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(54) **Clean performing gear oils**

(57) A clean performing gear oil for use in transmission oils and axle lubricants is provided. The gear oil having a Brookfield Viscosity at -12°C ranging from about 1,000 to about 150,000 cP, comprises a base oil having a kinematic viscosity at 100°C ranging from

about 4.0 to about 41.0 cSt. Combined with the base oil is a mixture of a pour point depressant and a dispersant viscosity index improver. In addition, the gear oil includes a performance additive which imparts additional necessary properties for the overall performance of the gear oil in transmission and axle lubricants.

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Description**BACKGROUND OF THE INVENTION**

5 This invention relates to gear oils for use as transmission oils and in rear axles. More particularly, this invention relates to gear oils having a good cleanliness performance in transmission and axle applications.

Although a substantial number of gear oils have been produced having various needed properties where such gear oils are used, there exists a need for an additive or a combination of additives to provide an improved clean performing gear oil that can be used, e.g., in transmission oils and axle lubricants to reduce the deposits (i.e., buildup
10 of sludge and other unwanted materials on metal surfaces).

Original equipment manufacturers desire lubricants having extended drain capabilities whereby their customers can operate the equipment for longer periods of time or for greater distances before draining the lubricant and replacing it with fresh lubricant. In view of the competitive situations in which they operate, lubricant manufacturers are also desirous of having the ability to provide lubricants having these prolonged service capabilities.

15 Actual drainage periods utilized will depend, to a large extent, upon the type of severity of service and the design of the equipment. The present invention will allow under certain circumstances extended drainage intervals for many axle and transmission applications.

SUMMARY OF THE INVENTION

20 A gear oil having an improved cleanliness performance comprising:

a) a base oil having a kinematic viscosity at 100°C ranging from about 4.0 to about 41.0 cSt and a Viscosity Index ranging from about 60 to about 140;

25 b) a combination of a pour point depressant and a dispersant Viscosity Index improver; and

c) a gear performance additive whereby the resulting gear oil has a Brookfield Viscosity at -12°C ranging from about 1,000 to about 150,000 cP. The gear performance additives contain components which can impart to the gear oils, properties as needed including antiwear, extreme pressure performance, rust control, corrosion inhibition, foam inhibition, and water separation. Preferably, the base oil has a flash point temperature ranging from about
30 93°C (200°F) to about 371°C (700°F) and the finished gear oil has a flash point temperature ranging from about 149°C (300°F) to about 299°C (570°F).

In addition, the invention provides, inter alia, lubricants and lubricant additive packages that can provide prolonged effective service life, such as extended drain and at least in some cases, operation for at least 100,000 miles without
35 replacement of the gear box and/or axle lubricant. In preferred embodiments, compositions are provided which are useful as transmission oils for heavy duty service, or as axle oils, and as gear oils for all types of service including heavy duty service. Moreover, this invention makes it possible to provide so-called "total driveline" lubricants whereby the same lubricant composition can be used for operation of both the transmission and the axle or differential gearing system. Additionally, the invention enables the achievement of the foregoing advantages with lubricants which are free
40 of metal-containing additive components in that the lubricants may contain as the only metal-containing additive component(s) thereof, a friction-modifying amount of one or more alkali or alkaline earth metal-containing additive components wherein the total concentration of such metal(s) in the finished gear oil is kept very low. That is, the total concentration of such metal(s) in the finished oil is at a maximum amount of about 25 ppm.

45 When referring to the gear oil as being metal free, the presence of boron and phosphorous are not considered metals.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

50 The present invention is directed to providing a clean performing lubricant useful as an automotive transmission gear oil and axle lubricant. By "clean performing gear oil" as used herein is meant those oils when tested in the L-60-1 Test described below, results in relatively clean gears at the end of the test.

Gear Oils

55 The finished gear oil is generally composed of (a) a base oil or mixture of base oils; (b) a combination of a pour point depressant and a dispersant Viscosity Index improver, and (c) a performance additive.

According to the present invention, the finished gear oils or other lubricants have different primary viscosity grades which are indicated by the temperatures at which their Brookfield Viscosities are measured. That is, the Brookfield

Viscosities of the finished gear oils as measured at (-12°C), (-26°C) and (-40°C) have grades of "SAE 75W to 85W". At all grades, the Brookfield Viscosity ranges from about 1,000 to about 150,000 cP. And, the gear oil contains from about 88.0 to about 96.0 wt % of the base oil.

