(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 624 043 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
**08.02.2006 Bulletin 2006/06**

(21) Application number: **05012489.0**

(22) Date of filing: **10.06.2005**

(51) Int Cl.:
***C10M 141/08*** *(2006.01)*
*C10M 135/06* *(2006.01)*
*C10N 40/04* *(2006.01)*
*C10M 141/08* *(2006.01)*
*C10M 135/36* *(2006.01)*

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR**
Designated Extension States:
**AL BA HR LV MK YU**

(30) Priority: **28.07.2004 US 591722 P**
**11.10.2004 US 963216**

(71) Applicant: **Afton Chemical Corporation**
**Richmond,**
**VA 23219 (US)**

(72) Inventor: **Henly, Timothy J.**
**Maidens, VA 23102 (US)**

(74) Representative: **Dunleavy, Kevin James**
**Knoble & Yoshida LLC,**
**p/o De Vries & Metman,**
**Overschiestraat 180**
**1062 XK Amsterdam (NL)**

# (54) Power transmission fluids with enhanced extreme pressure and antiwear characteristics

(57) A fluid composition is described for extreme pressure applications. The fluid composition includes a base oil, and an additive composition comprising sulfurized fatty oil in an amount sufficient to provide at least 1,000 ppm sulfur to the fluid composition, and dialkyl thiadiazole in an amount sufficient to provide at least 500 ppm sulfur to the fluid composition. Fluids containing these respective amounts of sulfurized fatty oil and dialkyl thiadiazole exhibit failure loads which equal or exceed 794 kg (1750 pounds) at 100°C and 150°C, respectively, as measured according to a Falex EP test of ASTM D-3233.

Printed by Jouve, 75001 PARIS (FR)

## Description

## FIELD OF THE INVENTION

**[0001]** The present disclosure relates to fluids having improved characteristics particularly for extreme pressure and antiwear applications. The fluids disclosed herein may include fluids suitable for use, for example, in power transmission applications.

## BACKGROUND OF THE INVENTION

**[0002]** New and advanced transmission systems are being developed by the automotive industry. These new systems often involve high energy requirements. Therefore, component protection technology must be developed to meet the increasing energy requirements of these advanced systems.

**[0003]** Extremely high metal-on-metal pressures are present in newer automatic and manual transmissions such as step automatic transmissions, continuously variable transmissions, and manual or automated manual transmissions. High pressures are also present in various gear drive components such as automotive differentials and power transmission gear drive components. The high pressures present in such transmission and gear drive components mean that lubricants used in these systems must be suitable for such extreme pressure applications to prevent wear and seizure of the rotating and contacting components. Thus, there continues to be a need for additives which reduce wear and prevent seizure under extremely high pressure operating conditions.

**[0004]** Commercially, it is known to add various additive packages to automatic transmission fluid, including, among other things, extreme pressure agents, antiwear agents, antioxidant systems, corrosion inhibitor systems, metal deactivators, anti-rust agents, friction modifiers, dispersants, detergents, anti-foam agents, and viscosity index improvers. However, not all additives interact predictably or well with one another.

## SUMMARY OF THE INVENTION

**[0005]** The present invention relates to the improvement of extreme pressure and antiwear performance of fluids by the inclusion therein of sulfurized fatty oil in an amount sufficient to provide at least about 1,000 ppm sulfur to the fluid, and dialkyl thiadiazole in an amount sufficient to provide at least about 500 ppm sulfur to the fluid. Extreme pressure and antiwear performance are surprisingly improved for fluids that combine sulfurized fatty oil and dialkyl thiadiazole components in levels introducing these respective amounts of sulfur into the fluid.

**[0006]** In one embodiment, a fluid includes sulfurized fatty oil in an amount sufficient to provide from about 1,000 ppm to about 2,500 ppm, particularly about 1,300 ppm to about 2,100 ppm, sulfur to the fluid, and dialkyl thiadiazole in an amount sufficient to provide from about 500 ppm to about 1,800 ppm, particularly about 550 to about 1,500 ppm, sulfur to the fluid.

**[0007]** In order to introduce sulfur in the above-indicated minimal levels, the sulfurized fatty oil may be present in an amount of about 0.5 wt.% to about 5.0 wt.%, and the dialkyl thiadiazole may be present in an amount an amount of about 0.15 wt.% to about 3.0 wt.%, based on total weight of the fluid composition. In one particular embodiment, the sulfurized fatty oil used in the indicated amount is sulfurized transesterified triglyceride, and the dialkyl thiadiazole used in the indicated amount is 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazole or a derivative thereof.

**[0008]** In another embodiment, a fluid includes a major amount of base oil, and a minor amount of an additive composition containing respective amounts of (A) sulfurized fatty oil and (B) dialkyl thiadiazole which are effective to provide a transmission fluid exhibiting failure loads which equal or exceed about 1750 pounds at 100°C and 150°C, as measured according to a Falex EP test of ASTM D-3233. A power transmission fluid including only one of components (A) or (B), but not both, in compliance with the above-indicated minimum respective sulfur contribution amounts will not achieve the above-indicated failure load performance criteria.

**[0009]** In another embodiment, an additive comprises (A) sulfurized fatty oil in an amount sufficient to provide at least about 1,000 ppm sulfur to the fluid composition, and (B) dialkyl thiadiazole in an amount sufficient to provide at least about 500 ppm sulfur to the fluid composition.

**[0010]** In another embodiment, an additive composition contains respective amounts of (A) sulfurized fatty oil and (B) dialkyl thiadiazole which, in combination, are effective, to provide a transmission fluid exhibiting failure loads which equal or exceed about 1750 pounds at 100°C and 150°C, as measured according to a Falex EP test of ASTM D-3233.

**[0011]** In another embodiment, a method for improving extreme pressure and/or wear performance in power transmitting apparatus comprises 1) adding a fluid to a power transmitting apparatus, said fluid comprising (a) a base oil, and (b) an additive package comprising sulfurized fatty oil in an amount sufficient to provide at least 1,000 ppm sulfur to the fluid, and dialkyl thiadiazole in an amount sufficient to provide at least 500 ppm sulfur to the fluid; and 2) operating the fluid in the power transmitting apparatus, wherein the extreme pressure and/or wear performance is improved relative to the extreme pressure and/or wear performance of a transmission without said fluid.

**[0012]** In another embodiment, a method of increasing the service life of a transmission comprises operating in a transmission a fluid comprising: a) a base oil, and (b) an additive package comprising sulfurized fatty oil in an amount sufficient to provide at least 1,000 ppm sulfur to the fluid, and dialkyl thiadiazole in an amount sufficient to provide at least 500 ppm sulfur to the fluid, wherein the service life of the transmission is improved relative to the service life of a transmission without said fluid.

**[0013]** The extreme pressure and antiwear enhanced additive compositions of embodiments of this invention may be advantageously used in a wide variety of applications, including, for example, in automatic transmission fluids, manual transmission fluids, fluids used in dual clutch transmissions, fluids used in continuously variable transmissions, and gear lubricants.

**[0014]** The foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the present invention, as claimed.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0015]** Vehicles meeting stringent demands of consumers require durability and performance in all of the vehicular systems. One of the most important systems is the power transmission system ("transmission") which transmits the power generated by the automobile engine to the wheels. It being one of the most complex systems in the vehicle, it is also one of the most costly to diagnose, repair, or replace. The transmission usually includes, *inter alia*, a clutch with plates, a torque converter, and a plurality of gears to alter the power delivered to the wheels by changing the gear ratio.

**[0016]** Discriminating consumers primarily desire high performance, low maintenance (high mileage between servicing), and extended life expectancy. However, with the advent of new transmission technologies, old standards of performance which were previously met with approval are now becoming problematic.

**[0017]** The advent of electronically controlled converter clutch (ECCC) designs, as well as vehicles equipped with a continuously variable transmission (CVT) and advances in aerodynamic body design generally result in passenger cars with smaller transmissions which tend to operate with higher energy densities and higher operating temperatures. Such changes challenge lubricant suppliers to formulate automatic transmission fluids with new and unique performance characteristics including higher torque and friction durability. Original equipment manufacturers (OEMs) desire automatic transmission fluids with frictional characteristics capable of meeting the requirements of ECCC, CVT, and other designs while retaining sufficient performance in the antiwear arena.

**[0018]** As power transmission fluids are desired which operate under increasingly severe conditions, the oils used to lubricate those transmissions ideally would be formulated to endure higher temperatures and pressures. To reduce equipment problems and increase the interval between transmission oil changes, the oil additive packages ideally would be formulated so that important oil properties change as little as possible in the face of these stresses. An important characteristic of a power transmission fluid is its extreme pressure properties. High metal-on-metal contact pressures found in newer automotive transmissions and in gear drives can cause damage to transmission parts and gear drives if the lubricant used in the system is not formulated to provide sufficient extreme pressure protective properties. Such damage may take the form, e.g., of simple wear (scoring, trenching, or grooving) or micropitting, pitting, welding, or spalling. All of these phenomena may lead ultimately to degradation in transmission performance and/or breakage of critical transmission components.

**[0019]** A need exists for an effective way of overcoming the wear problem associated with automatic transmissions, such as to meet the needs of OEM automobile designers and suppliers, for extended transmission fluid life and durability.

**[0020]** This invention overcomes the durability and antiwear (extreme pressure) problem by providing an automatic transmission fluid that exhibits good extreme pressure and anti-wear performance during its lifetime.

