 200, such as from
5 about 200 to about 500; preferably at least about 250, such as from about 250 to about 500; more preferably at least about 300, such as from about 300 to about 450.

Overbased ash-containing detergents based on metals other than magnesium are preferably present in amounts contributing no greater than 40 % of the TBN of the lubricating oil composition contributed by overbased detergent. More preferably,
10 lubricating oil compositions of the present invention contain overbased ash-containing detergents based on metals other than magnesium in amounts providing no greater than about 20% of the total TBN contributed to the lubricating oil composition by overbased detergent.

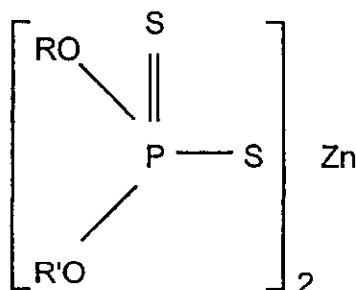
Lubricating oil compositions of the present invention may also contain ashless
15 (metal-free) detergents such as oil-soluble hydrocarbyl phenol aldehyde condensates described, for example, in US-2005-0277559-A1.

Preferably, detergent in total is used in an amount providing the lubricating oil composition with from about 0.35 to about 1.0 mass %, such as from about 0.5 to about 0.9 mass %, more preferably from about 0.6 to about 0.8 mass % of sulfated ash
20 (SASH). Preferably, the lubricating oil composition has a TBN of from about 7 to about 15, such as from about 8 to about 13, more preferably from about 9 to about 11. TBN may be contributed to the lubricating oil composition by additives other than detergents. Dispersants, antioxidants and antiwear agents may in some cases contribute 40 % or more of the total amount of lubricant TBN.

25 Conventionally, lubricating oil compositions formulated for use in a heavy duty diesel engine comprise from about 0.5 to about 10 mass %, preferably from about 1.5 to about 5 mass %, most preferably from about 2 to about 3 mass % of detergent, based on the total mass of the formulated lubricating oil composition. Detergents are conventionally formed in diluent oil. Conventionally, detergents are
30 referred to by the TBN, which is the TBN of the active detergent in the diluent. Therefore, while other additives are often referred to in terms of the amount of active ingredient (A.I.), stated amounts of detergent refer to the total mass of detergent including diluent.

Dihydrocarbyl dithiophosphate metal salts are frequently used as antiwear and antioxidant agents. The metal may be an alkali or alkaline earth metal, or aluminum, lead, tin, molybdenum, manganese, nickel or copper. The zinc salts are most commonly used in lubricating oil in amounts of 0.1 to 10, preferably 0.2 to 2 mass %, based upon the total weight of the lubricating oil composition. They may be prepared in accordance with known techniques by first forming a dihydrocarbyl dithiophosphoric acid (DDPA), usually by reaction of one or more alcohol or a phenol with P_2S_5 and then neutralizing the formed DDPA with a zinc compound. For example, a dithiophosphoric acid may be made by reacting mixtures of primary and secondary alcohols. Alternatively, multiple dithiophosphoric acids can be prepared where the hydrocarbyl groups on one are entirely secondary in character and the hydrocarbyl groups on the others are entirely primary in character. To make the zinc salt, any basic or neutral zinc compound could be used but the oxides, hydroxides and carbonates are most generally employed. Commercial additives frequently contain an excess of zinc due to the use of an excess of the basic zinc compound in the neutralization reaction.

The preferred zinc dihydrocarbyl dithiophosphates are oil soluble salts of dihydrocarbyl dithiophosphoric acids and may be represented by the following formula:



wherein R and R' may be the same or different hydrocarbyl radicals containing from 1 to 18, preferably 2 to 12, carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl and cycloaliphatic radicals. Particularly preferred as R and R' groups are alkyl groups of 2 to 8 carbon atoms. Thus, the radicals may, for example, be ethyl, n-propyl, i-propyl, n-butyl, i-butyl, sec-butyl, amyl, n-hexyl, i-hexyl, n-octyl, decyl, dodecyl, octadecyl, 2-ethylhexyl, phenyl, butylphenyl, cyclohexyl, methylcyclopentyl, propenyl, butenyl. In order to obtain oil solubility, the total number of carbon atoms (i.e. R and R') in the dithiophosphoric acid will generally be

about 5 or greater. The zinc dihydrocarbyl dithiophosphate (ZDDP) can therefore comprise zinc dialkyl dithiophosphates. Lubricating oil compositions of the present invention have a phosphorous content of no greater than about 0.12 mass % (1200 ppm). Conventionally, ZDDP is used in an amount close or equal to the maximum amount allowed. Thus, lubricating oil compositions in accordance with the present invention, formulated for use in heavy duty diesel engines, will preferably contain ZDDP or other metal salt of a dihydrocarbyl dithiophosphate, in an amount introducing from about 0.08 to about 0.12 mass % of phosphorus, based on the total mass of the lubricating oil composition. Preferably, ZDDP is the sole phosphorus-containing additive present.

Oxidation inhibitors or antioxidants reduce the tendency of mineral oils to deteriorate in service. Oxidative deterioration can be evidenced by sludge in the lubricant, varnish-like deposits on the metal surfaces, and by viscosity growth. Such oxidation inhibitors include hindered phenols, alkaline earth metal salts of alkylphenolthioesters having preferably C₅ to C₁₂ alkyl side chains, calcium nonylphenol sulfide, oil soluble phenates and sulfurized phenates, phosphosulfurized or sulfurized hydrocarbons or esters, phosphorous esters, metal thiocarbamates, oil soluble copper compounds as described in U.S. Patent No. 4,867,890, and molybdenum-containing compounds.

Aromatic amines having at least two aromatic groups attached directly to the nitrogen constitute another class of compounds that is frequently used for antioxidantancy. Typical oil soluble aromatic amines having at least two aromatic groups attached directly to one amine nitrogen contain from 6 to 16 carbon atoms. The amines may contain more than two aromatic groups. Compounds having a total of at least three aromatic groups in which two aromatic groups are linked by a covalent bond or by an atom or group (e.g., an oxygen or sulfur atom, or a -CO-, -SO₂- or alkylene group) and two are directly attached to one amine nitrogen also considered aromatic amines having at least two aromatic groups attached directly to the nitrogen. The aromatic rings are typically substituted by one or more substituents selected from alkyl, cycloalkyl, alkoxy, aryloxy, acyl, acylamino, hydroxy, and nitro groups. The amount of any such oil soluble aromatic amines having at least two aromatic groups attached directly to one amine nitrogen should preferably not exceed 0.4 mass %.

