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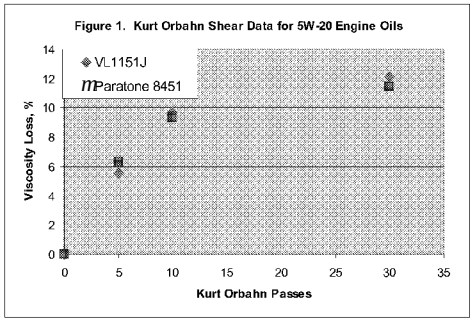



Fig. 1

**(57) Abstract:** A method for improving fuel efficiency in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a composition comprising: a lubricating oil base stock; and a viscosity index improver comprising at least one propylene-based polymer. The at least one propylene-based polymer comprises from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85: 15. Fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer. A lubricating engine oil having the above composition wherein, in an engine lubricated with the lubricating engine oil, fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer.

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# METHOD FOR IMPROVING ENGINE FUEL EFFICIENCY

## FIELD

**[0001]** This disclosure relates to lubricating engines using formulated lubricating oils to improve engine fuel efficiency.

## BACKGROUND

**[0002]** Fuel efficiency requirements for passenger vehicles are becoming increasingly more stringent. New legislation in the United States and European Union within the past few years has set fuel economy and emissions targets not readily achievable with today's vehicle and lubricant technology. In order to improve lubricant fuel economy performance, modification of viscosity is typically the utilized path.

**[0003]** The viscosity of lubricating oils is dependent on temperature. Lubricant oil formulations generally contain viscosity index ("VI") improving components to modify the rheological behavior to increase the lubricant viscosity, and promote a more constant viscosity over the range of temperatures over which the lubricant is used.

**[0004]** The viscosity index has been used to measure the rate of change of viscosity of a fluid in relation to temperature. In general, the higher the viscosity index, the smaller is the relative change in viscosity with temperature. The VI improver or viscosity modifier is used to reduce the temperature dependency of the viscosity of the lubricant compositions so that the lubricant compositions can be used over a wide temperature range. In other words, the VI improvers prevent the lubricant compositions from becoming too thin at a high temperature, e.g., hot summer temperatures, and too viscous at a low temperature, e.g., cold winter temperatures. Some known VI improvers include polymethacrylates, olefin copolymers, such as ethylene-propylene copolymers and ethylene-propylene diene-modified copolymers (EPDMs), and hydrogenated styrenic block copolymers such as styrene-ethylene/butylene-styrene copolymer (SEBS), styrene-butadiene copolymers, styrene-isoprene copolymers, and star polymers.

**[0005]** In recent years, ethylene/alpha-olefm copolymers have been widely used as viscosity modifiers, exhibiting the effect of improving viscosity index for the purpose of decreasing the temperature dependence of the lubricant's viscosity. See, for example, U.S. Patent Nos. 6,589,920; 5,391,617; 7,053,153; and 5,374,700. Lubricating oils lose fluidity at low temperatures because wax components therein tend to solidify to crystals.

**[0006]** Despite the advances in lubricant oil formulation technology, there exists a need for an engine oil lubricant that effectively improves fuel economy.

## SUMMARY

**[0007]** This disclosure relates in part to a method for improving fuel efficiency in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a composition comprising:

a lubricating oil base stock; and

a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

wherein fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer (i.e., an ethylene propylene VI improver having the same Mw and shear stability based on D6278).

**[0008]** This disclosure also relates in part to a method for improving fuel efficiency in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a composition comprising:

from 60 wt% to 98 wt%, based on the total weight of the formulated oil, of a lubricating oil base stock;

from 0.5 wt% to 15 wt%, based on the total weight of the formulated oil, of a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

from 0.1 wt% to 20 wt%, based on the total weight of the formulated oil, of one or more dispersants; and

from 0.0 wt% to 5 wt%, based on the total weight of the formulated oil, of one or more pour point depressants;

wherein fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer (i.e., an ethylene propylene VI improver having the same Mw and shear stability based on D6278).

**[0009]** This disclosure further relates in part to a lubricating engine oil having a composition comprising:

a lubricating oil base stock; and

a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

wherein, in an engine lubricated with said lubricating engine oil, fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating engine oil containing a viscosity index improver other than the at least one propylene-based polymer (i.e., an ethylene propylene VI improver having the same Mw and shear stability based on D6278).

**[0010]** This disclosure also relates in part to a lubricating engine oil having a composition comprising:

from 60 wt% to 98 wt%, based on the total weight of the lubricating engine oil, of a lubricating oil base stock;

from 0.5 wt% to 15 wt%, based on the total weight of the lubricating engine oil, of a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

from 0.1 wt% to 20 wt%, based on the total weight of the lubricating engine oil, of one or more dispersants; and

from 0.0 wt% to 5 wt%, based on the total weight of the lubricating engine oil, of one or more pour point depressants;

wherein, in an engine lubricated with said lubricating engine oil, fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer (i.e., an ethylene propylene VI improver having the same Mw and shear stability based on D6278).

**[0011]** In accordance with this disclosure, improvements in fuel economy are obtained without sacrificing engine durability.

**[0012]** Other objects and advantages of the present disclosure will become apparent from the detailed description that follows.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0013]** Fig. 1 graphically depicts Kurt Orbahn (ASTM D6278) shear stability results for the two formulations in the Examples measured at multiple test lengths.

## DETAILED DESCRIPTION

**[0014]** All numerical values within the detailed description and the claims herein are modified by "about" or "approximately" the indicated value, and take into account experimental error and variations that would be expected by a person having ordinary skill in the art.

**[0015]** In accordance with this disclosure, improved fuel efficiency can be attained in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil as described herein. The lubricating oils of this disclosure are particularly advantageous as passenger vehicle engine oil (PVEO) products.

### Lubricating Oil Base Stocks

**[0016]** A wide range of lubricating base oils is known in the art. Lubricating base oils that are useful in the present disclosure are both natural oils, and synthetic oils, and unconventional oils (or mixtures thereof) can be used unrefined, refined, or rerefmed (the latter is also known as reclaimed or reprocessed oil). Unrefined oils are those obtained directly from a natural or synthetic source and used without added purification. These include shale oil obtained directly from retorting operations, petroleum oil obtained directly from primary distillation, and ester oil obtained directly from an esterification process. Refined oils are similar to the oils discussed for unrefined oils except refined oils are subjected to one or more purification steps to improve at least one lubricating oil

property. One skilled in the art is familiar with many purification processes. These processes include solvent extraction, secondary distillation, acid extraction, base extraction, filtration, and percolation. Rerefmed oils are obtained by processes analogous to refined oils but using an oil that has been previously used as a feed stock.

**[0017]** Groups I, II, III, IV and V are broad base oil stock categories developed and defined by the American Petroleum Institute (API Publication 1509; www.API.org ) to create guidelines for lubricant base oils. Group I base stocks have a viscosity index of between 80 to 120 and contain greater than 0.03% sulfur and/or less than 90% saturates. Group II base stocks have a viscosity index of between 80 to 120, and contain less than or equal to 0.03%> sulfur and greater than or equal to 90%> saturates. Group III stocks have a viscosity index greater than 120 and contain less than or equal to 0.03 % sulfur and greater than 90%> saturates. Group IV includes polyalphaolefms (PAO). Group V base stock includes base stocks not included in Groups I-IV. The table below summarizes properties of each of these five groups.

| | Base Oil Properties | | |
|---|---|---|---|
| | Saturates | Sulfur | Viscosity Index |
| Group I | <90 and/or | >0.03% and | ≥80 and <120 |
| Group II | ≥90 and | ≤0.03% and | ≥80 and <120 |
| Group III | ≥90 and | ≤0.03% and | ≥120 |
| Group IV | Includes polyalphaolefins (PAO) and GTL products | | |
| Group V | All other base oil stocks not included in Groups I, II, III or IV | | |

**[0018]** Natural oils include animal oils, vegetable oils (castor oil and lard oil, for example), and mineral oils. Animal and vegetable oils possessing favorable thermal oxidative stability can be used. Of the natural oils, mineral oils are preferred. Mineral oils vary widely as to their crude source, for example, as to whether they are paraffinic, naphthenic, or mixed paraffinic-naphthenic. Oils derived from coal or shale are also useful. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrorefined, or solvent extracted.

**[0019]** Group II and/or Group III hydroprocessed or hydrocracked basestocks, including synthetic oils such as polyalphaolefms, alkyl aromatics and synthetic esters are also well known basestock oils.

**[0020]** Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefm copolymers, for example). Polyalphaolefm (PAO) oil base stocks are commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from $C_8$, $C_{10}$, $C_{12}$, $C_{14}$ olefins or mixtures thereof may be utilized. See U.S. Patent Nos. 4,956,122; 4,827,064; and 4,827,073.