**[0021]** In accordance with an embodiment of this invention there is provided a power transmission fluid which surprisingly gives improved extreme pressure and antiwear performance. To provide this improved performance, in one of its embodiments the power transmission fluid contains sulfurized fatty oil in an amount sufficient to provide at least about 1,000 ppm sulfur to the fluid, and dialkyl thiadiazole in an amount sufficient to provide at least about 500 ppm sulfur to the fluid. In another embodiment, the power transmission fluid contains sulfurized fatty oil in an amount sufficient to provide about 1,000 ppm to about 2,500 ppm, particularly about 1,300 ppm to about 2,100 ppm, sulfur to the fluid, and dialkyl thiadiazole in an amount sufficient to provide about 500 ppm to about 1,800 ppm, particularly about 550 to about 1,500 ppm, sulfur to the fluid. In a further embodiment, in addition to complying with the minimum sulfur contribution amounts applicable to each of sulfurized fatty oil and dialkyl thiadiazole as set forth herein, the combined sulfur added to the fluid by the sulfurized fatty oil and dialkyl thiadiazole is least about 1,500 ppm, and particularly at least about 2,500 ppm, and more particularly at least about 3,000 ppm.

**[0022]** In one embodiment, the fluids of the present invention are used in formulating automatic transmission fluids which exhibit failure loads which equal or exceed about 1750 pounds at 100°C and 150°C, as measured according to a Falex EP test of ASTM D-3233. The Falex EP test described in ASTM D-3233 is incorporated herein by reference.

There are several tests available to the lubricant and automotive industries to evaluate the extreme pressure/antiwear-enhancing capability of a transmission fluid. One of the most challenging of these tests is the Falex EP test, which measures the load at which an oil fails to successfully lubricate the metal-metal contact between a rotating steel pin and two Vee blocks. Lubricant failure is indicated either by failure to maintain torque or by seizure of the blocks against the pin. The test is severe not only because of the high loads involved, but also because of the high fluid temperatures (some specifications call for oil temperatures of up to 150°C). It is not uncommon for an oil to perform well in several industrial wear tests but at the same time show poor performance in the Falex EP test.

**[0023]** In another embodiment of the present invention, a method of improving extreme pressure and/or antiwear performance in automatic transmissions is set forth. The method comprises adding to, and operating in, an automatic transmission fluid (ATF) comprising (1) a major amount of a base oil and (2) a minor amount of an additive composition which comprises, as essential components, sulfurized fatty oil and dialkyl thiadiazole in the respective treat rates as described herein. "Operating", as used herein, includes, but is not limited to, any functional utilization of the fluid including transmitting power, lubricating, and wetting.

**[0024]** Although the additive composition Components described below are described occasionally with reference to a function, that function may be one of other functions served by the same component and should not be construed as a mandatory limiting function.

**[0025]** In an embodiment, a power transmission fluid may include a major amount of a base oil and a minor amount of an additive composition. The additive composition includes extreme pressure and antiwear performance improving amounts of a sulfurized fatty oil and a dialkyl thiadiazole in combination.

Additive Package

Component (A): Sulfurized Fatty Oil

**[0026]** Component (A) comprises a sulfurized fatty oil. For purposes herein, "sulfurized fatty oil" refers to sulfurized fatty acids, sulfurized fatty esters, individually or as mixtures thereof. Sulfurized fatty acid esters are preferred. The sulfurized fatty oils may be animal or vegetable in origin. Suitable sulfurized fatty oils include, for example, a sulfurized fatty acid ester containing about 10% sulfur and a sulfurized sperm oil containing about 10% sulfur.

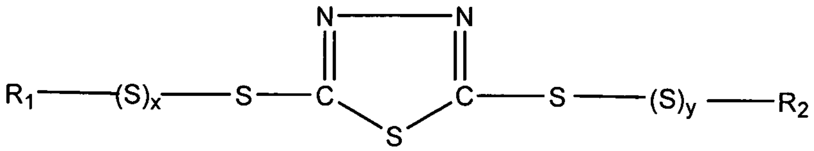
**[0027]** In one particular embodiment, suitable sulfurized fatty oils include sulfurized transesterified triglycerides, such as those described in U.S. Pat. No. 4,380,499, which descriptions are incorporated herein by reference. In one embodiment, a sulfurized transesterified triglyceride additive has a total acid component comprising no less than about 35 mol% saturated aliphatic acids and no more than about 65 mol% unsaturated fatty acids, and wherein the total acid component is further characterized as comprising more than about 20 mol% of monounsaturated acids, less than about 15 mol% of polyunsaturated fatty acids, more than about 20 mol% saturated aliphatic acids having 6 to 16 carbon atoms, including more than about 10 mol% saturated aliphatic acids having 6 to 14 carbon atoms, and less than about 15 mol% saturated aliphatic acids having 18 or more carbon atoms. Suitable sulfurized fatty oils also include those such as those described in U.S. Pat. No. 4,149,982, which descriptions are incorporated herein by reference.

**[0028]** Other suitable sulfurized fatty oils include, for example, sulfurized lard oils, sulfurized fatty compounds, sulfurized methyl esters, sulfurized hydrocarbons, sulfurized oleic acid, sulfurized fatty ester-polyalkanol amides, and sulfurized fatty olefins.

Component (B): Dialkyl Thiadiazole

**[0029]** Component (B) comprises a dialkyl thiadiazole, including but not limited to an ashless dialkyl thiadiazole.

**[0030]** Dialkyl thiadiazoles suitable for the practice of the present invention may be of the general formula (I):



wherein $R_1$ and $R_2$ may be the same or different hydrocarbyl groups, and x and y independently may be integers from 0 to 8. In one aspect, $R_1$ and $R_2$ may be the same or different, linear, branched, or aromatic, saturated or unsaturated hydrocarbyl group having from about 6 to about 18 carbon atoms, particularly from about 8 to about 12 carbon atoms, and x and y each may be 0 or 1.

**[0031]** An suitable dialkyl thiadiazoles includes 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazoles. Examples of other suitable dialkyl thiadiazoles include, for example, 2,5-bis(hydrocarbylthio)-1,3,4-thiadiazoles, 2-(tert-hydrocarbyldithio)-5-mercapto-1,3,4-thiadiazoles, and bis-tert-dodecylthiothiadiazole.

**[0032]** Suitable dialkyl thiadiazoles also include those such as described in U.S. Pat. Nos. 2,719,125, 2,719,126, 3,087,932, 4,149,982, and 4,591,645, and which descriptions are incorporated herein by reference. Mixtures of dialkyl thiadiazoles of formula (I) with monoalkyl thiadiazoles may also be used within the scope of the present invention.

**[0033]** As used herein, the term "hydrocarbyl group" or "hydrocarbyl" is used in its ordinary sense, which is well-known to those skilled in the art. Specifically, it refers to a group having a carbon atom directly attached to the remainder of a molecule and having a predominantly hydrocarbon character. Examples of hydrocarbyl groups include:

(1) hydrocarbon substituents, that is, aliphatic (e.g., alkyl or alkenyl), alicyclic (e.g., cycloalkyl, cycloalkenyl) substituents, and aromatic-, aliphatic-, and alicyclic-substituted aromatic substituents, as well as cyclic substituents wherein the ring is completed through another portion of the molecule (e.g., two substituents together form an alicyclic radical);
(2) substituted hydrocarbon substituents, that is, substituents containing non-hydrocarbon groups which, in the context of the description herein, do not alter the predominantly hydrocarbon substituent (e.g., halo (especially chloro and fluoro), hydroxy, alkoxy, mercapto, alkylmercapto, nitro, nitroso, and sulfoxy);
(3) hetero-substituents, that is, substituents which, while having a predominantly hydrocarbon character, in the context of this description, contain other than carbon in a ring or chain otherwise composed of carbon atoms. Heteroatoms include sulfur, oxygen, nitrogen, and encompass substituents such as pyridyl, furyl, thienyl, and imidazolyl. In general, no more than two, or as a further example, no more than one, non-hydrocarbon substituent will be present for every ten carbon atoms in the hydrocarbyl group; typically, there will be no non-hydrocarbon substituent in the hydrocarbyl group.

## Combined Use of Components (A) and (B)

**[0034]** Extreme pressure and antiwear characteristics are improved for a power transmission fluid which is formulated to contain a major amount of a base oil, and an additive composition providing at least about 0.5 wt.% of the sulfurized fatty oil (Component (A)) and at least about 0.15 wt.% of the dialkyl thiadiazole (Component (B)), based on the total weight of the base oil and additive composition. In an embodiment, the fluid composition contains sulfurized fatty oil in an amount of about 0.7 wt.% to about 5.0 wt.%, particularly about 0.73 wt.% to about 3.0 wt.%, and more particularly 0.75 wt.% to about 3.0 wt.%; and dialkyl thiadiazole is present in an amount of about 0.15 wt.% to about 3.0 wt.%, particularly about 0.3 wt.% to about 1.0 wt.%, and more particularly 0.35 wt.% to about 1.0 wt.%, based on total weight of the fluid composition.

**[0035]** A power transmission fluid including only one of components (A) or (B), but not both, in compliance with the above-indicated minimum respective sulfur contribution amounts can not predictably provide a transmission fluid exhibiting failure loads which equal or exceed about 1750 pounds at 100°C and 150°C, respectively, as measured according to a Falex EP test of ASTM D-3233.

## Other Additive Components

**[0036]** The power transmission fluid may also include conventional additives of the type used in automatic transmission fluid formulations and gear lubricants in addition to the extreme pressure and antiwear performance improving co-additives described above. Such additives include, but are not limited to, metallic detergents, dispersants, friction modifiers, antioxidants, viscosity index improvers, copper corrosion inhibitors, anti-rust additives, antiwear additives, antifoamants, pour point depressants, seal swell agents, colorants, metal deactivators, and/or air expulsion additives.

## Component (C): Metallic Detergents

**[0037]** Certain metallic detergents may optionally be included in the additive package and transmission fluids of the present invention. A suitable metallic detergent may include an oil-soluble neutral or overbased salt of alkali or alkaline earth metal with one or more of the following acidic substances (or mixtures thereof): (1) a sulfonic acid, (2) a carboxylic acid, (3) a salicylic acid, (4) an alkyl phenol, (5) a sulfurized alkyl phenol, and (6) an organic phosphorus acid characterized by at least one direct carbon-to-phosphorus linkage. Such an organic phosphorus acid may include those prepared by the treatment of an olefin polymer (e.g., polyisobutylene having a molecular weight of about 1,000) with a phosphorizing agent such as phosphorus trichloride, phosphorus heptasulfide, phosphorus pentasulfide, phosphorus trichloride and sulfur, white phosphorus and a sulfur halide, or phosphorothioic chloride.