Base Oils

Generally, the base oils of this invention may be formed from natural (e.g., mineral or vegetable oils) or synthetic base oils, or blends thereof. However, the base oils should be primarily of the petroleum mineral oil type.

Suitable mineral oils include those of appropriate viscosity refined from crude oil of any source. Standard refinery operations may be used in processing the mineral oil. Among the general types of petroleum oils useful in the compositions of this invention are bright stocks, residual oils, hydrocracked base stocks, and solvent extracted naphthenic oils. Such oils and blends of them are produced by a number of conventional techniques which are widely known by those skilled in the art.

Among the suitable synthetic oils are homo- and interpolymers of C₂-C₁₂ olefins, carboxylic acid esters of both monoalcohols and polyols, polyethers, silicones, polyglycols, silicates, alkylated aromatics, carbonates, thiocarbonates, orthoformates, phosphates and phosphites, borates, and halogenated hydrocarbons. Representative of such oils are homo- and interpolymers of C₂-C₁₂ monoolefinic hydrocarbons, alkylated benzenes (e.g., dodecyl benzenes, didodecyl benzenes, tetradecyl benzenes, dinonyl benzenes, di-(2-ethylhexyl)benzenes, wax-alkylated naphthalenes); and polyphenyls (e.g., biphenyls, terphenyls).

Alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification, etc., constitute a class of synthetic oils useful herein. These are exemplified by the oils prepared through polymerization of alkylene oxides such as ethylene oxide or propylene oxide, and the alkyl and aryl ethers of these polyoxyalkylene polymers (e.g., methyl polyisopropylene glycol ether having an average molecular weight of 1,000, diphenyl ether of polyethylene glycol having a molecular weight of 500-1,000, diethyl ether of polypropylene glycol having a molecular weight of 1,000-1,500 or mono- and poly-carboxylic esters thereof, for example, the acetic acid ester, mixed C₃-C₆ fatty acid esters, or the C₁₃ Oxo acid diester of tetraethylene glycol).

Another suitable class of synthetic oils comprises the esters of dicarboxylic acids (e.g., phthalic acid, linoleic acid dimer) with a variety of alcohols such as but not limited to butyl alcohol, hexyl alcohol, and dodecyl alcohol. Specific examples of these esters include dibutyl adipate, didodecyl adipate, di-n-hexyl fumarate, and the complex ester formed by reacting one mole of sebacate acid with two moles of tetraethylene-glycol and two moles of 2-ethylhexanoic acid.

Other esters which may be used include those made from C₃-C₁₈ monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylolpropane, pentaerythritol and dipentaerythritol. Trimethylol propane tripelargonate, pentaerythritol tetracaproate, and the polyesters derived from a C₄-C₁₄ dicarboxylic acid and one or more aliphatic dihydric C₃-C₁₂ alcohols such as derived from azelaic acid or sebacic acid and 2,2,4-trimethyl-1,6-hexanediol serve as examples.

Silicon-based oils such as the polyalkyl-, polyaryl-, polyalkoxy-, or polyaryloxy-siloxane oils and silicate oils comprise another class of synthetic lubricants, e.g., tetraethyl silicate, tetraisopropyl silicate, and poly(methylphenyl)siloxanes.

Also useful as base oils or as components of base oils are hydrogenated or unhydrogenated liquid oligomers of C₆-C₁₆ α-olefins, such as hydrogenated or unhydrogenated oligomers formed from 1-decene.

Typical vegetable oils that may be used as base oils or as components of the base oils include castor oil, olive oil, peanut oil, corn oil, soybean oil, linseed oil, and the like. Such oils may be partially or fully hydrogenated, if desired.

According to the present invention, the base oil should have a viscosity that meets at least the viscometric requirements and a flash point temperature such that it will not contribute to the breakdown of the performances of the finished gear oil used in transmission or axle lubricants. Thus, the kinematic viscosity of the present base oil at 100°C ranges from about 4.0 to about 41.0 cSt and the Viscosity Index ranges from about 60 to about 140, preferably from 75 to 120. The flash point temperature of the base oil should range from about 200° to about 700°F, preferably from 300° to 600°F.

