

LUBRICATING OIL COMPOSITION

TECHNICAL FIELD

[001] The present disclosure relates to lubricants for use in engines operated under sustained high load conditions, such as natural gas-fueled engines and low-speed or medium-speed diesel-fueled engines, and to methods for enhancing the deposit control capacity of the lubricants used in such engines, particularly those equipped with steel pistons.

BACKGROUND

[002] It is known that internal combustion engines place enormous stresses on the lubricating oils. The oil is required to provide good lubrication under all conditions, provide protection against wear and corrosion, be stable to sustained levels of contamination, keep engine surfaces relatively clean, resist thermal and/or oxidative breakdown and carry away excess heat from the engine.

[003] While all engines place such stresses on these lubricating oils, stationary diesel-fueled and stationary natural gas-fueled engines are particularly challenging to the lubricating oil. For engines that routinely run continuously, near full load conditions, for many days or weeks, as in the case of stationary natural gas-fueled engines, and in remote locations, the demands placed on the oils used in such engines are of a sustained rather than transient nature, often with little or no monitoring and little or no opportunity to respond quickly to engine upsets or oil failure. This is further aggravated by the trend to higher loads and longer oil drain periods.

[004] Original equipment manufacturers (OEMs) in recent years have been designing internal combustion engines in ways to provide greater power density, that is, higher power produced per unit of displacement. A recent development in engine design has been to replace aluminum pistons with steel pistons to maintain the strength of pistons while operating at higher pressures and temperatures.

[005] Steel piston engines operating at high Brake Mean Effective Pressure (i.e., BMEP > 20 bar) have shown a propensity to form excessive deposits on mechanical components (e.g., pistons, piston rings, cylinder liners, etc.) leading to shorter component life when lubricated with conventional lubricant additive packages formulated with the highest viscosity cut of API group base oil (e.g., a heavy neutral base oil) to achieve the oil life characteristics desired.

[006] It has now been surprisingly found that partial substitution of the heavy neutral base oil with lighter neutral base stocks provides a lubricating oil composition which exhibits improved resistance to deposit formation in engines, particularly steel piston engines, operating under sustained high load conditions.

SUMMARY

[007] In one aspect, there is provided a natural gas engine lubricating oil composition comprising: (a) a first base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 8.5 to 15 mm²/s; and (b) a second base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 4.0 to less than 8.5 mm²/s; wherein the weight ratio of the first base oil component to the second base oil component is in a range of from 1:10 to 1:1.15.

[008] In another aspect, there is provided a low-speed or medium-speed diesel engine lubricating oil composition comprising: (a) a first base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 8.5 to 15 mm²/s; and (b) a second base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 4.0 to less than 8.5 mm²/s; wherein the weight ratio of the first base oil component to the second base oil component is in a range of from 1:10 to 1:1.15.

[009] In another aspect, there is provided a method of controlling deposit formation in an internal combustion engine selected from a natural gas engine, a low-speed diesel engine or a medium-speed diesel engine which comprises operating the internal combustion engine with the lubricating oil composition disclosed herein.

[010] In yet another aspect, there is provided the use of the lubricating oil composition described herein for the purpose of controlling deposit formation in an internal combustion engine selected from a natural gas engine, a low-speed diesel engine or a medium-speed diesel engine.

DETAILED DESCRIPTION

Terms

[011] A "major amount" means 50 wt. % or more of a composition.

[012] A "minor amount" means less than 50 wt. % of a composition.

[013] As employed herein, the terms "base stock" and "base oil" are used synonymously and interchangeably.

[014] A "dual-fuel engine" refers to an engine that can run on a mixture of natural gas and diesel. The combination of natural gas and diesel may comprise at least 60% natural gas.

[015] All percentages reported are weight % on an active ingredient basis (i.e., without regard to carrier or diluent oil) unless otherwise stated.

[016] All ASTM standards referred to herein are the most current versions as of the filing date of the present application.