**[0038]** Suitable salts may include neutral or overbased salts of magnesium, calcium, or zinc. As a further example, suitable salts may include magnesium sulfonate, calcium sulfonate, zinc sulfonate, magnesium phenate, calcium phenate, and/or zinc phenate. See, e.g., US 6,482,778.

**[0039]** Oil-soluble neutral metal-containing detergents are those detergents that contain stoichiometrically equivalent amounts of metal in relation to the amount of acidic moieties present in the detergent. Thus, in general the neutral detergents will have a low basicity when compared to their overbased counterparts. The acidic materials utilized in forming such detergents include carboxylic acids, salicylic acids, alkylphenols, sulfonic acids, sulfurized alkylphenols and the like.

**[0040]** The term "overbased" in connection with metallic detergents is used to designate metal salts wherein the metal is present in stoichiometrically larger amounts than the organic radical. The commonly employed methods for preparing the overbased salts involve heating a mineral oil solution of an acid with a stoichiometric excess of a metal neutralizing agent such as the metal oxide, hydroxide, carbonate, bicarbonate, or sulfide at a temperature of about 50°C, and filtering the resultant product. The use of a "promoter" in the neutralization step to aid the incorporation of a large excess of metal likewise is known. Examples of compounds useful as the promoter include phenolic substances such as phenol, naphthol, alkyl phenol, thiophenol, sulfurized alkylphenol, and condensation products of formaldehyde with a phenolic substance; alcohols such as methanol, 2-propanol, octanol, ethylene glycol, stearyl alcohol, and cyclohexyl alcohol; and amines such as aniline, phenylene diamine, phenothiazine, phenyl-beta-naphthylamine, and dodecylamine. A particularly effective method for preparing the basic salts comprises mixing an acid with an excess of a basic alkaline earth metal neutralizing agent and at least one alcohol promoter, and carbonating the mixture at an elevated temperature such as 60°C to 200°C.

**[0041]** Examples of suitable metal-containing detergents include, but are not limited to, neutral and overbased salts such as a sodium sulfonate, a sodium carboxylate, a sodium salicylate, a sodium phenate, a sulfurized sodium phenate, a lithium sulfonate, a lithium carboxylate, a lithium salicylate, a lithium phenate, a sulfurized lithium phenate, a magnesium sulfonate, a magnesium carboxylate, a magnesium salicylate, a magnesium phenate, a sulfurized magnesium phenate, a calcium sulfonate, a calcium carboxylate, a calcium salicylate, a calcium phenate, a sulfurized calcium phenate, a potassium sulfonate, a potassium carboxylate, a potassium salicylate, a potassium phenate, a sulfurized potassium phenate, a zinc sulfonate, a zinc carboxylate, a zinc salicylate, a zinc phenate, and a sulfurized zinc phenate. Further examples include a lithium, sodium, potassium, calcium, and magnesium salt of a hydrolyzed phosphosulfurized olefin having about 10 to about 2,000 carbon atoms or of a hydrolyzed phosphosulfurized alcohol and/or an aliphatic-substituted phenolic compound having about 10 to about 2,000 carbon atoms. Even further examples include a lithium, sodium, potassium, calcium, and magnesium salt of an aliphatic carboxylic acid and an aliphatic substituted cycloaliphatic carboxylic acid and many other similar alkali and alkaline earth metal salts of oil-soluble organic acids. A mixture of a neutral or an overbased salt of two or more different alkali and/or alkaline earth metals can be used. Likewise, a neutral and/or an overbased salt of mixtures of two or more different acids can also be used.

**[0042]** As is well known, overbased metal detergents are generally regarded as containing overbasing quantities of inorganic bases, generally in the form of micro dispersions or colloidal suspensions. Thus the term "oil-soluble" as applied to metallic detergents is intended to include metal detergents wherein inorganic bases are present that are not necessarily completely or truly oil-soluble in the strict sense of the term, inasmuch as such detergents when mixed into base oils behave much the same way as if they were fully and totally dissolved in the oil. Collectively, the various metallic detergents referred to herein above, are sometimes called neutral, basic, or overbased alkali metal or alkaline earth metal-containing organic acid salts.

**[0043]** Methods for the production of oil-soluble neutral and overbased metallic detergents and alkaline earth metal-containing detergents are well known to those skilled in the art, and extensively reported in the patent literature. See, for example, U.S. Pat. Nos. 2,001,108; 2,081,075; 2,095,538; 2,144,078; 2,163,622; 2,270,183; 2,292,205; 2,335,017; 2,399,877; 2,416,281; 2,451,345; 2,451,346; 2,485,861; 2,501,731; 2,501,732; 2,585,520; 2,671,758; 2,616,904; 2,616,905; 2,616,906; 2,616,911; 2,616,924; 2,616,925; 2,617,049; 2,695,910; 3,178,368; 3,367,867; 3,496,105; 3,629,109; 3,865,737; 3,907,691; 4,100,085; 4,129,589; 4,137,184; 4,184,740; 4,212,752; 4,617,135; 4,647,387; and 4,880,550.

**[0044]** The metallic detergents utilized in this invention can, if desired, be oil-soluble boronated neutral and/or overbased alkali of alkaline earth metal-containing detergents. Methods for preparing boronated metallic detergents are described in, for example, U.S. Pat. Nos. 3,480,548; 3,679,584; 3,829,381; 3,909,691; 4,965,003; and 4,965,004.

**[0045]** While any effective amount of the metallic detergents may be used to enhance the benefits of this invention, typically these effective amounts will range from about 0.01 to about 0.2 wt.% in the finished fluid, or as a further example, from about 0.05 to about 0.1 wt.% in the finished fluid.

## Component (D): Dispersant

**[0046]** Component (D) comprises at least one oil-soluble dispersant. Suitable dispersants may include ashless dispersants such as succinimide dispersants, Mannich base dispersants, and polymeric polyamine dispersants. Hydrocarbyl-substituted succinic acylating agents are used to make hydrocarbyl-substituted succinimides. The hydrocarbyl-substituted succinic acylating agents include, but are not limited to, hydrocarbyl-substituted succinic acids, hydrocarbyl-substituted succinic anhydrides, the hydrocarbyl-substituted succinic acid halides (especially the acid fluorides and acid chlorides), and the esters of the hydrocarbyl-substituted succinic acids and lower alcohols (e.g., those containing up to 7 carbon atoms), that is, hydrocarbyl-substituted compounds which can function as carboxylic acylating agents.

**[0047]** Hydrocarbyl substituted acylating agents are made by reacting a polyalkyl olefin or chlorinated polyalkyl olefin of appropriate molecular weight with maleic anhydride. Similar carboxylic reactants can be used to make the acylating agents. Such reactants may include, but are not limited to, maleic acid, fumaric acid, malic acid, tartaric acid, itaconic acid, itaconic anhydride, citraconic acid, citraconic anhydride, mesaconic acid, ethylmaleic anhydride, dimethylmaleic anhydride, ethylmaleic acid, dimethylmaleic acid, hexylmaleic acid, and the like, including the corresponding acid halides and lower aliphatic esters.

**[0048]** The molecular weight of the olefin can vary depending upon the intended use of the substituted succinic anhydrides. Typically, the substituted succinic anhydrides will have a hydrocarbyl group of from about 8 to about 500 carbon atoms. However, substituted succinic anhydrides used to make lubricating oil dispersants will typically have a hydrocarbyl group of about 40 to about 500 carbon atoms. With high molecular weight substituted succinic anhydrides, it is more accurate to refer to number average molecular weight (Mn) since the olefins used to make these substituted succinic anhydrides may include a mixture of different molecular weight components resulting from the polymerization of low molecular weight olefin monomers such as ethylene, propylene, and isobutylene.

**[0049]** The mole ratio of maleic anhydride to olefin can vary widely. It may vary, for example, from about 5:1 to about 1:5, or for example, from about 1:1 to about 3:1. With olefins such as polyisobutylene having a number average molecular weight of about 500 to about 7000, or as a further example, about 800 to about 3000 or higher and the ethylene-alpha-olefin copolymers, the maleic anhydride may be used in stoichiometric excess, e.g. about 1.1 to about 3 moles maleic anhydride per mole of olefin. The unreacted maleic anhydride can be vaporized from the resultant reaction mixture.

**[0050]** The polyalkyl or polyalkenyl substituent on the succinic anhydrides employed herein is generally derived from polyolefins, which are polymers or copolymers of mono-olefins, particularly 1-mono-olefins, such as ethylene, propylene, and butylene. The mono-olefin employed may have about 2 to about 24 carbon atoms, or as a further example, about 3 to about 12 carbon atoms. Other suitable mono-olefins include propylene, butylene, particularly isobutylene, 1-octene, and 1-decene. Polyolefins prepared from such mono-olefins include polypropylene, polybutene, polyisobutene, and the polyalphaolefins produced from 1-octene and 1-decene.

**[0051]** Polyalkenyl succinic anhydrides may be converted to polyalkyl succinic anhydrides by using conventional reducing conditions such as catalytic hydrogenation. For catalytic hydrogenation, a suitable catalyst is palladium on carbon. Likewise, polyalkenyl succinimides may be converted to polyalkyl succinimides using similar reducing conditions.

**[0052]** In some embodiments, the ashless dispersant may include one or more alkenyl succinimides of an amine having at least one primary amino group capable of forming an imide group. The alkenyl succinimides may be formed by conventional methods such as by heating an alkenyl succinic anhydride, acid, acid-ester, acid halide, or lower alkyl ester with an amine containing at least one primary amino group. The alkenyl succinic anhydride may be made readily by heating a mixture of polyolefin and maleic anhydride to about 180°-220°C. The polyolefin may be a polymer or copolymer of a lower monoolefin such as ethylene, propylene, isobutene and the like, having a number average molecular weight in the range of about 300 to about 3000 as determined by gel permeation chromatography (GPC).