Pour Point Depressants

In the combination making up the present gear oil, the pour point depressant (PPD) may be any oil soluble PPD material, e.g., as a poly(alkylmethacrylate). And, accordingly, the PPD should lower the 'pour point' of the finished gear oil.

Poly(alkylmethacrylate) pour point depressants comprising higher alkyl esters, e.g., those including 12 or more carbon atoms per alkyl group, are known. In U.S. Patent No. 4,867,894, Pennewiss et al. disclose a poly(alkyl methacrylate) pour point depressant wherein from 10 to 30, preferably 10 to 20, mole percent methyl methacrylate is copolymerized with alkyl methacrylate monomers having relatively long, i.e., C₁₆ and higher, alkyl groups to form a pour point depressant additive. Pennewiss et al. teach that such an additive has a lower cost due to substitution of relatively

low cost methyl methacrylate for a portion of relatively high cost higher alkyl esters and that, within the disclosed ranges of methyl methacrylate mole percent, such a substitution does not diminish the effectiveness of the additive as a pour point depressant.

A satisfactory PPD according to the present invention is Acryloid 3004 (manufactured by Rohm & Haas of Philadelphia, PA) which is a polymethacrylate. The amount of PPD used in the finished gear oil is generally about 0.5 to about 2.0 wt %. Although Acryloid 3004 has been found to be effective, other PPD's may be used according to the present invention. For example and not as a limitation, other PPD's that may be used in the present invention include those identified below by commercial name/code and (manufacturer; location) :

Viscoplex I-330 (Rohm GmbH; HULS America Inc., Somerset, NJ)
 TC 10314 (Texaco Inc.; Houston, TX);
 TLA 388 (Texaco Inc.);
 TLA 664 (Texaco Inc.); and
 Acryloid 154 (Rohm & Haas; Philadelphia, PA).

Dispersant Viscosity Index Improvers

According to the present invention, the DVII is generally a polymer or a copolymer having both Viscosity Index improving and dispersancy properties. This is shown in the results of the L-60-1 oxidation performance test (described below) where the dispersancy as indicated by the numbers of both the carbon/varnish and sludge ratings.

The dispersant Viscosity Index improver (DVII) should also be oil soluble and enhance both the viscosity index and the dispersancy of the finished lubricant, e.g., gear oil. In addition, the DVII may also improve the pour point depressant properties of the finished gear oil.

A preferred DVII which has been found to be effective in providing a clean gear oil that is useful in transmission oils and axle lubricants is Acryloid 954. The gear oil cleanliness performance may be improved by incorporating therein a DVII. The level of DVII used is such that the finished gear oil has sufficient dispersancy to meet the requirements of the L-60-1 test (described below) which is a part of the API MT-1 gear oil specification.

The gear oil comprises from about 0.1 to about 3.0 wt %, preferably from 0.5 to 2.0 wt % of the combination of the PPD and DVII. However, in any instance, the combination of a PPD and a DVII should be at a maximum amount of about 3.0 wt %, or preferably, about 2.0 wt %.

Other DVII's that may be used are either a Dispersant polymethacrylate (DPMA) or a Dispersant olefin copolymer (DOCP). The DVII's useful in the present invention may, for example, and not by limitation, be selected from the following products identified by commercial name/code and (manufacturer; location):

DPMA's

Acryloid 953 (Rohm & Haas; Philadelphia, PA)
 Acryloid 953M (Rohm & Haas)
 Acryloid 954 (Rohm & Haas)
 Acryloid 958 (Rohm & Haas)
 Acryloid 985 (Rohm & Haas)

DOCP's

Castrol 731 (Castrol, N.A.; Los Angeles, CA)
 Castrol 731X (Castrol, N.A.)
 HiTEC® 6911 (Ethyl Corporation; Richmond, Virginia)
 HiTEC® 688 (Ethyl Corporation)
 HiTEC® 693 (Ethyl Corporation)
 HiTEC® 7575 (Ethyl Corporation)
 Texaco TLA 555 (Texaco Inc.; Houston, TX)
 Texaco TLA 6723 (Texaco Inc.)

Also, according to the present invention, a dispersant pour point depressant (DFPD) may be substituted for the combination of the PPD and DVII. The useful amount of the DPPD is similar to that of the combination, i.e., a maximum of about 3.0 wt %.

Gear Performance Additives

The gear performance additive is generally an ashless oil-soluble additive that may comprise a borated succinimide dispersant.

