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LUBRICATING COMPOSITIONS CONTAINING ASHLESS CATALYTIC
ANTIOXIDANT ADDITIVES

FIELD OF THE INVENTION

[001] The present invention relates to lubricant compositions including passenger car engine oils, commercial vehicle engine oils, industrial, marine, hydraulic, aviation, and driveline oils containing ashless catalytic antioxidant additives.

BACKGROUND OF THE INVENTION

[002] A wide variety of additives are used in lubricating oils, greases and hydraulic fluids to improve their properties and enhance their performance. Additives can improve the performance of lubricating oils, greases and hydraulic fluids with respect to oxidation, wear and corrosion. One important property is oxidative stability. Antioxidants slow oxidative degradation by retarding or inhibiting a variety of degradation chemistries, thereby protecting and extending the life of formulated oils. Antioxidancy is described as the ability of an additive to delay the onset of oxidation by effectively quenching radicals that are generated by a system. US 2,930,758 to Tierney, et al. discloses the use of aryl-substituted phenylenediamines in combination with other compounds as antioxidants in ester based lubricant compositions.

[003] Many conventional antioxidants are stoichiometrically consumed in the degradation process. That is, conventional antioxidants are consumed in neutralizing a variety of degradation chemistries. More effective antioxidants are catalytic antioxidants. Catalytic antioxidants extend the useful life of

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formulated lubricants and may be used in significantly reduced concentration while maintaining good performance levels.

[004] It would be desirable, therefore, to provide lubricating compositions and hydraulic fluids with antioxidants that perform more like catalysts in their antioxidation function, thereby enhancing the performance and extending the life of such lubricants and fluids.

[005] Furthermore, it would be of industrial interest to develop a process in which antioxidants that perform more like catalysts in their antioxidation function could be prepared from generally available starting compounds that are relatively inexpensive, available in commercial scale amounts and that are safe to handle.

SUMMARY OF THE INVENTION

[006] It has now been discovered that substituted N, N'-diaryl-*m*-phenylenediamine compounds impart good levels of oxidation inhibition in lubricants and hydraulic fluids to which the compounds have been added.

[007] In accordance with a first aspect of the invention, there is provided a catalytic antioxidant useful for improving the oxidative stability of compositions comprising lubricants or hydraulic fluids.

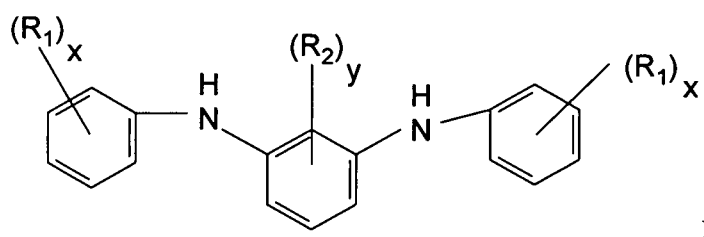
[008] In another aspect of the invention, there is provided a composition comprising a major amount of lubricant or hydraulic fluid and an effective amount of at least one substituted N, N'-diaryl-*m*-phenylenediamine antioxidant.

[009] In yet another aspect of the invention, there is provided a method of making substituted N, N'-diaryl-*m*-phenylenediamine antioxidants of the present invention.

[010] In still another aspect of the invention, there is provided a method for improving the antioxidative properties of compositions comprising lubricants or hydraulic fluids using substituted N, N'-diaryl-*m*-phenylenediamine antioxidant of the present invention.

[011] Other objects and advantages of the present invention will become apparent from the detailed description that follows.

[012] The antioxidants used in this composition include those having Formula I



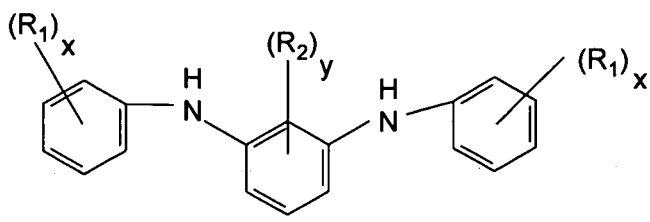
where R₁ and R₂ are independently H or C₁ to C₁₂ alkyl; x is 1 to 5; and, y is 1 to 4.