**[0053]** Amines which may be employed in forming the ashless dispersant include any that have at least one primary amino group which can react to form an imide group and at least one additional primary or secondary amino group and/or at least one hydroxyl group. A few representative examples are: N-methyl-propanediamine, N-dodecylpropanediamine, N-aminopropyl-piperazine, ethanolamine, N-ethanol-ethylenediamine, and the like.

**[0054]** Suitable amines may include polyalkylene polyamines, such as propylene diamine, dipropylene triamine, di-(1,2-butylene)triamine, and tetra-(1,2-propylene)pentamine. A further example includes the polyethylene polyamines which can be depicted by the formula $H_2N(CH_2CH_2NH)_nH$, wherein n may be an integer from about one to about ten. These include: ethylene diamine, diethylene triamine (DETA), triethylene tetramine (TETA), tetraethylene pentamine (TEPA), pentaethylene hexamine (PEHA), and the like, including mixtures thereof in which case n is the average value of the mixture. Such polyethylene polyamines have a primary amine group at each end so they may form mono-alkenylsuccinimides and bis-alkenylsuccinimides. Commercially available polyethylene polyamine mixtures may contain minor amounts of branched species and cyclic species such as N-aminoethyl piperazine, N,N'-bis(aminoethyl)piperazine, N,N'-bis(piperazinyl)ethane, and like compounds. The commercial mixtures may have approximate overall compositions falling in the range corresponding to diethylene triamine to tetraethylene pentamine. The molar ratio of polyalkenyl succinic anhydride to polyalkylene polyamines may be from about 1:1 to about 3.0:1.

**[0055]** In some embodiments, the ashless dispersant may include the products of the reaction of a polyethylene polyamine, e.g. triethylene tetramine or tetraethylene pentamine, with a hydrocarbon substituted carboxylic acid or anhydride made by reaction of a polyolefin, such as polyisobutene, of suitable molecular weight, with an unsaturated polycarboxylic acid or anhydride, e.g., maleic anhydride, maleic acid, fumaric acid, or the like, including mixtures of two or more such substances.

**[0056]** Polyamines that are also suitable in preparing the dispersants described herein include N-arylphenylenediamines, such as N-phenylphenylenediamines, for example, N-phenyl-1,4-phenylenediamine, N-phenyl-1,3-phenylenediamine, and N-phenyl-1,2-phenylenediamine; aminothiazoles such as aminothiazole, aminobenzothiazole, aminobenzothiadiazole, and aminoalkylthiazole; aminocarbazoles; aminoindoles; aminopyrroles; amino-indazolinones; aminomercaptotriazoles; aminoperimidines; aminoalkyl imidazoles, such as 1-(2-aminoethyl) imidazole, 1-(3-aminopropyl) imidazole; and aminoalkyl morpholines, such as 4-(3-aminopropyl) morpholine. These polyamines are described in more detail in U.S. Pat. Nos. 4,863,623 and 5,075,383. Such polyamines can provide additional benefits, such as anti-wear and antioxidancy, to the final products.

**[0057]** Additional polyamines useful in forming the hydrocarbyl-substituted succinimides include polyamines having at least one primary or secondary amino group and at least one tertiary amino group in the molecule as taught in U.S. Pat. Nos. 5,634,951 and 5,725,612. Examples of suitable polyamines include N,N,N",N"-tetraalkyldialkylenetriamines (two terminal tertiary amino groups and one central secondary amino group), N,N,N',N"-tetraalkyltrialkylenetetramines (one terminal tertiary amino group, two internal tertiary amino groups and one terminal primary amino group), N,N,N',N",N"'-pentaalkyltrialkylenetetramines (one terminal tertiary amino group, two internal tertiary amino groups and one terminal secondary amino group), tris(dialkylaminoalkyl)-aminoalkylmethanes (three terminal tertiary amino groups and one terminal primary amino group), and like compounds, wherein the alkyl groups are the same or different and typically contain no more than about 12 carbon atoms each, and which may contain from about 1 to about 4 carbon atoms each. As a further example, these alkyl groups may be methyl and/or ethyl groups. Polyamine reactants of this type may include dimethylaminopropylamine (DMAPA) and N-methyl piperazine.

**[0058]** Hydroxyamines suitable for herein include compounds, oligomers or polymers containing at least one primary or secondary amine capable of reacting with the hydrocarbyl-substituted succinic acid or anhydride. Examples of hydroxyamines suitable for use herein include aminoethylethanolamine (AEEA), aminopropyldiethanolamine (APDEA), ethanolamine, diethanolamine (DEA), partially propoxylated hexamethylene diamine (for example HMDA-2PO or HMDA-3PO), 3-amino-1,2-propanediol, tris(hydroxymethyl)aminomethane, and 2-amino-1,3-propanediol.

**[0059]** The mole ratio of amine to hydrocarbyl-substituted succinic acid or anhydride may range from about 1:1 to about 3.0:1. Another example of a mole ratio of amine to hydrocarbyl-substituted succinic acid or anhydride may range from about 1.5:1 to about 2.0:1.

**[0060]** The foregoing dispersant may also be a post-treated dispersant made, for example, by treating the dispersant with maleic anhydride and boric acid as described, for example, in U.S. Patent No. 5,789,353 to Scattergood, or by treating the dispersant with nonylphenol, formaldehyde and glycolic acid as described, for example, in U.S. Patent No. 5,137,980 to DeGonia, et al.

**[0061]** The Mannich base dispersants may be a reaction product of an alkyl phenol, typically having a long chain alkyl substituent on the ring, with one or more aliphatic aldehydes containing from about 1 to about 7 carbon atoms (especially formaldehyde and derivatives thereof), and polyamines (especially polyalkylene polyamines). For example, a Mannich base ashless dispersants may be formed by condensing about one molar proportion of long chain hydrocarbon-substituted phenol with from about 1 to about 2.5 moles of formaldehyde and from about 0.5 to about 2 moles of polyalkylene polyamine.

**[0062]** Hydrocarbon sources for preparation of the Mannich polyamine dispersants may be those derived from substantially saturated petroleum fractions and olefin polymers, such as polymers of mono-olefins having from about 2 to about 6 carbon atoms. The hydrocarbon source generally contains, for example, at least about 40 carbon atoms, and as a further example, at least about 50 carbon atoms to provide substantial oil solubility to the dispersant. The olefin polymers having a GPC number average molecular weight between about 600 and about 5,000 are suitable for reasons of easy reactivity and low cost. However, polymers of higher molecular weight can also be used. Especially suitable hydrocarbon sources are isobutylene polymers and polymers made from a mixture of isobutene and a raffinate I stream.

**[0063]** Suitable Mannich base dispersants may be Mannich base ashless dispersants formed by condensing about one molar proportion of long chain hydrocarbon-substituted phenol with from about 1 to about 2.5 moles of formaldehyde and from about 0.5 to about 2 moles of polyalkylene polyamine.

**[0064]** Polymeric polyamine dispersants suitable as the ashless dispersants are polymers containing basic amine groups and oil solubilizing groups (for example, pendant alkyl groups having at least about 8 carbon atoms). Such materials are illustrated by interpolymers formed from various monomers such as decyl methacrylate, vinyl decyl ether or relatively high molecular weight olefins, with aminoalkyl acrylates and aminoalkyl acrylamides. Examples of polymeric polyamine dispersants are set forth in U.S. Pat. Nos. 3,329,658; 3,449,250; 3,493,520; 3,519,565; 3,666,730; 3,687,849; and 3,702,300. Polymeric polyamines may include hydrocarbyl polyamines wherein the hydrocarbyl group is composed of the polymerization product of isobutene and a raffinate I stream as described above. PIB-amines and PIB-polyamines may also be used.

**[0065]** Methods for the production of ashless dispersants as described above are known to those skilled in the art and are reported in the patent literature. For example, the synthesis of various ashless dispersants of the foregoing types is described in such patents as U.S. Patent Nos. 2,459,112; 2,962,442, 2,984,550; 3,036,003; 3,163,603; 3,166,516; 3,172,892; 3,184,474; 3,202,678; 3,215,707; 3,216,936; 3,219,666; 3,236,770; 3,254,025; 3,271,310; 3,272,746;

3,275,554; 3,281,357; 3,306,908; 3,311,558; 3,316,177; 3,331,776; 3,340,281; 3,341,542; 3,346,493; 3,351,552; 3,355,270; 3,368,972; 3,381,022; 3,399,141; 3,413,347; 3,415,750; 3,433,744; 3,438,757; 3,442,808; 3,444,170; 3,448,047; 3,448,048; 3,448,049; 3,451,933; 3,454,497; 3,454,555; 3,454,607; 3,459,661; 3,461,172; 3,467,668; 3,493,520; 3,501,405; 3,522,179; 3,539,633; 3,541,012; 3,542,680; 3,543,678; 3,558,743; 3,565,804; 3,567,637; 3,574,101; 3,576,743; 3,586,629; 3,591,598; 3,600,372; 3,630,904; 3,632,510; 3,632,511; 3,634,515; 3,649,229; 3,697,428; 3,697,574; 3,703,536; 3,704,308; 3,725,277; 3,725,441; 3,725,480; 3,726,882; 3,736,357; 3,751,365; 3,756,953; 3,793,202; 3,798,165; 3,798,247; 3,803,039; 3,804,763; 3,836,471; 3,862,981; 3,872,019; 3,904,595; 3,936,480; 3,948,800; 3,950,341; 3,957,746; 3,957,854; 3,957,855; 3,980,569; 3,985,802; 3,991,098; 4,006,089; 4,011,380; 4,025,451; 4,058,468; 4,071,548; 4,083,699; 4,090,854; 4,173,540; 4,234,435; 4,354,950; 4,485,023; 5,137,980, and Re 26,433, herein incorporated by reference.