A gear performance additive that has been found to be effective is HiTEC®-385 (manufactured and sold by Ethyl Corporation of Richmond, Virginia) which contains the component of boron and a combination of sulfur and phosphorus containing materials which impart enhancing properties to the resulting gear oil. At an amount ranging from about 3.0 to about 10.0 wt % the gear performance additive, e.g., HiTEC®-385 is suitable to formulate gear oils for use in both axle and manual transmission lubricants. The gear oil additive useful herein is comprised of one or more components which enhance the performance of the gear oil. These enhanced features (i.e., properties) include:

- Antiwear;
- Extreme pressure performance;
- Rust control;
- Corrosion inhibition;
- Antioxidation;
- Foam inhibition;
- Frictional inhibition; and
- (Optionally) Water separation.

Other gear oil performance additives that may be effective include the following, identified by commercial name/code and (manufacturer; location):

- HiTEC® 381 (Ethyl Corporation; Richmond, Virginia)
- Anglamol 9000 (Lubrizol Corp.; Wickliffe, OH)
- Anglamol 6043B (Lubrizol Corp.)
- Anglamol 6043P (Lubrizol Corp.)
- Anglamol 6043U (Lubrizol Corp.)
- Mobilad 521 T (Mobil Oil; Princeton, NJ)

The gear performance additive components, i.e., oil-soluble sulfur-containing antiwear and/or extreme pressure agent(s) used may be of low activity. Subject to this proviso, categories of materials in which suitable materials may exist include sulfurized olefins, sulfurized unsaturated fatty acids and/or esters, dihydrocarbyl polysulfides, trithiones, sulfurized thienyl derivatives, sulfurized terpenes, sulfurized oligomers of C₂-C₈ monoolefins, sulfurized Diels-Alder adducts, and, in general, compounds which contain sulfur bound directly to carbon or to more sulfur. Specific examples of such materials include sulfurized triisobutylene, dicyclohexyl polysulfide, diphenyl polysulfide, dibenzyl polysulfide, dinonyl polysulfide, and mixtures of di-tert-butyl polysulfide such as mixtures of di-tert butyl trisulfide, di-tert-butyl tetrasulfide and di-tert-butyl pentasulfide, among others. Combinations of such categories of sulfur-containing antiwear and/or extreme pressure agents can also be used, such as a combination of sulfurized isobutylene and di-tert-butyl trisulfide, a combination of sulfurized isobutylene and dinonyl trisulfide, a combination of sulfurized tall oil and dibenzyl polysulfide, and the like.

Because of the toxicity of hydrogen sulfide, it is highly preferable, though not essential, to utilize in the practice of this invention oil-soluble sulfur-containing antiwear and/or extreme pressure agents, and more preferably oil-soluble active sulfur-containing antiwear and/or extreme pressure agents, that yield less than 25 ppm, and more preferably less than 10 ppm, of vapor space H₂S when heated in the concentrated state for one week at 65° C. Most preferred are materials of this type which yield no detectable vapor space H₂S when tested under these conditions.

From the most cost-effectiveness standpoint, the most preferred oil-soluble metal-free sulfur-containing antiwear and/or extreme pressure agents are the sulfurized olefins containing at least 30% weight of sulfur, the dihydrocarbyl polysulfides containing at least 25% by weight of sulfur, and mixtures of such sulfurized olefins and polysulfides. Of these materials, sulfurized isobutylenes having a sulfur content of at least 35% by weight of sulfur, and mixtures of such sulfurized olefins and polysulfides. Of these materials, sulfurized isobutylenes having a sulfur content of at least 35 % by weight and a chlorine content, if any, of less than 0.2% by weight are the most especially preferred materials.

Methods of preparing sulfurized olefins are described in U.S. Patent Nos. 2,995,569; 3,673,090; 3,703,504; 3,703,505; 3,796,661; and 3,873,454.

For purposes of this invention, a component which contains both phosphorus and sulfur in its chemical structure is deemed a phosphorus-containing antiwear and/or extreme pressure agent rather than a sulfur-containing antiwear and/or extreme pressure agent.