DETAILED DESCRIPTION OF THE INVENTION

[013] The present invention relates to substituted N, N'-diaryl-*m*-phenylenediamine compounds that impart good levels of oxidation inhibition in lubricants and hydraulic fluids to which the compounds have been added.

[014] The antioxidants used according to the invention are substituted N, N'-diaryl-*m*-phenylenediamines, preferably those having Formula I

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where R_1 and R_2 are independently H or C_1 to C_{12} alkyl; x is 1 to 5; and, y is 1 to 4. Preferably, R_1 is a C_1 to C_8 alkyl, more preferably, R_1 is methyl, ethyl or propyl, conveniently, methyl or isopropyl; and, R_2 is H. Preferably, x is 1 to 3, more preferably, x is 1 to 2.

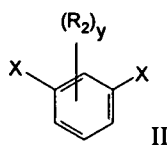
[015] In still another preferred embodiment, the substituted N, N'-diaryl-*m*-phenylenediamines of Formula I are N,N'-bis(2,6-dimethylphenyl)-*m*-phenylenediamine or N,N'-bis(2,6-diisopropylphenyl)-*m*-phenylenediamine.

[016] The average molecular weight of the substituted N, N'-diaryl-*m*-phenylenediamine antioxidant ranges from about 300 to about 600, preferably 350 to about 500.

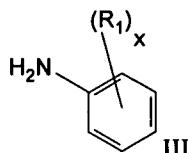
[017] Preferably, the substituted N, N'-diaryl-*m*-phenylenediamine antioxidant is an isopropyl substituted antioxidant, more preferably a methyl substituted antioxidant. Without being bound to any particular theory, it is believed that steric hindrance plays an important role in the antioxidants ability to combat oxidative properties in oils. While some steric hindrance allows for a proton to be donated to an oxidative radical, too much steric hindrance crowds the proton making it unavailable to radicals.

[018] In the present invention, substituted N, N'-diaryl-*m*-phenylenediamine antioxidants are prepared by reacting a 1,3-disubstituted arene having Formula II

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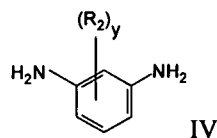


where X is a halogen or a triflate group and R_2 and y have the same meaning as in Formula I, with an aniline derivative having Formula III

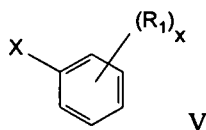


where R_1 and x have the same meaning as in Formula I, in the presence of a palladium catalyst. Preferably, the halogen is bromine or chlorine, more preferably, bromine.

[019] In another embodiment, substituted N, N'-diaryl-*m*-phenylenediamine antioxidants are prepared by reacting a 1,3-phenylenediamine of Formula IV



where R_2 and y have the same meaning as in Formula I, with a substituted arene of Formula V



where R_1 and x have the same meaning as in Formula I and X is a triflate or halogen, preferably chlorine or bromine, more preferably, bromine, in the presence of a palladium catalyst.

[020] Useful aniline derivatives of Formula III include, but are not limited to, 2-methylaniline; 3-methylaniline; 4-methylaniline; 2,3-dimethylaniline; 2,4-dimethylaniline; 2,5-dimethylaniline; 2,6-dimethylaniline; 3,4-dimethylaniline; 3,5-dimethylaniline; 3,6-dimethylaniline; 2,4,6-trimethylaniline; 2,3,4-

trimethylaniline; 2,3,5-trimethylaniline; 2,3,6-trimethylaniline; 2,4,5-trimethylaniline; 2-ethylaniline; 3-ethylaniline; 4-ethylaniline; 2,3-diethylaniline; 2,4-diethylaniline; 2,5-diethylaniline; 2,6-diethylaniline; 3,4-diethylaniline; 3,5-dimethylaniline; 3,6-diethylaniline; 2,4-diisopropylaniline; 2,5-diisopropylaniline; 2,6-diisopropylaniline; 3,4-diisopropylaniline; 3,5-diisopropylaniline; 3,6-diethylaniline; 2,4-di-*tert*-butylaniline; 2,5-di-*tert*-butylaniline; 3,5-di-*tert*-butylaniline; 3,4-di-*tert*-butylaniline; and, 2,6-di-*tert*-butylaniline.

