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(54) Titre : UTILISATION ET METHODE DE REDUCTION DE DEPOTS DE SOUPAPE DANS UN MOTEUR
(54) Title: USE AND METHOD OF REDUCING VALVE DEPOSITS IN AN ENGINE

(57) **Abrégé/Abstract:**

The present invention generally relates to a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine, the method comprising operating the engine with a lubricating oil composition comprising: (a) a major amount of an oil of lubricating viscosity; and (b) at least one foam inhibitor selected from the group consisting of silicon oils, polysiloxanes, polyacrylates, and polymethacrylates; wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the amount of said foam inhibitor in said lubricating oil composition is at an effective concentration to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with said lubricating oil composition without any foam inhibitor.

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(57) Abstract: The present invention generally relates to a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine, the method comprising operating the engine with a lubricating oil composition comprising: (a) a major amount of an oil of lubricating viscosity; and (b) at least one foam inhibitor selected from the group consisting of silicon oils, polysiloxanes, polyacrylates, and polymethacrylates; wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the amount of said foam inhibitor in said lubricating oil composition is at an effective concentration to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with said lubricating oil composition without any foam inhibitor.



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FIELD OF THE INVENTION

The present invention generally relates to a method for reducing intake valve deposits in Direct Injection Spark Ignition (DISI) engines. Also provided is a method for reducing intake valve deposits in a DISI engine by top treating an oil of lubricating viscosity with a lubricating oil additive concentrate.

BACKGROUND OF THE INVENTION

Recently a number of automotive engine manufacturers have introduced direct injection spark ignition (DISI) engines for gasoline. Such engines inject gasoline directly into the combustion chamber of the engine, rather than introducing the gasoline indirectly through the intake manifold by means of, for example, carburetors or port fuel injectors. Because the gasoline is injected directly into the combustion chambers, it enables precise control over the amount of fuel burned and the timing of the injection. One disadvantage of this approach, however, is that intake valves of DISI engines are likely to form large amounts of intake valve deposits (“IVD” hereinafter), since there is no gasoline at the site of the intake valves to provide deposit control additives to combat deposits or deposit precursors. These valve deposits interfere with valve operation, reduce the efficiency of the engine, and have a negative impact on driveability.

Some patent documents disclose solving the problem of intake valve deposits in direct injection spark ignition engines by using lubricant formulations.

Konishi, Japanese Patent Publication No. 2003-155492 discloses lubricants containing polybutenyl succinimide, dithio zinc phosphate, phenol and/or amine group ash-free antioxidant and alkaline-earth metal group cleaner, and which do not contain viscosity index improvers.

Calder, U.S. Patent Application Publication No.2004/0198614 discloses a method of reducing intake valve deposits in a direct injection engine, the method comprising lubricating the engine with a lubricating oil composition comprising a base oil mixture, the base oil mixture comprising (i) a Group III, a Group IV oil, or a mixture thereof, in combination with (ii) a synthetic ester oil, the weight ratio of (i) to (ii) being from about 0.2:1 to about 6:1.

5 Colucci et al., U.S. Patent Application Publication No. 2004/0231632 discloses a method and combustion system for reducing the formation of intake manifold deposits, such as including intake valve valves, and exhaust valve deposits in combustion engines by delivery of an organomolybdenum source from the vapor phase of an engine lubricant into a combustion chamber.

10 Adams et al., U.S. Patent Application Publication No. 2005/0236301 discloses a process to prepare a heavy and a light lubricating base oil from a partly isomerized Fischer-Tropsch derived feedstock, the feedstock having an initial boiling point of below 400 degrees C and a final boiling point of above 600 degrees C by (a) separating the fraction via distillation into a light base oil precursor fraction and a heavy base oil precursor fraction; (b) reducing the pour
15 point of each separate base oil precursor fraction via dewaxing; and, (c) isolating the desired base oil products from the dewaxed oil fractions as obtained in step (b).

Wedlock, U.S. Patent Application Publication No. 2006/0052252 discloses a lubricant composition containing a mixture of at least two Fischer-Tropsch derived base oils and one or more additives wherein one Fischer-Tropsch derived base oil (low viscosity component) has a
20 kinematic viscosity at 100.degree. C. of less than 7 cSt and the second Fischer-Tropsch derived base oil (high viscosity component) has a kinematic viscosity at 100.degree. C. of more than 18 cSt.

Locke et al., U.S. Patent Application Publication No. 2007/0197406 discloses, intake valve deposits in a direct injection internal combustion engine are reduced by lubricating the
25 engine with a lubricant that is substantially free of ashless organic friction modifiers and whose base oil has a Noack volatility of less than 12 mass %.

A number of patent documents disclose the use of foam inhibitors in a generic manner in gasoline direct injection engines. These include: U.S. Patent Application Publication Nos. 2008/0234153, 2008/0248981 and 2008/0110799; and Japanese Patent Publication Nos. 2008-
30 120908, 2001-262172, 2008-231192, and 2008-231191.

As described above, intake valve deposits are recognized as a problem in DISI engines. A number of attempts have been made to alleviate the problem of reducing intake valve deposits in DISI engines.

SUMMARY OF THE INVENTION

35 One embodiment of the present invention is directed to a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine, the method comprising operating the engine with a lubricating oil composition comprising:

- 5 (a) a major amount of an oil of lubricating viscosity; and
 (b) at least one foam inhibitor selected from the group consisting of silicon oils,
 polysiloxanes, polyacrylates, and polymethacrylates;

wherein the foam inhibitor is not poly(phenylmethyl) siloxane; and further wherein the amount of said foam inhibitor in said lubricating oil composition is at an effective concentration to
10 achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with said lubricating oil composition without any foam inhibitor.

Another embodiment of the present invention is directed to a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine, the method comprising:

- 15 (a) operating said engine with a lubricating oil; and
 (b) top treating said lubricating oil composition with a lubricating oil concentrate comprising at least one foam inhibitor selected from the group consisting of silicon oils, polysiloxanes, polyacrylates, and polymethacrylates to thereby provide a top treated lubricating oil composition;

20 wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the amount of said foam inhibitor in said top treated lubricating oil composition is at an effective concentration to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with the lubricating oil of step (a) without any top treatment.

25 In accordance with another embodiment, there is provided use of a foam inhibitor selected from the group consisting of polysiloxanes and polymethacrylates in a lubricating oil composition comprising a major amount of an oil of lubricating viscosity for reducing intake valve deposits in a Direct Injection Spark Ignition engine by at least 10% compared to operating the engine with said lubricating oil composition without any foam inhibitor; wherein the
30 concentration of said foam inhibitor in said lubricating oil composition is from 30 to 500 ppmw; and wherein the foam inhibitor is not poly (phenyl-methyl) siloxane.

35 In accordance with another embodiment, there is provided a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine that is equipped with positive crankcase ventilation, the method comprising operating the engine with a lubricating oil composition comprising: (a) a major amount of an oil of lubricating viscosity; and (b) at least

5 one foam inhibitor selected from the group consisting of polysiloxanes and polymethacrylates;
wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the
concentration of said foam inhibitor in said lubricating oil composition is from 30 to 500 ppmw
to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition
10 engine compared to operating the engine with said lubricating oil composition without any foam
inhibitor.