The antiwear agent ZDDP provides a strong antioxidant credit to lubricants. When less ZDDP is used in order to meet phosphorus and SASH limits, lubricant formulators must compensate for the resulting reduction in oxidation inhibition, preferably by use of highly effective, ashless, sulfur-free antioxidants. Lubricating oil compositions in accordance with the present invention therefore preferably contain at least about 0.5 mass%, preferably at least about 0.6 mass %, such as at least 0.8 mass%, more preferably, at least 1.0 mass % of an ashless antioxidant selected from the group consisting of sulfur-free phenolic antioxidant, aminic antioxidant, or a combination thereof. Preferably, lubricating oil compositions in accordance with the present invention contain a combination of sulfur-free phenolic antioxidant and aminic antioxidant.

Dispersants maintain in suspension materials resulting from oxidation during use that are insoluble in oil, thus preventing sludge flocculation and precipitation, or deposition on metal parts. The lubricating oil composition of the present invention comprises at least one dispersant, and may comprise a plurality of dispersants. The dispersant or dispersants are preferably nitrogen-containing dispersants and preferably contribute, in total, from about 0.08 to about 0.19 mass %, such as from about 0.09 to about 0.18 mass %, most preferably from about 0.09 to about 0.16 mass % of nitrogen to the lubricating oil composition.

Dispersants useful in the context of the present invention include the range of nitrogen-containing, ashless (metal-free) dispersants known to be effective to reduce formation of deposits upon use in gasoline and diesel engines, when added to lubricating oils and comprise an oil soluble polymeric long chain backbone having functional groups capable of associating with particles to be dispersed. Typically, such dispersants have amine, amine-alcohol or amide polar moieties attached to the polymer backbone, often via a bridging group. The ashless dispersant may be, for example, selected from oil soluble salts, esters, amino-esters, amides, imides and oxazolines of long chain hydrocarbon-substituted mono- and polycarboxylic acids or anhydrides thereof; thiocarboxylate derivatives of long chain hydrocarbons; long chain aliphatic hydrocarbons having polyamine moieties attached directly thereto; and Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and polyalkylene polyamine.

Generally, each mono- or dicarboxylic acid-producing moiety will react with a nucleophilic group (amine or amide) and the number of functional groups in the polyalkenyl-substituted carboxylic acylating agent will determine the number of nucleophilic groups in the finished dispersant.

5 The polyalkenyl moiety of the dispersant of the present invention has a number average molecular weight of from about 700 to about 3000, preferably between 950 and 3000, such as between 950 and 2800, more preferably from about 950 to 2500, and most preferably from about 950 to about 2400. In one embodiment of the invention, the dispersant comprises a combination of a lower molecular weight
10 dispersant (e.g., having a number average molecular weight of from about 700 to 1100) and a high molecular weight dispersant having a number average molecular weight of from about at least about 1500, preferably between 1800 and 3000, such as between 2000 and 2800, more preferably from about 2100 to 2500, and most preferably from about 2150 to about 2400. The molecular weight of a dispersant is
15 generally expressed in terms of the molecular weight of the polyalkenyl moiety as the precise molecular weight range of the dispersant depends on numerous parameters including the type of polymer used to derive the dispersant, the number of functional groups, and the type of nucleophilic group employed.

 The polyalkenyl moiety from which the high molecular weight dispersants are
20 derived preferably have a narrow molecular weight distribution (MWD), also referred to as polydispersity, as determined by the ratio of weight average molecular weight (M_w) to number average molecular weight (M_n). Specifically, polymers from which the dispersants of the present invention are derived have a M_w/M_n of from about 1.5 to about 2.0, preferably from about 1.5 to about 1.9, most preferably from about 1.6 to
25 about 1.8.

 Suitable hydrocarbons or polymers employed in the formation of the dispersants of the present invention include homopolymers, interpolymers or lower molecular weight hydrocarbons. One family of such polymers comprise polymers of ethylene and/or at least one C_3 to C_{28} alpha-olefin having the formula $H_2C=CHR^1$
30 wherein R^1 is straight or branched chain alkyl radical comprising 1 to 26 carbon atoms and wherein the polymer contains carbon-to-carbon unsaturation, preferably a high degree of terminal ethenylidene unsaturation. Preferably, such polymers comprise interpolymers of ethylene and at least one alpha-olefin of the above formula,

wherein R^1 is alkyl of from 1 to 18 carbon atoms, and more preferably is alkyl of from 1 to 8 carbon atoms, and more preferably still of from 1 to 2 carbon atoms. Therefore, useful alpha-olefin monomers and comonomers include, for example, propylene, butene-1, hexene-1, octene-1, 4-methylpentene-1, decene-1, dodecene-1, tridecene-1, 5 tetradecene-1, pentadecene-1, hexadecene-1, heptadecene-1, octadecene-1, nonadecene-1, and mixtures thereof (e.g., mixtures of propylene and butene-1, and the like). Exemplary of such polymers are propylene homopolymers, butene-1 homopolymers, ethylene-propylene copolymers, ethylene-butene-1 copolymers, propylene-butene copolymers and the like, wherein the polymer contains at least some 10 terminal and/or internal unsaturation. Preferred polymers are unsaturated copolymers of ethylene and propylene and ethylene and butene-1. The interpolymers of this invention may contain a minor amount, e.g. 0.5 to 5 mole % of a C_4 to C_{18} non-conjugated diolefin comonomer. However, it is preferred that the polymers of this invention comprise only alpha-olefin homopolymers, interpolymers of alpha-olefin 15 comonomers and interpolymers of ethylene and alpha-olefin comonomers. The molar ethylene content of the polymers employed in this invention is preferably in the range of 0 to 80 %, and more preferably 0 to 60 %. When propylene and/or butene-1 are employed as comonomer(s) with ethylene, the ethylene content of such copolymers is most preferably between 15 and 50 %, although higher or lower ethylene contents 20 may be present.