[021] Both methods of preparation described above are carried out in the presence of a palladium catalyst. Preferably, the palladium catalyst is a palladium/phosphine or palladium/carbene catalyst, such as palladium acetate/tri-*t*-butylphosphine. More preferably, the palladium catalyst is a preformed palladium complex coupling catalyst. By preformed palladium complex coupling catalyst, it is meant that the catalyst contains both a palladium and phosphine ligand. The preformed catalysts of the present invention are thermally stable and, in some cases, are air stable making them easier to handle unlike the catalyst system of the prior art which uses tri-*t*-butylphosphine, a known pyrophoric reagent.

[022] Preformed palladium complex coupling catalysts of the invention include

dichlorobis(triphenylphosphine)palladium(II),	
tetrakis(triphenylphosphine)palladium(0),	diacetato[1,3-
bis(diphenylphosphino)propane]palladium(II),	dichloro[1,2-
bis(diphenylphosphino)ethane]palladium(II),	
diacetatobis(triphenylphosphine)palladium(II),	dichloro[1,4-
bis(diphenylphosphino)butane]palladium(II),	dichloro[1,1'-
bis(diphenylphosphino)ferrocene]palladium(II)-dichloromethane	adduct,
dichloro[1,1'-bis(diphenylphosphino)ferrocene]palladium(II)-acetone	adduct,

di- μ -chlorobis(tris(2,4-di-*tert*-butylphenyl)phosphite-2-C,P)dipalladium(II), di- μ -bromobis(tri-*tert*-butylphosphine)dipalladium(I),
 dichlorobis(tricyclohexylphosphine)palladium(II), dichlorobis(tri-*ortho*-tolylphosphine)palladium(II), bis(tri-*tert*-butylphosphine)palladium(0),
 dichloro[bis(diphenylphosphinophenyl)ether]palladium(II), dichloro[1,1'-bis(di-*tert*-butylphosphino)ferrocene]palladium(II), dichloro[1,1'-bis(di-isopropylphosphino)ferrocene]palladium(II), dibromobis(tri-*ortho*-tolylphosphine)palladium(II), dibromo[1,1'-bis(diphenylphosphino)ferrocene]palladium(II), dichlorobis(di-*tert*-butylphenylphosphine)palladium(II), dichloro(2,2'-bis(diphenylphosphino)-1,1'-binaphthyl)palladium(II), dibromo(2,2'-bis(diphenylphosphino)-1,1'-binaphthyl)palladium(II), diiodo(2,2'-bis(diphenylphosphino)-1,1'-binaphthyl)palladium(II), dichloro[1,3-bis(diphenylphosphino)propane]palladium(II), Fiber supported Pd /P Bu₃ catalyst, 1,2,3,4,5-pentaphenyl-1'-(di-*tert*-butylphosphino)ferrocene, dichlorobis(benzonitrile)palladium(II), dichlorobis(acetonitrile)palladium(II), bis(acetylacetonato)palladium(II), dichloro(1,5-cyclooctadiene)palladium(II), dichloro(norbornadiene)palladium(II), bis(dibenzylideneacetone)palladium(0), tris(dibenzylideneacetone)dipalladium(0), tris(dibenzylideneacetone)dipalladium(0) chloroform adduct, allylpalladium chloride dimer and palladium(II)acetate trimer.

[023] More preferred preformed palladium complex coupling catalysts of the invention include diacetato[1,3-bis(diphenylphosphino)propane]palladium(II), dichloro[1,2-bis(diphenylphosphino)ethane]palladium(II), diacetatobis(triphenylphosphine)palladium(II), dichloro[1,4-bis(diphenylphosphino)butane]palladium(II), dichloro[1,1'-bis(diphenylphosphino)ferrocene]palladium(II)-dichloromethane adduct, dichloro[1,1'-bis(diphenylphosphino)ferrocene]palladium(II)-acetone adduct, di-