**[0021]** The number average molecular weights of the PAOs, which are known materials and generally available on a major commercial scale from suppliers such as ExxonMobil Chemical Company, Chevron Phillips Chemical Company, BP, and others, typically vary from 250 to 3,000, although PAO's may be made in viscosities up to 100 cSt (100°C). The PAOs are typically comprised of relatively low molecular weight hydrogenated polymers or oligomers of alphaolefins which include, but are not limited to, $C_2$ to $C_{32}$ alphaolefins with the $C_8$ to $C_{16}$ alphaolefins, such as 1-octene, 1-decene, 1-dodecene and the like, being preferred. The preferred polyalphaolefms are poly-1-octene, poly-1-decene and poly-1-dodecene and mixtures thereof and mixed olefin-derived polyolefms. However, the dimers of higher olefins in the range of $C_{14}$ to $C_{18}$ may be used to provide low viscosity basestocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly trimers and tetramers of the starting olefins, with minor amounts of the higher oligomers, having a viscosity range of 1.5 to 12 cSt.

**[0022]** The PAO fluids may be conveniently made by the polymerization of an alphaolefin in the presence of a polymerization catalyst such as the Friedel-Crafts catalysts including, for example, aluminum trichloride, boron trifluoride or complexes of boron trifluoride with water, alcohols such as ethanol, propanol or butanol, carboxylic acids or esters such as ethyl acetate or ethyl propionate. For example the methods disclosed by U.S. Patent Nos. 4,149,178 or 3,382,291 may be conveniently used herein.

Other descriptions of PAO synthesis are found in the following U.S. Patent Nos. 3,742,082; 3,769,363; 3,876,720; 4,239,930; 4,367,352; 4,413,156; 4,434,408; 4,910,355; 4,956,122; and 5,068,487. The dimers of the $C_{i4}$ to $C_{i8}$ olefins are described in U.S. Patent No. 4,218,330.

**[0023]** The hydrocarbyl aromatics can be used as base oil or base oil component and can be any hydrocarbyl molecule that contains at least 5% of its weight derived from an aromatic moiety such as a benzenoid moiety or naphthenoid moiety, or their derivatives. These hydrocarbyl aromatics include alkyl benzenes, alkyl naphthalenes, alkyl diphenyl oxides, alkyl naphthols, alkyl diphenyl sulfides, alkylated bis-phenol A, alkylated thiodiphenol, and the like. The aromatic can be mono-alkylated, dialkylated, polyalkylated, and the like. The aromatic can be mono- or poly-functionalized. The hydrocarbyl groups can also be comprised of mixtures of alkyl groups, alkenyl groups, alkynyl, cycloalkyl groups, cycloalkenyl groups and other related hydrocarbyl groups. The hydrocarbyl groups can range from $C_6$ up to $C_{60}$ with a range of $C_8$ to $C_{20}$ often being preferred. A mixture of hydrocarbyl groups is often preferred, and up to three such substituents may be present. The hydrocarbyl group can optionally contain sulfur, oxygen, and/or nitrogen containing substituents. The aromatic group can also be derived from natural (petroleum) sources, provided at least 5% of the molecule is comprised of an above-type aromatic moiety. Viscosities at 100°C of approximately 3 cSt to 50 cSt are preferred, with viscosities of approximately 3.4 cSt to 20 cSt often being more preferred for the hydrocarbyl aromatic component. In one embodiment, an alkyl naphthalene where the alkyl group is primarily comprised of 1-hexadecene is used. Other alkylates of aromatics can be advantageously used. Naphthalene or methyl naphthalene, for example, can be alkylated with olefins such as octene, decene, dodecene, tetradecene or higher, mixtures of similar olefins, and the like. Useful concentrations of hydrocarbyl aromatic in a lubricant oil composition can be 2% to 25%, preferably 4% to 20%, and more preferably 4% to 15%, depending on the application.

**[0024]** Esters comprise a useful base stock. Additive solvency and seal compatibility characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid,

alkyl succinic acid, alkenyl succinic acid, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.

**[0025]** Particularly useful synthetic esters are those which are obtained by reacting one or more polyhydric alcohols, preferably the hindered polyols (such as the neopentyl polyols, e.g., neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl- 1,3-propanediol, trimethylol propane, pentaerythritol and dipentaerythritol) with alkanoic acids containing at least 4 carbon atoms, preferably $C_5$ to $C_{30}$ acids such as saturated straight chain fatty acids including caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, and behenic acid, or the corresponding branched chain fatty acids or unsaturated fatty acids such as oleic acid, or mixtures of any of these materials.

**[0026]** Suitable synthetic ester components include the esters of trimethylol propane, trimethylol butane, trimethylol ethane, pentaerythritol and/or dipentaerythritol with one or more monocarboxylic acids containing from 5 to 10 carbon atoms. These esters are widely available commercially, for example, the Mobil P-41 and P-51 esters of ExxonMobil Chemical Company).

**[0027]** Other useful fluids of lubricating viscosity include non-conventional or unconventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance lubrication characteristics.

**[0028]** Non-conventional or unconventional base stocks/base oils include one or more of a mixture of base stock(s) derived from one or more Gas-to-Liquids (GTL) materials, as well as isomerate/isodewaxate base stock(s) derived from natural wax or waxy feeds, mineral and or non-mineral oil waxy feed stocks such as slack waxes, natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, or other mineral, mineral oil, or even non-

petroleum oil derived waxy materials such as waxy materials received from coal liquefaction or shale oil, and mixtures of such base stocks.

**[0029]** GTL materials are materials that are derived via one or more synthesis, combination, transformation, rearrangement, and/or degradation/deconstructive processes from gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks such as hydrogen, carbon dioxide, carbon monoxide, water, methane, ethane, ethylene, acetylene, propane, propylene, propyne, butane, butylenes, and butynes. GTL base stocks and/or base oils are GTL materials of lubricating viscosity that are generally derived from hydrocarbons; for example, waxy synthesized hydrocarbons, that are themselves derived from simpler gaseous carbon-containing compounds, hydrogen-containing compounds and/or elements as feed stocks. GTL base stock(s) and/or base oil(s) include oils boiling in the lube oil boiling range (1) separated/fractionated from synthesized GTL materials such as, for example, by distillation and subsequently subjected to a final wax processing step which involves either or both of a catalytic dewaxing process, or a solvent dewaxing process, to produce lube oils of reduced/low pour point; (2) synthesized wax isomerates, comprising, for example, hydrodewaxed or hydroisomerized cat and/or solvent dewaxed synthesized wax or waxy hydrocarbons; (3) hydrodewaxed or hydroisomerized cat and/or solvent dewaxed Fischer-Tropsch (F-T) material (i.e., hydrocarbons, waxy hydrocarbons, waxes and possible analogous oxygenates); preferably hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxing dewaxed F-T waxy hydrocarbons, or hydrodewaxed or hydroisomerized/followed by cat (or solvent) dewaxing dewaxed, F-T waxes, or mixtures thereof.

**[0030]** GTL base stock(s) and/or base oil(s) derived from GTL materials, especially, hydrodewaxed or hydroisomerized/followed by cat and/or solvent dewaxed wax or waxy feed, preferably F-T material derived base stock(s) and/or base oil(s), are characterized typically as having kinematic viscosities at 100°C of from 2 $mm^2/s$ to 50 $mm^2/s$ (ASTM D445). They are further characterized typically as having pour points of -5°C to -40°C or lower (ASTM D97). They are also characterized typically as having viscosity indices of 80 to 140 or greater (ASTM D2270).

**[0031]** In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffms. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than 10 ppm, and more typically less than 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this materially especially suitable for the formulation of low SAP products.

**[0032]** The term GTL base stock and/or base oil and/or wax isomerate base stock and/or base oil is to be understood as embracing individual fractions of such materials of wide viscosity range as recovered in the production process, mixtures of two or more of such fractions, as well as mixtures of one or two or more low viscosity fractions with one, two or more higher viscosity fractions to produce a blend wherein the blend exhibits a target kinematic viscosity.

**[0033]** The GTL material, from which the GTL base stock(s) and/or base oil(s) is/are derived is preferably an F-T material (i.e., hydrocarbons, waxy hydrocarbons, wax).

**[0034]** In addition, the GTL base stock(s) and/or base oil(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffms. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stock(s) and/or base oil(s) and hydrodewaxed, or hydroisomerized/cat (and/or solvent) dewaxed base stock(s) and/or base oil(s) typically have very low sulfur and nitrogen content, generally containing less than 10 ppm, and more typically less than 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock(s) and/or base oil(s) obtained from F-T material, especially F-T wax, is essentially nil. In addition, the absence of phosphorous and aromatics make this material especially suitable for the formulation of low sulfur, sulfated ash, and phosphorus (low SAP) products.