These polymers may be prepared by polymerizing alpha-olefin monomer, or mixtures of alpha-olefin monomers, or mixtures comprising ethylene and at least one C_3 to C_{28} alpha-olefin monomer, in the presence of a catalyst system comprising at least one metallocene (e.g., a cyclopentadienyl-transition metal compound) and an 25 alumoxane compound. Using this process, a polymer in which 95 % or more of the polymer chains possess terminal ethenylidene-type unsaturation can be provided. The percentage of polymer chains exhibiting terminal ethenylidene unsaturation may be determined by FTIR spectroscopic analysis, titration, or C^{13} NMR. Interpolymers of this latter type may be characterized by the formula $POLY-C(R^1)=CH_2$ wherein R^1 is 30 C_1 to C_{26} alkyl, preferably C_1 to C_{18} alkyl, more preferably C_1 to C_8 alkyl, and most preferably C_1 to C_2 alkyl, (e.g., methyl or ethyl) and wherein POLY represents the polymer chain. The chain length of the R^1 alkyl group will vary depending on the comonomer(s) selected for use in the polymerization. A minor amount of the polymer

chains can contain terminal ethenyl, i.e., vinyl, unsaturation, i.e. POLY-CH=CH_2 , and a portion of the polymers can contain internal monounsaturation, e.g. $\text{POLY-CH=CH(R}^1\text{)}$, wherein R^1 is as defined above. These terminally unsaturated interpolymers may be prepared by known metallocene chemistry and may also be prepared as described in U.S. Patent Nos. 5,498,809; 5,663,130; 5,705,577; 5,814,715; 6,022,929 and 6,030,930.

Another useful class of polymers is polymers prepared by cationic polymerization of isobutene, styrene, and the like. Common polymers from this class include polyisobutenes obtained by polymerization of a C_4 refinery stream having a butene content of about 35 to about 75 mass %, and an isobutene content of about 30 to about 60 mass %, in the presence of a Lewis acid catalyst, such as aluminum trichloride or boron trifluoride. A preferred source of monomer for making poly-n-butenes is petroleum feedstreams such as Raffinate II. These feedstocks are disclosed in the art such as in U.S. Patent No. 4,952,739. Polyisobutylene is a most preferred backbone of the present invention because it is readily available by cationic polymerization from butene streams (e.g., using AlCl_3 or BF_3 catalysts). Such polyisobutylenes generally contain residual unsaturation in amounts of about one ethylenic double bond per polymer chain, positioned along the chain. A preferred embodiment utilizes polyisobutylene prepared from a pure isobutylene stream or a Raffinate I stream to prepare reactive isobutylene polymers with terminal vinylidene olefins. Preferably, these polymers, referred to as highly reactive polyisobutylene (HR-PIB), have a terminal vinylidene content of at least 65%, e.g., 70%, more preferably at least 80%, most preferably, at least 85%. The preparation of such polymers is described, for example, in U.S. Patent No. 4,152,499. HR-PIB is known and HR-PIB is commercially available, for example, under the tradenames GlissopalTM (from BASF) and UltravisTM (from BP-Amoco).

Polyisobutylene polymers that may be employed are generally based on a hydrocarbon chain of from about 700 to 3000. Methods for making polyisobutylene are known. Polyisobutylene can be functionalized by halogenation (e.g. chlorination), the thermal "ene" reaction, or by free radical grafting using a catalyst (e.g. peroxide), as described below.

The hydrocarbon or polymer backbone can be functionalized, e.g., with carboxylic acid producing moieties (preferably acid or anhydride moieties) selectively

at sites of carbon-to-carbon unsaturation on the polymer or hydrocarbon chains, or randomly along chains using any of the three processes mentioned above or combinations thereof, in any sequence.

Processes for reacting polymeric hydrocarbons with unsaturated carboxylic acids, anhydrides or esters and the preparation of derivatives from such compounds are disclosed in U.S. Patent Nos. 3,087,936; 3,172,892; 3,215,707; 3,231,587; 3,272,746; 3,275,554; 3,381,022; 3,442,808; 3,565,804; 3,912,764; 4,110,349; 4,234,435; 5,777,025; 5,891,953; as well as EP 0 382 450 B1; CA-1,335,895 and GB-A-1,440,219. The polymer or hydrocarbon may be functionalized, for example, with carboxylic acid producing moieties (preferably acid or anhydride) by reacting the polymer or hydrocarbon under conditions that result in the addition of functional moieties or agents, i.e., acid, anhydride, ester moieties, etc., onto the polymer or hydrocarbon chains primarily at sites of carbon-to-carbon unsaturation (also referred to as ethylenic or olefinic unsaturation) using the halogen assisted functionalization (e.g. chlorination) process or the thermal "ene" reaction.

Selective functionalization can be accomplished by halogenating, e.g., chlorinating or brominating the unsaturated α -olefin polymer to about 1 to 8 mass %, preferably 3 to 7 mass % chlorine, or bromine, based on the weight of polymer or hydrocarbon, by passing the chlorine or bromine through the polymer at a temperature of 60 to 250°C, preferably 110 to 160°C, e.g., 120 to 140°C, for about 0.5 to 10, preferably 1 to 7 hours. The halogenated polymer or hydrocarbon (hereinafter backbone) is then reacted with sufficient monounsaturated reactant capable of adding the required number of functional moieties to the backbone, e.g., monounsaturated carboxylic reactant, at 100 to 250°C, usually about 180°C to 235°C, for about 0.5 to 10, e.g., 3 to 8 hours, such that the product obtained will contain the desired number of moles of the monounsaturated carboxylic reactant per mole of the halogenated backbones. Alternatively, the backbone and the monounsaturated carboxylic reactant are mixed and heated while adding chlorine to the hot material.

While chlorination normally helps increase the reactivity of starting olefin polymers with monounsaturated functionalizing reactant, it is not necessary with some of the polymers or hydrocarbons contemplated for use in the present invention, particularly those preferred polymers or hydrocarbons which possess a high terminal bond content and reactivity. Preferably, therefore, the backbone and the

monounsaturated functionality reactant, e.g., carboxylic reactant, are contacted at elevated temperature to cause an initial thermal "ene" reaction to take place. Ene reactions are known.