Industrial Applicability

[017] The lubricating oil composition disclosed herein is utilized in a natural gas engine, a low-speed diesel engine or a medium-speed diesel engine. The engine may be a two-stroke engine, three-stroke engine, four-stroke engine, five-stroke engine, or six-stroke engine. The engine may also include any number of combustion chambers, pistons, and associated cylinders (e.g., 1-24). For example, in certain

embodiments, the engine may be a large-scale industrial reciprocating engine having 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 16, 18, 20, 24 or more pistons reciprocating in cylinders. In certain embodiments, the piston may be an aluminum piston or a steel piston (e.g., steel or any of a variety of steel alloys, such as 42CrMo4V or 38MnVS6).

[018] The natural gas engine may be a stationary natural gas engine, a stationary biogas engine, a stationary landfill gas engine, a stationary unconventional natural gas engine, or a dual-fuel engine.

[019] Diesel engines may generally be classified as low-speed, medium-speed or high-speed engines. Herein, a “low-speed” diesel engine means a compression-ignition internal combustion engine that is driven at a rotational speed that is less than 500 revolutions per minute (rpm), such as marine crosshead diesel engines; a “medium-speed” diesel engine means a compression-ignition internal combustion engine that is driven at a rotational speed of 500 to 1800 rpm, such as locomotive diesel engines, marine trunk piston diesel engines, or land-based stationary power diesel engines; and a “high-speed” diesel engine means a compression-ignition internal combustion engine that is driven at a rotational speed that is higher than 1800 rpm, such as diesel engines for highway vehicles.

[020] The lubricating oil composition disclosed herein may be utilized in controlling deposits in engines operating under high sustained load conditions, such as a Brake Mean Effective Pressure (BMEP) of at least 20 bar (2.0 MPa), e.g., at least 22 bar (2.2 MPa), at least 24 bar (2.4 MPa), at least 26 bar (2.6 MPa), 20 to 30 bar (2.0 to 3.0 MPa), 22 to 30 bar (2.2 to 3.0 MPa), 22 to 28 bar (2.2 to 2.8 MPa), or 24 to 30 bar (2.4 to 3.0 MPa).

[021] The lubricating oil composition of the present disclosure may provide advantaged deposit control performance in any of a number of mechanical components of an engine. The mechanical component may be a piston, a piston ring, a cylinder liner, a cylinder, a cam, a tappet, a lifter, a gear, a valve, a valve guide, or a bearing including a journal, a roller, a tapered, a needle, or a ball bearing. In some aspects, the mechanical component comprises steel.

Base Oils

[022] Groups I, II, III, IV and V are broad categories of base oil stocks developed and defined by the American Petroleum Institute (API Publication 1509 – Appendix E) to create guidelines for lubricant base oils. Group I base stocks contain less than 90% saturates and/or greater than 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120. Group II base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120. Group III base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 120. Group IV base stocks are polyalphaolefins. Group V base stocks include all other base stocks not included in Groups I, II, III or IV. Table 1 summarizes properties of each of these five groups.

TABLE 1

	<u>Base Oil Properties</u>		
Group ⁽¹⁾	Saturates ⁽²⁾	Sulfur ⁽³⁾	Viscosity Index ⁽⁴⁾
Group I	<90% and/or	>0.03%	80 to < 120
Group II	≥90%	≤0.03%	80 to < 120
Group III	≥90%	≤0.03%	≥ 120
Group IV	Polyalphaolefins (PAOs)		
Group V	All other base stocks not included in Groups I, II, III or IV		

⁽¹⁾ Groups I-III are mineral oil base stocks

⁽²⁾ ASTM D2007

⁽³⁾ ASTM D2622, ASTM D3120, ASTM D4294 or ASTM D4927

⁽⁴⁾ ASTM D2270

[023] The lubricating oil composition of the present disclosure is a mixture of at least two base oil components. The mixture of the at least two base oil components comprises a minor amount of first base oil component having a kinematic viscosity at 100°C of from 8.5 to 15.0 mm²/s (e.g., 9.0 to 14.0 mm²/s or 10.0 to 13.0 mm²/s or 10.0 to 12.0 mm²/s), which base oil component is selected from

one or more of a Group I base stock, a Group II base stock, and a Group III base stock, in combination with a major amount of a second base oil component having a kinematic viscosity at 100°C of from 4.0 to less than 8.5 mm²/s (e.g. 4.5 to 8.0 mm²/s, 5.0 to 8.0 mm²/s, or 5.0 to 7.5 mm²/s), which base oil component is selected from one or more of a Group I base stock, a Group II base stock and a Group III base stock. In some aspects, the first base oil component may be selected from a Group II base stock, a Group III base stock, or a combination thereof. On some aspects, the second base oil component may be selected from a Group II base stock, a Group III base stock, or a combination thereof.