**[0035]** Base oils for use in the formulated lubricating oils useful in the present disclosureare any of the variety of oils corresponding to API Group I, Group II, Group III, Group IV, and Group V oils and mixtures thereof, preferably API Group II, Group III, Group IV, and Group V oils and mixtures thereof, more preferably the Group III to Group V base oils due to their exceptional volatility, stability, viscometric and cleanliness features. Minor quantities of Group I stock, such as the amount used to dilute additives for blending into formulated lube oil products, can be tolerated but should be kept to a minimum, i.e. amounts only associated with their use as diluent/carrier oil for additives used on an "as-received" basis. Even in regard to the Group II stocks, it is preferred that the Group II stock be in the higher quality range associated with that stock, i.e. a Group II stock having a viscosity index in the range $100 < VI < 120$.

**[0036]** The base oil constitutes the major component of the engine oil lubricant composition of the present disclosure and typically is present in an amount ranging from 50 to 99 weight percent, preferably from 70 to 95 weight percent, and more preferably from 85 to 95 weight percent, based on the total weight of the composition. The base oil may be selected from any of the synthetic or natural oils typically used as crankcase lubricating oils for spark-ignited and compression-ignited engines. The base oil conveniently has a kinematic viscosity, according to ASTM standards, of 2.5 cSt to 12 cSt (or $mm^2$ /s) at 100°C and preferably of 2.5 cSt to 9 cSt (or $mm^2$ /s) at 100° C. Mixtures of synthetic and natural base oils may be used if desired.

Viscosity Index Improvers

**[0037]** Viscosity index improvers provide lubricants with high and low temperature operability. These additives impart shear stability at elevated temperatures and acceptable viscosity at low temperatures.

**[0038]** Propylene-based polymers are used as viscosity index improvers. These polymers have acceptable properties as viscosity index improvers with good shear stability and viscosity characteristics. More particularly, it has been found that propylene-based polymers having low a-olefm content that, when used as VI improvers, promote oil thickening, shear stability and low temperature viscometrics, while lowering

the oil pour point. These propylene-based VI improvers reduce the temperature dependency of the viscosity of the lubricant compositions so that the lubricant compositions can be used over a wide temperature range without solids or gel formations and thereby improve engine fuel efficiency. Illustrative propylene-based polymers useful as viscosity index improvers in this disclosure are disclosed in WO 2010/016847, which is incorporated herein in its entirety.

**[0039]** The propylene-based polymer can be one or more propylene-alpha-olefm-copolymers, propylene-alpha-olefm-diene terpolymers, or propylene-diene copolymers. For simplicity and ease of description, however, the terms "propylene-based polymer" and "PCP" are used interchangeably herein and refer to one or more propylene-alpha-olefin-copolymers, propylene-alpha-olefm-diene terpolymers and propylene-diene copolymers having 60 wt% to 99.7 wt% propylene derived units. Further, for ease of description, when referring to the PCPs of the present disclosure, one may interchangeably refer to the PCP being made up of multiple monomers (i.e., propylene and ethylene) or units derived from monomers (i.e., propylene-derived units and/or units derived from alpha-olefms).

**[0040]** In another embodiment, the propylene-based polymer can be prepared by polymerizing propylene with ethylene and/or one or more C4-C20 alpha-olefms, or a combination of ethylene and one or more C4-C20 alpha-olefm and one or more dienes. The one or more dienes can be conjugated or non-conjugated. Preferably, the one or more dienes are non-conjugated.

**[0041]** In another embodiment, the propylene-based polymer can be prepared by polymerizing propylene with one or more dienes. In yet another embodiment, the propylene- based polymer can be prepared by polymerizing propylene with ethylene and/or at least one C4-C20 alpha-olefm, or a combination of ethylene and at least one $C_4$-C20 alpha-olefm and one or more dienes. The one or more dienes can be conjugated or non-conjugated. Preferably, the one or more dienes are non-conjugated.

**[0042]** The comonomers can be linear or branched. Preferred linear comonomers include ethylene or $C_4$ to $C_8$ alpha-olefms, more preferably ethylene, 1-butene, 1-

hexene, and 1-octene, even more preferably ethylene or 1-butene. Preferred branched comonomers include 4-methyl-l-pentene, 3-methyl-l-pentene, and 3,5,5-trimethyl-l-hexene. In one or more embodiments, the comonomer can include styrene.

**[0043]** Illustrative dienes can include but are not limited to 5-ethylidene-2-norbornene (ENB); 1,4-hexadiene; 5-methylene-2-norbornene (MNB); 1,6-octadiene; 5-methyl-l,4-hexadiene; 3,7-dimethyl- 1,6-octadiene; 1,3-cyclopentadiene; 1,4-cyclohexadiene; vinyl norbornene (VNB); dicyclopendadiene (DCPD), and combinations thereof. Preferably, the diene is ENB.

**[0044]** Preferred methods and catalysts for producing the propylene-based polymers are found in publications U.S. 2004/0236042 and WO 2005/049672 and in U.S. Patent No. 6,881,800, which are all incorporated by reference herein. Pyridine amine complexes, such as those described in WO 2003/040201 are also useful to produce the propylene-based polymers useful herein. The catalyst can involve a fluxional complex, which undergoes periodic intra-molecular re-arrangement so as to provide the desired interruption of stereoregularity as in U.S. 6,559,262. The catalyst can be a stereorigid complex with mixed influence on propylene insertion, see Rieger EP 1 070 087. The catalyst described in EP 1 614 699 could also be used for the production of backbones suitable for the invention.

**[0045]** The propylene-based polymer can have an average propylene content on a weight percent basis of from 60 wt% to 99.7 wt%, more preferably from 60 wt% to 99.5 wt%, more preferably from 60 wt% to 98 wt%, more preferably from 60 wt% to 97 wt%, more preferably from 60 wt% to 95 wt% based on the weight of the polymer. Other preferred ranges are from 70 wt% to 95 wt% propylene-derived units, more preferably from 75 wt% to 95 wt% propylene-derived units, more preferably from 80 wt% to 95 wt% propylene- derived units, and more preferably from 80 wt% to 90 wt% propylene-derived units, and more preferably from 80 wt% to 88 wt% propylene based on the weight of the polymer. In one embodiment, the balance comprises units derived from one or more alpha-olefms. The one or more alpha-olefms may comprise ethylene, or one or more C4-C20 alpha-olefm or a combination of ethylene and one or more C4-C20 alpha-olefin. In another embodiment, the one or more alpha-olefms may compromise ethylene,

or one or more C4-C 12 alpha-olefms or a combination of ethylene and one or more $C_4$-C 12 alpha-olefms. In a preferred embodiment, the one or more alpha-olefms comprises ethylene. In another embodiment, the one or more alpha-olefms comprises butene.

**[0046]** The mole ratio of propylene to the one or more other alpha olefins (e.g., butylene) can range from 50:50 to 85:15, preferably from 50:50 to 80:20, and more preferably from 50:50 to 75:25.

**[0047]** In another embodiment, the balance comprises units derived from one or more dienes and optionally one or more of the alpha-olefms described previously. In one or more embodiments above or elsewhere herein, the alpha-olefm is ethylene, butene, hexene or octene. In other embodiments, two alpha-olefms are present, preferably ethylene and one of butene, hexene or octene.

**[0048]** In the diene containing embodiments, the propylene-based polymer comprises 0.2 wt% to 24 wt%, units derived from a non-conjugated diene based on the weight of the polymer, more preferably from 0.5 wt% to 12 wt%, more preferably 0.6 wt% to 8 wt%, and more preferably 0.7 wt% to 5 wt%. In other embodiments, the diene content ranges from 0.2 wt% to 10 wt%, more preferably from 0.2 to 5 wt%, more preferably from 0.2 wt% to 4 wt%, preferably from 0.2wt% to 3.5 wt%, preferably from 0.2wt% to 3.0 wt%, and preferably from 0.2 wt% to 2.5 wt% based on the weight of the polymer. In one or more embodiments above or elsewhere herein, the propylene-based polymer comprises units derived from ENB in an amount of from 0.5 to 4 wt%, more preferably from 0.5 to 2.5 wt%, and more preferably from 0.5 to 2.0 wt%.

**[0049]** In other diene containing embodiments, the propylene-based polymer preferably comprises propylene-derived units and diene-derived units in one or more of the ranges described above with the balance comprising one or more $C_2$ and/or $C_4$-$C_{20}$ olefins. In general, this will amount to the propylene-based polymer preferably comprising from 5 to 40 wt% of one or more $C_2$ and/or $C_4$-$C_{20}$ olefins based the weight of the polymer. When $C_2$ and/or a $C_4$-$C_{20}$ olefins are present the combined amounts of these olefins in the polymer is preferably at least 5 wt% and falling within the ranges described herein. Other preferred ranges for the one or more alpha-olefms include from

5 wt% to 35 wt%, more preferably from 5 wt% to 30 wt%, more preferably from 5 wt% to 25 wt%, more preferably from 5 wt% to 20 wt%, more preferably from 5 to 17 wt% and more preferably from 5 wt% to 16 wt%.