The hydrocarbon or polymer backbone can be functionalized by random attachment of functional moieties along the polymer chains by a variety of methods. For example, the polymer, in solution or in solid form, may be grafted with the monounsaturated carboxylic reactant, as described above, in the presence of a free-radical initiator. When performed in solution, the grafting takes place at an elevated temperature in the range of about 100 to 260°C, preferably 120 to 240°C. Preferably, free-radical initiated grafting would be accomplished in a mineral lubricating oil solution containing, e.g., 1 to 50 mass %, preferably 5 to 30 mass % polymer based on the initial total oil solution.

The free-radical initiators that may be used are peroxides, hydroperoxides, and azo compounds, preferably those that have a boiling point greater than about 100°C and decompose thermally within the grafting temperature range to provide free-radicals. Representative of these free-radical initiators are azobutyronitrile, 2,5-dimethylhex-3-ene-2, 5-bis-tertiary-butyl peroxide and dicumene peroxide. The initiator, when used, typically is used in an amount of between 0.005% and 1% by weight based on the weight of the reaction mixture solution. Typically, the aforesaid monounsaturated carboxylic reactant material and free-radical initiator are used in a weight ratio range of from about 1.0:1 to 30:1, preferably 3:1 to 6:1. The grafting is preferably carried out in an inert atmosphere, such as under nitrogen blanketing. The resulting grafted polymer is characterized by having carboxylic acid (or ester or anhydride) moieties randomly attached along the polymer chains: it being understood, of course, that some of the polymer chains remain ungrafted. The free radical grafting described above can be used for the other polymers and hydrocarbons of the present invention.

The preferred monounsaturated reactants that are used to functionalize the backbone comprise mono- and dicarboxylic acid material, i.e., acid, anhydride, or acid ester material, including (i) monounsaturated C₄ to C₁₀ dicarboxylic acid wherein (a) the carboxyl groups are vicinyl, (i.e., located on adjacent carbon atoms) and (b) at least one, preferably both, of said adjacent carbon atoms are part of said mono unsaturation; (ii) derivatives of (i) such as anhydrides or C₁ to C₅ alcohol derived

mono- or diesters of (i); (iii) monounsaturated C₃ to C₁₀ monocarboxylic acid wherein the carbon-carbon double bond is conjugated with the carboxy group, i.e., of the structure -C=C-CO-; and (iv) derivatives of (iii) such as C₁ to C₅ alcohol derived mono- or diesters of (iii). Mixtures of monounsaturated carboxylic materials (i) - (iv) also may be used. Upon reaction with the backbone, the monounsaturation of the monounsaturated carboxylic reactant becomes saturated. Thus, for example, maleic anhydride becomes backbone-substituted succinic anhydride, and acrylic acid becomes backbone-substituted propionic acid. Exemplary of such monounsaturated carboxylic reactants are fumaric acid, itaconic acid, maleic acid, maleic anhydride, chloromaleic acid, chloromaleic anhydride, acrylic acid, methacrylic acid, crotonic acid, cinnamic acid, and lower alkyl (e.g., C₁ to C₄ alkyl) acid esters of the foregoing, e.g., methyl maleate, ethyl fumarate, and methyl fumarate.

To provide the required functionality, the monounsaturated carboxylic reactant, preferably maleic anhydride, typically will be used in an amount ranging from about equimolar amount to about 100 mass % excess, preferably 5 to 50 mass % excess, based on the moles of polymer or hydrocarbon. Unreacted excess monounsaturated carboxylic reactant can be removed from the final dispersant product by, for example, stripping, usually under vacuum, if required.

The functionalized oil-soluble polymeric hydrocarbon backbone is then derivatized with a nitrogen-containing nucleophilic reactant, such as an amine, amino-alcohol, amide, or mixture thereof, to form a corresponding derivative. Amine compounds are preferred. Useful amine compounds for derivatizing functionalized polymers comprise at least one amine and can comprise one or more additional amine or other reactive or polar groups. These amines may be hydrocarbyl amines or may be predominantly hydrocarbyl amines in which the hydrocarbyl group includes other groups; e.g., hydroxy groups, alkoxy groups, amide groups, nitriles, imidazoline groups, and the like. Particularly useful amine compounds include mono- and polyamines, e.g., polyalkene and polyoxyalkylene polyamines of about 2 to 60, such as 2 to 40 (e.g., 3 to 20) total carbon atoms having about 1 to 12, such as 3 to 12, preferably 3 to 9, most preferably from about 6 to about 7 nitrogen atoms per molecule. Mixtures of amine compounds may advantageously be used, such as those prepared by reaction of alkylene dihalide with ammonia. Preferred amines are aliphatic saturated amines, including, for example, 1,2-diaminoethane; 1,3-

diaminopropane; 1,4-diaminobutane; 1,6-diaminohexane; polyethylene amines such as diethylene triamine; triethylene tetramine; tetraethylene pentamine; and polypropyleneamines such as 1,2-propylene diamine; and di-(1,2-propylene)triamine. Such polyamine mixtures, known as PAM, are commercially available. Particularly
5 preferred polyamine mixtures are mixtures derived by distilling the light ends from PAM products. The resulting mixtures, known as "heavy" PAM, or HPAM, are also commercially available. The properties and attributes of both PAM and/or HPAM are described, for example, in U.S. Patent Nos. 4,938,881; 4,927,551; 5,230,714; 5,241,003; 5,565,128; 5,756,431; 5,792,730; and 5,854,186.

10 Other useful amine compounds include: alicyclic diamines such as 1,4-di(aminomethyl) cyclohexane and heterocyclic nitrogen compounds such as imidazolines. Another useful class of amines is the polyamido and related amido-amines as disclosed in U.S. Patent Nos. 4,857,217; 4,956,107; 4,963,275; and 5,229,022. Also usable is tris(hydroxymethyl)amino methane (TAM) as described in
15 U.S. Patent Nos. 4,102,798; 4,113,639; 4,116,876; and UK 989,409. Dendrimers, star-like amines, and comb-structured amines may also be used. Similarly, one may use condensed amines, as described in U.S. Patent No. 5,053,152. The functionalized polymer is reacted with the amine compound using conventional techniques as described, for example, in U.S. Patent Nos. 4,234,435 and 5,229,022, as well as in
20 EP-A-208,560.