In accordance with another embodiment, there is provided a method for reducing intake
valve deposits in a Direct Injection Spark Ignition engine that is equipped with positive
crankcase ventilation, the method comprising: (a) operating said engine with a lubricating oil;
(b) top treating said lubricating oil with a lubricating oil concentrate comprising at least one
15 foam inhibitor selected from the group consisting of polysiloxanes and polymethacrylates to
thereby provide a top treated lubricating oil composition; wherein the foam inhibitor is not poly
(phenyl-methyl) siloxane; and further wherein the final concentration of said foam inhibitor in
said top treated lubricating oil composition is from 30 to 500 ppmw to achieve at least 10%
reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to
20 operating the engine with the lubricating oil in step (a) without any top treatment, optionally
wherein the concentration of said foam inhibitor in said lubricating oil concentrate is from 0.01
to 1.0 wt-%, or from 0.02 to 0.8 wt-%, or from 0.03 to 0.7 wt-%, or from 0.04 to 0.6 wt-%.

In another embodiment, the lubricating oil composition disclosed herein further
comprises at least one additive selected from the group consisting of antioxidants, antiwear
25 agents, detergents, rust inhibitors, demulsifiers, friction modifiers, extreme pressure agents,
viscosity index improvers, pour point depressants, dispersants, corrosion inhibitors, and
combinations thereof.

DEFINITIONS

The term “top treating” means adding the lubricating oil concentrate described herein to
30 the crankcase oil already present in the DISI engine.

DETAILED DESCRIPTION OF THE INVENTION

Among other factors, the present invention is based on the surprising discovery that the
addition of larger than typical amounts of foam inhibiting additives to lubricants used to
lubricate direct injection gasoline engines can substantially decrease the amount of intake valve
35 deposits in said engines. The typical amount of foam inhibiting additives used in many

5 lubricants varies from about 5 to about 30 ppmw. The increased amount of added foam inhibitor is quite small, and enables a large reduction in IVD deposits without the use of expensive specialty lubricants or base oils such as polyalphaolefins (Group IV) or ester (Group V) lubricants. This finding also enables the aftermarket addition of small amounts of foam inhibitor boosters in gasoline direct injection engines lubricated with conventional lubricants.

10 In accordance with one embodiment of the present invention, provided herein is a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine, the method comprising operating the engine with a lubricating oil composition comprising:

- (a) a major amount of an oil of lubricating viscosity; and
- (b) at least one foam inhibitor selected from the group consisting of silicon oils,
15 polysiloxanes, polyacrylates, and polymethacrylates;

wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the amount of said foam inhibitor in said lubricating oil composition is at an effective concentration to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with said lubricating oil composition without any foam
20 inhibitor.

In accordance with another embodiment of the present invention, provided herein is a method for reducing intake valve deposits in a Direct Injection Spark Ignition engine, the method comprising:

- (a) operating said engine with a lubricating oil; and
- 25 (b) top treating said lubricating oil with a lubricating oil concentrate comprising at least one foam inhibitor selected from the group consisting of silicon oils, polysiloxanes, polyacrylates, and polymethacrylates to thereby provide a top treated lubricating oil composition;

wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the amount of said foam inhibitor in said top treated lubricating oil composition is at an effective
30 concentration to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with the lubricating oil step (a) without any top treatment.

In one embodiment of the invention the Direct Injection Spark Ignition engine is an engine that
35 is equipped with positive crankcase ventilation. Positive crankcase ventilation is a method for reducing emissions in an engine in which combustion gases that escape from the combustion chamber past the piston and piston rings into the crankcase (often called "blow-by") are returned

5 through the intake manifold to the combustion chamber, where the re-circulated hydrocarbons are burned.

THE OIL OF LUBRICATING VISCOSITY:

The oil of lubricating viscosity for use in the lubricating oil compositions of the present invention, also referred to as a base oil, is typically present therein in a major amount, e.g., an
10 amount of greater than 50 wt. %, preferably greater than about 70 wt. %, more preferably from about 80 to about 99.5 wt. % and most preferably from about 85 to about 98 wt. %, based on the total weight of the composition. The expression "base oil" as used herein shall be understood to mean a base stock or blend of base stocks which is a lubricant component that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's
15 location); that meets the same manufacturer's specification; and that is identified by a unique formula, product identification number, or both.

The base oil for use herein can be any presently known or later-discovered oil of lubricating viscosity used in formulating lubricating oil compositions for any and all such applications, e.g., engine oils, marine cylinder oils, functional fluids such as hydraulic oils, gear
20 oils, transmission fluids, etc. The selection of the particular base oil depends on the contemplated application of the lubricant and the presence of other additives. For example, the oil of lubricating viscosity useful in the practice of the invention may range in viscosity from light distillate mineral oils to heavy lubricating oils such as gasoline engine oils, mineral lubricating oils and heavy duty diesel oils. Additionally, the base oils for use herein can
25 optionally contain viscosity index improvers, e.g., polymeric alkylmethacrylates; olefinic copolymers, e.g., an ethylene-propylene copolymer or a styrene-butadiene copolymer; and the like and mixtures thereof. The lubricating oil compositions of this invention can be prepared by admixing, by conventional techniques, an appropriate amount of the foam inhibitor compounds disclosed herein in an additive concentrate with an oil of lubricating viscosity and conventional
30 lubricating oil additives

As one skilled in the art would readily appreciate, the viscosity of the base oil is dependent upon the application. Accordingly, the viscosity of a base oil for use herein will ordinarily range from about 2 to about 2000 centistokes (cSt) at 100° Centigrade (C). Generally, individually the base oils used as engine oils will have a kinematic viscosity range at 100°C of
35 about 2 cSt to about 30 cSt, preferably about 3 cSt to about 16 cSt, and most preferably about 4 cSt to about 12 cSt and will be selected or blended depending on the desired end use and the additives in the finished oil to give the desired grade of engine oil, e.g., a lubricating oil

5 composition having an SAE Viscosity Grade of 0W, 0W-20, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W-50, 5W-60, 10W, 10W-20, 10W-30, 10W-40, 10W-50, 15W, 15W-20, 15W-30 or 15W-40. Oils used as gear oils can have viscosities ranging from about 2 cSt to about 2000 cSt at 100°C.

10 Base stocks may be manufactured using a variety of different processes including, but not limited to, distillation, solvent refining, hydrogen processing, oligomerization, esterification, and rerefining. Rerefined stock shall be substantially free from materials introduced through manufacturing, contamination, or previous use. The base oil of the lubricating oil compositions of this invention may be any natural or synthetic lubricating base oil. Suitable hydrocarbon synthetic oils include, but are not limited to, oils prepared from the polymerization of ethylene or from the polymerization of 1-olefins to provide polymers such as polyalphaolefin or PAO
15 oils, or from hydrocarbon synthesis procedures using carbon monoxide and hydrogen gases such as in a Fischer-Tropsch process. For example, a suitable base oil is one that comprises little, if any, heavy fraction; e.g., little, if any, lube oil fraction of viscosity 20 cSt or higher at 100°C.

