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(54) Title: LUBRICANT COMPOSITIONS

(57) Abrégé/Abstract:
A lubricant composition characterized by the Society of Automotive Engineers ("SAE") as 75W-140 capable of meeting the American Petroleum Institute's ("API") GL-5 performance classification requirements for use in association with a device involving metal to metal contact of moving parts comprising: (a) base-stock comprising (i) at least one relatively low viscosity polyalphaolefin, and (ii) at least one diester; (b) viscosity improver comprising (i) at least one relatively high viscosity polyalphaolefin, and (ii) polyisobutylene; and (c) a performance additive comprising at least one additive effective to improve at least one property of the lubricant and/or the performance of the equipment in which the lubricant is to be used.

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(54) **Title**: LUBRICANT COMPOSITIONS

(57) **Abstract**: A lubricant composition characterized by the Society of Automotive Engineers ("SAE") as 75W-140 capable of meeting the American Petroleum Institute's ("API") GL-5 performance classification requirements for use in association with a device involving metal to metal contact of moving parts comprising: (a) base-stock comprising (i) at least one relatively low viscosity polyalphaolefin, and (ii) at least one diester; (b) viscosity improver comprising (i) at least one relatively high viscosity polyalphaolefin, and (ii) polyisobutylene; and (c) a performance additive comprising at least one additive effective to improve at least one property of the lubricant and/or the performance of the equipment in which the lubricant is to be used.

LUBRICANT COMPOSITIONS

FIELD OF THE INVENTION

This invention relates to lubricant compositions having utility in numerous applications, particularly in connection with gear, transmission and/or axle applications in the automotive and machinery industries.

BACKGROUND OF THE INVENTION

An important function of lubricant compositions, and in particular gear and axle lubricant fluids, is to provide a high degree of reliability and durability in the service life of equipment in which it is installed. Lubricating oils in general, and gear and axle lubricants in particular, frequently must satisfy a relatively large number of performance criteria to be commercially successful. For example, a commercially successful axle lubricant will frequently be required to possess a high degree of oxidative stability, compatibility, shear stability, corrosion avoidance or resistance, wear protection, shiftability, and extended drain. These properties represent a difficult to achieve set of performance criteria.

Gear lubricant compositions are classified by the American Petroleum Institute ("API") using "GL" ratings. These classifications are subdivided into six classes. The lowest rating, API GL-1, classifies oils used for light conditions, which consist of base oils without additives. The highest rating, API GL-6, classifies oils for very heavy conditions, such as high speeds of sliding and significant shock loading, and which contain up to 10% high performance antiscuffing additives. However, class API GL-6 is not applied any more as it is considered that class API GL-5 will meet most severe requirements. Lubricant compositions classified meeting API GL-5 performance requirements are generally applied, for example, in hypoid gears having significant displacement of axles.

The viscosity-temperature relationship of a lubricating composition is another of the critical criteria to be considered when selecting a lubricant for a particular application. Mineral oils commonly used as a base for single and multigraded lubricants exhibit a relatively large change in viscosity with a change in temperature. Fluids exhibiting such a relatively large change in viscosity with temperature have a low viscosity index. The SAE J306 describes viscometric qualifications for axle and gear lubricant compositions. This classification is based on the lubricant viscosity measured at both high and low temperatures. The high-temperature kinematic viscosity values are determined according to ASTM D 445, with the results reported in centistokes (cSt). The low-temperature viscosity values are determined according to ASTM D 2983 and the results are reported in centipoise (cP). These two viscosity units are related as follows in Equation 1:

$$(cP / (Density, g / cm^3)) = cSt \qquad (Eq. 1)$$

The following Table 1 summarizes high and low temperature requirements for qualifications of axle and gear lubricant compositions.

Table 1

SAE Viscosity Grade	Maximum Temperature for Viscosity of 150,000 cP, °C	Viscosity at 100°C, cSt	
		Minimum	Maximum
70W	-55	4.1	—
75W	-40	4.1	—
80W	-26	7.0	—
85W	-12	11.0	—
80	—	7.0	<11.0
85	—	11.0	<13.5
90	—	13.5	<18.5
110	—	18.5	<24.0
140	—	24.0	<32.5
190	—	32.5	<41.0
250	—	41.0	—

These Society of Automotive Engineers ("SAE") standards are intended for use by equipment manufacturers in defining and recommending automotive gear, axle, and manual transmission lubricants, for oil marketers in labeling such lubricants with respect to their viscosity, and for users in following their owner's manual recommendations.