**[0050]** In one or more embodiments above or elsewhere herein, the propylene-based polymer can have a Mw of 100,000 to 500,000 g/mole, more preferably a Mw of 125,000 to 475,000, more preferably a Mw of 150,000 to 450,000, more preferably a Mw of 175,000 to 425,000, more preferably a Mw of 200,000 to 400,000, more preferably a Mw of 225,000 to 375,000, wherein Mw is determined as described herein. In one or more embodiments, the propylene-based polymer can have a Mw ranging from a low of 100,000, 110,000, 120,000, 130,000, or 140,000 to a high of 450,000, 460,000, 470,000, 480,000, or 500,000.

**[0051]** In one or more embodiments above or elsewhere herein, the propylene-based polymer can have a Mn of 100,000 to 400,000 g/mole, more preferably a Mn of 125,000 to 375,000, more preferably a Mn of 150,000 to 350,000, more preferably a Mn of 175,000 to 325,000, wherein Mn is determined as described herein.

**[0052]** The molecular weight distribution index (MWD = (Mw/Mn)), sometimes referred to as a "polydispersity index" (PDI), of the propylene-based polymer can be 1 to 2. In an embodiment the MWD can have an upper limit of 2, or 1.95, or 1.9, or 1.85, or 1.8, or 1.75, or 1.7, or 1.65, or 1.6, or 1.55 and a lower limit of 1, or 1.05, or 1.1, or 1.15, or 1.2, or 1.25. In one or more embodiments above or elsewhere herein, the MWD of the propylene-based polymer is 1.0 to 1.95, more preferably 1.0 to 1.75, and most preferably 1.0 to 1.5. Techniques for determining the molecular weight (Mn and Mw) and molecular weight distribution (MWD) can be found in U.S. Patent No. 4,540,753 (which is incorporated by reference herein for purposes of U.S. practices) and references cited therein, in Macromolecules, 1988, volume 21, p 3360 (Verstrate et al), which is herein incorporated by reference for purposes of U.S. practice, and references cited therein, and in accordance with the procedures disclosed in U.S. Patent No. 6,525,157, column 5, lines 1-44, which patent is hereby incorporated by reference in its entirety.

**[0053]** In one or more embodiments above or elsewhere herein, the propylene-based polymer can have a density of 0.85 g/cm$^3$ to 0.92 g/cm$^3$, more preferably, 0.87 g/cm$^3$ to 0.90 g/cm$^3$, more preferably 0.88 g/cm$^3$ to 0.89 g/cm$^3$ at room temperature as measured per the ASTM D-1505 test method.

**[0054]** In one or more embodiments above or elsewhere herein, the propylene-based polymer can have a melt flow rate (MFR, 2.16 kg weight @ 230°C), equal to or greater than 0.2 g/10 min as measured according to the ASTM D-1238 test method as modified. Preferably, the MFR (2.16 kg @ 230°C) is from 0.5 g/10 min to 200 g/10 min and more preferably from 1 g/10 min to 100 g/10 min. In an embodiment, the propylene-based polymer has an MFR upper limit of 200 g/10 min, 150 g/10 min, 100 g/10 min, 75 g/10 min, 50 g/10 min, 30 g/10 min, 25 g/10 min, or 20 g/10 min and a lower limit of 0.1 g/10 min, 0.5 g/10 min, 1 g/10 min, 2 g/10 min, 3 g/10 min, 4 g/10 min, 5 g/10 min, 8 g/10 min, or 10 g/10 min. In another embodiment, the propylene-based polymer has an MFR of 0.5 g/10 min to 200 g/10 min, preferably from 2 g/10 min to 30 g/10 min, more preferably from 3g/10 min to 21 g/lOmin, more preferably from 5 g/10 min to 30 g/10 min, more preferably 10 g/10 min to 30 g/10 min, more preferably 10 g/10 min to 25 g/10 min, or more preferably 2 g/10 min to 10 g/10 min.

**[0055]** The propylene-based polymer can have a Mooney viscosity ML (1+4)@125°C, as determined according to ASTM D 1646, of less than 100, more preferably less than 75, even more preferably less than 60, most preferably less than 30. In one or more embodiments above or elsewhere herein, the Mooney viscosity can range from a low of 1, 5, 10, or 15 to a high of 30, 60, 75 or 100.

**[0056]** In one or more embodiments above or elsewhere herein, the propylene-based polymer can have a heat of fusion (Hf) determined according to the DSC procedure described herein, which is greater than or equal to 0.5 Joules per gram (J/g), and is less than or equal to 80 J/g, preferably less than or equal to 75 J/g, preferably less than or equal to 70 J/g, more preferably less than or equal to 60 J/g, more preferably less than or equal to 50 J/g, more preferably less than or equal to 35 J/g. Also preferably, the propylene-based polymer has a heat of fusion that is greater than or equal to 1 J/g, preferably greater than or equal to 5 J/g. In another embodiment, the propylene-based

polymer can have a heat of fusion (Hf), which is from 0.5 J/g to 75 J/g, preferably from 1 J/g to 75 J/g, more preferably from 0.5 J/g to 35 J/g. Preferred propylene-based polymers and compositions can be characterized in terms of both their melting points (Tm) and heats of fusion, which properties can be influenced by the presence of comonomers or steric irregularities that hinder the formation of crystallites by the polymer chains. In one or more embodiments, the heat of fusion ranges from a lower limit of 1.0 J/g, or 1.5 J/g, or 3.0 J/g, or 4.0 J/g, or 6.0 J/g, or 7.0 J/g, to an upper limit of 30 J/g, or 35 J/g, or 40 J/g, or 50 J/g, or 60 J/g or 70 J/g, or 75 J/g, or 80 J/g.

**[0057]** The crystallinity of the propylene-based polymer can also be expressed in terms of percentage of crystallinity (i.e. % crystallinity). In certain embodiments above or elsewhere herein, the propylene-based polymer is substantially amorphous characterized in that it has 0 % crystallinity as determined according to the DSC procedure described herein. In other embodiments above or elsewhere herein, the propylene-based polymer has a % crystallinity of from 0.5 % to 40%, preferably 1% to 30%, more preferably 5% to 25% wherein % crystallinity is determined according to the DSC procedure described herein. In another embodiment, the propylene-based polymer preferably has a crystallinity of less than 40%, preferably 0.25% to 25%, more preferably from 0.5% to 22%, and most preferably from 0.5%> to 20%>. As disclosed above, the thermal energy for the highest order of polypropylene is estimated at 189 J/g (i.e., *100%* crystallinity is equal to 209 J/g.).

**[0058]** In addition to this level of crystallinity, the propylene-based polymer preferably has a single broad melting transition. However, the propylene-based polymer can show secondary melting peaks adjacent to the principal peak, but for purposes herein, such secondary melting peaks are considered together as a single melting point, with the highest of these peaks (relative to baseline as described herein) being considered the melting point of the propylene-based polymer.

**[0059]** Heat of fusion, % crystallinity and melting temperature of the propylene-based polymer can be determined, for example by a Differential Scanning Calorimetry (DSC) as described n WO 2010/016847, *supra.*

**[0060]** In one or more embodiments, the propylene-based polymer can be blended with other polymeric viscosity index modifiers, such as polybutenes, polymers of styrene with butadiene or isoprene that may optionally be hydrogenated or a combination of butadiene or isoprene, ester based viscosity index modifiers such as esters of styrene/maleic anhydride polymers, esters of styrene/maleic anhydride/acrylate terpolymers, and polymethacrylates. Examples for such viscosity index modifiers for such blends include acrylate-or methacrylate-containing copolymers or copolymers of styrene and an ester of an unsaturated carboxylic acid such as styrene/maleic ester (typically prepared by esterification of a styrene/maleic anhydride copolymer).

**[0061]** In one or more embodiments, the propylene-based polymer can itself be a blend of discrete random propylene-based polymers. Such blends can include ethylene-based polymers and propylene-based polymers, or at least one of each such ethylene -based polymers and propylene-based polymers. The number of propylene-based polymers can be three or less, more preferably two or less. In embodiments where the propylene-based polymer is a blend of discrete random propylene-based polymers, it may further be blended with other polymeric viscosity index modifiers, such as polybutenes, polymers of styrene with butadiene or isoprene or a combination of butadiene or isoprene, ester based viscosity index modifiers such as esters of styrene/maleic anhydride polymers, esters of styrene/maleic anhydride/acrylate terpolymers, and polymethacrylates. Examples for such viscosity index modifiers for such blends include acrylate-or methacrylate-containing copolymers or copolymers of styrene and an ester of an unsaturated carboxylic acid such as styrene/maleic ester (typically prepared by esterification of a styrene/maleic anhydride copolymer).

**[0062]** In one or more embodiments above or elsewhere herein, the propylene-based polymer can include a blend of two propylene-based polymers differing in the olefin content, the diene content, or both.

**[0063]** In another embodiment, the propylene-based polymers can include copolymers prepared according to the procedures in WO 02/36651. Likewise, the propylene-based polymer can include polymers consistent with those described in WO 2003/040201, WO 2003/040202, WO 2003/040095, WO 2003/040201, WO

2003/040233, and/or WO 2003/040442. Additionally, the propylene-based polymer can include polymers consistent with those described in EP 1 233 191, and U.S. 6,525,157, along with suitable propylene homo- and copolymers described in U.S. 6,770,713 and U.S. Patent Application Publication 2005/215964, all of which are incorporated by reference. The propylene-based polymer can also include one or more polymers consistent with those described in EP 1 614 699 or EP 1 017 729.