**[0066]** An example of a suitable ashless dispersant is a borated dispersant. Borated dispersants may be formed by boronating (borating) an ashless dispersant having basic nitrogen and/or at least one hydroxyl group in the molecule, such as a succinimide dispersant, succinamide dispersant, succinic ester dispersant, succinic ester-amide dispersant, Mannich base dispersant, or hydrocarbyl amine or polyamine dispersant.

Methods that can be used for boronating the various types of ashless dispersants described above are described in U.S. Pat. Nos. 3,087,936; 3,254,025; 3,281,428; 3,282,955; 2,284,409; 2,284,410; 3,338,832; 3,344,069; 3,533,945; 3,658,836; 3,703,536; 3,718,663; 4,455,243; and 4,652,387.

**[0067]** The borated dispersant may include a high molecular weight dispersant treated with boron such that the borated dispersant includes up to about 2 wt.% of boron. As another example the borated dispersant may include from about 0.8 wt.% or less of boron. As a further example, the borated dispersant may include from about 0.1 to about 0.7 wt.% of boron. As an even further example, the borated dispersant may include from about 0.25 to about 0.7 wt.% of boron. As a further example, the borated dispersant may include from about 0.35 to about 0.7 wt.% of boron. The borated dispersant may further include a mixture of borated dispersants. As a further example, the borated dispersant may include a nitrogen-containing dispersant and/or may be free of phosphorus. The dispersant may be dissolved in oil of suitable viscosity for ease of handling. It should be understood that the weight percentages given here are for neat dispersant, without any diluent oil added.

**[0068]** A dispersant may be further reacted with an organic acid, an anhydride, and/or an aldehyde/phenol mixture. Such a process may enhance compatibility with elastomer seals, for example.

**[0069]** A dispersant may be present in the power transmission fluid in an amount of about 0.1 wt.% to about 10 wt.%. Further, the power transmission fluid may include from about 2 wt.% to about 7 wt.% of the borated dispersant. Further, the power transmission fluid may include from about 3 wt.% to about 5 wt.% of the borated dispersant. Further, the power transmission fluid may include an amount of the borated dispersant sufficient to provide up to 1900 parts per million (ppm) by weight of boron in the finished fluid, such as for example, from about 50 to about 500 ppm by weight of boron in the finished fluid.

## Component (E): Antiwear Agents

**[0070]** In addition to the extreme pressure and antiwear enhancements achieved using Components (A) and (B) in transmission fluids at the relatively high rates indicated herein, the antiwear characteristics of the finished fluid also optionally may be further modified by addition of supplemental antiwear agents. The supplemental antiwear agents may include phosphorus-containing antiwear agents, such as those comprising an organic ester of phosphoric acid, phosphorous acid, or an amine salt thereof. For example, the phosphorus-containing antiwear agent may include one or more of a dihydrocarbyl phosphite, a trihydrocarbyl phosphite, a dihydrocarbyl phosphate, a trihydrocarbyl phosphate, any sulfur analogs thereof, and any amine salts thereof. As a further example, the phosphorus-containing antiwear agent may include at least one of dibutyl hydrogen phosphite and an amine salt of sulfurized dibutyl hydrogen phosphite.

**[0071]** The phosphorus-containing antiwear agent may be present in an amount sufficient to provide about 50 to about 500 parts per million by weight of phosphorus in the power transmission fluid. As a further example, the phosphorus-containing antiwear agent may be present in an amount sufficient to provide about 150 to about 300 parts per million by weight of phosphorus in the power transmission fluid.

**[0072]** The power transmission fluid may include from about 0.01 wt.% to about 1.0 wt.% of the phosphorus-containing antiwear agent. As a further example, the power transmission fluid may include from about 0.2 wt.% to about 0.3 wt.% of the phosphorus-containing antiwear agent. As an example, the power transmission fluid may include from about 0.1 wt.% to about 0.2 wt.% of a dibutyl hydrogen phosphite or 0.3 wt.% to about 0.4 wt.% an amine salt of a sulfurized dibutyl hydrogen phosphate.

## Component (F): Friction Modifiers

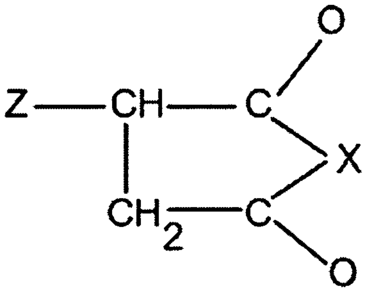
**[0073]** Friction modifiers are used in automatic transmission fluids to decrease friction between surfaces (e.g., the members of a torque converter clutch or a shifting clutch) at low sliding speeds. The result is a friction-vs.-velocity (μ-v) curve that has a positive slope, which in turn leads to smooth clutch engagements and minimizes "stick-slip" behavior (e.g., shudder, noise, and harsh shifts).

**[0074]** Friction modifiers include such compounds as aliphatic amines or ethoxylated aliphatic amines, ether amines, alkoxylated ether amines, aliphatic fatty acid amides, acylated amines, aliphatic carboxylic acids, aliphatic carboxylic esters, polyol esters, aliphatic carboxylic ester-amides, imidazolines, tertiary amines, aliphatic phosphonates, aliphatic phosphates, aliphatic thiophosphonates, aliphatic thiophosphates, etc., wherein the aliphatic group usually contains one or more carbon atoms so as to render the compound suitably oil soluble. As a further example, the aliphatic group may contain about 8 or more carbon atoms.

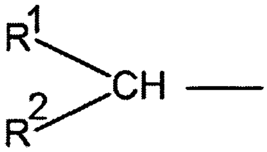
**[0075]** The succinimide may include the reaction product of a succinic acid or anhydride and ammonia or primary amine. The alkenyl group of the alkenyl succinic acid may be a short chain alkenyl group, for example, the alkenyl group may include from about 12 to about 36 carbon atoms. Further, the succinimide may include an about $C_{12}$ to about $C_{36}$ aliphatic hydrocarbyl succinimide. As a further example, the succinimide may include an about $C_{16}$ to about $C_{28}$ aliphatic hydrocarbyl succinimide. As an even further example, the succinimide may include an about $C_{18}$ to about $C_{24}$ aliphatic hydrocarbyl succinimide.

**[0076]** The succinimide may be prepared from a succinic anhydride and ammonia as described in European Patent Application No. 0 020 037, herein incorporated by reference. In some embodiments, no non-metallic friction modifier other than the succinimide disclosed herein is included.

**[0077]** The succinimide may include one or more of a compound having the following structure:



wherein Z may have the structure:



wherein either $R^1$ or $R^2$ may be hydrogen, but not both, and wherein $R^1$ and $R^2$ may be independently straight or branched chain hydrocarbon groups containing from about 1 to about 34 carbon atoms such that the total number of carbon atoms in $R^1$ and $R^2$ is from about 11 to about 35; X is an amino group derived from ammonia or a primary amine; and wherein, in addition to or in the alternative, the parent succinic anhydride may be formed by reacting maleic acid, anhydride, or ester with an internal olefin containing about 12 to about 36 carbon atoms, said internal olefin being formed by isomerizing the olefinic double bond of a linear α-olefin or mixture thereof to obtain a mixture of internal olefins. The reaction may involve an equimolar amount of ammonia and may be carried out at elevated temperatures with the removal of water.

**[0078]** One group of friction modifiers includes the N-aliphatic hydrocarbyl-substituted diethanol amines in which the N-aliphatic hydrocarbyl-substituent is at least one straight chain aliphatic hydrocarbyl group free of acetylenic unsaturation and having in the range of about 14 to about 20 carbon atoms.

**[0079]** An example of a suitable friction modifier system is composed of a combination of at least one N-aliphatic hydrocarbyl-substituted diethanol amine and at least one N-aliphatic hydrocarbyl-substituted trimethylene diamine in which the N-aliphatic hydrocarbyl-substituent is at least one straight chain aliphatic hydrocarbyl group free of acetylenic unsaturation and having in the range of about 14 to about 20 carbon atoms. Further details concerning this friction modifier system are set forth in U.S. Pat. Nos. 5,372,735 and 5,441,656.

**[0080]** Another friction modifier system is based on the combination of (i) at least one di(hydroxyalkyl) aliphatic tertiary amine in which the hydroxyalkyl groups, being the same or different, each contain from about 2 to about 4 carbon atoms, and in which the aliphatic group is an acyclic hydrocarbyl group containing from about 10 to about 25 carbon atoms, and (ii) at least one hydroxyalkyl aliphatic imidazoline in which the hydroxyalkyl group contains from about 2 to about 4 carbon atoms, and in which the aliphatic group is an acyclic hydrocarbyl group containing from about 10 to about 25 carbon atoms. For further details concerning this friction modifier system, reference should be had to U.S. Pat. No. 5,344,579.

**[0081]** Another suitable group of friction modifiers include polyolesters, for example, glycerol monooleate (GMO), glycerol monolaurate (GML), and the like.

**[0082]** Generally speaking, the compositions may contain up to about 1.25 wt.%, or, as a further example, from about 0.05 to about 1 wt.% of one or more friction modifiers.

## Component (G): Antioxidants

**[0083]** In some embodiments, antioxidant compounds may be included in the compositions. Antioxidants include phenolic antioxidants, aromatic amine antioxidants, sulfurized phenolic antioxidants, and organic phosphites, among others. Examples of phenolic antioxidants include 2,6-di-tert-butylphenol, liquid mixtures of tertiary butylated phenols, 2,6-di-tert-butyl-4-methylphenol, 4,4'-methylenebis(2,6-di-tert-butylphenol),2,2'-methylenebis(4-methyl6-ter t-butylphenol), mixed methylene-bridged polyalkyl phenols, and 4,4'-thiobis(2-methyl-6-tert-butylphenol). N,N'-di-sec-butyl-phenylenediamine, 4-isopropylaminodiphenylamine, phenyl-.alpha.-naphthyl amine, phenyl-.alpha.-naphthyl amine, and ring-alkylated diphenylamines. Examples include the sterically hindered tertiary butylated phenols, bisphenols and cinnamic acid derivatives and combinations thereof. The amount of antioxidant in the transmission fluid compositions described herein may range from about 0.01 to about 3.0 wt.% based on the total weight of the fluid formulation. As a further example, antioxidant may be present in an amount from about 0.1 wt.% to about 1.0 wt.%.