High temperature viscosity is related to the hydrodynamic lubrication characteristics of the fluid. Some lubricant compositions may contain high molecular weight polymers, known as viscosity modifiers or viscosity index improvers, which function to increase the viscosity of the fluids. During use, however, these polymers may shear to a lower molecular weight, thereby resulting in a fluid with a lower viscosity than that of the new fluid. Low temperature viscosity requirements are related to the ability of the fluid to flow and provide adequate lubrication to critical parts under low ambient temperature conditions.

Although a substantial number of lubricant compositions have been produced having various needed properties where such lubricant compositions are used, there exists a need for an additive or a combination of additives to provide an improved clean performing lubricant composition that can be used. While acceptable performance of the gear oil is a requirement, it is also highly desirable that the additive or additives be low in cost and easily produced. Accordingly, there is a need in the art for a lubricant composition that meets these industry standards and further provides cost-effective alternatives that may be easily produced, and in particular lubricant compositions classified as SAE 75W-140 and meet GL-5 performance requirements.

SUMMARY OF THE INVENTION

Applicants have developed improved lubricant compositions, and in many embodiments, lubricant compositions that satisfy a relatively high level of performance for the criteria mentioned above. As used herein, the term “lubricant composition” is used in its broadest sense to include fluid compositions that are used in applications involving metal to metal contact of parts in which at least one function of the fluid is to inhibit or reduce friction between the parts. As such, the term “lubricant composition” as used herein includes gear oils, axle oils, and the like.

In certain embodiments, the lubricant compositions of the present invention comprise: (a) base-stock; (b) viscosity improver; and (c) at least one additive. Certain lubricant compositions of the present invention comprise: (a) base-stock comprising (i) a low viscosity polyalphaolefin (“PAO”), and (ii) at least one diester; (b) viscosity improver comprising (i) at least one relatively high viscosity PAO-type viscosity improver, and (ii) polyisobutylene; and (c) a performance additive package comprising at least one additive effective to improve at least one property of the lubricant and/or the performance of the equipment in which the lubricant is to be used. In certain embodiments the lubricant compositions of the present invention are multiviscosity-grade lubricants having a SAE viscosity classification of 75W-140, and meet API GL-5 performance requirements.

Applicants have found that certain embodiments of the present lubricant compositions having an SAE viscosity classification of 75W-140 and meeting API GL-5 performance requirements comprise:

(a) about 10-35% by weight of a low viscosity PAO;

(b) about 30-75% by weight of a high viscosity PAO;

(c) about 5-30% by weight of a diester;

(d) about 2-25% by weight of PIB;

(e) about 5-10% by weight of an additive package; and, optionally

(f) about 0.001-0.004% by weight of an antifoam agent.

Applicants have found that certain SAE 75W-140 lubricant compositions of the present invention meet API GL-5 performance requirements and provide cost-effective lubricant compositions that exhibit improved performance in ring and pinion gears with respect to one or more, and preferably all, of the following advantageous properties: ridging, rippling, pitting, spalling, scoring, and wear.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is directed in one aspect to lubricant compositions comprising: (a) base-stock; (b) viscosity improver; and (c) at least one additive. In certain embodiments the lubricant composition is a multiviscosity-grade lubricant having a SAE viscosity classification of 75W-140, and meets API GL-5 performance requirements. In certain embodiments, the base-stock of the present invention comprises: (i) a low viscosity polyalphaolefin ("PAO"); and (ii) at least one diester. In certain embodiments, the viscosity improver of the present invention comprises: (i) at least one relatively high viscosity PAO-type viscosity improver; and (ii) polyisobutylene. In certain embodiments, the performance additive package comprises at least one additive effective to improve at least one property of the equipment in which the lubricant is to be used. The present invention also provides methods of making and using a fully formulated lubricant, including a fully formulated heavy duty axle fluid, and to axle, gear, transmission or drive systems containing such oils.

In general, it is contemplated that these components of the present invention may be present in compositions in widely varying amounts depending on the particular needs of each application, and all such variations are considered to be within the broad scope of the invention. Nevertheless, applicants have found that in certain embodiments the present lubricant compositions comprise:

(a) about 15- 65% by weight of base-stock;

(b) about 30-75% by weight of viscosity improver; and

(c) about 7-35% by weight of additive.