μ -chlorobis(tris(2,4-di-*tert*-butylphenyl)phosphite-2-C,P)dipalladium(II), di- μ -
 bromobis(tri-*tert*-butylphosphine)dipalladium(I),
 dichlorobis(tricyclohexylphosphine)palladium(II), bis(tri-*tert*-
 butylphosphine)palladium(0),
 dichloro[bis(diphenylphosphinophenyl)ether]palladium(II), dichloro[1,1'-bis(di-
tert-butylphosphino)ferrocene]palladium(II), dichloro[1,1'-bis(di-
 isopropylphosphino)ferrocene]palladium(II), dibromobis(tri-*ortho*-
 tolylphosphine)palladium(II), dibromo[1,1'-
 bis(diphenylphosphino)ferrocene]palladium(II), dichlorobis(di-*tert*-
 butylphenylphosphine)palladium(II), dichloro(2,2'-bis(diphenylphosphino)-1,1'-
 binaphthyl)palladium(II), dibromo(2,2'-bis(diphenylphosphino)-1,1'-
 binaphthyl)palladium(II), diiodo(2,2'-bis(diphenylphosphino)-1,1'-
 binaphthyl)palladium(II), dichloro[1,3-
 bis(diphenylphosphino)propane]palladium(II), Fiber supported Pd /P Bu₃
 catalyst and 1,2,3,4,5-pentaphenyl-1'-(di-*tert*-butylphosphino)ferrocene. The
 preformed palladium complex coupling catalysts are commercially available
 from Johnson Matthey.

[024] The synthesis of N, N'-diaryl-*m*-phenylenediamines is done under
 conditions well known to those skilled in the art. In a typical procedure, the
 reactants are mixed under inert atmosphere (e.g., nitrogen, argon) in a solvent
 (e.g., toluene) and heated to the boiling temperature of the solvent (e.g., 100-
 120°C) under reflux, for a period of about 5 to 24 hours.

[025] The composition of the invention comprises a major amount of
 lubricant or hydraulic fluid, in particular those lubricant or hydraulic fluids based
 on paraffinic and naphthenic oils or synthetic oils. Thus, the lubricant can be, for
 example, an oil or a grease based on a mineral oil or a synthetic oil.

[026] Typical paraffinic and naphthenic oils include conventional mineral oils or hydrotreated oil. Other useful fluids of lubricating viscosity include non-conventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance lubrication characteristics.

[027] Formulated lubricant compositions comprise a mixture of at least one base stock and/or base oil and at least one performance additive. Usually, the base stock is a single oil secured from a single crude source and subjected to a single processing scheme and meeting a particular specification. Base oils comprise at least one base stock.

[028] Non-conventional or unconventional base oils include one or more of a mixture of base stock(s) derived from one or more Gas-to-Liquids (GTL) materials, as well as hydrodewaxed, or hydroisomerized/conventional catalytically (or solvent) dewaxed base stock(s) derived from natural wax or waxy feeds, mineral and or non-mineral oil waxy feed stocks such as slack waxes, natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials received from coal liquefaction or shale oil, and mixtures of such base stocks.

[029] GTL base oils comprise base stock(s) obtained from GTL materials that are derived via one or more synthesis, combination, transformation, rearrangement, and/or degradation/deconstructive processes from gaseous carbon containing compounds. Preferably, the GTL base stocks are derived from the Fischer-Tropsch (FT) synthesis process wherein a synthesis gas comprising a mixture of H₂ and CO is catalytically converted to lower boiling materials by hydroisomerisation and/or dewaxing. The process is described, for

example, in U.S. Patent Nos. 5,348,982 and 5,545,674, and examples of suitable catalysts are described in U.S. Patent No. 4,568,663, each of which is incorporated herein by reference.

[030] GTL base stock(s) are characterized typically as having kinematic viscosities at 100°C of from about 2 mm²/s to about 50 mm²/s, preferably from about 3 mm²/s to about 50 mm²/s, more preferably from about 3.5 mm²/s to about 30 mm²/s. The GTL base stock and/or other hydrodewaxed, or hydroisomerized/ catalytically (or solvent) dewaxed wax derived base stock(s) used in the present invention have kinematic viscosities at 100°C in the range of about 3.5 mm²/s to 7 mm²/s, preferably about 4 mm²/s to about 7 mm²/s, more preferably about 4.5 mm²/s to 6.5 mm²/s. Reference herein to kinematic viscosity refers to a measurement made by ASTM method D445.