## Component (H): Anti-Rust agents

**[0084]** Rust or corrosion inhibitors are another type of inhibitor additive for use in embodiments of the present disclosure. Such materials include monocarboxylic acids and polycarboxylic acids. Examples of suitable monocarboxylic acids are octanoic acid, decanoic acid and dodecanoic acid. Suitable polycarboxylic acids include dimer and trimer acids such as are produced from such acids as tall oil fatty acids, oleic acid, linoleic acid, or the like. Another useful type of rust inhibitor may comprise alkenyl succinic acid and alkenyl succinic anhydride corrosion inhibitors such as, for example, tetrapropenylsuccinic acid, tetrapropenylsuccinic anhydride, tetradecenylsuccinic acid, tetradecenylsuccinic anhydride, hexadecenylsuccinic acid, hexadecenylsuccinic anhydride, and the like. Also useful are the half esters of alkenyl succinic acids having about 8 to about 24 carbon atoms in the alkenyl group with alcohols such as the polyglycols. Other suitable rust or corrosion inhibitors include ether amines; acid phosphates; amines; polyethoxylated compounds such as ethoxylated amines, ethoxylated phenols, and ethoxylated alcohols; imidazolines; aminosuccinic acids or derivatives thereof, and the like. Materials of these types are commercially available. Mixtures of such rust or corrosion inhibitors can be used. The amount of corrosion inhibitor in the transmission fluid formulations described herein may range from about 0.01 to about 2.0 wt.% based on the total weight of the formulation.

## Component (I): Copper Corrosion Inhibitors

**[0085]** In some embodiments, copper corrosion inhibitors may constitute another class of additives suitable for inclusion in the compositions. Such compounds include thiazoles, triazoles, and thiadiazoles. Examples of such compounds include benzotriazole, tolyltriazole, octyltriazole, decyltriazole, dodecyltriazole, 2-mercapto benzothiazole, 2,5-dimercapto-1,3,4-thiadiazole, 2-mercapto-5-hydrocarbylthio-1,3,4-thiadiazoles, 2-mercapto-5- hydrocarbyldithio-1,3,4-thiadiazoles, 2,5-bis(hydrocarbylthio)- 1,3,4-thiadiazoles, and 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazoles. Suitable compounds include the 1,3,4-thiadiazoles, a number of which are available as articles of commerce, and also combinations of triazoles such as tolyltriazole with a 1,3,5-thiadiazole such as a 2,5-bis(alkyldithio)-1,3,4-thiadiazole. Regarding dialkyl thiadiazoles, for imparting corrosion inhibition, that additive previously has been used in much smaller treat levels than the levels used in the present invention to enhance extreme pressure and antiwear properties (when used in combination with relatively high levels of sulfurized fatty oil as indicated herein). The 1,3,4-thiadiazoles are generally synthesized from hydrazine and carbon disulfide by known procedures. See, for example, U.S. Pat. Nos. 2,765,289; 2,749,311; 2,760,933; 2,850,453; 2,910,439; 3,663,561; 3,862,798; and 3,840,549.

## Component (J): Viscosity Index Improvers

**[0086]** Viscosity index improvers for use in the above described fluid transmission and gear lubricant compositions may be selected from polyisoalkylene compounds, polymethacrylate compounds, and any conventional viscosity index improvers. An example of a suitable polyisoalkylene compound for use as a viscosity index improver includes polyisobutylene having a weight average molecular weight ranging from about 700 to about 2,500. Embodiments may include a mixture of one or more viscosity index improvers of the same or different molecular weight.

**[0087]** Suitable viscosity index improvers may include styrene-maleic esters, polyalkylmethacrylates, and olefin copolymer viscosity index improvers. Mixtures of the foregoing products can also be used as well as dispersant and dispersant-antioxidant viscosity index improvers.

### Component (K): Antifoam agents

**[0088]** In some embodiments, a foam inhibitor may form another component suitable for use in the compositions. Foam inhibitors may be selected from silicones, polyacrylates, surfactants, and the like. The amount of antifoam agent in the transmission fluid formulations described herein may range from about 0.01 wt.% to about 0.5 wt.% based on the total weight of the formulation. As a further example, antifoam agent may be present in an amount from about 0.01 wt.% to about 0.1 wt.%.

### Component (L): Seal Swell agents

**[0089]** The seal swell agent used in the transmission fluid compositions described herein is selected from oil-soluble diesters, oil-soluble sulfones, and mixtures thereof. Generally speaking the most suitable diesters include the adipates, azelates, and sebacates of $C_8$-$C_{13}$ alkanols (or mixtures thereof), and the phthalates of $C_4$-$C_{13}$ alkanols (or mixtures thereof). Mixtures of two or more different types of diesters (e.g., dialkyl adipates and dialkyl azelates, etc.) can also be used. Examples of such materials include the n-octyl, 2-ethylhexyl, isodecyl, and tridecyl diesters of adipic acid, azelaic acid, and sebacic acid, and the n-butyl, isobutyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, and tridecyl diesters of phthalic acid.

**[0090]** Other esters which may give generally equivalent performance are polyol esters. Suitable sulfone seal swell agents are described in U.S. Pat. Nos. 3,974,081 and 4,029,587. Typically these products are employed at levels in the range of about 0.25 wt.% to about 5 wt.% in the finished transmission fluid. As a further example, they may be provided in an amount of about 0.25 wt.% to about 1 wt.%.

**[0091]** Suitable seal swell agents are the oil-soluble dialkyl esters of (i) adipic acid, (ii) sebacic acid, or (iii) phthalic acid. The adipates and sebacates should be used in amounts in the range of from about 1 to about 15 wt.% in the finished fluid. In the case of the phthalates, the levels in the transmission fluid should fall in the range of from about 1.5 to about 10 wt.%. Generally speaking, the higher the molecular weight of the adipate, sebacate or phthalate, the higher should be the treat rate within the foregoing ranges.

### Component (M): Dye:

**[0092]** A colorant may be added to the fluid to give it a detectable character. Generally, azo class dyes are used, such as C.I. Solvent Red 24 or C.I. Solvent Red 164, as set forth in the "Color Index" of the American Association of textile Chemists and Colorists and the Society of Dyers and Colourists (U.K.). For automatic transmission fluids, Automatic Red Dye is preferred. Dye is present in a very minimal amount, such as about 200 to about 300 ppm in the finished fluid.

### Component (N): Diluent

**[0093]** If the additives are provided in an additive package concentrate, a suitable carrier diluent is added to ease blending, solubilizing, and transporting the additive package. The diluent oil needs to be compatible with the base oil and the additive package. In one embodiment, the diluent is present in the concentrate in an amount of between about 5 to about 20%, although it can vary widely with application. Generally speaking, less diluent is preferable as it lowers transportation costs and treat rates.

**[0094]** Additives used in formulating the compositions described herein can be blended into base oil individually or in various sub-combinations. However, it is suitable to blend all of the components concurrently using an additive concentrate (i.e., additives plus a diluent, such as a hydrocarbon solvent). The use of an additive concentrate takes advantage of the mutual compatibility afforded by the combination of ingredients when in the form of an additive concentrate. Also, the use of a concentrate reduces blending time and lessens the possibility of blending errors.

### Base Oil

**[0095]** Transmission fluids of the present invention typically (but not necessarily always) are formulated with a major amount of a base oil and a minor amount of the additive package which includes the extreme-pressure/antiwear enhancing combination of sulfurized fatty oil and dialkyl thiadiazole at the prescribed addition levels. In one embodiment, a power transmission fluid composition is formulated to contain a major amount of base oil and about 10 wt.% to about 20 wt.% of an additive composition containing the sulfurized fatty oil and dialkyl thiadiazole in the respective levels prescribed herein.

**[0096]** Base oils suitable for use in formulating transmission fluid compositions according to the invention may be selected from any of the synthetic or natural oils or mixtures thereof. Natural oils include animal oils and vegetable oils (e.g., castor oil, lard oil) as well as mineral lubricating oils such as liquid petroleum oils and solvent treated or acid-treated mineral lubricating oils of the paraffinic, naphthenic or mixed paraffinic-naphthenic types. Oils derived from coal or shale are also suitable. The base oil typically has a viscosity of, for example, from about 2 to about 15 cSt and, as a further example, from about 2 to about 10 cSt at 100° C. Further, oils derived from a gas-to-liquid process are also suitable.

**[0097]** Synthetic oils include hydrocarbon oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, etc.); polyalphaolefins such as poly(1-hexenes), poly-(1-octenes), poly(1-decenes), etc. and mixtures thereof; alkylbenzenes (e.g., dodecylbenzenes, tetradecylbenzenes, di-nonylbenzenes, di-(2-ethylhexyl)benzenes, etc.); polyphenyls (e.g., biphenyls, terphenyl, alkylated polyphenyls, etc.); alkylated diphenyl ethers and alkylated diphenyl sulfides and the derivatives, analogs and homologs thereof and the like.

**[0098]** Alkylene oxide polymers and interpolymers and derivatives thereof where the terminal hydroxyl groups have been modified by esterification, etherification, etc., constitute another class of known synthetic oils that may be used. Such oils are exemplified by the oils prepared through polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers (e.g., methyl-polyisopropylene glycol ether having an average molecular weight of about 1000, diphenyl ether of polyethylene glycol having a molecular weight of about 500-1000, diethyl ether of polypropylene glycol having a molecular weight of about 1000-1500, etc.) or mono- and polycarboxylic esters thereof, for example, the acetic acid esters, mixed $C_{3-8}$ fatty acid esters, or the $C_{13}$ Oxo acid diester of tetraethylene glycol.