Applicants have found that certain lubricant compositions of the present invention, when used in connection with ring and pinion gears, exhibit and/or produce advantageous properties with respect to one or more, and preferably all, of the following: ridging, rippling, pitting, spalling, scoring, and wear.

The PAOs of the present invention comprise a class of hydrocarbons that can be manufactured by the catalytic oligomerization (polymerization to low-molecular-weight procedures) of linear α-olefins typically ranging from 1-octene to 1-dodecene, with 1-decene being a preferred material, although polymers of lower olefins such as ethylene and propylene may also be used, including copolymers of ethylene with higher olefins. In general, numerous particular compounds or combinations of compounds are available for use in connection with each of the components as described herein.

In certain embodiments, the base-stock of the present invention comprises at least one relatively low viscosity PAO and at least one diester. With respect to the low viscosity PAO of the present invention, in certain embodiments the low viscosity PAO comprises a polyalphaolefin having a viscosity of not greater than about 12 cSt. In one embodiment, the low viscosity PAO of the present invention comprises ChevronPhillips PAO-2 and Ineos PAO-6. Further examples of such low viscosity PAOs should be apparent to one of ordinary skill in the art. With respect to the diester of the present invention, in certain embodiments the diester comprises an adipate ester. In yet other embodiments, the adipate ester comprises a decyl adipate, and even more particularly one or more adipate esters selected from the group consisting of di-isodecyl adipate, di-isodecyl azelate, and di-tridecyl adipate. While it is contemplated that a large range of relative concentrations of such components may be present, in general, the base-stock of the present invention comprises in certain embodiments a low viscosity PAO:ester weight ratio of from about 7:1 to about 1:3, and preferably of from about 2.6:1 to about 1:1.6. In certain embodiments, the lubricant compositions of the present invention comprise a low viscosity PAO in an amount of from about 10-35% by weight, and in yet other embodiments of from about 12-20% by weight. In certain embodiments, the lubricant compositions of the present invention comprise a diester in an amount of from about 5-30% by weight, and in yet other embodiments of from about 7.5-20% by weight.

In certain embodiments, the viscosity improver of the present invention comprises at least one relatively high viscosity PAO and polyisobutylene. With respect to the high viscosity PAO of the present invention, in certain embodiments the high viscosity PAO comprises a polyalphaolefin having a viscosity of not greater than about 40 cSt, and preferably from about 40 to about 1000 cSt. In one embodiment, the high viscosity PAO of the present invention comprises ExxonMobil or Chemtura PAO-100. Further examples of such high viscosity PAOs should be apparent to one of ordinary skill in the art. With respect to the polyisobutylenes of the present invention, in certain embodiments the polyisobutylene comprises Ineos H-1500-SPA or Lubrizol 8404. Further examples of such polyisobutylenes should be apparent to one of ordinary skill in the art. While it is contemplated that a large range of relative concentrations of such components may be present, in general, the viscosity improver of the present invention comprises in certain embodiments a high viscosity PAO:polyisobutylene weight ratio of from about 37.5:1 to about 1.2:1, and preferably of from about 12:1 to about 2.6:1. In certain embodiments, the lubricant compositions of the present invention comprise a high viscosity PAO in an amount of from about 30-75% by weight, and in yet other embodiments of from about 40-60% by weight. In certain embodiments, the lubricant compositions of the present invention comprise polyisobutylene in amount of from about 2-25% by weight, and in yet other embodiments of from about 5-15% by weight.

In certain embodiments, the at least one performance additive of the present invention comprises a performance additive package comprising at least one additive effective to improve at least one property of the lubricant and/or the performance of the equipment in which the lubricant is to be used. In certain embodiments, the performance additive comprises at least one additive based on sulfur chemistry and at least one additive based on phosphorous chemistry. A typical additive package would normally contain one or more of a dispersant, antioxidant, corrosion inhibitor, anti-wear agent, anti-rust agent, and extreme pressure agent. In one embodiment, the additive package comprises Afton HiTec 317. Further examples of such additives should be apparent to one of ordinary skill in the art. In certain embodiments, the additive package optionally comprises an antifoam agent. In certain other embodiments, the antifoam agents comprise silicones and miscellaneous organic compounds. In certain other embodiments, the antifoam agent comprises lower molecular weight dimethyl siloxane. In one embodiment, the antifoam agent comprises Dow Corning DC-200 / 300 to 60,000 cSt. Further examples of such antifoam agents should be apparent to one of ordinary skill in the art. In certain embodiments, the lubricant compositions of the present invention comprise an additive package in an amount of from about 5-10% by weight, and in other embodiments of from about 7.5-9% by weight. In certain embodiments, the lubricant compositions of the present invention comprise an antifoam agent in an amount of from about 0.001-0.004% by weight.