20 The base oil may be derived from natural lubricating oils, synthetic lubricating oils or mixtures thereof. Suitable base oil includes base stocks obtained by isomerization of synthetic wax and slack wax, as well as hydrocracked base stocks produced by hydrocracking (rather than solvent extracting) the aromatic and polar components of the crude. Suitable base oils include those in all API categories I, II, III, IV and V as defined in API Publication 1509, 14th Edition, Addendum I, Dec. 1998. Group IV base oils are polyalphaolefins (PAO). Group V base oils
25 include all other base oils not included in Group I, II, III, or IV.

As will be demonstrated herein, an advantage of the present invention is that low amounts of IVD can be obtained without the use of large amounts of expensive Group IV or Group V basestocks. Accordingly, in one embodiment of the present invention, the oil of lubricating viscosity comprises at least 50 wt-% of a Group III basestock. In another
30 embodiment of the present invention, the oil of lubricating viscosity comprises at least 50 wt-% of an API Group II basestock. In a further embodiment of the present invention, the oil of lubricating viscosity comprises at least 50 wt-% of a mixture of Group II and Group III basestocks. In one embodiment of the present invention, the oil of lubricating viscosity does not contain either a Group IV or a Group V basestocks. In one embodiment of the present invention,
35 the base oil is a mixture of Group II, Group III, and Group IV basestocks.

Natural oils may also be employed and include mineral lubricating oils such as, for example, liquid petroleum oils, solvent-treated or acid-treated mineral lubricating oils of the

5 paraffinic, naphthenic or mixed paraffinic-naphthenic types, oils derived from coal or shale, animal oils, vegetable oils (e.g., rapeseed oils, castor oils and lard oil), and the like.

Synthetic lubricating oils may also be employed and include, but are not limited to, hydrocarbon oils and halo-substituted hydrocarbon oils such as polymerized and
10 interpolymerized olefins, e.g., polybutylenes, polypropylenes, propylene-isobutylene copolymers, chlorinated polybutylenes, poly(1-hexenes), poly(1-octenes), poly(1-decenes), and the like and mixtures thereof; alkylbenzenes such as dodecylbenzenes, tetradecylbenzenes, dinonylbenzenes, di(2-ethylhexyl)-benzenes, and the like; polyphenyls such as biphenyls, terphenyls, alkylated polyphenyls, and the like; alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivative, analogs and homologs thereof and the like.

15 Other synthetic lubricating oils employed include, but are not limited to, oils made by polymerizing olefins of less than 5 carbon atoms such as ethylene, propylene, butylenes, isobutene, pentene, and mixtures thereof. Methods of preparing such polymer oils are well known to those skilled in the art.

Additional synthetic hydrocarbon oils employed include liquid polymers of alpha olefins
20 having the proper viscosity. Especially useful synthetic hydrocarbon oils are the hydrogenated liquid oligomers of C₆ to C₁₂ alpha olefins such as, for example, 1-decene trimer.

Another class of synthetic lubricating oils include, but are not limited to, alkylene oxide polymers, i.e., homopolymers, interpolymers, and derivatives thereof where the terminal hydroxyl groups have been modified by, for example, esterification or etherification. These oils
25 are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and phenyl ethers of these polyoxyalkylene polymers (e.g., methyl polypropylene glycol ether having an average molecular weight of 1,000, diphenyl ether of polyethylene glycol having a molecular weight of 500 to 1000, diethyl ether of polypropylene glycol having a molecular weight of 1,000 to 1,500, etc.) or mono- and polycarboxylic esters
30 thereof such as, for example, the acetic esters, mixed C₃-C₈ fatty acid esters, or the C₁₃ oxo acid diester of tetraethylene glycol.

Yet another class of synthetic lubricating oils include, but are not limited to, the esters of dicarboxylic acids e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid
35 dimer, malonic acids, alkyl malonic acids, alkenyl malonic acids, etc., with a variety of alcohols, e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc. Specific examples of these esters include

5 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, the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid and the like.

10 Esters may also be employed as synthetic oils and include, but are not limited to, those made from carboxylic acids having from about 5 to about 12 carbon atoms with alcohols, e.g., methanol, ethanol, etc., polyols and polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, and the like.

15 Silicon-based oils such as, for example, polyalkyl-, polyaryl-, polyalkoxy- or polyaryloxy-siloxane oils and silicate oils, comprise another class of synthetic lubricating oils which may be employed in the present invention. Specific examples of these include, but are not limited to, tetraethyl silicate, tetra-isopropyl silicate, tetra-(2-ethylhexyl) silicate, tetra-(4-methyl-hexyl) silicate, tetra-(p-tert-butylphenyl) silicate, hexyl-(4-methyl-2-pentoxy) disiloxane, poly (methyl) siloxanes, poly (methylphenyl) siloxanes, and the like.

20 The lubricating oil may be derived from unrefined, refined and rerefined oils, either natural, synthetic or mixtures of two or more of any of these of the type disclosed hereinabove. Unrefined oils are those obtained directly from a natural or synthetic source (e.g., coal, shale, or tar sands bitumen) without further purification or treatment. Examples of unrefined oils include, but are not limited to, a shale oil obtained directly from retorting operations, a petroleum oil
25 obtained directly from distillation or an ester oil obtained directly from an esterification process, each of which is then used without further treatment. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. These purification techniques are known to those of skill in the art and include, for example, solvent extractions, secondary distillation, acid or base extraction, filtration,
30 percolation, hydrotreating, dewaxing, etc. Rerefined oils are obtained by treating used oils in processes similar to those used to obtain refined oils. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives and oil breakdown products.

35 Lubricating oil base stocks derived from the hydroisomerization of wax may also be used, either alone or in combination with the aforesaid natural and/or synthetic base stocks. Such wax isomerate oil is produced by the hydroisomerization of natural or synthetic waxes or mixtures thereof over a hydroisomerization catalyst.

5 Natural waxes are typically the slack waxes recovered by the solvent dewaxing of mineral oils; synthetic waxes are typically the wax produced by the Fischer-Tropsch process.

FOAM INHIBITORS:

A foam inhibitor is a lubricant additive that, when added in small amounts to a lubricant, either inhibits the formation of foam, accelerates the breaking of foam, or both. At least one
10 foam inhibitor or mixtures thereof is employed in the lubricating oil composition of the presently claimed invention. The foam inhibitor employed is selected from the group consisting of silicon oils, polysiloxanes, polyacrylates, polymethacrylates, and combinations thereof, provided that the foam inhibitor may not be poly (phenyl-methyl) siloxane.

In one embodiment, the foam inhibitor is a poly dimethyl siloxane.

15 In one embodiment, the foam inhibitor is a poly (dimethyl, phenyl-methyl) siloxane. In one embodiment, the foam inhibitor is a mixture of poly dimethyl siloxane and poly (dimethyl, phenyl-methyl) siloxane.