[024] The first base oil component of high viscosity can be made up of a single base stock meeting the recited kinematic viscosity range or be made up of two or more base stocks, each meeting the recited kinematic viscosity limits.

[025] The second base oil component of low viscosity can be made up of a single base stock meeting the recited kinematic viscosity range or it may be made up of two or more base stocks, each of which meet the recited kinematic viscosity limit.

[026] The weight ratio of the first base oil component to the second base oil component may range from 1:10 to 1:1.15 (e.g., 1:10 to 1:6, 1:8 to 1:5, 1:5 to 1:1.15, 1:6 to 1:4, 1:4 to 1:2, 1:3 to 1:1.15, 1:6 to 1:2, or 1:3 to 1:1.15).

Lubricating Oil Composition

[027] The lubricating oil composition of this disclosure can be identified by viscosity standards of the Society of Automotive Engineers (SAE) for engine oils (i.e., the SAE J300 standard). The SAE J300 viscosity grades are summarized in Table 2.

TABLE 2

SAE Viscosity Grade	Low Temp. (°C) Cranking Viscosity ⁽¹⁾ , mPa-s Max	Low Temp. (°C) Pumping Viscosity ⁽²⁾ , mPa-s Max with No Yield Stress	Low Shear Rate Kinematic Viscosity ⁽³⁾ (mm ² /s) at 100°C Min	Low Shear Rate Kinematic Viscosity ⁽³⁾ (mm ² /s) at 100°C Max	High Shear Rate Viscosity ⁽⁴⁾ , (mPa-s) at 150°C Min
0W	6200 at -35	60000 at -40	3.8	-	-
5W	6600 at -30	60000 at -35	3.8	-	-
10W	7000 at -25	60000 at -30	4.1	-	-
15W	7000 at -20	60000 at -25	5.6	-	-
20W	9500 at -15	60000 at -20	5.6	-	-
25W	13000 at -10	60000 at -15	9.3	-	-
8	-	-	4.0	<6.1	1.7
12	-	-	5.0	<7.1	2.0
16	-	-	6.1	<8.2	2.3
20	-	-	6.9	<9.3	2.6
30	-	-	9.3	<12.5	2.9
40	-	-	12.5	<16.3	3.5 ⁽⁵⁾
40	-	-	12.5	<16.3	3.7 ⁽⁶⁾
50	-	-	16.3	<21.9	3.7
60	-	-	21.9	<26.1	3.7

⁽¹⁾ ASTM D5293⁽²⁾ ASTM D4684⁽³⁾ ASTM D445⁽⁴⁾ ASTM D4683, ASTM D4741, ASTM D5481 or CEC L-36-90⁽⁵⁾ For 0W-40, 5W-40 and 10W-40 grades⁽⁶⁾ For 15W-40, 20W-40, 25W-40 and 40 grades

[028] The lubricating oil composition of this disclosure may be a monograde engine oil, e.g., a SAE 20, SAE 30, SAE 40, SAE 50 or SAE 60 viscosity grade engine oil.

[029] The lubricating oil composition of this disclosure may be a multi-grade engine oil, e.g., an engine oil with a SAE viscosity grade of 15W-x, 20W-x or 25W-x, where x may be selected from 30, 40, 50, or 60.

[030] To obtain a finished lubricating oil composition having a desired viscosity grade, a thickener may be added to the lubricating oil composition to increase its viscosity. Any suitable thickener may be used such as polyisobutylene (PIB). PIB is a commercially available material from several manufacturers. Polyisobutylene is typically a viscous oil-miscible liquid having a number average molecular weight of 800 to 5000 (e.g., 1000 to 2500) and a kinematic viscosity at 100°C of 200 to 5000 mm²/s (e.g., 200 to 1000 mm²/s). The amount of PIB added to the lubricating oil composition will normally be from 1 to 20 wt. % (e.g., 2 to 15 wt. % or 4 to 12 wt. %) of the finished oil.