One soluble type of oil-soluble metal-free phosphorus-and nitrogen-containing antiwear and/or extreme pressure agent which can be employed in the practice of this invention is the phosphorus- and nitrogen-containing compositions of the type described in G.B. 1,009,913; G.B. 1,009,914; U.S. 3,197,405 and/or U.S. 3,197,496. In general, these

compositions are formed by forming an acidic intermediate by the reaction of a hydroxy-substituted triester of a phosphorothioic acid with an inorganic phosphorous acid, phosphorous oxide or phosphorous halide, and neutralizing a substantial portion of said acidic intermediate with an amine or hydroxy-substituted amine.

It should be noted that by containing the preferred amount of a suitable performance additive, the finished gear oil would contain about 500 to 2500 ppm phosphorus, 1000 to 30,000 ppm sulfur, and 50 to 500 ppm boron.

The finished gear oils to be used in the lubricants for transmissions and axles may be tested for their effectiveness by a well known oxidation performance test, i.e., L-60-1 as described below.

OXIDATION PERFORMANCE TEST: L-60-1

In providing a suitable gear oil, the L-60 test predecessor of L-60-1 Test has been used for many years to evaluate the oxidation performance of automotive axle and transmission oils. It is one of the tests present in the API-GL-5 classification for gear oils, and is also used in qualifying gear oils to the U.S. military specification, MIL-2105D. The L-60 test as used may be generally described as to:

SCOPE: Determines the deterioration of lubricants under severe oxidation conditions.

METHOD: A measured sample of test oil is placed in a special gear case with two spur gears and a copper catalyst strip. The test is run for 50 hours, at 163°C, whilst the gears are being driven at 1725 rpm, and air is being bubbled through the sample.

RESULTS: Viscosity increase and pentane and toluene insolubles are determined.

RATING: The gears are rated for carbon, varnish, and sludge deposits.

At the end of the test, a sample of the oxidized oil is evaluated for pentane and toluene insolubles (insolubles build up in the oil as a result of oxidation), and the rise in viscosity (viscosity of the oil tends to rise as a result of oxidation).

Over the past few years, a procedure has been established where, in addition to evaluating the oil in the L-60 test, the gears are also evaluated. As the oil oxidizes, there is a tendency for material to be deposited on the surface of the gears. The amount of deposit is rated with respect to carbon/varnish and with respect to sludge. Within the past year, the ASTM has improved the precision of the L-60 test which has subsequently been renamed the L-60-1 test. New specifications (API MT-1, MIL-PRF-2105E) have stipulated that the limits (i.e., rating) of these new features of carbon/varnish and of sludge are 7.5 MIN (minimum) and 9.4 (minimum), respectively. The L-60-1 test procedure is practically identical to the L-60 test except that the conditions and parameters are more rigorously controlled in the industry. The Test Monitoring Center (TMC) records and reports the precision of each approved stand within the industry.

The relevance of the rating of the gear surfaces from the L-60-1 test is two-fold. Firstly, clean gears are used to market the lubricant as a positive feature as the industry moves to lubricants with improved oxidation and longer life. Pictures of the gears are often used in marketing the lubricant. Secondly, it is hypothesized in the industry that the deposits which build up on the shafts of the pinions of the gears during application cause an increase of friction with the seal and, thus, lead to premature seal erosion and even failure. It is, thus, important for both commercial and practical reasons to be able to market gear lubricant technology which exhibits enhanced performance in the **L-60-1** test.

In order to show the advantages and effectiveness of the gear oils of this invention, blends of gear oils have been prepared with all or some of the components, i.e., additives, **PPD's** and **DVII's**. These blends of finished gear oils were tested according to the **L-60-1** test.

The components used in the finished gear oils as identified and described below, are:

Gear Additive A--containing sulfur, phosphorus and boron, respectively at about 23.0, 1.3, and 0.17 wt %, **HITEC®**

PPD--having a kinematic viscosity at 100°C of about 8.5 cSt and a specific gravity of about 27, **Acryloid 3004**.

Base Oil I --having a kinematic viscosity at 100°C of about 4.99 cSt, a Viscosity Index of about 100, a flash point temperature of about 203°C (398°F), and a refractive index of about 1.479.

Base Oil II --having a kinematic viscosity at 100°C of about 31.4 cSt, a Viscosity Index of 90, a flash point temperature of about 291°C (555°F), and a refractive index of about 1.497.

DVII--a dispersant polymethacrylate, **Acryloid 954**.