**[0064]** In one or more embodiments, the propylene-based polymer can be grafted (i.e. "functionalized") using one or more grafting monomers as described in WO 2010/016847, *supra.* As used herein, the term "grafting" denotes covalent bonding of the grafting monomer to a polymer chain of the propylene-based polymer. The grafted propylene-based polymer can be prepared using conventional techniques.

Other Additives

**[0065]** The formulated lubricating oil useful in the present disclosure may additionally contain one or more of the other commonly used lubricating oil performance additives including but not limited to dispersants, detergents, pour point depressants (PPDs), corrosion inhibitors, rust inhibitors, metal deactivators, other anti-wear agents and/or extreme pressure additives, anti-seizure agents, wax modifiers, viscosity modifiers, fluid-loss additives, seal compatibility agents, friction modifiers, lubricity agents, anti-staining agents, chromophoric agents, defoamants, demulsifiers, emulsifiers, densifiers, wetting agents, gelling agents, tackiness agents, colorants, and others. For a review of many commonly used additives, see Klamann in Lubricants and Related Products, Verlag Chemie, Deerfield Beach, FL; ISBN 0-89573-177-0. Reference is also made to "Lubricant Additives" by M. W. Ranney, published by Noyes Data Corporation ofParkridge, NJ (1973).

**[0066]** The types and quantities of performance additives used in combination with the instant disclosurein lubricant compositions are not limited by the examples shown herein as illustrations.

Dispersants

**[0067]** During engine operation, oil-insoluble oxidation byproducts are produced. Dispersants help keep these byproducts in solution, thus diminishing their deposition on metal surfaces. Dispersants used in the formulation of the lubricating oil may be ashless or ash-forming in nature. Preferably, the dispersant is ashless. So called ashless dispersants are organic materials that form substantially no ash upon combustion. For example, non-metal-containing or borated metal-free dispersants are considered ashless. In contrast, metal-containing detergents discussed above form ash upon combustion.

**[0068]** Suitable dispersants typically contain a polar group attached to a relatively high molecular weight hydrocarbon chain. The polar group typically contains at least one element of nitrogen, oxygen, or phosphorus. Typical hydrocarbon chains contain 50 to 400 carbon atoms.

**[0069]** Chemically, many dispersants may be characterized as phenates, sulfonates, sulfurized phenates, salicylates, naphthenates, stearates, carbamates, thiocarbamates, phosphorus derivatives. A particularly useful class of dispersants are the alkenylsuccinic derivatives, typically produced by the reaction of a long chain hydrocarbyl substituted succinic compound, usually a hydrocarbyl substituted succinic anhydride, with a polyhydroxy or polyamino compound. The long chain hydrocarbyl group constituting the oleophilic portion of the molecule which confers solubility in the oil, is normally a polyisobutylene group. Many examples of this type of dispersant are well known commercially and in the literature. Exemplary U.S. patents describing such dispersants are U.S. Patent Nos. 3,172,892; 3,215,707; 3,219,666; 3,316,177; 3,341,542; 3,444,170; 3,454,607; 3,541,012; 3,630,904; 3,632,51 1; 3,787,374 and 4,234,435. Other types of dispersant are described in U.S. Patent Nos. 3,036,003; 3,200,107; 3,254,025; 3,275,554; 3,438,757; 3,454,555; 3,565,804; 3,413,347; 3,697,574; 3,725,277; 3,725,480; 3,726,882; 4,454,059; 3,329,658; 3,449,250; 3,519,565; 3,666,730; 3,687,849; 3,702,300; 4,100,082; 5,705,458. A further description of dispersants may be found, for example, in European Patent Application No. 471 071, to which reference is made for this purpose.

**[0070]** Hydrocarbyl-substituted succinic acid and hydrocarbyl-substituted succinic anhydride derivatives are useful dispersants. In particular, succinimide, succinate esters, or succinate ester amides prepared by the reaction of a hydrocarbon-substituted succinic acid compound preferably having at least 50 carbon atoms in the hydrocarbon substituent, with at least one equivalent of an alkylene amine are particularly useful.

**[0071]** Succinimides are formed by the condensation reaction between hydrocarbyl substituted succinic anhydrides and amines. Molar ratios can vary depending on the polyamine. For example, the molar ratio of hydrocarbyl substituted succinic anhydride to TEPA can vary from 1:1 to 5:1. Representative examples are shown in U.S. Patent Nos. 3,087,936; 3,172,892; 3,219,666; 3,272,746; 3,322,670; and 3,652,616, 3,948,800; and Canada Patent No. 1,094,044.

**[0072]** Succinate esters are formed by the condensation reaction between hydrocarbyl substituted succinic anhydrides and alcohols or polyols. Molar ratios can vary depending on the alcohol or polyol used. For example, the condensation product of a hydrocarbyl substituted succinic anhydride and pentaerythritol is a useful dispersant.

**[0073]** Succinate ester amides are formed by condensation reaction between hydrocarbyl 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. Representative examples are shown in U.S. Patent No. 4,426,305.

**[0074]** The molecular weight of the hydrocarbyl substituted succinic anhydrides used in the preceding paragraphs will typically range between 800 and 2,500. The above products can be post-reacted with various reagents such as sulfur, oxygen, formaldehyde, carboxylic acids such as oleic acid. The above products can also be post reacted with boron compounds such as boric acid, borate esters or highly borated dispersants, to form borated dispersants generally having from 0.1 to 5 moles of boron per mole of dispersant reaction product.

**[0075]** Mannich base dispersants are made from the reaction of alkylphenols, formaldehyde, and amines. See U.S. Patent No. 4,767,551, which is incorporated herein by reference. Process aids and catalysts, such as oleic acid and sulfonic acids, can also be part of the reaction mixture. Molecular weights of the alkylphenols range from 800 to 2,500. Representative examples are shown in U.S. Patent Nos. 3,697,574; 3,703,536; 3,704,308; 3,751,365; 3,756,953; 3,798,165; and 3,803,039.

**[0076]** Typical high molecular weight aliphatic acid modified Mannich condensation products useful in this disclosure can be prepared from high molecular weight alkyl-substituted hydroxyaromatics or $HN(R)_2$ group-containing reactants.

**[0077]** Hydrocarbyl substituted amine ashless dispersant additives are well known to one skilled in the art; see, for example, U.S. Patent Nos. 3,275,554; 3,438,757; 3,565,804; 3,755,433, 3,822,209, and 5,084,197.

**[0078]** Preferred dispersants include borated and non-borated succinimides, including those derivatives from mono-succinimides, bis-succinimides, and/or mixtures of mono- and bis-succinimides, wherein the hydrocarbyl succinimide is derived from a hydrocarbylene group such as polyisobutylene having a Mn of from 500 to 5000 or a mixture of such hydrocarbylene groups. Other preferred dispersants include succinic acid-esters and amides, alkylphenol-polyamine-coupled Mannich adducts, their capped derivatives, and other related components. Such additives may be used in an amount of 0.1 to 20 weight percent, preferably 0.5 to 8 weight percent.

Pour Point Depressants (PPDs)

**[0079]** Conventional pour point depressants (also known as lube oil flow improvers) may be added to the compositions of the present disclosure if desired. These pour point depressant may be added to lubricating compositions of the present disclosure to lower the minimum temperature at which the fluid will flow or can be poured. Examples of suitable pour point depressants include polymethacrylates, polyacrylates, polyarylamides, condensation products of haloparaffm waxes and aromatic compounds, vinyl carboxylate polymers, and terpolymers of dialkylfumarates, vinyl esters of fatty

acids and allyl vinyl ethers. U.S. Patent Nos. 1,815,022; 2,015,748; 2,191,498; 2,387,501; 2,655, 479; 2,666,746; 2,721,877; 2,721,878; and 3,250,715 describe useful pour point depressants and/or the preparation thereof. Such additives may be used in an amount of 0.01 to 5 weight percent, preferably 0.01 to 1.5 weight percent.

Detergent Additives

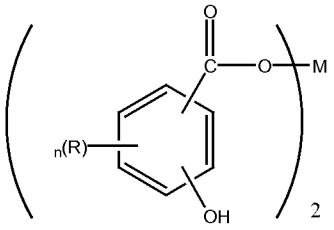
**[0080]** Illustrative detergent useful in this disclosure include, for example, alkali metal detergents, alkaline earth metal detergents, or mixtures of one or more alkali metal detergents and one or more alkaline earth metal detergents. A typical detergent is an anionic material that contains a long 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.