[031] The lubricating oil composition may contain low levels of sulfated ash, as determined by ASTM D874. The composition may have a sulfated ash content of less than 1.0 wt. % (e.g., less than 0.6 wt. % or even less than 0.15 wt. %), based on the total weight of the composition.

[032] In some embodiments, the lubricating oil composition may be substantially zinc-free.

[033] In some embodiments, the lubricating oil composition may be substantially free of bright stock.

Additional Additives

[034] The lubricating oil compositions of the present disclosure may contain one or more performance additives that can impart or improve any desirable property of the lubricating oil composition. Any additive known to those of skill in the art may be used in the lubricating oil composition disclosed herein. Some suitable additives have been described by R.M. Mortier *et al.* "Chemistry and Technology of Lubricants," 3rd Edition, Springer (2010) and L.R. Rudnik "Lubricant Additives: Chemistry and Applications," Second Edition, CRC Press (2009).

[035] In general, the concentration of each of the additives in the lubricating oil composition, when used, may range from 0.001 to 10 wt. % (e.g., 0.01 to 5 wt. %, or 0.05 to 2.5 wt. %) of the lubricating oil composition. Further, the total amount of additives in the lubricating oil composition may range from 0.001 to 20 wt. % (e.g., 0.01 to 15 wt. % or 0.1 to 10 wt. %) of the lubricating oil composition.

[036] The present lubricating oil composition may additionally contain one or more of the other commonly used lubricating oil performance additives including antioxidants, anti-wear agent, metal detergents, dispersants, friction modifiers, corrosion inhibitors, demulsifiers, viscosity modifiers, pour point depressants, foam inhibitors, and others.

Antioxidants

[037] Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant. Useful antioxidants include hindered phenols, aromatic amines, and sulfurized alkylphenols and alkali and alkaline earth metal salts thereof.

[038] The hindered phenol antioxidant may contain a secondary butyl and/or a tertiary butyl group as a sterically hindering group. The phenol group may be further substituted with a hydrocarbyl group and/or a bridging group linking to a second aromatic group. Examples of suitable hindered phenol antioxidants include 2,6-di-*tert*-butylphenol, 4-methyl-2,6-di-*tert*-butylphenol, 2,2'-methylenebis(6-*tert*-butyl-4-methylphenol), 4,4'-bis(2,6-di-*tert*-butylphenol) and 4,4'-methylenebis(2,6-di-*tert*-butylphenol). The hindered phenol antioxidant may be an ester or an addition product derived from 2,6-di-*tert*-butylphenol and an alkyl acrylate, wherein the alkyl group may contain from 1 to 18 carbon atoms.

[039] Suitable aromatic amine antioxidants include diarylamines such as alkylated diphenylamines (e.g., dioctyl diphenylamine, dinonyl diphenylamine), phenyl- α -naphthalene and alkylated phenyl- α -naphthalenes.

Anti-wear Agents

[040] Anti-wear agents reduce wear of metal parts. Examples of anti-wear agents include phosphorus-containing anti-wear/extreme pressure agents such as metal thiophosphates, phosphoric acid esters and salts thereof, phosphorus-containing carboxylic acids, esters, ethers, and amides; and phosphites. The anti-wear agent may be a zinc dialkyldithiophosphate. Non-phosphorus-containing anti-wear agents include borate esters (including borated epoxides), dithiocarbamate compounds, molybdenum-containing compounds, and sulfurized olefins.

Metal Detergents

[041] A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of the detergent is typically derived from an organic acid such as a sulfur acid, carboxylic acid, phosphorous acid, phenol, or mixtures thereof. The counterion is typically an alkaline earth or alkali metal.