A preferred dispersant composition is one comprising at least one polyalkenyl succinimide, which is the reaction product of a polyalkenyl substituted succinic anhydride (e.g., PIBSA) and a polyamine (PAM) that has a coupling ratio of from about 0.65 to about 1.25, preferably from about 0.8 to about 1.1, most preferably from
25 about 0.9 to about 1. In the context of this disclosure, "coupling ratio" may be defined as a ratio of the number of succinyl groups in the PIBSA to the number of primary amine groups in the polyamine reactant.

Another class of high molecular weight ashless dispersants comprises Mannich base condensation products. Generally, these products are prepared by
30 condensing about one mole of a long chain alkyl-substituted mono- or polyhydroxy benzene with about 1 to 2.5 moles of carbonyl compound(s) (e.g., formaldehyde and paraformaldehyde) and about 0.5 to 2 moles of polyalkylene polyamine, as disclosed, for example, in U.S. Patent No. 3,442,808. Such Mannich base condensation

products may include a polymer product of a metallocene catalyzed polymerization as a substituent on the benzene group, or may be reacted with a compound containing such a polymer substituted on a succinic anhydride in a manner similar to that described in U.S. Patent No. 3,442,808. Examples of functionalized and/or
5 derivatized olefin polymers synthesized using metallocene catalyst systems are described in the publications identified *supra*.

The dispersant(s) of the present invention are preferably non-polymeric (e.g., are mono- or bis-succinimides).

Dispersant(s), particularly the lower molecular weight dispersants, may
10 optionally be borated. Such dispersants can be borated by conventional means, as generally taught in U.S. Patent Nos. 3,087,936, 3,254,025 and 5,430,105. Boration of the dispersant is readily accomplished by treating an acyl nitrogen-containing dispersant with a boron compound such as boron oxide, boron halide boron acids, and esters of boron acids, in an amount sufficient to provide from about 0.1 to about 20
15 atomic proportions of boron for each mole of acylated nitrogen composition. Borated dispersants can be used to provide the lubricating oil compositions of the present invention with all, or a portion, of the requisite amount of boron.

Dispersants derived from highly reactive polyisobutylene have been found to provide lubricating oil compositions with a wear credit relative to a corresponding
20 dispersant derived from conventional polyisobutylene. This wear credit is of particular importance in lubricants containing reduced levels of ash-containing antiwear agents, such as ZDDP. Thus, in one preferred embodiment, at least one dispersant used in the lubricating oil compositions of the present invention is derived from highly reactive polyisobutylene.

25 Non-dispersant/detergent boron sources are prepared by reacting a boron compound with an oil-soluble or oil-dispersible additive or compound. Boron compounds include boron oxide, boron oxide hydrate, boron trioxide, boron trifluoride, boron tribromide, boron trichloride, boron acid such as boronic acid, boric acid, tetraboric acid and metaboric acid, boron hydrides, boron amides and various
30 esters of boron acids. Suitable "non-dispersant boron sources" may comprise any oil-soluble, boron-containing compound, but preferably comprise one or more boron-containing additives known to impart enhanced properties to lubricating oil compositions. Such boron-containing additives include, for example, borated

dispersant VI improver; alkali metal, mixed alkali metal or alkaline earth metal borate; borated overbased metal detergent; borated epoxide; borate ester; and borate amide.

Alkali metal and alkaline earth metal borates are generally hydrated particulate metal borates, which are known in the art. Alkali metal borates include mixed alkali and alkaline earth metal borates. These metal borates are available commercially. Representative patents describing suitable alkali metal and alkaline earth metal borates and their methods of manufacture include U.S. Patent Nos. 3,997,454; 3,819,521; 3,853,772; 3,907,601; 3,997,454; and 4,089,790.

The borated amines maybe prepared by reacting one or more of the above boron compounds with one or more of fatty amines, e.g., an amine having from four to eighteen carbon atoms. Borated amines may be prepared by reacting the amine with the boron compound at a temperature of from 50 to 300, preferably from 100 to 250 °C and at a ratio from 3:1 to 1:3 equivalents of amine to equivalents of boron compound.

Borated fatty epoxides are generally the reaction product of one or more of the above boron compounds with at least one epoxide. The epoxide is generally an aliphatic epoxide having from 8 to 30, preferably from 10 to 24, more preferably from 12 to 20, carbon atoms. Examples of useful aliphatic epoxides include heptyl epoxide and octyl epoxide. Mixtures of epoxides may also be used, for instance commercial mixtures of epoxides having from 14 to 16 carbon atoms and from 14 to 18 carbon atoms. The borated fatty epoxides are generally known and are described in U.S. Patent 4,584,115.

Borate esters may be prepared by reacting one or more of the above boron compounds with one or more alcohol of suitable oleophilicity. Typically, the alcohol contains from 6 to 30, or from 8 to 24, carbon atoms. Methods of making such borate esters are known in the art.

The borate esters can be borated phospholipids. Such compounds, and processes for making such compounds, are described in EP-A-0 684 298. Borated overbased metal detergents are known in the art where the borate substitutes the carbonate in the core either in part or in full.

Additional additives may be incorporated into the compositions of the invention to enable particular performance requirements to be met. Examples of

additives which may be included in the lubricating oil compositions of the present invention are metal rust inhibitors, viscosity index improvers, corrosion inhibitors, oxidation inhibitors, friction modifiers, anti-foaming agents, anti-wear agents and pour point depressants. Some are discussed in further detail below.