The practical advantages of this invention are illustrated by the following examples of blends of gear oils (i.e., Examples I through IV), and the results of the **L-60-1** test are provided, respectively, below in TABLES I and II. The percentages are by weight unless otherwise specified, and the limits or ratings of the **L-60-1** test results are indicated as maximum (MAX) or minimum (MN).

EXAMPLES I-IV

The components of the blends of inventive gear oils (wt %) are provided in TABLE I:

TABLE I

GEAR OILS				
Component	I	II	III	IV
Gear Additive A (HiTEC® 385)	7.50	7.50	7.50	7.50
PPD (Acryloid 3004)	2.00	0.50	1.00	
Base Oil I	34.50		34.50	
Base Oil II	56.00	92.00	56.00	92.00
DVII (Acryloid 954)			1.00	0.50

The results of the **L-60-1** test of the gear oil blends of EXAMPLES I-IV are provided in TABLE II:

TABLE II

RESULTS OF L-60-1 TEST					
Result	Limit	Gear Oil			
		I	II	III	IV
VISCOSITY RISE (%)	100 (MAX)	78.5	97.2	58.38	84.74
PENTANE INSOLS (%)	3 (MAX)	4.93	2.73	1.0	1.89
TOLUENE INSOLS (%)	2 (MAX)	2.11	2.01	0.8	1.25
CARBON/VARNISH	*7.5 (MIN)	7.22	6.0	9.4	9.0
SLUDGE	*9.4 (MIN)	8.80	9.26	9.45	9.4
* Rating					

As shown above, Table II describes the results obtained when the four oils described in Table I are tested in the **L-60-1** gear oil oxidation test. It can be seen that Gear Oil I contains no dispersant VII, whereas Gear Oil III contains 1.0 % of **DVII**--Acryloid 954. The results in Table II show that Gear Oil III results in less viscosity rise, pentane insolubles and toluene insolubles compared to Gear Oil I. This indicates that the **DVII** in Gear Oil III gives rise to better oxidation control compared to that of Gear Oil I. In addition, the gear cleanliness ratings of carbon/varnish and sludge are higher (better) in the case of Gear Oil III than those of Gear Oil I. Improved gear cleanliness as seen in these **L-60-1** tests is a very desirable feature for a gear lubricant as explained above.

Similarly, Table I provides a comparison of Gear Oils II and IV. Gear Oil IV contains **DVII** whereas Gear Oil II does not. The degree of oxidation of the Gear Oil II during the test is indicated by the rise in viscosity, the pentane insolubles, and the toluene insolubles shown in Table II. It can be seen that the Gear Oil IV with the **DVII** gives superior performance with respect to rise in viscosity, the pentane insolubles and the toluene insolubles as shown in Table II. In addition, Gear Oil IV also gives rise to greater gear cleanliness than Gear Oil II as shown by the higher (better) carbon/varnish and sludge ratings.

Therefore, Tables I and II clearly show the advantage of adding **DVII** to gear Oils in the **L-60-1** Test and are examples of the present invention.

The compositions of this invention preferably may contain at least one oil-soluble trihydrocarbyl-dithiophosphate. This group of optional but preferred compounds is composed of O,O-dihydrocarbyl-S-hydrocarbyl thiothionophosphates (also known as O,O-dihydrocarbyl-S-hydrocarbyl phosphorothiothionates).

These compounds can be made by various known methods. Probably the most efficacious method involves reacting phosphorus pentasulfide (P_2S_5 , often regarded as P_4S_{10}) with the appropriate alcohols or mixture of alcohols. Compounds in which one of the hydrocarbyl groups differs from the other two are preferably made by first reacting the phosphorus pentasulfide with an appropriate alcohol to form an intermediate product, viz, $(RO)_2PSSH$, which in turn is reacted with a compound containing at least one reactive olefinic double bond. See, in this connection, U.S. Pat. Nos. 2,528,732; 2,561,773; 2,665,295; 2,767,206; 2,802,856; 3,023,209, and J. Org. Chem., 1963, 28, 1262-8.

Exemplary compounds suitable for use in the compositions of this invention include such compounds as trioctylphosphorothiothionate, tridecylphosphorothiothionate, trilaurylphosphorothiothionate, O,O-diethyl bicyclo(2.2.1)-hepten-2-yl phosphorothiothionate, O,O-diethyl 7,7-dimethyl-bicyclo(2.2.1)-5-hepten-2-ylphosphorothiothionate, the product formed by reaction of dithiophosphoric acid-O,O-dimethyl ester with cis-endomethylene-tetrahydrophthalic

acid dimethyl ester, the product formed by reaction of dithiophosphoric acid-O,O-dimethyl ester with cis-endomethylene-tetrahydrophthalic acid dibutyl ester.