[042] In some embodiments, the lubricating oil composition provided herein comprises at least a neutral or overbased metal detergent as an additive, or additive components. In certain embodiments, the metal detergents in lubricating oil compositions acts as a neutralizer of acidic products within the oil. In certain embodiments, the metal detergent prevents the formation of deposits on the surface of an engine. Depending on the nature of the acid used, the detergent may have additional functions, for example, antioxidant properties. In certain aspects, lubricating oil compositions contain metal detergents comprising either overbased detergents or mixtures of neutral and overbased detergents. The term "overbased" is intended to define additives which contain a metal content in excess of that required by the stoichiometry of the particular metal and the particular organic acid used. The excess metal exists in the form of particles of inorganic base (e.g., a hydroxide or carbonate) surrounded by a sheath of metal salt. The sheath serves to maintain the particles in dispersion in a liquid oleaginous vehicle. The amount of excess metal is commonly expressed as the ratio of total equivalence of excess metal to equivalence of organic acid and is typically in a range of 0.1 to 30.

[043] Some examples of suitable metal detergents include sulfurized or unsulfurized alkyl or alkenyl phenates, alkyl or alkenyl aromatic sulfonates, borated sulfonates, sulfurized or unsulfurized metal salts of multi-hydroxy alkyl or alkenyl aromatic compounds, alkyl or alkenyl hydroxy aromatic sulfonates, sulfurized or unsulfurized alkyl or alkenyl naphthenates, metal salts of alkanolic acids, metal salts of an alkyl or alkenyl multiacid, and chemical and physical mixtures thereof. Other examples of suitable metal detergents include metal sulfonates, phenates, salicylates, phosphonates, thiophosphonates and combinations thereof. The metal can be any metal suitable for making sulfonate, phenate, salicylate or phosphonate detergents. Non-limiting examples of suitable metals include alkali metals, alkaline metals and transition metals. In some embodiments, the metal is Ca, Mg, Ba, K, Na, Li or the like. An exemplary metal detergent which may be employed in the lubricating oil compositions includes overbased calcium phenate.

Ashless Dispersants

[044] A dispersant is an additive whose primary function is to hold solid and liquid contaminations in suspension, thereby passivating them and reducing engine deposits at the same time as reducing sludge depositions. For example, a dispersant maintains in suspension oil-insoluble substances that result from oxidation during use of the lubricant, thus preventing sludge flocculation and precipitation or deposition on metal parts of the engine.

[045] Dispersants are usually "ashless", being non-metallic organic materials that form substantially no ash on combustion, in contrast to metal-containing, and hence ash-forming materials. They comprise a long hydrocarbon chain with a polar head, the polarity being derived from inclusion of at least one nitrogen, oxygen or phosphorus atom. The hydrocarbon is an oleophilic group that confers oil-solubility, having, for example, 40 to 500 carbon atoms. Thus, ashless dispersants may comprise an oil-soluble polymeric backbone.

[046] A preferred class of olefin polymers is constituted by polybutylenes, specifically polyisobutylenes (PIB) or poly-*n*-butylenes, such as may be prepared by polymerization of a C₄ refinery stream.

[047] Dispersants include, for example, derivatives of long chain hydrocarbon-substituted carboxylic acids, examples being derivatives of high molecular weight hydrocarbyl-substituted succinic acid. A noteworthy group of dispersants is constituted by hydrocarbon-substituted succinimides, made, for example, by reacting the above acids (or derivatives) with a nitrogen-containing compound, advantageously a polyalkylene polyamine, such as a polyethylene polyamine. Typical commercially available polyisobutylene-based succinimide dispersants contain polyisobutylene polymers having a number average molecular weight ranging from 900 to 2500, functionalized by maleic anhydride, and derivatized with polyamines having a molecular weight of from 100 to 350.

[048] Other suitable dispersants include succinic esters and ester-amides, Mannich bases, polyisobutylene succinic acid (PIBSA), and other related components.

[049] Succinic esters are formed by the condensation reaction between hydrocarbon-substituted succinic anhydrides and alcohols or polyols. For example, the condensation product of a hydrocarbon-substituted succinic anhydride and pentaerythritol is a useful dispersant.