[031] GTL base stocks and base oils derived from GTL base stocks which can be used as base stock components of this invention are further characterized typically as having pour points of about -5°C or lower, preferably about -10°C or lower, more preferably about -15°C or lower, still more preferably about -20°C or lower, and under some conditions may have advantageous pour points of about -25°C or lower, with useful pour points of about -30°C to about -40°C or lower. In the present invention, however, the GTL base stock(s) used generally are those having pour points of about -30°C or higher, preferably about -25°C or higher, more preferably about -20°C or higher. References herein to pour point refer to measurement made by ASTM D97 and similar automated versions.

[032] The GTL base stock(s) derived from GTL materials, especially hydrodewaxed or hydroisomerized/ catalytically (or solvent) dewaxed F-T material derived base stock(s), and other such wax-derived base stock(s) which are base stock components which can be used in this invention are also characterized

typically as having viscosity indices of 80 or greater, preferably 100 or greater, and more preferably 120 or greater. Additionally, in certain particular instances, the viscosity index of these base stocks may be preferably 130 or greater, more preferably 135 or greater, and even more preferably 140 or greater. For example, GTL base stock(s) that derive from GTL materials, preferably F-T materials, especially F-T wax, generally have a viscosity index of 130 or greater. References herein to viscosity index refer to ASTM method D2270.

[033] In addition, the GTL base stock(s) are typically highly paraffinic (>90% saturates), and may contain mixtures of monocycloparaffins and multicycloparaffins in combination with non-cyclic isoparaffins. The ratio of the naphthenic (i.e., cycloparaffin) content in such combinations varies with the catalyst and temperature used. Further, GTL base stocks and base oils typically have very low sulfur and nitrogen content, generally containing less than about 10 ppm, and more typically less than about 5 ppm of each of these elements. The sulfur and nitrogen content of GTL base stock and base oil obtained by the hydroisomerization/isodewaxing of F-T material, especially F-T wax is essentially nil.

[034] In a preferred embodiment, the GTL base stock(s) comprises paraffinic materials that consist predominantly of non-cyclic isoparaffins and only minor amounts of cycloparaffins. These GTL base stock(s) typically comprise paraffinic materials that consist of greater than 60 wt% non-cyclic isoparaffins, preferably greater than 80 wt% non-cyclic isoparaffins, more preferably greater than 85 wt% non-cyclic isoparaffins, and most preferably greater than 90 wt% non-cyclic isoparaffins.

[035] Examples of useful compositions of GTL base stock(s) are recited in U.S. Patent Nos. 6,080,301; 6,090,989, and 6,165,949 for example, which are herein incorporated by reference.

[036] Base stock(s), derived from waxy feeds, which are also suitable for use in this invention, are paraffinic fluids of lubricating viscosity derived from hydrodewaxed, or hydroisomerized/catalytically (or solvent) dewaxed waxy feedstocks of mineral oil, non-mineral oil, non-petroleum, or natural source origin, e.g., feedstocks such as one or more of gas oils, slack wax, waxy fuels hydrocracker bottoms, hydrocarbon raffinates, natural waxes, hydrocrackates, thermal crackates, foots oil, wax from coal liquefaction or from shale oil, or other suitable mineral oil, non-mineral oil, non-petroleum, or natural source derived waxy materials, linear or branched hydrocarbyl compounds with carbon number of about 20 or greater, preferably about 30 or greater, and mixtures of such isomerate/isodewaxate base stocks and base oils.

[037] Slack wax is the wax recovered from any waxy hydrocarbon oil including synthetic oil such as F-T waxy oil or petroleum oils by solvent or autorefrigerative dewaxing. Solvent dewaxing employs chilled solvent such as methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), mixtures of MEK/MIBK, mixtures of MEK and toluene, while autorefrigerative dewaxing employs pressurized, liquefied low boiling hydrocarbons such as propane or butane.