The present lubricant compositions may be prepared by mixing the components together at a temperature of from about 35°C to about 95°C, preferably from about 65°C to about 85°C. The base-stocks, viscosity improvers, and additives are placed in a suitable metal or glass vessel. Mechanical agitation is supplied to promote mixing. Sufficient mixing time is utilized to ensure that a homogeneous product is present. The process for making the lubricant compositions of the present invention should be known to and appreciated by one of ordinary skill in the art given the present disclosure. One of ordinary skill in the art would appreciate that this method of preparation is not limiting to the invention, and that one or more components may be modified in accordance with the teachings herein or that which is known in the art.

The lubricant compositions of the present invention preferably meet the requirements of both low-temperature and high-temperature grade lubricants, and in certain embodiments are multiviscosity-grade lubricants. Certain lubricant compositions of the present invention are classified as SAE 75W-140 lubricants and meet the low-temperature requirements for SAE 75W and the high-temperature requirements for SAE 140. Lubricant compositions classified as SAE 75W have a viscosity of about 150,000 cP at -40°C. Lubricant compositions classified as SAE 140 are those having a kinematic viscosity at 100°C of at least about 24.0 cSt and less than about 32.5 cSt.

In certain embodiments the lubricant compositions of the present invention meet API Category GL-5 performance requirements, and in yet other embodiments meet the SAE J2360 performance standard. Certain lubricant compositions of the present invention are intended for gears. In certain embodiments, the lubricant compositions are intended for gears in automotive axles equipped with hypoid gears, operating under various combinations of high-speed/shock-load and low-speed/high-torque conditions. Certain lubricant compositions of the present invention meet the API Category GL-5 performance requirements outlined by the following tests and acceptance criteria: (1) Standard Version of L-42; (2) Canadian Version of L-42; (3) Standard Version of test method ASTM D 6121; (4) Canadian Version of test method ASTM D 6121; (5) test method ASTM D 7038 or L-33; (6) test method ASTM D 5704 or L-60; (7) test method ASTM D 892; and (8) test method ASTM D 130.

Based on the foregoing, one embodiment of the lubricant compositions of the present invention comprises: (a) a low viscosity polyalphaolefin ("PAO"); (b) a high viscosity PAO; (c) a diester; (d) polyisobutylene ("PIB"); (e) an additive; and, optionally (f) an antifoam agent; wherein the lubricant composition is a multiviscosity-grade lubricant having a SAE viscosity classification of 75W-140 and meets API Category GL-5 performance requirements. Applicants have found that in certain embodiments the present lubricant compositions comprise:

(a) 10-35% by weight of a low viscosity PAO;
(b) 30-75% by weight of a high viscosity PAO;
(c) 5-30% by weight of a diester;
(d) 2-25% by weight of PIB;
(e) 5-10% by weight of an additive package; and, optionally
(f) 0.001-0.004% by weight of an antifoam agent.

In certain other embodiments, the present lubricant composition comprises:

(a) 12-20% by weight of a low viscosity PAO;
(b) 40-60% by weight of a high viscosity PAO;
(c) 7.5-20% by weight of a diester;
(d) 5-15% by weight of PIB;
(e) 7.5-9% by weight of an additive package; and, optionally
(f) 0.001-0.004% by weight of an antifoam agent.

The instant invention is not necessarily limited to the foregoing. One of ordinary skill in the art would appreciate that this embodiment is not limiting to the invention, and that one or more components may be modified in accordance with the teachings herein or that which is known in the art.

EXAMPLES

The following examples are provided for the purpose of illustrating the present invention, but without limiting the scope thereof.

Example Lubricant Composition 1 was prepared by mixing together the components as shown in Table 2 as follows.