In one embodiment, the foam inhibitor is a polymethacrylate.

In one embodiment, the foam inhibitor is a poly (trifluoropropylmethyl) siloxane.

20 In one embodiment, the amount of the foam inhibitor in the lubricating oil composition may vary from about 30 to about 500 ppmw, or from about 50 to about 500 ppmw, or from about 75 to about 500 ppmw, or from about 100 to about 500 ppmw, or from about 150 to about 500 ppmw, or from about 200 ppmw to about 400 ppmw, based on the total weight of the lubricating oil composition.

25 In one embodiment, the reduction in intake valve deposits is at least 10%, or at least 20%, or at least 30%, or at least 40%, or at least 50% compared to operating the engine with the lubricating oil composition without any foam inhibitor.

In one embodiment, the amount of the foam inhibitor in the lubricating oil concentrate may vary from about 0.01 wt.% to about 1 wt.%, from about 0.02 wt.% to about 0.8 wt.%,
30 from about 0.03 wt.% to about 0.7 wt.%, or from about 0.04 wt.% to about 0.6 wt.%, based on the total weight of the lubricating oil concentrate. The foam inhibitor can be conveniently added to the lubricating oil concentrate in the form of a foam inhibitor concentrate, which contains the foam inhibitor and at least one solvent.

ADDITIONAL LUBRICATING OIL ADDITIVES:

35 The lubricating oil compositions of the present invention may also contain other conventional additives for imparting auxiliary functions to give a finished lubricating oil composition in which these additives are dispersed or dissolved. For example, the lubricating

5 oil compositions can be blended with antioxidants, anti-wear agents, ashless dispersants, detergents, rust inhibitors, dehazing agents, demulsifying agents, metal deactivating agents, friction modifiers, pour point depressants, co-solvents, package compatibilisers, corrosion-inhibitors, dyes, extreme pressure agents and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous
10 compounds, may be employed for the preparation of the lubricating oil compositions of the invention by the usual blending procedures.

Examples of antioxidants include, but are not limited to, aminic types, e.g., diphenylamine, phenyl-alpha-naphthyl-amine, N,N-di(alkylphenyl) amines; and alkylated phenylene-diamines; phenolics such as, for example, BHT, sterically hindered alkyl phenols
15 such as 2,6-di-tert-butylphenol, 2,6-di-tert-butyl-p-cresol and 2,6-di-tert-butyl-4-(2-octyl-3-propanoic) phenol; and mixtures thereof.

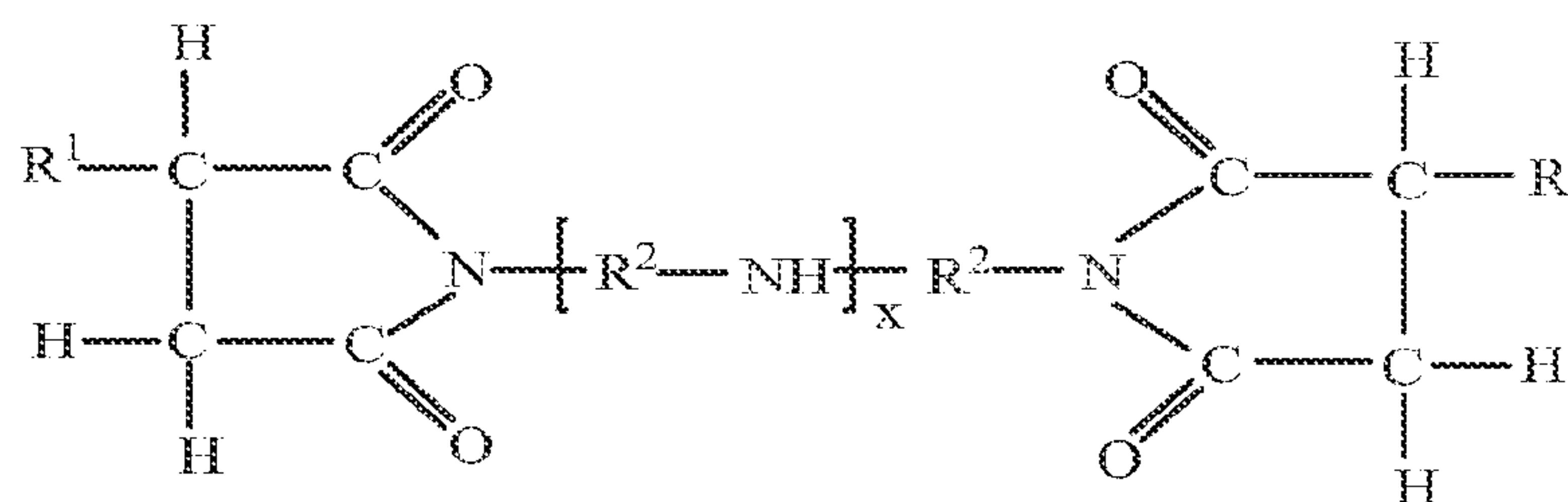
Examples of antiwear agents include, but are not limited to, zinc dialkyldithiophosphates and zinc diaryldithiophosphates, e.g., those described in an article by Born et al. entitled
20 "Relationship between Chemical Structure and Effectiveness of some Metallic Dialkyl- and Diaryl-dithiophosphates in Different Lubricated Mechanisms", appearing in Lubrication Science 4-2 January 1992, see for example pages 97-100; aryl phosphates and phosphites, sulfur-containing esters, phosphosulfur compounds, metal or ash-free dithiocarbamates, xanthates, alkyl sulfides and the like and mixtures thereof.

Representative examples of ashless dispersants include, but are not limited to, amines,
25 alcohols, amides, or ester polar moieties attached to the polymer backbones via bridging groups. An ashless dispersant of the present invention may be, for example, selected from oil soluble salts, esters, amino-esters, amides, imides, and oxazolines of long chain hydrocarbon substituted mono and dicarboxylic acids or their anhydrides; thiocarboxylate derivatives of long chain hydrocarbons, long chain aliphatic hydrocarbons having a polyamine attached directly thereto;
30 and Mannich condensation products formed by condensing a long chain substituted phenol with formaldehyde and polyalkylene polyamine.

Carboxylic dispersants are reaction products of carboxylic acylating agents (acids, anhydrides, esters, etc.) comprising at least about 34 and preferably at least about 54 carbon
35 atoms with nitrogen containing compounds (such as amines), organic hydroxy compounds (such as aliphatic compounds including monohydric and polyhydric alcohols, or aromatic compounds including phenols and naphthols), and/or basic inorganic materials. These reaction products include imides, amides, and esters.

5 Succinimide dispersants are a type of carboxylic dispersant. They are produced by reacting hydrocarbyl-substituted succinic acylating agent with organic hydroxy compounds, or with amines comprising at least one hydrogen atom attached to a nitrogen atom, or with a mixture of the hydroxy compounds and amines. The term "succinic acylating agent" refers to a hydrocarbon-substituted succinic acid or a succinic acid-producing compound, the latter
10 encompasses the acid itself. Such materials typically include hydrocarbyl-substituted succinic acids, anhydrides, esters (including half esters) and halides.