**[0081]** Salts that contain a substantially stochiometric amount of the metal are described as neutral salts and have a total base number (TBN, as measured by ASTM D2896) of from 0 to 80. Many compositions are overbased, containing large amounts of a metal base that is achieved by reacting an excess of a metal compound (a metal hydroxide or oxide, for example) with an acidic gas (such as carbon dioxide). Useful detergents can be neutral, mildly overbased, or highly overbased.

**[0082]** Alkaline earth phenates are another useful class of detergent. These detergents can be made by reacting alkaline earth metal hydroxide or oxide (CaO, $Ca(OH)_2$, BaO, $Ba(OH)_2$, MgO, $Mg(OH)_2$, for example) with an alkyl phenol or sulfurized alkylphenol. Useful alkyl groups include straight chain or branched $C_{1}$-$C_{30}$ alkyl groups, preferably, $C_4$-$C_{20}$. Examples of suitable phenols include isobutylphenol, 2-ethylhexylphenol, nonylphenol, dodecyl phenol, and the like. It should be noted that starting alkylphenols may contain more than one alkyl substituent that are each independently straight chain or branched. When a non-sulfurized alkylphenol is used, the sulfurized product may be obtained by methods well known in the art. These methods include heating a mixture of alkylphenol and sulfurizing agent (including

elemental sulfur, sulfur halides such as sulfur dichloride, and the like) and then reacting the sulfurized phenol with an alkaline earth metal base.

**[0083]** Metal salts of carboxylic acids are also useful as detergents. These carboxylic acid detergents may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing free water from the reaction product. These compounds may be overbased to produce the desired TBN level. Detergents made from salicylic acid are one preferred class of detergents derived from carboxylic acids. Useful salicylates include long chain alkyl salicylates. One useful family of compositions is of the formula




where R is an alkyl group having 1 to 30 carbon atoms, n is an integer from 1 to 4, and M is an alkaline earth metal. Preferred R groups are alkyl chains of at least Cn, preferably $C_{13}$ or greater. R may be optionally substituted with substituents that do not interfere with the detergent's function. M is preferably, calcium, magnesium, or barium. More preferably, M is calcium.

**[0084]** Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Patent No. 3,595,791). The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent such as water or alcohol.

**[0085]** Alkaline earth metal phosphates are also used as detergents and are known in the art.

**[0086]** Detergents may be simple detergents or what is known as hybrid or complex detergents. The latter detergents can provide the properties of two detergents without the need to blend separate materials. See U.S. Patent No. 6,034,039.

**[0087]** Preferred detergents include calcium phenates, calcium sulfonates, calcium salicylates, magnesium phenates, magnesium sulfonates, magnesium salicylates and other related components (including borated detergents), and mixtures thereof. Preferred detergents include magnesium sulfonate and calcium salicylate.

**[0088]** The detergent mixture concentration in the lubricating oils of this disclosure can range from 1.0 to 6.0 weight percent, preferably 2.0 to 5.0 weight percent, and more preferably from 2.0 weight percent to 4.0 weight percent, based on the total weight of the lubricating oil.

Antioxidants

**[0089]** Antioxidants retard the oxidative degradation of base oils during service. Such degradation may result in deposits on metal surfaces, the presence of sludge, or a viscosity increase in the lubricant. One skilled in the art knows a wide variety of oxidation inhibitors that are useful in lubricating oil compositions. See, Klamann in Lubricants and Related Products, op cite, and U.S. Patent Nos. 4,798,684 and 5,084,197, for example.

**[0090]** Useful antioxidants include hindered phenols. These phenolic antioxidants may be ashless (metal-free) phenolic compounds or neutral or basic metal salts of certain phenolic compounds. Typical phenolic antioxidant compounds are the hindered phenolics which are the ones which contain a sterically hindered hydroxyl group, and these include those derivatives of dihydroxy aryl compounds in which the hydroxyl groups are in the o- or p-position to each other. Typical phenolic antioxidants include the hindered phenols substituted with $C_6$+ alkyl groups and the alkylene coupled derivatives of these hindered phenols. Examples of phenolic materials of this type 2-t-butyl-4-heptyl phenol; 2-t-butyl-4-octyl phenol; 2-t-butyl-4-dodecyl phenol; 2,6-di-t-butyl-4-heptyl phenol; 2,6-di-t-butyl-4-dodecyl phenol; 2-methyl-6-t-butyl-4-heptyl phenol; and 2-methyl-6-t-butyl-4-dodecyl phenol. Other useful hindered mono-phenolic antioxidants may include for example hindered 2,6-di-alkyl-phenolic proprionic ester derivatives. Bis-phenolic antioxidants may also be advantageously used in combination with the instant disclosure. Examples of ortho-coupled phenols include: 2,2'-bis(4-

heptyl-6-t-butyl-phenol); 2,2'-bis(4-octyl-6-t-butyl-phenol); and 2,2'-bis(4-dodecyl-6-t-butyl-phenol). Para-coupled bisphenols include for example 4,4'-bis(2,6-di-t-butyl phenol) and 4,4'-methylene-bis(2,6-di-t-butyl phenol).

**[0091]** Non-phenolic oxidation inhibitors which may be used include aromatic amine antioxidants and these may be used either as such or in combination with phenolics. Typical examples of non-phenolic antioxidants include: alkylated and non-alkylated aromatic amines such as aromatic monoamines of the formula $R^8R^9R^{10}$ where $R^8$ is an aliphatic, aromatic or substituted aromatic group, $R^9$ is an aromatic or a substituted aromatic group, and $R^{10}$ is H, alkyl, aryl or $R^{11}S(0)xR^{12}$ where $R^{11}$ is an alkylene, alkenylene, or aralkylene group, $R^{12}$ is a higher alkyl group, or an alkenyl, aryl, or alkaryl group, and x is 0, 1 or 2. The aliphatic group $R^8$ may contain from 1 to 20 carbon atoms, and preferably contains from 6 to 12 carbon atoms. The aliphatic group is a saturated aliphatic group. Preferably, both $R^8$ and $R^9$ are aromatic or substituted aromatic groups, and the aromatic group may be a fused ring aromatic group such as naphthyl. Aromatic groups $R^8$ and $R^9$ may be joined together with other groups such as S.

**[0092]** Typical aromatic amines antioxidants have alkyl substituent groups of at least 6 carbon atoms. Examples of aliphatic groups include hexyl, heptyl, octyl, nonyl, and decyl. Generally, the aliphatic groups will not contain more than 14 carbon atoms. The general types of amine antioxidants useful in the present compositions include diphenylamines, phenyl naphthylamines, phenothiazines, imidodibenzyls and diphenyl phenylene diamines. Mixtures of two or more aromatic amines are also useful. Polymeric amine antioxidants can also be used. Particular examples of aromatic amine antioxidants useful in the present disclosure include: p,p'-dioctyldiphenylamine; t-octylphenyl-alpha-naphthylamine; phenyl-alphanaphthylamine; and p-octylphenyl-alpha-naphthylamine.

**[0093]** Sulfurized alkyl phenols and alkali or alkaline earth metal salts thereof also are useful antioxidants.

**[0094]** Preferred antioxidants include hindered phenols, arylamines. These antioxidants may be used individually by type or in combination with one another. Such additives may be used in an amount of 0.01 to 5 weight percent, preferably 0.01 to 1.5 weight percent, more preferably zero to less than 1.5 weight percent, most preferably zero.

Antiwear Additives

**[0095]** A metal alkylthiophosphate and more particularly a metal dialkyl dithio phosphate in which the metal constituent is zinc, or zinc dialkyl dithio phosphate (ZDDP) is an essential component of the lubricating oils of this disclosure. ZDDP can be primary, secondary or mixtures thereof. ZDDP compounds generally are of the formula $Zn[SP(S)(OR^1)(OR^2)]_2$ where $R^1$ and $R^2$ are Ci-Cig alkyl groups, preferably $C_2$-$Ci_2$ alkyl groups. These alkyl groups may be straight chain or branched.

**[0096]** Preferable zinc dithiophosphates which are commercially available include secondary zinc dithiophosphates such as those available from for example, The Lubrizol Corporation under the trade designations "LZ 677A", "LZ 1095" and "LZ 1371", from for example Chevron Oronite under the trade designation "OLOA 262" and from for example Afton Chemical under the trade designation "HITEC 7169".

**[0097]** The ZDDP is typically used in amounts of from 0.4 weight percent to 1.2 weight percent, preferably from 0.5 weight percent to 1.0 weight percent, and more preferably from 0.6 weight percent to 0.8 weight percent, based on the total weight of the lubricating oil, although more or less can often be used advantageously. Preferably, the ZDDP is a secondary ZDDP and present in an amount of from 0.6 to 1.0 weight percent of the total weight of the lubricating oil.

Seal Compatibility Agents

**[0098]** Seal compatibility agents help to swell elastomeric seals by causing a chemical reaction in the fluid or physical change in the elastomer. Suitable seal compatibility agents for lubricating oils include organic phosphates, aromatic esters,

aromatic hydrocarbons, esters (butylbenzyl phthalate, for example), and polybutenyl succinic anhydride. Such additives may be used in an amount of 0.01 to 3 weight percent, preferably 0.01 to 2 weight percent.