[050] Succinic ester-amides are formed by condensation reaction between hydrocarbon-substituted succinic anhydrides and alkanol amines. For example, suitable alkanol amines include ethoxylated polyalkylpolyamines, propoxylated polyalkylpolyamines and polyalkenylpolyamines such as polyethylene polyamines. One example is propoxylated hexamethylenediamine.

[051] Mannich bases are made from the reaction of an alkylphenols, formaldehyde, and a polyalkylene polyamines. Molecular weights of the alkylphenol may range from 800 to 2500.

[052] Nitrogen-containing dispersants may be post-treated by conventional methods to improve their properties by reaction with any of a variety of agents.

Among these are boron compounds (e.g., boric acid) and cyclic carbonates (e.g., ethylene carbonate).

Friction Modifiers

[053] A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material(s). Friction modifiers include 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 used herein, the term "fatty" means a hydrocarbon chain having 10 to 22 carbon atoms, typically a straight hydrocarbon chain.

[054] Other known friction modifiers comprise oil-soluble organo-molybdenum compounds. Such organo-molybdenum friction modifiers also provide antioxidant and anti-wear credits to a lubricating oil composition. Suitable oil-soluble organo-molybdenum compounds have a molybdenum-sulfur core. As examples, there may be mentioned dithiocarbamates, dithiophosphates, dithiophosphinates, xanthates, thioxanthates, sulfides, and mixtures thereof. The molybdenum compound may be dinuclear or trinuclear.

Corrosion Inhibitors

[055] Corrosion inhibitors protect lubricated metal surfaces against chemical attack by water or other contaminants. Suitable corrosion inhibitors include polyoxyalkylene polyols and esters thereof, polyoxyalkylene phenols, thiadiazoles and anionic alkyl sulfonic acids.

Viscosity Modifiers

[056] Viscosity modifiers provide lubricants with high and low temperature operability. These additives increase the viscosity of the oil composition at elevated temperatures which increases film thickness, while having limited effect on viscosity at low temperatures.

[057] Suitable viscosity improvers include high molecular weight hydrocarbons, polyesters and viscosity index improver dispersants that function as both a viscosity index improver and a dispersant. Typical molecular weights of these polymers are in a range of 1000 to 1,000,000 (e.g., 2000 to 500,000 or 25,000 to 100,000).

[058] Examples of suitable viscosity improvers are polymers and copolymers of methacrylate, butadiene, olefins, or alkylated styrenes. Polyisobutylene is a commonly used viscosity modifier. Another suitable viscosity modifier is polymethacrylate (copolymers of various chain length alkyl methacrylates, for example), some formulations of which also serve as pour point depressants. Other suitable viscosity modifiers include copolymers of ethylene and propylene, hydrogenated block copolymers of styrene and isoprene, and polyacrylates (copolymers of various chain length acrylates, for example). Specific examples include styrene-isoprene or styrene-butadiene based polymers of 50,000 to 200,000 molecular weight.

Pour Point Depressants

[059] Pour point depressants lower the minimum temperature at which a fluid will flow or can be poured. Suitable pour point depressants include C₈ to C₁₈ dialkyl fumarate/vinyl acetate copolymers, polyalkylmethacrylates and the like.

Foam Inhibitors

[060] Foam inhibitors retard the formation of stable foams. Examples of suitable foam inhibitors include polysiloxanes, polyacrylates, and the like.

EXAMPLES

[061] The following illustrative examples are intended to be non-limiting.

[062] To determine the effect of base oil on deposit control in an engine, lubricating oil compositions were prepared having the formulations set forth in the following Examples. The compositions were prepared by mixing the base oil(s) with additive packages according to conventional preparation methods. Base oil

properties are listed in Table 3. Deposit performance of the lubricant oil compositions was measured using the Penn State Micro-Oxidation Test after 35 minutes at 260°C (SAE Technical Paper 801362).