Succinic-based dispersants have a wide variety of chemical structures. One class of succinic-based dispersants may be represented by the formula:



15 wherein each R^1 is independently a hydrocarbyl group, such as a polyolefin-derived group. Typically the hydrocarbyl group is an alkyl group, such as a polyisobutyl group. Alternatively expressed, the R^1 groups can contain about 40 to about 500 carbon atoms, and these atoms may be present in aliphatic forms. R^2 is an alkylene group, commonly an ethylene (C_2H_4) group. Examples of succinimide dispersants include those described in, for example, U.S. Patent Nos.
20 3,172,892, 4,234,435 and 6,165,235.

The polyalkenes from which the substituent groups are derived are typically homopolymers and interpolymers of polymerizable olefin monomers of 2 to about 16 carbon atoms, and usually 2 to 6 carbon atoms. The amines which are reacted with the succinic acylating agents to form the carboxylic dispersant composition can be monoamines or
25 polyamines.

Succinimide dispersants are referred to as such since they normally contain nitrogen largely in the form of imide functionality, although the amide functionality may be in the form of amine salts, amides, imidazolines as well as mixtures thereof. To prepare a succinimide dispersant, one or more succinic acid-producing compounds and one or more amines are heated
30 and typically water is removed, optionally in the presence of a substantially inert organic liquid solvent/diluent. The reaction temperature can range from about $80^\circ C$ up to the decomposition temperature of the mixture or the product, which typically falls between about $100^\circ C$ to about

5 300°C. Additional details and examples of procedures for preparing the succinimide dispersants of the present invention include those described in, for example, U.S. Patent Nos. 3,172,892, 3,219,666, 3,272,746, 4,234,435, 6,165,235 and 6,440,905.

Suitable ashless dispersants may also include amine dispersants, which are reaction products of relatively high molecular weight aliphatic halides and amines, preferably polyalkylene polyamines. Examples of such amine dispersants include those described in, for
10 example, U.S. Patent Nos. 3,275,554, 3,438,757, 3,454,555 and 3,565,804.

Suitable ashless dispersants may further include "Mannich dispersants," which are reaction products of alkyl phenols in which the alkyl group contains at least about 30 carbon atoms with aldehydes (especially formaldehyde) and amines (especially polyalkylene polyamines). Examples of such dispersants include those described in, for example, U.S. Patent
15 Nos. 3,036,003, 3,586,629, 3,591,598 and 3,980,569.

Suitable ashless dispersants may also be post-treated ashless dispersants such as post-treated succinimides, e.g., post-treatment processes involving borate or ethylene carbonate as disclosed in, for example, U.S. Patent Nos. 4,612,132 and 4,746,446; and the like as well as
20 other post-treatment processes. The carbonate-treated alkenyl succinimide is a polybutene succinimide derived from polybutenes having a molecular weight of about 450 to about 3000, preferably from about 900 to about 2500, more preferably from about 1300 to about 2400, and most preferably from about 2000 to about 2400, as well as mixtures of these molecular weights. Preferably, it is prepared by reacting, under reactive conditions, a mixture of a polybutene
25 succinic acid derivative, an unsaturated acidic reagent copolymer of an unsaturated acidic reagent and an olefin, and a polyamine, such as disclosed in U.S. Patent No. 5,716,912.

Suitable ashless dispersants may also be polymeric, which are interpolymers of oil-solubilizing monomers such as decyl methacrylate, vinyl decyl ether and high molecular weight olefins with monomers containing polar substitutes. Examples of polymeric dispersants include
30 those described in, for example, U.S. Patent Nos. 3,329,658; 3,449,250 and 3,666,730.

In one preferred embodiment of the present invention, an ashless dispersant for use in the lubricating oil composition is a bis-succinimide derived from a polyisobutenyl group having a number average molecular weight of about 700 to about 2300. The dispersant(s) for use in the lubricating oil compositions of the present invention are preferably non-polymeric (e.g., are
35 mono- or bis-succinimides).

5 Generally, the one or more ashless dispersants are present in the lubricating oil composition in an amount ranging from about 0.01 wt. % to about 10 wt. %, based on the total weight of the lubricating oil composition.

 Representative examples of metal detergents include sulphonates, alkylphenates, sulfurized alkyl phenates, carboxylates, salicylates, phosphonates, and phosphinates. Commercial products are generally referred to as neutral or overbased. Overbased metal detergents are generally produced by carbonating a mixture of hydrocarbons, detergent acid, for example: sulfonic acid, alkylphenol, carboxylate etc., metal oxide or hydroxides (for example calcium oxide or calcium hydroxide) and promoters such as xylene, methanol and water. For example, for preparing an overbased calcium sulfonate, in carbonation, the calcium oxide or
10 hydroxide reacts with the gaseous carbon dioxide to form calcium carbonate. The sulfonic acid is neutralized with an excess of CaO or Ca(OH)₂, to form the sulfonate.
15

 Metal-containing or ash-forming detergents function as both detergents to 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
20 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 would typically have a total base number or TBN (as can be measured by ASTM D2896) of from 0 to about 80. 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
25 the outer layer of a metal base (e.g., carbonate) micelle. Such overbased detergents may have a TBN of about 150 or greater, and typically will have a TBN of from about 250 to about 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 magnesium with sodium. Particularly convenient metal detergents
30 are neutral and overbased calcium sulfonates having TBN of from about 20 to about 450, neutral and overbased calcium phenates and sulfurized phenates having TBN of from about 50 to about 450 and neutral and overbased magnesium or calcium salicylates having a TBN of from about
35

5 20 to about 450. Combinations of detergents, whether overbased or neutral or both, may be used.

In one embodiment, the detergent can be one or more alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid. Suitable hydroxyaromatic compounds include mononuclear monohydroxy and polyhydroxy aromatic hydrocarbons having 1 to 4, and preferably 1 to 3, hydroxyl groups. Suitable hydroxyaromatic compounds include phenol, catechol, resorcinol, hydroquinone, pyrogallol, cresol, and the like. The preferred hydroxyaromatic compound is phenol.

The alkyl substituted moiety of the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is derived from an alpha olefin having from about 10 to about 80 carbon atoms. The olefins employed may be linear, isomerized linear, branched or partially branched linear. The olefin may be a mixture of linear olefins, a mixture of isomerized linear olefins, a mixture of branched olefins, a mixture of partially branched linear or a mixture of any of the foregoing.

In one embodiment, the mixture of linear olefins that may be used is a mixture of normal alpha olefins selected from olefins having from about 12 to about 30 carbon atoms per molecule. In one embodiment, the normal alpha olefins are isomerized using at least one of a solid or liquid catalyst.

In another embodiment, the olefins are a branched olefinic propylene oligomer or mixture thereof having from about 20 to about 80 carbon atoms, i.e., branched chain olefins derived from the polymerization of propylene. The olefins may also be substituted with other functional groups, such as hydroxy groups, carboxylic acid groups, heteroatoms, and the like. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from about 20 to about 60 carbon atoms. In one embodiment, the branched olefinic propylene oligomer or mixtures thereof have from about 20 to about 40 carbon atoms.