Table 2

Component	Composition	Amount (weight %)
Base-stock	Low Viscosity PAO (73.9% ChevronPhillips PAO-2, 26.1% Ineos PAO-6)	23
Base-stock	Diester (Cognis Synative 2970 / diisodecladipate)	14
Viscosity Improver	High Viscosity PAO (ExxonMobil or Chemtura PAO-100)	45
Viscosity Improver	Polyisobutylene (Ineos H-1500-SPA)	10
Additive	API GL-5 Additive Package (Afton HiTec 317)	8.5
Additive	Antifoam Additive (Dow Corning DC-200 / 60,000)	0.002

Performance of Lubricant Compositions in Axles Under High Speed and Shock Loading: L-42 (ASTM D 7452)

The objective of this procedure is to evaluate the anti-scoring properties of gear lubricants under high-speed and shock conditions. The performance of procedure lubricants is compared to that of reference oils. A specially selected rear axle-mounting assembly and two large dynamometers serve as the procedure apparatus. A break-in is conducted at moderate speed and load at a lubricant temperature of 225°F (107.2 °C). This is followed by a series of moderate accelerations and decelerations with temperatures approaching 280°F (137.8 °C). The final series of runs consists of high-speed accelerations with rapid decelerations. This test may be performed under two different sets of operating conditions, commonly referred to as "Standard" and "Canadian." The ring and pinion gears are evaluated on a pass/fail basis. The pass/fail criteria require that there be less quantity of scoring on the ring and pinion gears than on the associated pass reference oil procedure. "Scoring," with respect to ring and pinion gears, as defined by ASTM D 7450, is the rapid removal of metal from the tooth surfaces caused by the tearing out of small contacting particles that have welded together as a result of metal-to-metal contact; a scored surface is characterized by a matte or dull finish. The results of the L-42 Standard and Canadian tests performed are reported in the following Tables 3 and 4, respectively.

Table 3

L-42 Standard Test	Example 1	Reference
% Scoring, Pinion		
Drive Side	0	0
Cost Side	16	22
% Scoring, Ring		
Drive Side	0	0
Cost Side	10	16

Table 4

L-42 Canadian Test	Example 1	Reference
% Scoring, Pinion		
Drive Side	0	0
Cost Side	10	22
% Scoring, Ring		
Drive Side	0	0
Cost Side	6	16

As can be seen from Tables 3 and 4 above, the lubricant composition in accordance with the present invention passed both the L-42 Standard and Canadian tests by exhibiting an equal to or better (lower) score than the mean scoring values of the passing reference oil test results used to calibrate the standard.

Performance of Lubricant Compositions at High Speed, Low Torque, Followed by Low Speed, High Torque: ASTM D 6121

This method is used for determining the load-carrying, wear, and extreme pressure characteristics of gear lubricants in hypoid axle assemblies under conditions of high-speed, low-torque, and low-speed, high-torque operation. A specially selected rear axle assembly, engine, and transmission, and two large dynamometers serve as the procedure apparatus. The procedure axle is operated for 100 minutes at 440 axle rpm, 295°F (146.1 °C) lubricant temperature, and 9460 lb-in (109 m kg) of torque. The axle is then operated for 24 hours at 80 axle rpm, 275°F (135.0 °C) lubricant temperature, and 41,800 lb-in (482 m kg) of torque. The ring and pinion gears are evaluated for an ASTM merit rating based on the ridging, rippling, wear, pitting/spalling, and scoring.

"Ridging," with respect to ring and pinion gears, as defined by ASTM D 7450, is the alteration of the tooth surface to give a series of parallel raised and polished ridges running diagonally in the direction of sliding motion, either partially or completely across the tooth surfaces or gears. "Rippling," with respect to ring and pinion gears, as defined by ASTM D 7450, refers to an alteration of the tooth surface resulting to give an appearance of a more or less regular pattern resembling ripples on water or fish scales. "Wear," with respect to ring and pinion gears, as defined by ASTM D 7450, is the removal of metal, without evidence of surface fatigue or adhesive wear, resulting in partial or complete elimination of tool or grinding marks or development of a discernible shoulder ridge at the bottom of the contact area near the root or at the toe or heel end of pinion tooth contact area (abrasive wear). "Pitting," with respect to ring and pinion gears, as defined by ASTM D 7450, refers to small irregular cavities in the tooth surface, resulting from the breaking out of small areas of surface metal. "Spalling," with respect to ring and pinion gears, as defined by ASTM D 7450, is the breaking out of flakes of irregular area of the tooth surface, a condition more extensive than pitting. "Scoring," with respect to ring and pinion gears, as defined by ASTM D 7450, is the rapid removal of metal from the tooth surfaces caused by the tearing out of small contacting particles that have welded together as a result of metal-to-metal contact; a scored surface is characterized by a matte or dull finish.