TABLE 3

Base Oil Properties

Property	ASTM Method	Base Oil 1	Base Oil 2
Kinematic Viscosity, 100°C, mm ² /s	D445	11.46	6.58
Viscosity Index	D2270	106	105
Saturates, %	D2007	97.2	97.6
Aromatics, %	D2007	2.6	2.5
Sulfur, wt. %	D2622	0.0018	0.0008
NOACK Volatility, %	D5800	1.95	10.87
CCS Viscosity, -35°C, mPa-s	D5293	175800	23650
CCS Viscosity, -30°C, mPa-s	D5293	69400	13100
CCS Viscosity, -25°C, mPa-s	D5293	30900	6400
CCS Viscosity, -20°C, mPa-s	D5293	15200	3300
CCS Viscosity, -15°C, mPa-s	D5293	7500	1875
CCS Viscosity, -10°C, mPa-s	D5293	4100	1205

EXAMPLES 1-2

[063] Lubricating oil compositions 1 and 2 were formulated to meet ashless natural gas engine oil specifications and major natural gas engine manufacturers' requirements. The results are presented in Table 4.

TABLE 4

	Example 1	Example 2
Base Oil 1, wt. %	93.40	18.68
Base Oil 2, wt. %	-	74.72
Additive Package, wt. %	6.60	6.60
<u>Physical Properties of Lubricant</u>		
SAE Viscosity Grade	40	20
Kinematic Viscosity, 100°C, mm ² /s	12.96	8.06
Sulfated Ash, wt. %	0.03	0.03
<u>Test Results</u>		
Deposit, wt. %	24.42	14.37

EXAMPLES 3-4

[064] Lubricating oil compositions 3 and 4 were formulated to meet dual fuel engine oil specifications and major dual fuel engine manufacturers' requirements. The results are presented in Table 5.

TABLE 5

	Example 3	Example 4
Base Oil 1, wt. %	90.54	18.11
Base Oil 2, wt. %	-	72.43
Additive Package, wt. %	9.46	9.46
<u>Physical Properties of Lubricant</u>		
SAE Viscosity Grade	40	20
Kinematic Viscosity, 100°C, mm ² /s	13.46	8.37
Sulfated Ash, wt. %	0.70	0.70
<u>Test Results</u>		
Deposit, wt. %	14.37	12.39

EXAMPLES 5-6

[065] Lubricating oil compositions 5 and 6 were formulated to meet low ash natural engine oil specifications and major natural gas engine manufacturers' requirements. The results are presented in Table 6.

TABLE 6

	Example 5	Example 6
Base Oil 1, wt. %	91.8	18.36
Base Oil 2, wt. %	-	73.44
Additive Package, wt. %	8.20	8.20
<u>Physical Properties of Lubricant</u>		
SAE Viscosity Grade	40	20
Kinematic Viscosity, 100°C, mm ² /s	13.64	8.61
Sulfated Ash, wt. %	0.45	0.45
<u>Test Results</u>		
Deposit, wt. %	28.76	13.73

EXAMPLES 7-8

[066] Lubricating oil compositions 7 and 8 were formulated to meet marine engine oil specifications and major marine engine manufacturers' requirements. The results are presented in Table 7.

TABLE 7

	Example 7	Example 8
Base Oil 1, wt. %	88.60	17.72
Base Oil 2, wt. %	-	70.88
Additive Package, wt. %	11.40	11.40
<u>Physical Properties of Lubricant</u>		
SAE Viscosity Grade	40	20
Kinematic Viscosity, 100°C, mm ² /s	13.40	8.55
Sulfated Ash, wt. %	3.10	3.10
<u>Test Results</u>		
Deposit, wt. %	2.51	1.28

EXAMPLES 9-10

[067] Lubricating oil compositions 9 and 10 were formulated to meet locomotive engine oil requirements and major locomotive engine manufacturers' requirements. The results are listed in Table 8.

TABLE 8

	Example 9	Example 10
Base Oil 1, wt. %	90.30	18.06
Base Oil 2, wt. %	-	72.24
Additive Package, wt. %	9.70	9.70
<u>Physical Properties of Lubricant</u>		
SAE Viscosity Grade	40	20
Kinematic Viscosity, 100°C, mm ² /s	14.02	8.79
Sulfated Ash, wt. %	1.15	1.15
<u>Test Results</u>		
Deposit, wt. %	24.7	9.62

[068] Examples 1-10 show that lubricating oil compositions containing a heavy base stock in combination with a light base stock provided improved deposit control over lubricating oil compositions containing solely heavy base stock.