30 In one embodiment, at least about 75 mole% (e.g., at least about 80 mole%, at least about 85 mole%, at least about 90 mole%, at least about 95 mole%, or at least about 99 mole%) of the alkyl groups contained within the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid such as the alkyl groups of an alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid detergent are a C₂₀ or higher. In another embodiment, the alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid that is derived

5 from an alkyl-substituted hydroxybenzoic acid in which the alkyl groups are the residue of normal alpha-olefins containing at least 75 mole% C₂₀ or higher normal alpha-olefins.

In another embodiment, at least about 50 mole % (e.g., at least about 60 mole %, at least about 70 mole %, at least about 80 mole %, at least about 85 mole %, at least about 90 mole %, at least about 95 mole %, or at least about 99 mole %) of the alkyl groups contained within the
10 alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid such as the alkyl groups of an alkali or alkaline earth metal salt of an alkyl-substituted hydroxybenzoic acid are about C₁₄ to about C₁₈.

The resulting alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid will be a mixture of ortho and para isomers. In one embodiment, the product will
15 contain about 1 to 99% ortho isomer and 99 to 1% para isomer. In another embodiment, the product will contain about 5 to 70% ortho and 95 to 30% para isomer.

The alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid can be neutral or overbased. Generally, an overbased alkali or alkaline earth metal salt of an alkyl-substituted hydroxyaromatic carboxylic acid is one in which the BN of the
20 alkali or alkaline earth metal salts of an alkyl-substituted hydroxyaromatic carboxylic acid has been increased by a process such as the addition of a base source (e.g., lime) and an acidic overbasing compound (e.g., carbon dioxide).

Overbased salts may be low overbased, e.g., an overbased salt having a BN below about 100. In one embodiment, the BN of a low overbased salt may be from about 5 to about 50. In
25 another embodiment, the BN of a low overbased salt may be from about 10 to about 30. In yet another embodiment, the BN of a low overbased salt may be from about 15 to about 20.

Overbased detergents may be medium overbased, e.g., an overbased salt having a BN from about 100 to about 250. In one embodiment, the BN of a medium overbased salt may be from about 100 to about 200. In another embodiment, the BN of a medium overbased salt may
30 be from about 125 to about 175.

Overbased detergents may be high overbased, e.g., an overbased salt having a BN above about 250. In one embodiment, the BN of a high overbased salt may be from about 250 to about 450.

Sulfonates may be prepared from sulfonic acids which are typically obtained by the
35 sulfonation of alkyl substituted aromatic hydrocarbons such as those obtained from the fractionation of petroleum or by the alkylation of aromatic hydrocarbons. Examples included those obtained by alkylating benzene, toluene, xylene, naphthalene, diphenyl or their halogen

5 derivatives. 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 more carbon atoms, preferably from about 16 to about 60 carbon atoms per alkyl substituted aromatic moiety.

10 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 having regard to the desired TBN of the final product but typically ranges from about 100 to about 220 wt. % (preferably at least about 125 wt. %) of that stoichiometrically required.

15 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 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.

20 Generally, the one or more detergents are present in the lubricating oil composition in an amount ranging from about 0.01 wt. % to about 10 wt. %, based on the total weight of the lubricating oil composition.

25 Examples of rust inhibitors include, but are not limited to, nonionic polyoxyalkylene agents, e.g., polyoxyethylene lauryl ether, polyoxyethylene higher alcohol ether, polyoxyethylene nonylphenyl ether, polyoxyethylene octylphenyl ether, polyoxyethylene octyl stearyl ether, polyoxyethylene oleyl ether, polyoxyethylene sorbitol monostearate, polyoxyethylene sorbitol monooleate, and polyethylene glycol monooleate; stearic acid and other fatty acids; dicarboxylic acids; metal soaps; fatty acid amine salts; metal salts of heavy sulfonic acid; partial carboxylic acid ester of polyhydric alcohol; phosphoric esters; (short-chain) 30 alkenyl succinic acids; partial esters thereof and nitrogen-containing derivatives thereof; synthetic alkarylsulfonates, e.g., metal dinonylnaphthalene sulfonates; and the like and mixtures thereof.

35 Examples of friction modifiers include, but are not limited to, alkoxyated fatty amines; borated fatty epoxides; fatty phosphites, fatty epoxides, fatty amines, borated alkoxyated fatty amines, metal salts of fatty acids, fatty acid amides, glycerol esters, borated glycerol esters; and fatty imidazolines as disclosed in U.S. Patent No. 6,372,696; friction modifiers obtained from a reaction product of a C₄ to C₇₅,

5 preferably a C₆ to C₂₄, and most preferably a C₆ to C₂₀, fatty acid ester and a nitrogen-containing compound selected from the group consisting of ammonia, and an alkanolamine and the like and mixtures thereof.

10 Examples of a pour point depressant include, but are not limited to, polymethacrylates, alkyl acrylate polymers, alkyl methacrylate polymers, di(tetra-paraffin phenol)phthalate, condensates of tetra-paraffin phenol, condensates of a chlorinated paraffin with naphthalene and combinations thereof. In one embodiment, a pour point depressant comprises an ethylene-vinyl acetate copolymer, a condensate of chlorinated paraffin and phenol, polyalkyl styrene and the like and combinations thereof. The amount of the pour point depressant may vary from about 0.01 wt. % to about 10 wt. %.

15 Examples of a demulsifier include, but are not limited to, anionic surfactants (e.g., alkyl-naphthalene sulfonates, alkyl benzene sulfonates and the like), nonionic alkoxyated alkylphenol resins, polymers of alkylene oxides (e.g., polyethylene oxide, polypropylene oxide, block copolymers of ethylene oxide, propylene oxide and the like), esters of oil soluble acids, polyoxyethylene sorbitan ester and the like and combinations thereof. The amount of the demulsifier may vary from about 0.01 wt. % to about 10 wt. %.

20 Examples of a corrosion inhibitor include, but are not limited to, half esters or amides of dodecylsuccinic acid, phosphate esters, thiophosphates, alkyl imidazolines, sarcosines and the like and combinations thereof. The amount of the corrosion inhibitor may vary from about 0.01 wt. % to about 5 wt. %.

25 Examples of an extreme pressure agent include, but are not limited to, sulfurized animal or vegetable fats or oils, sulfurized animal or vegetable fatty acid esters, fully or partially esterified esters of trivalent or pentavalent acids of phosphorus, sulfurized olefins, dihydrocarbyl polysulfides, sulfurized Diels-Alder adducts, sulfurized dicyclopentadiene, sulfurized or co-sulfurized mixtures of fatty acid esters and monounsaturated olefins, co-sulfurized blends of fatty acid, fatty acid ester and alpha-olefin, functionally-substituted dihydrocarbyl polysulfides, thia-aldehydes, thia-ketones, epithio compounds, sulfur-containing acetal derivatives, co-sulfurized blends of terpene and acyclic olefins, and polysulfide olefin products, amine salts of phosphoric acid esters or thiophosphoric acid esters and the like and combinations thereof. The amount of the extreme pressure agent may vary from about 0.01 wt. % to about 5 wt. %.