Antifoam Agents

**[0099]** Anti-foam agents may advantageously be added to lubricant compositions. These agents retard the formation of stable foams. Silicones and organic polymers are typical anti-foam agents. For example, polysiloxanes, such as silicon oil or polydimethyl siloxane, provide antifoam properties. Anti-foam agents are commercially available and may be used in conventional minor amounts along with other additives such as demulsifiers; usually the amount of these additives combined is less than 1 weight percent and often less than 0.1 weight percent.

Friction Modifiers

**[00100]** A friction modifier is any material or materials that can alter the coefficient of friction of a surface lubricated by any lubricant or fluid containing such material(s). Friction modifiers, also known as friction reducers, or lubricity agents or oiliness agents, and other such agents that change the ability of base oils, formulated lubricant compositions, or functional fluids, to modify the coefficient of friction of a lubricated surface may be effectively used in combination with the base oils or lubricant compositions of the present disclosure if desired. Friction modifiers that lower the coefficient of friction are particularly advantageous in combination with the base oils and lube compositions of this disclosure. Friction modifiers may include metal-containing compounds or materials as well as ashless compounds or materials, or mixtures thereof. Metal-containing friction modifiers may include metal salts or metalligand complexes where the metals may include alkali, alkaline earth, or transition group metals. Such metal-containing friction modifiers may also have low-ash characteristics. Transition metals may include Mo, Sb, Sn, Fe, Cu, Zn, and others. Ligands may include hydrocarbyl derivative of alcohols, polyols, glycerols, partial ester glycerols, thiols, carboxylates, carbamates, thiocarbamates, dithiocarbamates, phosphates, thiophosphates, dithiophosphates, amides, imides, amines, thiazoles, thiadiazoles, dithiazoles, diazoles,

triazoles, and other polar molecular functional groups containing effective amounts of O, N, S, or P, individually or in combination. In particular, Mo-containing compounds can be particularly effective such as for example Mo-dithiocarbamates, Mo(DTC), Mo-dithiophosphates, Mo(DTP), Mo-amines, Mo (Am), Mo-alcoholates, Mo-alcohol-amides, etc. See U.S. Patent Nos. 5,824,627, 6,232,276, 6,153,564, 6,143,701, 6,1 10,878, 5,837,657, 6,010,987, 5,906,968, 6,734,150, 6,730,638, 6,689,725, 6,569,820; WO 99/66013; WO 99/47629; and WO 98/26030.

**[00101]** Ashless friction modifiers may also include lubricant materials that contain effective amounts of polar groups, for example, hydroxyl-containing hydrocarbyl base oils, glycerides, partial glycerides, glyceride derivatives, and the like. Polar groups in friction modifiers may include hydrocarbyl groups containing effective amounts of O, N, S, or P, individually or in combination. Other friction modifiers that may be particularly effective include, for example, salts (both ash-containing and ashless derivatives) of fatty acids, fatty alcohols, fatty amides, fatty esters, hydroxyl-containing carboxylates, and comparable synthetic long-chain hydrocarbyl acids, alcohols, amides, esters, hydroxy carboxylates, and the like. In some instances fatty organic acids, fatty amines, and sulfurized fatty acids may be used as suitable friction modifiers.

**[00102]** Useful concentrations of friction modifiers may range from 0.01 weight percent to 10-15 weight percent or more, often with a preferred range of 0.1 weight percent to 5 weight percent. Concentrations of molybdenum-containing materials are often described in terms of Mo metal concentration. Advantageous concentrations of Mo may range from 10 ppm to 3000 ppm or more, and often with a preferred range of 20-2000 ppm, and in some instances a more preferred range of 30-1000 ppm. Friction modifiers of all types may be used alone or in mixtures with the materials of this disclosure. Often mixtures of two or more friction modifiers, or mixtures of friction modifier(s) with alternate surface active material(s), are also desirable.

**[00103]** When lubricating oil compositions contain one or more of the additives discussed above, the additive(s) are blended into the composition in an amount sufficient for it to perform its intended function. Typical amounts of such additives useful in the present disclosure are shown in Table A below.

[00104] It is noted that many of the additives are shipped from the additive manufacturer as a concentrate, containing one or more additives together, with a certain amount of base oil diluent. Accordingly, the weight amounts in the table below, as well as other amounts mentioned in this specification, are directed to the amount of active ingredient (that is the non-diluent portion of the ingredient). The weight percent (wt%) indicated below is based on the total weight of the lubricating oil composition.

TABLE A

Typical Amounts of Other Lubricating Oil Components

| Compound | Approximate wt% (Useful) | Approximate wt% (Preferred) |
|---|---|---|
| Dispersant | 0.1-20 | 0.1-8 |
| Friction Modifier | 0.01-5 | 0.01-1.5 |
| Antioxidant | 0.1-5 | 0.1-2 |
| Pour Point Depressant (PPD) | 0.0-5 | 0.01-1.5 |
| Anti-foam Agent | 0.001-3 | 0.001-0.15 |
| Viscosity Index Improver (solid polymer basis) | 0.0-2 | 0.0-1 |

[00105] The foregoing additives are all commercially available materials. These additives may be added independently but are usually precombined in packages which can be obtained from suppliers of lubricant oil additives. Additive packages with a variety of ingredients, proportions and characteristics are available and selection of the appropriate package will take the requisite use of the ultimate composition into account.

[00106] In an embodiment, improved fuel efficiency can be attained, while wear protection is maintained or improved, in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil as described herein. Improved engine fuel efficiency can be achieved without sacrificing engine durability. The engine oil lubricants of this disclosure can effectively improve fuel economy while providing desired antiwear performance over a wide temperature range. The lubricating oils of this

disclosure are particularly advantageous as passenger vehicle engine oil (PVEO) products.

**[00107]** The following non-limiting examples are provided to illustrate the disclosure.

## EXAMPLES

**[00108]** One SAE 5W-20 engine oil was blended with VLI 151J (The Lubrizol Corporation) viscosity index (VI) improver and another SAE 5W-20 engine oil was blended with Paratone 8451 (Chevron Oronite Company) VI improver. Both of the VI improvers are olefin copolymers. VLI 151J uses propylene and butylene as the olefins which are polymerized while Paratone 8451 uses ethylene and propylene as the olefins which are polymerized. VLI 151J was used as a concentrate containing 11.5 wt% solid polymer in a Group II base oil, and Paratone 8451 was used as a concentrate containing 6.3 wt% solid polymer in a Group I base oil. Both of these oils meet the requirements for an SAE 5W-20 viscosity grade as defined by SAE J300. The formulation containing VLI 151J has a slightly higher HTHS viscosity. This is significant because fuel economy performance is inversely correlated with HTHS viscosity. Table 1 compares the physical properties of two SAE 5W-20 engine oils.

Table 1

| | | | 10070319 | 10072926 |
|---|---|---|---|---|
| | Additives, % | | 9.86 | 9.86 |
| | VL1151J VII, % | | 4.5 | 0 |
| | Paratone 8451 VII, % | | 0 | 4.7 |
| | Basestocks, % | | 85.54 | 85.34 |
| | | | | |
| D445 | KV at 100 C | mm2/s | 7.88 | 7.78 |
| D4683 | HTHS Visc at 150C | cP | 2.65 | 2.59 |
| D5293-7 | CCS @ -35C | mPa s | 6850 | 6350 |

**[00109]** Figure 1 provides Kurt Orbahn (ASTM D6278) shear stability results for the above two formulations measured at multiple test lengths. The Kurt Orbahn shear stability results are equivalent for the formulations blended with the two different VI improvers at 0, 5, 10, and 30 test cycles.

**[00110]** Sequence VID (ASTM D7589) fuel economy testing was conducted for the two 5W-20 formulations blended with the VLl 151J and Paratone 8451 VI improvers. Table 2 provides the Sequence VID fuel economy testing results. The results show the superior fuel economy benefits obtained using the VLl 15 1J VI improvers. Reduced fuel consumption occurred in Sequence VID stages 1, 3, 4, 5 and for the overall test (reported after FEI 1 measurement). The precision for the FEI 1 measurement is 0.13%. Thus, the benefit for the VLl 151J VI improver was 3.4 standard deviation units above the Paratone VI improver. This benefit is statistically significant at a greater than 95% confidence level.

Table 2

| | 10070319 | 10072926 |
|---|---|---|
| VI Improver | VL1151J | Paratone 8451 |
| Stage 1 | 1.54 | 1.25 |
| Stage 2 | 2.71 | 2.70 |
| Stage 3 | 0.82 | 0.54 |
| Stage 4 | 0.61 | -0.13 |
| Stage 5 | 5.66 | 5.20 |
| Stage 6 | 0.30 | 0.65 |
| | | |
| FEI 1 Initial | 1.35 | 0.96 |
| Severity Adjustment | -0.04 | -0.10 |
| Final FEI 1 | 1.31 | 0.86 |

**[00111]** Table 3 compares Gel Permeation Chromatography characterization of the VL1 151J and Paratone 8451 VI improvers. Of note is the very similar weight average molecular weight for the two VI improvers. However, the VLl 15 1J VI improver has a much lower polydispersity index or molecular weight distribution which results in improved fuel economy performance.