[038] Slack wax(es) secured from synthetic waxy oils such as F-T waxy oil will usually have zero or nil sulfur and/or nitrogen containing compound content. Slack wax(es) secured from petroleum oils, may contain sulfur and nitrogen containing compounds. Such heteroatom compounds must be removed by hydrotreating (and not hydrocracking), as for example by

hydrodesulfurization (HDS) and hydrodenitrogenation (HDN) so as to avoid subsequent poisoning/deactivation of the hydroisomerization catalyst.

[039] The preferred base stocks or base oils derived from GTL materials and/or from waxy feeds are characterized as having predominantly paraffinic compositions and are further characterized as having high saturates levels, low-to-nil sulfur, low-to-nil nitrogen, low-to-nil aromatics, and are essentially water-white in color.

[040] A preferred GTL liquid hydrocarbon composition is one comprising paraffinic hydrocarbon components in which the extent of branching, as measured by the percentage of methyl hydrogens (BI), and the proximity of branching, as measured by the percentage of recurring methylene carbons which are four or more carbons removed from an end group or branch ($\text{CH}_2 \geq 4$), are such that: (a) $\text{BI} - 0.5(\text{CH}_2 \geq 4) > 15$; and (b) $\text{BI} + 0.85(\text{CH}_2 \geq 4) < 45$ as measured over said liquid hydrocarbon composition as a whole.

[041] The preferred GTL base oil can be further characterized, if necessary, as having less than 0.1 wt% aromatic hydrocarbons, less than 20 wppm nitrogen containing compounds, less than 20 wppm sulfur containing compounds, a pour point of less than -18°C , preferably less than -30°C , a preferred $\text{BI} \geq 25.4$ and $(\text{CH}_2 \geq 4) \leq 22.5$. They have a nominal boiling point of 370°C^+ , on average they average fewer than 10 hexyl or longer branches per 100 carbon atoms and on average have more than 16 methyl branches per 100 carbon atoms. They also can be characterized by a combination of dynamic viscosity, as measured by CCS at -40°C , and kinematic viscosity, as measured at 100°C represented by the formula: $\text{DV (at } -40^\circ\text{C)} < 2900 (\text{KV at } 100^\circ\text{C}) - 7000$.

[042] The preferred GTL base oil is also characterized as comprising a

mixture of branched paraffins characterized in that the lubricant base oil contains at least 90% of a mixture of branched paraffins, wherein said branched paraffins are paraffins having a carbon chain length of about C₂₀ to about C₄₀, a molecular weight of about 280 to about 562, a boiling range of about 650°F to about 1050°F, and wherein said branched paraffins contain up to four alkyl branches and wherein the free carbon index of said branched paraffins is at least about 3.

[043] GTL base oils, and hydrodewaxed, or hydroisomerized/catalytically (or solvent) dewaxed wax base oils, for example, hydroisomerized or hydrodewaxed waxy synthesized hydrocarbon, e.g., Fischer-Tropsch waxy hydrocarbon base oils are of low or zero sulfur and phosphorus content. There is a movement among original equipment manufacturers and oil formulators to produce formulated oils of ever increasingly reduced sulfated ash, phosphorus and sulfur content to meet ever increasingly restrictive environmental regulations. Such oils, known as low SAPS oils, would rely on the use of base oils which themselves, inherently, are of low or zero initial sulfur and phosphorus content. Such oils when used as base oils can be formulated with additives. Even if the additive or additives included in the formulation contain sulfur and/or phosphorus the resulting formulated lubricating oils will be lower or low SAPS oils as compared to lubricating oils formulated using conventional mineral oil base stocks.

[044] Low SAPS formulated oils for vehicle engines (both spark ignited and compression ignited) will have a sulfur content of 0.7 wt% or less, preferably 0.6 wt% or less, more preferably 0.5 wt% or less, most preferably 0.4 wt% or less, an ash content of 1.2 wt% or less, preferably 0.8 wt% or less, more preferably 0.4 wt% or less, and a phosphorus content of 0.18% or less, preferably 0.1 wt% or less, more preferably 0.09 wt% or less, most preferably 0.08 wt% or less, and in certain instances, even preferably 0.05 wt% or less.