35 Each of the foregoing additives, when used, is used at a functionally effective amount to impart the desired properties to the lubricant. Thus, for example, if an additive is a friction modifier, a functionally effective amount of this friction modifier would be an amount sufficient

5 to impart the desired friction modifying characteristics to the lubricant. Generally, the concentration of each of these additives, when used, may range, unless otherwise specified, from about 0.001% to about 20% by weight, and in one embodiment about 0.01% to about 10% by weight based on the total weight of the lubricating oil composition.

10 In another embodiment of the invention, the lubricating oil additives of the present invention may be provided as an additive package or concentrate in which the additives are incorporated into a substantially inert, normally liquid organic diluent such as, for example, mineral oil, naphtha, benzene, toluene or xylene to form an additive concentrate.

CONCENTRATES AND DILUENTS:

15 Lubricating oil concentrates are also contemplated herein. These concentrates usually include at least from about 90 wt. % to about 10 wt. %, or from about 80 wt. % to about 20 wt. %, or from about 70 wt. % to about 30 wt. %, or from about 60 wt. % to about 40 wt. % of a diluent oil, and from about 10 wt. % to about 90 wt. %, or from about 20 wt. % to about 80 wt. %, or from about 30 wt. % to about 70 wt. %, or from about 40 wt. % to about 60 wt. %, of the foam inhibitor described in the lubricating oil composition of the present invention, or
20 combinations thereof. Typically, the concentrates contain sufficient diluent to make them easy to handle during shipping and storage. Suitable diluents for the concentrates include any inert diluent, preferably an oil of lubricating viscosity, so that the concentrate may be readily mixed with lubricating oils to prepare lubricating oil compositions. Suitable lubricating oils that may be used as diluents typically have viscosity in the range from about 35 to about 500 Saybolt
25 Universal Seconds (SUS) at 100° F (38° C), although any oil of lubricating viscosity may be used.

If desired, other additives can be admixed with the foregoing lubricating oil concentrate to enhance performance. Examples of these additives include, but are not limited to antioxidants, antiwear agents, detergents, rust inhibitors, demulsifiers, friction modifiers, extreme pressure
30 agents, viscosity index improvers, pour point depressants, dispersants, corrosion inhibitors, and the like, at the usual levels in accordance with well known practice.

It is also contemplated that the foam inhibitors of the present invention, along with other additional additives described herein, may be employed as a top treatment for crankcase lubricants employed in DISI engines. When so employed, the top treatment lubricating oil
35 concentrate may be added at from about 0.01 to 5% by weight to the oil, or from about 0.5 to about 2% by weight to the oil, based on the total weight of the lubricant composition.

5 In another embodiment, the top treatment lubricating oil concentrate is added to the original DISI engine lubricating oil composition in an amount such that the final concentration of the foam inhibitor of the present invention is between 150 and 500 ppmw, and preferably between 200 and 400 ppmw, based on the total weight of the lubricant oil composition in the engine.

10 In one embodiment, the addition of the top treatment lubricating oil concentrate results in at least a 10% reduction in IVD compared to operating the engine with a lubricating oil without any top treatment lubricating oil concentrate.

In one embodiment, the addition of the top treatment lubricating oil concentrate results in at least a 20% reduction in IVD compared to operating the engine with a lubricating oil without any top treatment lubricating oil concentrate.

15 In one embodiment, the addition of the top treatment lubricating oil concentrate results in at least a 30% reduction in IVD compared to operating the engine with a lubricating oil without any top treatment lubricating oil concentrate.

In one embodiment, the addition of the top treatment lubricating oil concentrate results in at least a 40% reduction in IVD compared to operating the engine with a lubricating oil without any top treatment lubricating oil concentrate.

20 In one embodiment, the addition of the top treatment lubricating oil concentrate results in at least a 50% reduction in IVD compared to operating the engine with a lubricating oil without any top treatment lubricating oil concentrate.

25 **PERFORMANCE TESTING**

The lubricating oil compositions of Examples 1 and 2 below were evaluated using the 2001 Mitsubishi™ 1.8L DISI 212 hour Intake Valve Deposit Test (“Mitsubishi™ IVD Test”), described hereinafter. The 2001 Mitsubishi™ 1.8L DISI engine used in this procedure is mounted on an engine stand and connected to a dynamometer with load and speed control. The Mitsubishi™ DISI engine is a wall guided engine with capability to run both homogenous and lean-stratified combustion. For carrying out the tests described herein, the engine was run on a lean-stratified combustion mode.

30 The engine is first flushed with the oil to be tested,refilled with test oil, and then operated for 30 minutes running at the test cycle. The engine is then stopped, the oil drained,

5 and a fresh sample of test oil is added to the engine. The 212 hr test is then started, which consists of approximately 636 repeats of the test cycle. In the test cycle the engine is operated for 1 minute at idle speed (750 +/- 150 rpm) and no load, followed by 19 minutes of operation at low load (20.0 N/m) and low speed (1400 +/- 10 rpm). At 106 hours the engine is stopped, and the oil level checked, and if necessary additional test oil is added to the full mark.

10 After 212 hours, the engine head is removed and the intake valves as well as the combustion chamber are rated for the deposit weights. The eight intake valves (two per cylinder) in the engine are rinsed using hexane and weighed. Intake valves are weighed before and after the test and the difference in weight represent the weight of the deposit accumulated during the test.

15 **EXAMPLES**

The following non-limiting examples are illustrative of the present invention. The efficacy of the use of high concentrations of foam inhibitor crankcase lubricants for direct injection spark ignition engines was demonstrated by means of the 2001 Mitsubishi™ 1.8L DISI 212 hour Intake Valve Deposit Test (the “Mitsubishi™ IVD Test”), described above. All lubricants tested contained identical amounts of additives of the “baseline additive package” which includes dispersant, detergents, zinc dialkyldithiophosphate, aminic antioxidant, friction modifier, polymethacrylate pour point depressant, and olefin copolymer viscosity index improver, but no foam inhibitor additive.

GROUP III LUBRICANTS CONTAINING SILICONE FOAM INHIBITOR

25 Mitsubishi™ IVD Tests were performed on lubricants containing the baseline additive package in approximately 75 wt-% Yubase™ 4 Group III base oil and varying active ingredient concentrations of different foam inhibitors. Foam Inhibitor A was a poly (phenyl-methyl) siloxane; B a mixture of poly dimethyl siloxane and poly (dimethyl,phenyl-methyl) siloxane; C a polymethacrylate; D a poly (trifluoropropylmethyl) siloxane; and E a poly (dimethyl,phenyl-
30 methyl) siloxane. The results are shown in Table 1 below.