Table 3

| **Polymer Characterization** | VL1151J | Paratone 8451 |
|---|---|---|
| Mw | 312,000 | 300,200 |
| Mn | 265,000 | 194,100 |
| PDI | 1.2 | 1.5 |

[00112] All patents and patent applications, test procedures (such as ASTM methods, UL methods, and the like), and other documents cited herein are fully incorporated by reference to the extent such disclosure is not inconsistent with this disclosure and for all jurisdictions in which such incorporation is permitted.

[00113] When numerical lower limits and numerical upper limits are listed herein, ranges from any lower limit to any upper limit are contemplated. While the illustrative embodiments of the disclosure have been described with particularity, it will be understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the spirit and scope of the disclosure. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the examples and descriptions set forth herein but rather that the claims be construed as encompassing all the features of patentable novelty which reside in the present disclosure, including all features which would be treated as equivalents thereof by those skilled in the art to which the disclosure pertains.

[00114] The present disclosure has been described above with reference to numerous embodiments and specific examples. Many variations will suggest themselves to those skilled in this art in light of the above detailed description. All such obvious variations are within the full intended scope of the appended claims

**CLAIMS:**

1. A method for improving fuel efficiency in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a composition comprising:

a lubricating oil base stock; and

a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

wherein fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer.

2. The method of clause 1 wherein the lubricating oil base stock comprises a Group I, Group II, Group III, Group IV or Group V base oil.

3. The method of clauses 1 and 2 wherein the one or more other alpha olefins comprise butylene.

4. The method of clauses 1-3 wherein the one or more other alpha olefins comprise one or more C4 to C12 alpha-olefms.

5. The method of clauses 1-4 wherein the weight average molecular weight (Mw) as measured by GPC is from 150,000 to 450,000, the number average molecular weight (Mn) as measured by GPC is from 150,000 to 350,000, the molecular weight distribution (MWD =Mw/Mn) is from 1.0 to 1.75, and the mole ratio of propylene to one or more other alpha olefins is from 50:50 to 80:20.

6. The method of clauses 1-5 wherein the formulated oil further comprises one or more dispersants.

7. The method of clauses 1-6 wherein the formulated oil further comprises one or more pour point depressants.

8. A method for improving fuel efficiency in an engine lubricated with a lubricating oil by using as the lubricating oil a formulated oil having a composition comprising:

from 60 wt% to 98 wt%, based on the total weight of the formulated oil, of a lubricating oil base stock;

from 0.5 wt% to 15 wt%, based on the total weight of the formulated oil, of a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

from 0.1 wt% to 20 wt%, based on the total weight of the formulated oil, of one or more dispersants; and

from 0.0 wt% to 5 wt%, based on the total weight of the formulated oil, of one or more pour point depressants;

wherein fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer.

9. The method of clauses 1-8 wherein the lubricating oil is a passenger vehicle engine oil (PVEO).

10. The method of clauses 1-9 wherein the viscosity index improver other than the at least one propylene-based polymer comprises an ethylene-based polymer.

11. A lubricating engine oil having a composition comprising:

a lubricating oil base stock; and

a viscosity index improver comprising at least one propylene-based polymer, said

at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

wherein, in an engine lubricated with said lubricating engine oil, fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating engine oil containing a viscosity index improver other than the at least one propylene-based polymer.

12. The lubricating engine oil of clause 11 wherein the weight average molecular weight (Mw) as measured by GPC is from 150,000 to 450,000, the number average molecular weight (Mn) as measured by GPC is from 150,000 to 350,000, the molecular weight distribution (MWD =Mw/Mn) is from 1.0 to 1.75, and the mole ratio of propylene to one or more other alpha olefins is from 50:50 to 80:20.

13. A lubricating engine oil having a composition comprising:

from 60 wt% to 98 wt%, based on the total weight of the lubricating engine oil, of a lubricating oil base stock;

from 0.5 wt% to 15 wt%, based on the total weight of the lubricating engine oil, of a viscosity index improver comprising at least one propylene-based polymer, said at least one propylene-based polymer comprising from 60 wt% to 98 wt% propylene derived units and from 2 wt% to 40 wt% units derived from one or more other alpha olefins, a weight average molecular weight (Mw) as measured by GPC of from 100,000 to 500,000, a number average molecular weight (Mn) as measured by GPC of from 100,000 to 400,000, a molecular weight distribution (MWD =Mw/Mn) of from 1 to 2; and a mole ratio of propylene to one or more other alpha olefins from 50:50 to 85:15;

from 0.1 wt% to 20 wt%, based on the total weight of the lubricating engine oil, of one or more dispersants; and

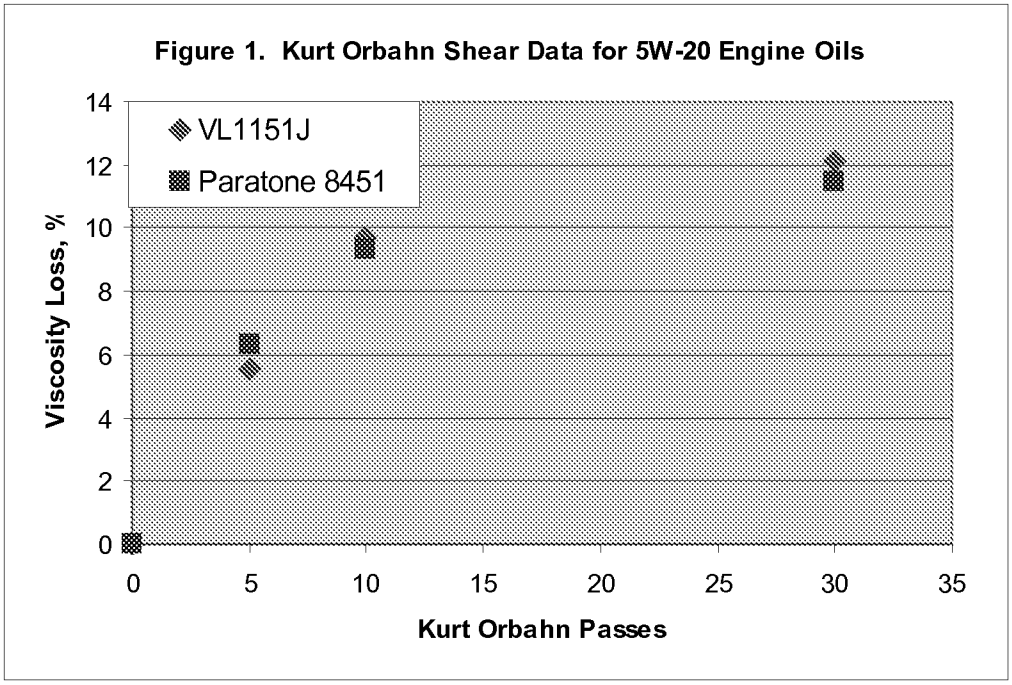
from 0.0 wt% to 5 wt%, based on the total weight of the lubricating engine oil, of one or more pour point depressants;

wherein, in an engine lubricated with said lubricating engine oil, fuel efficiency is improved as compared to fuel efficiency achieved using a lubricating oil containing a viscosity index improver other than the at least one propylene-based polymer.

14. The lubricating engine oil of clauses 11-13 wherein the lubricating oil is a passenger vehicle engine oil (PVEO).

15. The lubricating engine oil of clauses 11-14 wherein the viscosity index improver other than the at least one propylene-based polymer comprises an ethylene-based polymer.

Fig. 1


Figure 1. Kurt Orbahn Shear Data for 5W-20 Engine Oils
VL1151J
Paratone 8451
Viscosity Loss, %
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
Kurt Orbahn Passes

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/070767

A. CLASSIFICATION OF SUBJECT MATTER
INV. C10M143/00 C10M143/06 C10M143/08
ADD. C10N30/06 C10N40/25

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
CIOM

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | WO 2010/016847 Al (EXXONMOBIL CHEM PATENTS INC [US]; RAVISHANKAR PERIAGARAM S [US]; NASS) 11 February 2010 (2010-02-11) cited in the application paragraphs [0066], [0086]; claim 1 | 11, 13-15 |
| X | W0 2011/038331 Al (MITSUI CHEMICALS INC [JP]; LUBRIZ0L CORP [US]; IKEDA SAT0SHI [JP]; KAM) 31 March 2011 (2011-03-31) claims 1,6,; examples 6,7; table 3 | 1-15 |
| X | JP 2009 029983 A (SUMITOMO CHEMICAL CO) 12 February 2009 (2009-02-12) example 1; table 1 | 11, 13-15 |

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 26 February 2013 | 14/03/2013 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Bertrand, Samuel |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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