**[0099]** Another class of synthetic oils that may be used includes the esters of dicarboxylic acids (e.g., phthalic acid, succinic acid, alkyl succinic acids, alkenyl succinic acids, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acids, alkenyl malonic acids, etc.) with a variety of alcohols (e.g., butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, ethylene glycol, diethylene glycol monoether, propylene glycol, etc.) Specific examples of these esters include dibutyl adipate, di(2-ethylhexyl)sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, the 2-ethylhexyl diester of linoleic acid dimer, the complex ester formed by reacting one mole of sebacic acid with two moles of tetraethylene glycol and two moles of 2-ethylhexanoic acid and the like.

**[0100]** Esters useful as synthetic oils also include those made from $C_5$ to $C_{12}$ monocarboxylic acids and polyols and polyol ethers such as neopentyl glycol, trimethylol propane, pentaerythritol, dipentaerythritol, tripentaerythritol, etc.

**[0101]** Hence, the base oil used which may be used to make the transmission fluid compositions as described herein may be selected from any of the base oils in Groups I-V as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines.

**[0102]** Such base oil groups are as follows:

| Base Oil Group[1] | Sulfur (wt.%) | | Saturates (wt.%) | Viscosity Index |
|---|---|---|---|---|
| Group I | > 0.03 | and/or | < 90 | 80 to 120 |
| Group II | ≤ 0.03 | And | ≥ 90 | 80 to 120 |
| Group III | ≤ 0.03 | And | ≥ 90 | ≥ 120 |
| Group IV | all polyalphaolefins (PAOs) | | | |
| Group V | all others not included in Groups I-IV | | | |
| [1]Groups I-III are mineral oil base stocks. | | | | |

**[0103]** As set forth above, the base oil may be a poly-alpha-olefin (PAO). Typically, the poly-alpha-olefins are derived from monomers having from about 4 to about 30, or from about 4 to about 20, or from about 6 to about 16 carbon atoms. Examples of useful PAOs include those derived from octene, decene, mixtures thereof, and the like. PAOs may have a viscosity of from about 2 to about 15, or from about 3 to about 12, or from about 4 to about 8 cSt at 100° C. Examples of PAOs include 4 cSt at 100° C poly-alpha-olefins, 6 cSt at 100° C poly-alpha-olefins, and mixtures thereof. Mixtures of mineral oil with the foregoing poly-alpha-olefins may be used.

**[0104]** The base oil may be an oil derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing $H_2$ and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. For example, the hydrocarbons may be hydroisomerized using processes disclosed in U.S. Pat. Nos. 6,103,099 or 6,180,575; hydrocracked and hydroisomerized using processes disclosed in U.S. Pat. Nos. 4,943,672 or 6,096,940; dewaxed using processes disclosed in U.S. Pat. No. 5,882,505; or hydroisomerized and dewaxed using processes disclosed in U.S. Pat. Nos. 6,013,171; 6,080,301; or 6,165,949.

**[0105]** Unrefined, refined and rerefined oils, either natural or synthetic (as well as mixtures of two or more of any of these) of the type disclosed hereinabove can be used in the base oils. Unrefined oils are those obtained directly from a natural or synthetic source without further purification treatment. For example, a shale oil obtained directly from retorting operations, a petroleum oil obtained directly from primary distillation or ester oil obtained directly from an esterification process and used without further treatment would be an unrefined oil. Refined oils are similar to the unrefined oils except they have been further treated in one or more purification steps to improve one or more properties. Many such purification techniques are known to those skilled in the art such as solvent extraction, secondary distillation, acid or base extraction, filtration, percolation, etc. Rerefined oils are obtained by processes similar to those used to obtain refined oils applied to refined oils which have been already used in service. Such rerefined oils are also known as reclaimed or reprocessed oils and often are additionally processed by techniques directed to removal of spent additives, contaminants, and oil breakdown products.

**[0106]** In selecting any of the foregoing optional additives, it is important to ensure that the selected component(s) is/are soluble or stably dispersible in the additive package and finished ATF composition, are compatible with the other components of the composition, and do not interfere significantly with the performance properties of the composition, such as the extreme pressure, antiwear, friction, viscosity and/or shear stability properties, needed or desired, as applicable, in the overall finished composition.

**[0107]** In general, the ancillary additive components are employed in the oils in minor amounts sufficient to improve the performance characteristics and properties of the base fluid. The amounts will thus vary in accordance with such factors as the viscosity characteristics of the base fluid employed, the viscosity characteristics desired in the finished fluid, the service conditions for which the finished fluid is intended, and the performance characteristics desired in the finished fluid.

**[0108]** However, generally speaking, the following generally concentrations (weight percent unless otherwise indicated) of the additional components in the base fluids are illustrative:

| Optional Additive Component | Range |
|---|---|
| C | 0.00-1.00 |
| D | 1.00-15.00 |
| E | 0.00-1.00 |
| F | 0.01-1.25 |
| G | 0.10-5.00 |
| H | 0.01-0.30 |
| I | 0.00-0.50 |
| J | 1.0-25.0 |
| K | 0.005-0.05 |
| L | 1.0-30.0 |
| M | 1-400 ppm |
| N | 1.0-25.0 (in concentrate balance) |

**[0109]** It will be appreciated that the individual components employed can be separately blended into the base fluid or can be blended therein in various subcombinations, if desired. Ordinarily, the particular sequence of such blending steps is not crucial. Moreover, such components can be blended in the form of separate solutions in a diluent. It is preferable, however, to blend the additive components used in the form of a concentrate, as this simplifies the blending operations, reduces the likelihood of blending errors, and takes advantage of the compatibility and solubility characteristics afforded by the overall concentrate.

**[0110]** Additive concentrates can thus be formulated to contain all of the additive components and if desired, some of the base oil component, in amounts proportioned to yield finished fluid blends consistent with the concentrations described above. In most cases, the additive concentrate will contain one or more diluents such as light mineral oils, to facilitate handling and blending of the concentrate. Thus concentrates containing up to about 50 wt.% of one or more diluents or solvents can be used, provided the solvents are not present in amounts that interfere with the low and high temperature and flash point characteristics and the performance of the finished power transmission fluid composition. In this regard, the additive components used pursuant to this invention may be selected and proportioned such that an additive concentrate or package formulated from such components will have a flash point of about 170°C or above, using the ASTM D-92 test procedure.

**[0111]** Power transmission fluids of the embodiments herein are formulated to provide enhanced extreme pressure properties for applications where metal-to-metal contact is made under high pressures, e.g., pressures in excess of 2 GPa. Such fluids are suitable for automatic and manual transmissions such as step automatic transmissions, continuously variable transmissions, automated manual transmissions, and dual clutch transmissions. High metal-to-metal contact pressures such as those found in automotive transmissions, for example, may cause damage to transmission parts if a lubricant is used that does not possess sufficient extreme pressure protection characteristics. However, power transmission fluid compositions as described herein have greatly improved extreme pressure performance characteristics. Further, the power transmission fluids of the present disclosure also are suitable for use in transmissions with an electronically controlled converter clutch, a slipping torque converter, a lock-up torque converter, a starting clutch, and/or one or more shifting clutches. Such transmissions include four-, five-, six-, and seven-speed transmissions, and continuously variable transmissions (chain, belt, or disk type). They also may be used in gear applications, such as industrial gear applications and automotive gear applications. Gear-types may include, but are not limited to, spur, spiral bevel, helical, planetary, and hypoid. They may be used in axles, transfer cases, and the like. Further, they may also be useful in metalworking applications.

## EXAMPLES

**[0112]** Illustrative compositions suitable for use in the practice of this invention are presented in the following Examples, wherein all parts and percentages are by weight unless specified otherwise.

**[0113]** The following tables illustrate the steel-on-steel extreme pressure characteristics of transmission fluids as described herein evaluated using a Falex extreme pressure (EP) test according to ASTM D 3233. The Falex EP test measures the load carrying ability of an oil. According to the test, a 1/4 inch (6.35 mm) diameter test journal or pin is rotated at 290 rpm between two Vee Blocks immersed in the oil preheated to 51.7°C. Procedure A employs a constant increase in load applied by an automatic ratchet until failure as indicated by seizure of the test coupon or rapid loss of load caused by excessive wear. Procedure B employs load increments of 250 lbs with running for 1 minute at each increment until failure. The standard test pin is AISI 3135 Steel, HRB 87 and the standard Vee Blocks are AISI C-1137 Steel, HRC 20 to 24. Procedure B was used to determine the failure load of test fluid for purposes of the tests run and described below. The failure loads reported below are averages of two experiments run on a given test fluid back-to-back. The various transmission fluid compositions were tested at 100°C and 150°C. A separate sample of each test fluid was used at each of these test temperatures. Higher loads to seizure signify better extreme pressure (EP) performance. The baseline fluid for these tests contained the following components:

(a) Metallic detergents- from about 0.00 to about 0.1 wt.%
(b) Friction modifiers — from about 0.01 to about 0.5 wt.%
(c) Anti-oxidants — from about 0.01 to about 2.0 wt.%
(d) Anti-rust agents — from about 0.01 to about 0.3 wt.%
(e) Dispersants — from about 0.5 to about 10.0 wt.%
(f) Anti-foam agents — from about 0.0001 to about 0.5 wt.%
(g) Base Oil (mineral or synthetic) — balance of baseline fluid

**[0114]** A series of test fluids was prepared by dissolving a dialkyl thiadiazole and one of various sulfurized fatty oils in different respective amounts in baseline fluid. The additive package is dissolved in the baseline fluid at a total concentration of 14-17%.

**[0115]** The dialkyl thiadiazole used was a 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazole. The sulfurized fatty oils used were SFO1, SFO2, SFO3, and SFO4. All of the test fluids were fully-formulated ATFs. They are designated as Examples (Ex.) 1-7 and Comparative Examples (CEx.) 1-5 below in Table 1. The respective addition rates of the sulfurized fatty oil and dialkyl thiadiazole in the test fluids, as well as the performance of these test fluids in the Falex EP tests is indicated in Table 1.