Table 1

	Comparative Example 1	Comparative Example 2	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
Foam inhibitor	None	A	B	B	B	C	D	E
Foam Inhibitor concentration, ppmw	0	200	30	200	350	300	50	350
IVD, average mg	141	150	85	38	52	89	122	105
% IVD Reduction	NA	NA	40	73	63	37	13	25

5 The results in Table 1 show the surprising effectiveness of different foam inhibitors in reducing intake valve deposits in Group III lubricants.

GROUP II/GROUP III/GROUP IV LUBRICANTS CONTAINING SILICONE FOAM INHIBITOR

10

Mitsubishi IVD Tests were performed on lubricants containing the baseline additive package in approximately 75 wt-% of a mixture containing (1) 50 wt-% PT 100D Group II base oil, (2) 30 wt-% Yubase 6 group III base oil, and (3) 20 wt-% PAO 8 Group IV base oil, and varying active ingredient concentrations of foam inhibitor B from above. The results are shown in Table 2 below.

15

Table 2

	Example 7	Example 8
Foam inhibitor	B	B
Foam Inhibitor concentration, ppmw	30	150
IVD, average mg	38	26

The results in Table 2 show that mixed Group II/Group III/Group IV lubricants containing a foam inhibitor of the invention also exhibit low amounts of intake valve deposits.

20

BMW 5W30 LUBRICATING OIL TOP TREATED WITH FOAM INHIBITOR:

Mitsubishi IVD Tests were performed on a commercial 5W30 lubricating oil which was top treated with 350 ppm active ingredient concentration of foam inhibitor B from above. The results are shown in Table 3 below.

5

Table 3

	Comparative Example 4	Example 4
	Baseline 5W30 Oil	Baseline 5W30 Oil + 350 ppmw Foam Inhibitor B
IVD, average mg	95	49
% IVD Reduction	NA	48

The results in Table 3 show the surprising effectiveness in reducing intake valve deposits of top treating a lubricating oil with a concentrate containing foam inhibitor.

10

5 **WHAT IS CLAIMED IS:**

1. Use of a foam inhibitor selected from the group consisting of polysiloxanes and polymethacrylates in a lubricating oil composition comprising a major amount of an oil of lubricating viscosity for reducing intake valve deposits in a Direct Injection Spark Ignition engine by at least 10% compared to operating the engine with said lubricating oil composition without any foam inhibitor;

10 wherein the concentration of said foam inhibitor in said lubricating oil composition is from 30 to 500 ppmw; and

 wherein the foam inhibitor is not poly (phenyl-methyl) siloxane.

2. The use of claim 1, wherein the foam inhibitor is selected from the group consisting of: polydimethyl siloxane, poly (dimethyl, phenyl-methyl) siloxane, poly (trifluoropropylmethyl) siloxane, and a mixture of polydimethyl siloxane and poly (dimethyl, phenyl-methyl) siloxane.

3. The use of claim 1 or 2, wherein the concentration of said foam inhibitor in said lubricating oil composition is from 100 to 500 ppmw, or 150 to 500 ppmw, or 200 to 400 ppmw.

4. The use of any one of claims 1 to 3, wherein the reduction of intake valve deposits is at least 20%, or at least 30%, or at least 40%, or at least 50%.

5. The use of any one of claims 1 to 4, wherein said lubricating oil composition further comprises at least one additive selected from the group consisting of: detergents, dispersants, antioxidants, anti-wear agents, rust inhibitors, dehazing agents, demulsifying agents, metal deactivating agents, friction modifiers, pour point depressants, co-solvents, package compatibilisers, corrosion inhibitors, dyes, extreme pressure agents, and mixtures thereof.

- 5 6. The use of any one of claims 1 to 5, wherein said oil of lubricating viscosity comprises at least 50 wt-% of an API Group II or a Group III base stock, or mixtures thereof.
7. The use of any one of claims 1 to 6, wherein the lubricating oil composition is top-treated with a lubricating oil concentrate comprising the foam inhibitor,
10 optionally wherein the concentration of said foam inhibitor in said lubricating oil concentrate is from 0.01 to 1.0 wt-%, or from 0.02 to 0.8 wt-%, or from 0.03 to 0.7 wt-%, or from 0.04 to 0.6 wt-%.
8. The use of any one of claims 1 to 7, wherein the Direct Injection Spark Ignition engine is equipped with positive crankcase ventilation.
- 15 9. A method for reducing intake valve deposits in a Direct Injection Spark Ignition engine that is equipped with positive crankcase ventilation, the method comprising operating the engine with a lubricating oil composition comprising:
- (a) a major amount of an oil of lubricating viscosity; and
- (b) at least one foam inhibitor selected from the group consisting of
20 polysiloxanes and polymethacrylates;
- wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the concentration of said foam inhibitor in said lubricating oil composition is from 30 to 500 ppmw to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with
25 said lubricating oil composition without any foam inhibitor.
10. A method for reducing intake valve deposits in a Direct Injection Spark Ignition engine that is equipped with positive crankcase ventilation, the method comprising:
- (a) operating said engine with a lubricating oil;
- 30 (b) top treating said lubricating oil with a lubricating oil concentrate comprising at least one foam inhibitor selected from the group consisting of

5 polysiloxanes and polymethacrylates to thereby provide a top treated lubricating oil composition;

wherein the foam inhibitor is not poly (phenyl-methyl) siloxane; and further wherein the final concentration of said foam inhibitor in said top treated lubricating oil composition is from 30 to 500 ppmw to achieve at least 10% reduction in intake valve deposits in said Direct Injection Spark Ignition engine compared to operating the engine with the lubricating oil in step (a) without any top treatment, optionally
10 wherein the concentration of said foam inhibitor in said lubricating oil concentrate is from 0.01 to 1.0 wt-%, or from 0.02 to 0.8 wt-%, or from 0.03 to 0.7 wt-%, or from 0.04 to 0.6 wt-%.

15 11. The method of claim 10, wherein the final concentration of said foam inhibitor in said top treated lubricating oil composition is from 100 to 500 ppmw, or from 150 to 500 ppmw, or from 200 to 400 ppmw.

12. The method of claim 10 or 11, wherein said top treated lubricating oil composition further comprises at least one additive selected from the group
20 consisting of: detergents, dispersants, antioxidants, anti-wear agents, rust inhibitors, dehazing agents, demulsifying agents, metal deactivating agents, friction modifiers, pour point depressants, co-solvents, package compatibilisers, corrosion inhibitors, dyes, extreme pressure agents, and mixtures thereof.

13. The method of any one of claims 9 to 12, wherein the foam inhibitor is
25 selected from the group consisting of: polydimethyl siloxane, poly (dimethyl, phenyl-methyl) siloxane, poly (trifluoropropylmethyl) siloxane, and a mixture of polydimethyl siloxane and poly (dimethyl, phenyl-methyl) siloxane.

14. The method of any one of claims 9 to 13, wherein the reduction of intake valve deposits is at least 20%, or least 30%, or at least 40%, or at least 50%.

30 15. The method of any one of claims 9 to 14, wherein said lubricating oil comprises at least 50 wt-% of an API Group II or a Group III base stock, or mixtures thereof.