[045] While the preferred base oils used according to this invention are GTL base oils, other synthetic oils may be used. Other synthetic oils that can be used in the invention include polyalphaolefins (PAOs), aliphatic or aromatic carboxylic esters, phosphoric acid esters, and the like. The PAOs, which are known materials and generally available on a major commercial scale from suppliers such as ExxonMobil Chemical Company, Chevron, BP-Amoco, and others, typically vary in number average molecular weight from about 250 to about 3000, or higher. PAOs are commercially available in wide range of kinematic viscosities, such as, up to about 100 cSt (kV at 100°C) and up to about 3000 cSt (kV at 100°C), or higher. The PAOs are typically comprised of hydrogenated polymers or oligomers of alphaolefins which include, but are not limited to, about C₂ to about C₃₂ alphaolefins with about C₈ to about C₁₆ alphaolefins, such as 1-octene, 1-decene, 1-dodecene and the like, being preferred. The preferred polyalphaolefins are poly-1-octene, poly-1-decene and poly-1-dodecene and mixtures thereof and mixed olefin-derived polyolefins. The dimers of higher olefins in the range of about C₈ to C₂₀, preferably C₁₄ to C₁₈, may be used to provide low viscosity base stocks of acceptably low volatility. Depending on the viscosity grade and the starting oligomer, the PAOs may be predominantly trimers and tetramers of the starting olefins, with minor amounts of the higher oligomers. Most commonly, PAOs having a kinematic viscosity at 100°C ranging from about 1.5 to 12 cSt are used.

[046] PAO base oils may be conveniently made by the polymerization of an alphaolefin in the presence of a polymerization catalyst such as the Friedel-Crafts catalysts including, for example, aluminum trichloride, boron trifluoride or complexes of boron trifluoride with water, alcohols such as ethanol, propanol or butanol, carboxylic acids or esters such as ethyl acetate or ethyl propionate. For example the methods disclosed by USP 4,149,178 or USP 3,382,291 may be

conveniently used herein. Other descriptions of PAO synthesis are found in the following U.S. Patent Nos. 3,742,082; 3,769,363; 3,876,720; 4,239,930; 4,367,352; 4,413,156; 4,434,408; 4,910,355; 4,956,122; and 5,068,487. The dimers of the C₁₄ to C₁₈ olefins are described in USP 4,218,330.

[047] Other useful synthetic lubricating base stock oils such as silicon-based oil or esters of phosphorus containing acids may also be utilized. Examples of other synthetic lubricating base stocks are disclosed in "Synthetic Lubricants", Gunderson and Hart, Reinhold Publ. Corp., NY 1962, which is incorporated in its entirety.

[048] Other suitable synthetic base oils include alkylated aromatic base oils, such as mono- or poly-alkylbenzenes or mono- or poly-alkyl naphthalenes. In these types of base oils, alkyl substituents are typically alkyl groups of about 8 to 25 carbon atoms, usually from about 10 to 18 carbon atoms and up to about three such substituents may be present, as described for the alkylbenzenes in ACS Petroleum Chemistry Preprint 1053-1058, "Poly n-Alkylbenzene Compounds: A Class of Thermally Stable and Wide Liquid Range Fluids", Eapen et al, Phila. 1984. Tri-alkylbenzenes may be produced by the cyclodimerization of 1-alkynes of 8 to 12 carbon atoms as described in U.S. Patent 5,055,626. Other alkylbenzenes are described in European Patent Application 168 534 and U.S. Patent 4,658,072. Alkylbenzenes are used as lubricant base stocks and base oils, especially for low-temperature applications (arctic vehicle service and refrigeration oils) and in papermaking oils. They are commercially available from producers of linear alkylbenzenes (LABs) such as Vista Chem. Co., Huntsman Chemical Co., Chevron Chemical Co., and Nippon Oil Co. Linear alkylbenzenes typically have good low pour points and low temperature viscosities and VI values greater than about 100, together with good solvency for additives. Other alkylated aromatics which may be used when desirable are described, for

example, in "Synthetic Lubricants and High Performance Functional Fluids", Dressler, H., chap 5, (R. L. Shubkin (Ed.)), Marcel Dekker, NY, 1993.