5 In addition to the dispersants described above, lubricating oil compositions, particularly lubricating oil compositions for HDD engines, preferably include additives effective in the dispersion of soot. U.S. Published Patent Application 2006/0189492 A1 to Bera et al. discloses certain reaction products of acylating agents and oligomers having the following structure:



where each Ar independently represents an aromatic moiety having 0 to 3 substituents selected from alkyl, alkoxy, alkoxyalkyl, hydroxy, hydroxyalkyl, acyloxy, acyloxyalkyl, aryloxy, aryloxy alkyl, halo and combinations thereof; each L is independently a linking moiety comprising a carbon-carbon single bond or a linking group; each Y' is independently a moiety of the formula $Z(\text{O}(\text{CR}'_2)_n)_y\text{X}-$, where X is selected from $(\text{CR}'_2)_z$, O and S; R and R' are each independently selected from H, C_1 to C_6 alkyl and aryl; z is 1 to 10; n is 0 to 10 when X is $(\text{CR}'_2)_z$, and 2 to 10 when X is O or S; y is 1 to 30; Z is H, an acyl group, an alkyl group or an aryl group; each a is independently 0 to 3, at least one Ar moiety bears at least one group Y in which Z is not H; and m is 1 to 100. Such compounds are described as useful soot dispersants (see also U.S. Patent Nos. 6,495,496 and 6,750,183 and U.S. Patent Application Serial No. 11/672,660).

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Friction modifiers and fuel economy agents that are compatible with the other ingredients of the final oil may also be included. Examples of such materials include glyceryl monoesters of higher fatty acids, for example, glyceryl mono-oleate; esters of long chain polycarboxylic acids with diols, for example, the butane diol ester of a dimerized unsaturated fatty acid; oxazoline compounds; and alkoxyated alkyl-substituted mono-amines, diamines and alkyl ether amines, for example, ethoxylated tallow amine and ethoxylated tallow ether amine.

25

30 Other known friction modifiers comprise oil-soluble organo-molybdenum compounds. Such organo-molybdenum friction modifiers also provide antioxidant

and antiwear credits to a lubricating oil composition. Examples of such oil soluble organo-molybdenum compounds include dithiocarbamates, dithiophosphates, dithiophosphinates, xanthates, thioxanthates, sulfides, and the like, and mixtures thereof. Particularly preferred are molybdenum dithiocarbamates, dialkyldithiophosphates, alkyl xanthates and alkylthioxanthates.

Additionally, the molybdenum compound may be an acidic molybdenum compound. These compounds will react with a basic nitrogen compound as measured by ASTM test D-664 or D-2896 titration procedure and are typically hexavalent. Included are molybdic acid, ammonium molybdate, sodium molybdate, potassium molybdate, and other alkaline metal molybdates and other molybdenum salts, e.g., hydrogen sodium molybdate, MoOCl_4 , MoO_2Br_2 , $\text{Mo}_2\text{O}_3\text{Cl}_6$, molybdenum trioxide or similar acidic molybdenum compounds.

Among the molybdenum compounds useful in the compositions of this invention are organo-molybdenum compounds of the formula



wherein R is an organo group selected from the group consisting of alkyl, aryl, aralkyl and alkoxyalkyl, generally of from 1 to 30 carbon atoms, and preferably 2 to 12 carbon atoms and most preferably alkyl of 2 to 12 carbon atoms. Especially preferred are the dialkyldithiocarbamates of molybdenum.

Another group of organo-molybdenum compounds useful in the lubricating compositions of this invention are trinuclear molybdenum compounds, especially those of the formula $\text{Mo}_3\text{S}_k\text{L}_n\text{Q}_z$ and mixtures thereof wherein the L are independently selected ligands having organo groups with a sufficient number of carbon atoms to render the compound soluble or dispersible in the oil, n is from 1 to 4, k varies from 4 through 7, Q is selected from the group of neutral electron donating compounds such as water, amines, alcohols, phosphines, and ethers, and z ranges from 0 to 5 and includes non-stoichiometric values. At least 21 total carbon atoms should be present among all the ligand organo groups, such as at least 25, at least 30, or at least 35 carbon atoms.

The molybdenum compounds described above, in addition to providing friction-reducing properties, also provide antiwear credits and, therefore, molybdenum compounds have been used in lubricating oil compositions formulated with reduced amounts of ZDDP. When used in such reduced phosphorus lubricating oil compositions,

molybdenum compounds have been used in amounts introducing from about 10 to about 1000 ppm, such as 10 to about 350 ppm, or 10 to about 100 ppm of molybdenum (measured as atoms of molybdenum).

The viscosity index of the base stock is increased, or improved, by
5 incorporating therein certain polymeric materials that function as viscosity modifiers (VM) or viscosity index improvers (VII). Generally, polymeric materials useful as viscosity modifiers are those having number average molecular weights (M_n) of from about 5,000 to about 250,000, preferably from about 15,000 to about 200,000, more preferably from about 20,000 to about 150,000. These viscosity modifiers can be
10 grafted with grafting materials such as, for example, maleic anhydride, and the grafted material can be reacted with, for example, amines, amides, nitrogen-containing heterocyclic compounds or alcohol, to form multifunctional viscosity modifiers (dispersant-viscosity modifiers). Polymer molecular weight, specifically $\overline{M}_n$, can be determined by various known techniques. One convenient method is gel permeation
15 chromatography (GPC), which additionally provides molecular weight distribution information (see W. W. Yau, J. J. Kirkland and D. D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979). Another useful method for determining molecular weight, particularly for lower molecular weight polymers, is vapor pressure osmometry (see, e.g., ASTM D3592).

20 One class of diblock copolymers useful as viscosity modifiers has been found to provide a wear credit relative to, for example, olefin copolymer viscosity modifiers. This wear credit is of particular importance in lubricants containing reduced levels of ash-containing antiwear agents, such as ZDDP. Thus, in one preferred embodiment, at least one viscosity modifier used in the lubricating oil compositions of the present
25 invention is a linear diblock copolymer comprising one block derived primarily, preferably predominantly, from vinyl aromatic hydrocarbon monomer, and one block derived primarily, preferably predominantly, from diene monomer. Useful vinyl aromatic hydrocarbon monomers include those containing from 8 to about 16 carbon atoms such as aryl-substituted styrenes, alkoxy-substituted styrenes, vinyl
30 naphthalene, alkyl-substituted vinyl naphthalenes and the like. Dienes, or diolefins, contain two double bonds, commonly located in conjugation in a 1,3 relationship. Olefins containing more than two double bonds, sometimes referred to as polyenes, are also considered within the definition of "diene" as used herein. Useful dienes

include those containing from 4 to about 12 carbon atoms, preferably from 8 to about 16 carbon atoms, such as 1,3-butadiene, isoprene, piperylene, methylpentadiene, phenylbutadiene, 3,4-dimethyl-1,3-hexadiene, 4,5-diethyl-1,3-octadiene, with 1,3-butadiene and isoprene being preferred.