Preferably, the finished gear oil compositions of this invention are ashless or low-ash compositions, that is, they contain, if any, at most 2,000 parts by weight of metal introduced as one or more than 500 ppm of metal, and most preferably zero to at most 25 ppm of metal introduced as one or more additive components. Accordingly, the additive concentrates of this invention are preferably proportioned such that if one or more metal-containing components (e. g., zinc dihydrocarbyldithiophosphate and/or metal detergent) are included therein, the additive concentrate when employed in a base oil at the selected or recommended dosage level will yield a finished lubricant having at most 2,000 ppm, preferably at most 500 ppm, and more preferably at most 25 ppm of added metal. When one or more metal additives are employed, the metal content thereof most preferably is confined to one or more alkali metals and/or one or more alkaline earth metals. Thus, for example, these particular preferred compositions are zinc-free. Compositions devoid of added metal content are most especially preferred. In this connection, neither boron nor phosphorus is subject to these preferred limitations on metal content, as neither such element is a metal. Thus, the mere fact that boron and/or phosphorus components may leave residues during usage, is of no relevance as regards these preferred limitations on metal content.

While the preferred embodiments have been fully described and depicted for the purposes of explaining the principles of the present invention, it will be appreciated by those skilled in the art that modifications and changes may be made thereto without departing from the scope of the invention set forth in the appended claims.

Claims

1. A lubricant having a Brookfield Viscosity at -12°C in the range from 1,000 to 150,000 cP, and comprising:
 - a) a base oil having a kinematic viscosity at 100°C ranging from 4.0 to 41.0 cSt and a Viscosity Index ranging from 60 to 140;
 - b) a combination of a pour point depressant and a dispersant Viscosity Index improver in the amount of 0.1 to about 3.0 wt %; and
 - c) a gear performance additive in the amount of 3.0 to 10.0 wt %.
2. A lubricant as claimed in Claim 1, characterised in that a dispersant pour point depressant is substituted for said combination of said pour point depressant and dispersant Viscosity Index improver.
3. A lubricant as claimed in Claim 1 or Claim 2, characterised in that said gear performance additive comprises a borated succinimide dispersant.
4. A lubricant as claimed in any one of the preceding claims, characterised in that said lubricant contains from about 88.0 to about 96.0 wt% of said base oil.
5. A lubricant as claimed in any one of the preceding claims, characterised in that said lubricant is essentially free of metal containing additive components.
6. A lubricant as claimed in Claim 5, characterised in that said lubricant has a maximum concentration of said metal-containing additive components of 25 ppm.
7. A lubricant as claimed in any one of Claims 1 to 6 which is a gear oil.
8. A gear oil as claimed in Claim 7 having a Brookfield Viscosity at -26°C ranging from about 1,000 to about 150,000 cP.
9. A gear oil as claimed in Claim 7 having a Brookfield Viscosity at -40°C ranging from about 1,000 to about 150,000 cP.
10. A gear oil as claimed in any one of Claims 7 to 9 wherein said dispersant Viscosity Index improver is a polymer containing both Viscosity Index improving and dispersancy properties.
11. A gear oil as claimed in any one of Claims 7 to 10, characterised in that said dispersant Viscosity Index improver is a dispersant polymethacrylate.
12. A gear oil as claimed in any one of Claims 7 to 10, characterised in that said dispersant Viscosity Index improver

is a dispersant olefin copolymer.

13. A gear oil as claimed in any one of Claims 7 to 12, characterised in that said base oil has a flash point temperature ranging from 93°C to 371°C (200° to 700°F).

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14. A gear oil as claimed in any one of Claims 7 to 12, characterised in that said gear oil has a flash point temperature ranging from 149°C to 299°C (300° to 570°F).

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15. A gear oil as claimed in any one of Claims 7 to 14, characterised in that said gear oil contains about 500 to 2,500 ppm phosphorus, about 1,000 to 30,000 ppm sulfur, and about 50 to 500 ppm boron.

16. A gear oil as claimed in any one of Claims 7 to 15, characterised in that said gear performance additive is an ashless oil-soluble additive.

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