This test was performed under two different sets of operating conditions, referred to as "Standard" using "non-lubrited" hardware, and "Canadian" using "lubrited" hardware. "Lubrited," as defined by ASTM D 7450, refers to a surface coated with phosphate. The results of the ASTM D 6121 Standard, Non-Lubrited, and Canadian, Lubrited tests performed are reported in the following Tables 5 and 6, respectively.

Table 5

ASTM D 6121 Test (Standard, Non-Lubrited)	Example 1		Minimum Requirement	
	Ring (ASTM merit rating)	Pinion (ASTM merit rating)	Ring (ASTM merit rating)	Pinion (ASTM merit rating)
Ridging	10	8	8	8
Rippling	10	9	8	8
Wear	8	8	5	5
Pitting/Spalling	9.9	9.9	9.3	9.3
Scoring	10	10	10	10

Table 6

ASTM D 6121 Test (Canadian, Lubrited)	Example 1		Minimum Requirement	
	Ring (ASTM merit rating)	Pinion (ASTM merit rating)	Ring (ASTM merit rating)	Pinion (ASTM merit rating)
Ridging	10	8	8	8
Rippling	10	9	8	8
Wear	8	8	5	5
Pitting/Spalling	9.9	9.9	9.3	9.3
Scoring	10	10	10	10

As can be seen from Tables 5 and 6 above, the lubricant composition in accordance with the present invention passed both the ASTM D 6121 Standard and Canadian tests by exhibiting an equal to or better (higher) ASTM merit rating than the minimum ratings specified.

Performance of Lubricant Compositions While Subjected to Water Contamination and Elevated Temperature: ASTM D 7038

This method is used for evaluating the rust and corrosion inhibiting properties of a gear lubricant while subjected to water contamination and elevated temperature. An electric motor, specially selected hypoid differential housing assembly, cooling fan, heating lamps, and heated storage box serve as the procedure apparatus. The differential housing assembly is operated for 4 hours at 2,500 input rpm at 180°F (82.2 °C) lubricant temperature with 1 fl. oz. of distilled water mixed in the lubricant. The procedure unit is then placed in the storage box and stored for 162 hours at 125°F (51.7 °C). At the end of the procedure, the procedure parts of the assembly are rated for the presence of rust. All internal moving parts (ring, pinion, bearings, differential gears, etc.) are evaluated for a final rust merit rating.

API Category GL-5 candidate fluids are required to have a Final Rust Corrosion Merit Rating of 9.0 or greater. Example Lubricant Composition 1 passed the ASTM D 7038 test by exhibiting a 9.3 Final Rust Corrosion Merit Rating.

Thermal and Oxidative Stability of Lubricant Compositions: ASTM D 5704

This method is used for determining the deterioration of lubricants under severe thermal and oxidative conditions. A gear case assembly, two spur gears, two copper strips, a bearing, a temperature control system, an alternator, a motor, and a regulated air supply serve as major parts of the procedure fixture. The spur gears are rotated under load at 1750-rpm input for 50 hours. The lubricant temperature is maintained at 325°F (162.8 °C). Airflow through the lubricant is controlled at 22.1 mg/min for the procedure's duration. The physical and chemical properties of the oil and deposits on the gears are evaluated at the end of the procedure. The large and small gears are evaluated for carbon/varnish and sludge. The used oil is evaluated for any increase in viscosity, pentane insolubles, and toluene insolubles. The results of the ASTM D 5470 test performed are reported in Table 7 as follows.

Table 7

ASTM D 5704 Test	Example 1	API GL-5 Requirement
Viscosity Increase, %	16	≤ 100
Pentane Insolubles, wt. %	0.5	≤ 3.0
Toluene Insolubles, wt. %	0.7	≤ 2.0
Carbon/Varnish	7.8	≥ 7.5
Sludge	9.4	≥ 9.4

As can be seen from Table 7 above, the lubricant composition in accordance with the present invention passed the ASTM D 5704 test by exhibiting % viscosity increase, weight % pentane and toluene insolubles, and carbon/varnish and sludge values as required by the API GL-5 acceptance criteria.