EXAMPLES 11-13

[069] Lubricating oil compositions 11-13 were formulated to meet natural gas engine oil specifications and major natural gas engine manufacturers' requirements. The results are presented in Table 9.

TABLE 9

	Example 11	Example 12	Example 13
Base Oil 1 wt. %	39.33	15.73	88.67
Base Oil 2, wt. %	39.34	62.94	-
Additive Package, wt. %	11.33	11.33	11.33
2300 MW Polyisobutylene, wt. %	10	10	0
<u>Physical Properties of Lubricant</u>			
SAE Viscosity Grade	40	40	40
Kinematic Viscosity, 100°C, mm ² /s	15.98	13.61	13.56
Sulfated Ash, wt. %	0.71	0.71	0.71
<u>Test Results</u>			
Deposit, wt. %	13.46	8.43	20.19

CLAIMS

1. A natural gas engine lubricating oil composition comprising:
 - (a) a first base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 8.5 to 15 mm²/s;
 - (b) a second base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 4.0 to less than 8.5 mm²/s;wherein the weight ratio of the first base oil component to the second base oil component is in a range of from 1:5 to 1:1.15; and
wherein the lubricating oil composition is a SAE 40, SAE 50 or SAE 60 viscosity grade engine oil.

2. A low-speed or medium-speed diesel engine lubricating oil composition comprising:
 - (a) a first base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 8.5 to 15 mm²/s;
 - (b) a second base oil component selected from a Group I base stock, a Group II base stock, a Group III base stock, or a combination thereof, each having a kinematic viscosity at 100°C of from 4.0 to less than 8.5 mm²/s;wherein the weight ratio of the first base oil component to the second base oil component is in a range of from 1:5 to 1:1.15; and
wherein the lubricating oil composition is a SAE 40, SAE 50 or SAE 60 viscosity grade engine oil.

3. The lubricating oil composition of any one of claims 1 or 2, which is a 15W-x, 20W-x or 25W-x SAE viscosity grade engine oil, wherein x is 40, 50 or 60.
4. The lubricating oil composition of claim 2, wherein the medium-speed diesel engine lubricating oil composition is zinc-free.
5. Use of the lubricating oil composition of claim 1 to lubricate a natural gas engine selected from a stationary natural gas engine, a stationary biogas engine, a stationary landfill gas engine, a stationary unconventional natural gas engine, or a dual-fuel engine.
6. Use of the lubricating oil composition of claim 2 to lubricate a low-speed diesel engine and the low-speed diesel engine is a marine crosshead diesel engine.
7. Use of the lubricating oil composition of claim 2 to lubricate a medium-speed diesel engine selected from a locomotive diesel engine, a marine trunk piston diesel engine or a land-based stationary power diesel engine.
8. The lubricating oil composition of any one of claims 1 or 2, further comprising 1 to 20 wt. %, based on the total weight of the composition, of a polyisobutylene having a kinematic viscosity at 100°C of from 200 to 5000 mm²/s.
9. The lubricating oil composition of any one of claims 1 or 2, further comprising at least one additive selected from an antioxidant, anti-wear agent, metal detergent, dispersant, friction modifier, corrosion inhibitor, demulsifier, viscosity modifier, pour point depressant, foam inhibitor, and mixtures thereof.

10. A method of controlling deposit formation in a mechanical component of an internal combustion engine selected from a natural gas engine, a low-speed diesel engine or a medium-speed diesel engine, the method comprising operating the internal combustion engine with a lubricating oil composition according to any one of claims 1-4, 8 or 9.
11. The method of claim 10, wherein the mechanical component is a piston, a piston ring, a cylinder liner, a cylinder, a cam, a tappet, a lifter, a gear, a valve, a valve guide, or a bearing including a journal, a roller, a tapered, a needle, or a ball bearing.
12. The method of claim 10, wherein the mechanical component comprises steel.
13. The method of claim 10, wherein the internal combustion engine is operated under a load with a Brake Mean Effective Pressure of greater than 20 bar (2.0 MPa).