5 As used herein in connection with polymer block composition, “predominantly” means that the specified monomer or monomer type that is the principle component in that polymer block is present in an amount of at least 85% by weight of the block.

10 Polymers prepared with diolefins will contain ethylenic unsaturation, and such polymers are preferably hydrogenated. When the polymer is hydrogenated, the hydrogenation may be accomplished using any of the techniques known in the prior art. For example, the hydrogenation may be accomplished such that both ethylenic and aromatic unsaturation is converted (saturated) using methods such as those taught, for example, in U.S. Pat. Nos. 3,113,986 and 3,700,633 or the hydrogenation may be
15 accomplished selectively such that a significant portion of the ethylenic unsaturation is converted while little or no aromatic unsaturation is converted as taught, for example, in U.S. Pat. Nos. 3,634,595; 3,670,054; 3,700,633 and Re 27,145. Any of these methods can also be used to hydrogenate polymers containing only ethylenic unsaturation and which are free of aromatic unsaturation.

20 The block copolymers may include mixtures of linear diblock polymers as disclosed above, having different molecular weights and/or different vinyl aromatic contents as well as mixtures of linear block copolymers having different molecular weights and/or different vinyl aromatic contents. The use of two or more different polymers may be preferred to a single polymer depending on the rheological
25 properties the product is intended to impart when used to produce formulated engine oil. Examples of commercially available styrene/hydrogenated isoprene linear diblock copolymers include Infineum SV140™, Infineum SV150™ and Infineum SV160™, available from Infineum USA L.P. and Infineum UK Ltd.; Lubrizol® 7318, available from The Lubrizol Corporation; and Septon 1001™ and Septon 1020™,
30 available from Septon Company of America (Kuraray Group). Suitable styrene/1,3-butadiene hydrogenated block copolymers are sold under the tradename Glissoviscal™ by BASF.

Pour point depressants (PPD), otherwise known as lube oil flow improvers (LOFIs) lower the temperature. Compared to VM, LOFIs generally have a lower number average molecular weight. Like VM, LOFIs can be grafted with grafting materials such as, for example, maleic anhydride, and the grafted material can be
5 reacted with, for example, amines, amides, nitrogen-containing heterocyclic compounds or alcohol, to form multifunctional additives.

In the present invention it may be necessary to include an additive which maintains the stability of the viscosity of the blend. Thus, although polar group-containing additives achieve a suitably low viscosity in the pre-blending stage it has
10 been observed that some compositions increase in viscosity when stored for prolonged periods. Additives which are effective in controlling this viscosity increase include the long chain hydrocarbons functionalized by reaction with mono- or dicarboxylic acids or anhydrides which are used in the preparation of the ashless dispersants as hereinbefore disclosed. In another preferred embodiment, the
15 lubricating oil compositions of the present invention contain an effective amount of a long chain hydrocarbons functionalized by reaction with mono- or dicarboxylic acids or anhydrides.

When lubricating compositions contain one or more of the above-mentioned additives, each additive is typically blended into the base oil in an amount that enables
20 the additive to provide its desired function. Representative effective amounts of such additives, when used in crankcase lubricants, are listed below. All the values listed, except for those referring to metal detergents, are stated as mass percent active ingredient (A.I.).

ADDITIVE	MASS % (Broad)	MASS % (Preferred)
Dispersant	0.1 - 20	1 - 8
Metal Detergents	0.1 - 15	0.2 - 9
Corrosion Inhibitor	0 - 5	0 - 1.5
Metal Dihydrocarbyl Dithiophosphate	0.1 - 6	0.1 - 4
Antioxidant	0 - 5	0.01 - 2.5
Pour Point Depressant	0.01 - 5	0.01 - 1.5
Antifoaming Agent	0 - 5	0.001 - 0.15
Supplemental Antiwear Agents	0 - 1.0	0 - 0.5
Friction Modifier	0 - 5	0 - 1.5
Viscosity Modifier	0.01 - 10	0.25 - 3
Base stock	Balance	Balance

Preferably, the Noack volatility of the fully formulated lubricating oil composition (oil of lubricating viscosity plus all additives) will be no greater than 20 mass %, such as no greater than 15 mass %, preferably no greater than 13 mass %.

It may be desirable, although not essential to prepare one or more additive concentrates comprising additives (concentrates sometimes being referred to as additive packages) whereby several additives can be added simultaneously to the oil to form the lubricating oil composition.

The final composition may employ from 5 to 25 mass %, preferably 5 to 22 mass %, typically 10 to 20 mass % of the concentrate, the remainder being oil of lubricating viscosity.

As used herein, the terms phosphorus content, boron content, molybdenum content, magnesium content, calcium content, etc. refer to the content as measured by ASTM D5185; and sulfated ash content refers to the content as measured by ASTM D874.

This invention will be further understood by reference to the following examples, wherein all parts are parts by mass, unless otherwise noted and which include preferred embodiments of the invention.

EXAMPLES

- A SAE 5W40 grade lubricants containing base stock, dispersant (combination of borated dispersant and non-borated dispersant), detergent (a combination of calcium phenate, calcium sulfonate and magnesium sulfonate detergents), ZDDP, soot dispersant, a combination of ashless, sulfur-free phenolic and aminic antioxidants (0.7 mass % total), a molybdenum dithiocarbamate compound, viscosity modifier, pour point depressant and 1 mass % of 950 Mn polybutene (PIB) was formulated consistent with API CJ-4 and CI-4 specifications (1.0 mass % SASH; 0.4 mass % sulfur and 0.12 mass % phosphorus) in a blend of 4 and 6 cSt. Group III base stocks.
- 10 The resulting oil had a boron content of 65 ppm, a magnesium content of 1156 ppm, a molybdenum content of 44 ppm and a TBN of 9.9; 79 % of the TBN contributed by overbased detergent (52% of the TBN of the composition), was provided by the overbased magnesium detergents.