Foaming Properties of Lubricant Compositions: ASTM D 892

This method is used for determining the foaming properties of a gear lubricant at 24°C and 93.5°C. Foaming is undesirable since foam cannot adequately protect gear or bearing surfaces in an automotive drive train. Oil is placed in a large glass cylinder and air is blown in from the bottom using a porous stone. The amount of any resulting foam is measured visibly. The used oil is evaluated in three sequences for tendency/stability. The results of the ASTM D 892 test performed are reported in Table 8 as follows.

Table 8

ASTM D 892 Test	Example 1	API GL-5 Requirement
Sequence 1, ml (tendency / stability)	0 / 0	≤ 20
Sequence 2, ml (tendency / stability)	0 / 0	≤ 50
Sequence 3, ml (tendency / stability)	0 / 0	≤ 20

As can be seen from Table 8 above, the lubricant composition in accordance with the present invention passed the ASTM D 892 test by exhibiting tendency / stability foaming properties as required by the API GL-5 acceptance criteria.

Copper Corrosion Properties of Lubricant Compositions: ASTM D 130

This method is used for determining a lubricant's compatibility with "yellow metal" or copper. Attack on copper, brass, or bronze would be undesirable for those parts located in an automotive drive train. A small metal strip is placed in a sample of test oil. The oil is heated in a block or oven for 3 hours at 210°F (98.9 °C). The strip is given an ASTM rating for color change in comparison to a set of known standards. API Category GL-5 candidate fluids are required to have an ASTM rating of less than or equal to 3. Example Lubricant Composition 1 passed the ASTM D 130 test by exhibiting a 2e ASTM rating.

CLAIMS

1. A lubricant composition for use in association with a device involving metal to metal contact of moving parts comprising:

(a) base-stock comprising (i) at least one relatively low viscosity polyalphaolefin, and (ii) at least one diester;

(b) viscosity improver comprising (i) at least one relatively high viscosity polyalphaolefin, and (ii) polyisobutylene; and

(c) a performance additive comprising at least one additive effective to improve at least one property of the lubricant and/or the performance of the equipment in which the lubricant is to be used;

wherein said lubricant composition meets the American Petroleum Institute's GL-5 performance classification requirements.

2. The lubricant composition of claim 1 wherein said lubricant composition is a multiviscosity-grade lubricant having a viscosity of 150,000 cP at -40°C and a kinematic viscosity at 100°C of at least 24.0 cSt and less than 32.5 cSt.

3. The lubricant composition of claims 1 and/or 2 wherein said base-stock comprises at least one polyalphaolefin having a viscosity of not greater than 12 centistokes (cSt).

4. The lubricant composition of at least one of the claims 1 – 3 wherein said viscosity improver comprises a polyalphaolefin having a viscosity of greater than 40 centistokes (cSt).

5. The lubricant composition of at least one of claims 1 - 4 comprising:

(a) about 15-65% by weight of base-stock;

(b) about 30-75% by weight of viscosity improver; and

(c) about 7-35% by weight of additive.

6. A lubricant composition for use in association with a device involving metal to metal

contact of moving parts comprising:

(a) 10-35% by weight of a low viscosity polyalphaolefin;
(b) 30-75% by weight of a high viscosity polyalphaolefin;
(c) 5-30% by weight of a diester;
(d) 2-25% by weight of polyisobutylene;
(e) 5-10% by weight of an additive package; and, optionally
(f) 0.001-0.004% by weight of an antifoam agent;

wherein said lubricant composition meets the American Petroleum Institute's GL-5 performance classification requirements.

7. The lubricant composition of claim 6 wherein said lubricant composition is a multiviscosity-grade lubricant having a viscosity of 150,000 cP at -40°C and a kinematic viscosity at 100°C of at least 24.0 cSt and less than 32.5 cSt.

8. The lubricant composition of claims 6 and/or 7 wherein said low viscosity polyalphaolefin has a viscosity of not greater than about 12 centistokes (cSt).

9. The lubricant composition of at least one of the claims 6 - 8 wherein said high viscosity polyalphaolefin has a viscosity of greater than about 40 centistokes (cSt).

10. The lubricant composition of at least one of the claims 6 - 9 wherein said lubricant composition comprises:

(a) 12-20% by weight of a low viscosity polyalphaolefin;
(b) 40-60% by weight of a high viscosity polyalphaolefin;
(c) 7.5-20% by weight of a diester;
(d) 5-15% by weight of polyisobutylene;
(e) 7.5-9% by weight of an additive package; and, optionally
(f) 0.001-0.004% by weight of an antifoam agent.