**Table 1**

| Component | CEx. 1 | CEx. 2 | Ex. 1 | CEx. 3 | CEx. 4 | Ex. 2 | CEx. 5 | Ex. 3 |
|---|---|---|---|---|---|---|---|---|
| Sulf. Fatty oil, wt.% | SFO1, 0.50% | SFO1, 2.0% | SFO1, 2.0% | SFO1, 0.50% | SFO2, 3.4% | SFO2, 3.4% | SFO3, 2.0% | SFO3, 2.0% |
| ppm S from sulf. Fatty oil | 500 | 2000 | 2000 | 500 | 2000 | 2000 | 2000 | 2000 |
| Thiadiazole, wt.% | 0.10% | 0.10% | 0.40% | 0.50% | 0.10% | 0.40% | 0.10% | 0.40% |
| ppm S from thiadiazole | 350 | 350 | 1400 | 1750 | 350 | 1400 | 350 | 1400 |
| Falex EP load, lbs, 100°C | 1375 | 1875 | 2125 | 1625 | 1875 | 2000 | 1750 | 1750 |
| Falex EP load, lbs, 150°C | 1000 | 1000 | 1750 | 1875 | 1500 | 1750 | 750 | 1500 |

Table 1 (continued)

| Component | Ex. 4 | Ex. 5 | Ex. 6 | Ex. 7 |
|---|---|---|---|---|
| Sulf. Fatty oil, wt.% | SFO4, 1.3% | SFO4, 0.80% | SFO4, 0.80% | SFO4, 1.3% |
| ppm S from sulf. Fatty oil | 2000 | 1400 | 1400 | 2000 |
| Thiadiazole, wt.% | 0.40% | 0.17% | 0.40% | 0.17% |
| ppm S from thiadiazole | 1400 | 600 | 1400 | 600 |
| Falex EP load, lbs, 100°C | 2375 | 1500 | 2000 | 1750 |
| Falex EP load, lbs, 150°C | 2000 | 1500 | 2000 | 2000 |

**[0116]** These experimental results show that that test fluids containing high concentrations of both sulfurized fatty oils and dialkyl perform very well in the Falex EP test. Specifically, the transmission fluids tested that contained sufficient 2,5-dihydrocarbylmercapto-1,3,4-thiadiazole to contribute at least 600 ppm S and sufficient sulfurized fatty oil to contribute at least 1,000 ppm S exhibited a failure load performance of at least about 1750 pounds at both 100°C and 150°C (see Examples 1, 2, 4, 6, and 7). Examples 3 and 5 had failure loads that were both somewhat below 1750 pounds, but they were nonetheless consistently high in value. Comparative Examples 1-5, in which the transmission fluids tested contained either insufficient 2,5-dihydrocarbylmercapto-1,3,4-thiadiazole to contribute at least 600 ppm S or insufficient sulfurized fatty oil to contribute at least 1,000 ppm S, exhibited a failure load performance below 1750 pounds at 100°C and/or 150°C. At numerous places throughout this specification, reference has been made to a number of U.S. Patents. All such cited documents are expressly incorporated in full into this disclosure as if fully set forth herein.

**[0117]** As used throughout the specification and claims, "a" and/or "an" may refer to one or more than one. Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, percent, ratio, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

**[0118]** Other embodiments of the present invention will be apparent to those skilled in the art from consideration of the specification, Figure and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

## Claims

**1.** A fluid composition, including:

(1) a major amount of a base oil, and
(2) a minor amount of an additive including:

(A) sulfurized fatty oil in an amount sufficient to provide at least 1,000 ppm sulfur to the fluid composition, and
(B) dialkyl thiadiazole in an amount sufficient to provide at least 500 ppm sulfur to the fluid composition.

**2.** The fluid composition of claim 1, which provides a transmission fluid exhibiting failure loads which equal or exceed 1750 pounds at 100°C and 150°C, respectively, as measured according to a Falex EP test of ASTM D-3233.

**3.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount sufficient to provide 1,000 ppm to 2,500 ppm sulfur to the fluid composition, and component (B) is present in an amount sufficient to provide 500 ppm to 1,800 ppm sulfur to the fluid composition.

**4.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount sufficient to provide 1,300 ppm to 2,100 ppm sulfur to the fluid composition, and component (B) is present in an amount sufficient to provide 550 ppm to 1,500 ppm sulfur to the fluid composition.

**5.** The fluid composition of any one of claims 1-4 wherein combined sulfur added to the fluid composition by the sulfurized fatty oil and dialkyl thiadiazole is least 1,500 ppm.

**6.** The fluid composition of any one of claims 1-4, wherein combined sulfur added to the fluid composition by the sulfurized fatty oil and dialkyl thiadiazole is least 2,500 ppm.

**7.** The fluid composition of any one of claims 1-4, wherein combined sulfur added to the fluid composition by the sulfurized fatty oil and dialkyl thiadiazole is least 3,000 ppm.

**8.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount of at least 0.5 wt.%, and component (B) is present in an amount of at least 0.15 wt.%, based on the total weight of the fluid composition.

**9.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount of 0.5 wt.% to 5.0 wt.%, and component (B) is present in an amount of 0.15 wt.% to 3.0 wt.%, based on the total weight of the fluid composition.

**10.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount of 0.7 wt.% to 3.0 wt.%, and component (B) is present in an amount an amount of 0.15 wt.% to 1.0 wt.%, based on the total weight of the fluid composition.

**11.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount of 0.73 wt.% to 3.0 wt.%, and component (B) is present in an amount of 0.3 wt.% to 1.0 wt.%, based on the total weight of the fluid composition.

**12.** The fluid composition of any one of claims 1-2, wherein component (A) is present in an amount of 0.75 wt.% to 3.0 wt.%, and component (B) is present in an amount of 0.35 wt.% to 1.0 wt.%, based on the total weight of the fluid composition.

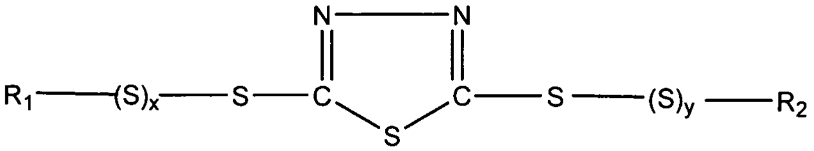
**13.** The fluid composition of any one of claims 1-2, wherein the additive composition is present in an amount of 10 wt.% to 20 wt.%, based on the total weight of the fluid composition.

**14.** The fluid composition of any one of claims 1-13, wherein component (A) is sulfurized transesterified triglyceride.

**15.** The fluid composition of any one of claims 1-13, wherein component (A) is selected from the group consisting of a sulfurized fat, a sulfurized fatty acid, a sulfurized fatty acid ester, and a sulfurized fatty olefin.

**16.** The fluid composition of any one of claims 1-13, wherein component (A) is 2,5-bis(hydrocarbyldithio)-1,3,4-thiadiazole or a derivative thereof.

**17.** The fluid composition of any one of claims 1-16, wherein component (B) is a compound of the formula:



wherein $R_1$ and $R_2$ may be the same or different hydrocarbyl groups, and x any y independently may be integers from 0 to 8, and the sum of x and y being at least 1.

**18.** The fluid composition of claim 17, wherein $R_1$ and $R_2$ are the same or different hydrocarbyl group having from 6 to 18 carbon atoms.

**19.** The fluid composition of claim 17, wherein $R_1$ and $R_2$ may be the same or different hydrocarbyl group having 8 to 12 carbon atoms, and x and y each are 1.

**20.** The fluid composition of any one of claims 1-19, wherein the base oil includes one or more of a natural oil, a mixture of natural oils, a synthetic oil, a mixture of synthetic oils, a mixture of natural and synthetic oils, and a base oil derived from a Fischer-Tropsch or gas-to-liquid process.

**21.** The fluid composition of any one of claims 1-20, wherein the base oil has a kinematic viscosity of from 2 centistokes to 10 centistokes at 100° C.

**22.** The fluid composition of any one of claims 1-21, wherein the additive composition further includes one or more of a detergent, a dispersant, a friction modifier, an antioxidant, an antiwear agent, an antifoam agent, a viscosity index improver, a copper corrosion inhibitor, an anti-rust additive, a seal swell agent, a metal deactivator, and an air expulsion additive.

**23.** The fluid composition of any one of claims 1-22, wherein the fluid is suitable for use in a transmission employing one or more of an electronically controlled converter clutch, a slipping torque converter, a lock-up torque converter, a starting clutch, and one or more shifting clutches.

**24.** The fluid composition of any one of claims 1-22, wherein the fluid is suitable for use in a belt, chain, or disk-type continuously variable transmission, a 4-, 5-, 6-, or 7-speed automatic transmission, a manual transmission, an automated manual transmission, or a dual clutch transmission.

**25.** The fluid composition of any one of claims 1-22, wherein the fluid is suitable for use in an industrial gear or an automotive gear.

**26.** A transmission containing the fluid composition of any one of claims 1-22.

**27.** The transmission of claim 26, wherein the transmission is a continuously variable transmission.

**28.** The transmission of claim 26, wherein the transmission is a dual clutch transmission.

**29.** The transmission of claim 26, wherein the transmission is an automatic transmission.

**30.** The transmission of claim 26, wherein the transmission is a manual transmission.

**31.** A vehicle including an engine and a transmission, the transmission including the transmission fluid of any one of claims 26-30.

**32.** A vehicle including a differential, the differential including a lubricant containing the fluid composition of any one of claims 1-22.

**33.** A method for improving extreme pressure and/or wear performance in power transmitting apparatus including:

1) adding a fluid as claimed in any one of claims 1-22, to a power transmitting apparatus; and
2) operating the fluid in the power transmitting apparatus, wherein the extreme pressure and/or wear performance is improved relative to the extreme pressure and/or wear performance of a transmission without said fluid.

**34.** The method of claim 33, wherein the power transmitting apparatus includes a transmission.

**35.** The method of claim 33, wherein the power transmitting apparatus includes an industrial gear or an automotive gear.