- Valve train wear resulting from the use of the above lubricant was measured in a Cummins ISB engine test; one of the engine tests for the API CJ-4/CI-4 specifications for HDD lubricants. The ISB engine test includes two stages. Stage 1 runs for 100 hours to produce soot in the oil. Stage 2 is a 250 hour cyclic portion, intended to produce heavy load on the engine in short bursts. At the end of the test, the valve train parts are measured for wear, reported as tappet weight loss, in milligrams, and camshaft lobe wear, in microns.
- 20

The results achieved with the exemplified oil are shown in Table 2.

Table 2

Oil	Oil 1	Passing Limit
Grade	5W40	
Tappet Weight Loss (mg.)	85	100 max
Cam Shaft Lobe Wear, Snap Gauge (µm)	43	55 max

- 25 As shown, Oil 1, a 5W40 grade lubricant formulated with all Group III base stock and having a phosphorus content of less than 1200 ppm, was able to meet the wear performance requirements of the API CJ-4/CI-4 specifications.

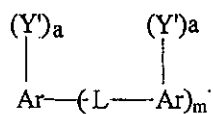
The disclosures of all patents, articles and other materials described herein are hereby incorporated, in their entirety, into this specification by reference.

Compositions described as "comprising" a plurality of defined components are to be construed as including compositions formed by admixing the defined plurality of defined components. The principles, preferred embodiments and modes of operation of the present invention have been described in the foregoing specification. What
5 applicants submit is their invention, however, is not to be construed as limited to the particular embodiments disclosed, since the disclosed embodiments are regarded as illustrative rather than limiting. Changes may be made by those skilled in the art without departing from the spirit of the invention.

CLAIMS:

1. An SAE 0W or 5W multigrade lubricating oil composition having a sulfated ash content of no greater than 1.0 mass %, a sulfur content of no greater than 0.4 mass %, and a phosphorus content of no greater than 0.12 mass %, and meeting the wear performance requirements of at least one of API CJ-4; API CI-4; and ACEA E7, said lubricating oil composition comprising:
 - (a) a major amount of oil of lubricating viscosity wherein said oil of lubricating viscosity comprises no greater than 30 mass % of one or more Group IV base stock and/or Group V base stock;
 - (b) at least 0.3 mass % of a non-hydrogenated olefin polymer, wherein the non-hydrogenated olefin polymer is selected from polybutene and polyisobutene; and
 - (c) at least 40 ppm of boron.
2. A lubricating oil composition, as claimed in claim 1, wherein said oil of lubricating viscosity consists essentially of Group III base stock.
3. A lubricating oil composition, as claimed in claim 1 or 2, comprising from 0.5 to 5.0 mass % of said polybutene or polyisobutene.
4. A lubricating oil composition, as claimed in claim 1, 2, or 3, wherein
 - the sulfated ash content is from 0.7 to 1.0 mass %,
 - the phosphorus content is from 0.08 to 0.12 mass %,
 - the oil of lubricating viscosity is no greater than 10 mass %;
 - the polybutene or polyisobutene is from 0.3 to 5 mass%, and
 - from 50 to 100 ppm of boron.
5. A lubricating oil composition, as claimed in claim 4, wherein said polybutene or polyisobutene has a number average molecular weight from 450 to 2300.
6. A lubricating oil composition, as claimed in any one of claims 1 to 5, further comprising one or more metal detergents including a magnesium detergent in an amount providing said composition with at least 0.09 mass % of magnesium.

7. A lubricating oil composition, as claimed in claim 6, wherein said magnesium detergent provides said composition with at least 0.115 mass % of magnesium.
8. A lubricating oil composition, as claimed in any one of the preceding claims, having a TBN of from 7 to 15.
9. A lubricating oil composition, as claimed in any one of the preceding claims, further comprising a molybdenum compound in an amount providing said composition with from 10 to 350 ppm of molybdenum.
10. A lubricating oil composition, as claimed in any one of the preceding claims, further comprising at least 0.5 mass % of an ashless antioxidant selected from the group consisting of sulfur-free phenolic antioxidants, aminic antioxidants, and mixtures thereof.
11. A lubricating oil composition, as claimed in any one of the preceding claims, further comprising at least one nitrogen-containing dispersant, in an amount providing said lubricating oil composition with at least 0.08 mass% of nitrogen.
12. A lubricating oil composition, as claimed in claim 11, wherein said nitrogen-containing dispersant comprises at least one dispersant derived from highly reactive polyisobutylene.
13. A lubricating oil composition, as claimed in any one of the preceding claims, further comprising a minor amount of at least one soot dispersing compound of the formula:



where

each Ar independently represents an aromatic moiety having 0 to 3 substituents selected from alkyl, alkoxy, alkoxyalkyl, hydroxy, hydroxyalkyl, acyloxy, acyloxyalkyl, aryloxy, aryloxy alkyl, halo and combinations thereof;

each L is independently a linking moiety comprising a carbon-carbon single bond or a linking group;

each Y' is independently a moiety of the formula $Z(O(CR_2)_n)_yX-$,
where X is selected from $(CR'_2)_z$, O and S;
R and R' are each independently selected from H, C₁ to C₆ alkyl and aryl;
z is 1 to 10;
n is 0 to 10 when X is $(CR'_2)_z$, and 2 to 10 when X is O or S;
y is 1 to 30;
Z is H, an acyl group, an alkyl group or an aryl group;
each a is independently 0 to 3,
at least one Ar moiety bears at least one group Y' in which Z is not H; and
m is 1 to 100.

14. A lubricating oil composition, as claimed in any one of the preceding claims, further comprising a minor amount of a linear block copolymer comprising one block derived primarily from vinyl aromatic hydrocarbon monomer, and one block derived primarily from diene monomer.

15. A heavy duty diesel (HDD) engine lubricated with a lubricating oil composition as claimed in any one of the preceding claims.

16. A method for improving the wear performance of a heavy duty diesel (HDD) engine, which method comprises the steps of lubricating the engine with a lubricating oil composition, as claimed in any one of the preceding claims, and operating the lubricated engine.