[049] Alkylene oxide polymers and interpolymers and their derivatives containing modified terminal hydroxyl groups obtained by, for example, esterification or etherification are useful synthetic lubricating oils. By way of example, these oils may be obtained by polymerization of ethylene oxide or propylene oxide, the alkyl and aryl ethers of these polyoxyalkylene polymers (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, and the diethyl ether of polypropylene glycol having a molecular weight of about 1000 to 1500, for example) or mono- and polycarboxylic esters thereof (the acidic acid esters, mixed C₃₋₈ fatty acid esters, or the C₁₃Oxo acid diester of tetraethylene glycol, for example).

[050] Esters comprise a useful base stock. Additive solvency and seal compatibility characteristics may be secured by the use of esters such as the esters of dibasic acids with monoalkanols and the polyol esters of monocarboxylic acids. Esters of the former type include, for example, the esters of dicarboxylic acids such as phthalic acid, succinic acid, alkyl succinic acid, alkenyl succinic acid, maleic acid, azelaic acid, suberic acid, sebacic acid, fumaric acid, adipic acid, linoleic acid dimer, malonic acid, alkyl malonic acid, alkenyl malonic acid, etc., with a variety of alcohols such as butyl alcohol, hexyl alcohol, dodecyl alcohol, 2-ethylhexyl alcohol, etc. Specific examples of these types of esters include dibutyl adipate, di(2-ethylhexyl) sebacate, di-n-hexyl fumarate, dioctyl sebacate, diisooctyl azelate, diisodecyl azelate, dioctyl phthalate, didecyl phthalate, dieicosyl sebacate, etc.

[051] Particularly useful synthetic esters are those full or partial esters which are obtained by reacting one or more polyhydric alcohols (preferably the

hindered polyols such as the neopentyl polyols, e.g., neopentyl glycol, trimethylol ethane, 2-methyl-2-propyl-1,3-propanediol, trimethylol propane, pentaerythritol and dipentaerythritol) with alkanolic acids containing at least about 4 carbon atoms (preferably C₅ to C₃₀ acids such as saturated straight chain fatty acids including caprylic acid, capric acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachic acid, and behenic acid, or the corresponding branched chain fatty acids or unsaturated fatty acids such as oleic acid).

[052] Suitable synthetic ester components include the esters of trimethylol propane, trimethylol butane, trimethylol ethane, pentaerythritol and/or dipentaerythritol with one or more monocarboxylic acids containing from about 5 to about 10 carbon atoms.

[053] Silicon-based oils are another class of useful synthetic lubricating oils. These oils include polyalkyl-, polyaryl-, polyalkoxy-, and polyaryloxy-siloxane oils and silicate oils. Examples of suitable silicon-based oils include tetraethyl silicate, tetraisopropyl silicate, tetra-(2-ethylhexyl)silicate, tetra-(4-methylhexyl)silicate, tetra-(p-tert-butylphenyl) silicate, hexyl-(4-methyl-2-pentoxo) disiloxane, poly(methyl) siloxanes, and poly-(methyl-2-methylphenyl) siloxanes.

[054] Another class of synthetic lubricating oil is esters of phosphorous-containing acids. These include, for example, tricresyl phosphate, trioctyl phosphate, diethyl ester of decanephosphonic acid.

[055] Another class of oils includes polymeric tetrahydrofurans, their derivatives, and the like.

[056] The compositions of the invention comprise a major amount of a lubricant or hydraulic fluid and an effective amount of at least one substituted N, N'-diaryl-*m*-phenylenediamine antioxidant. By a major amount of a lubricant or

hydraulic fluid, it is meant that the lubricant or hydraulic fluid is present in an amount ranging from about 50 wt.% to about 99 wt. %, e.g., from about 85 wt.% to about 95 wt. %, based on the total weight of the composition. By an effective amount of at least one substituted N, N'-diaryl-*m*-phenylenediamine antioxidant, it is meant that the catalytic antioxidant is present in amounts ranging from about 0.001 to about 5 wt%, and preferably from about 0.01 to about 1 wt% based on the total weight of composition. The antioxidant may be used alone or may be combined with other additives.

[057] Antioxidative properties of the lubricant or hydraulic fluid compositions of the invention are improved by adding an effective amount of at least one substituted N, N'-diaryl-*m*-phenylenediamine antioxidant to the compositions.

[058] Fully formulated compositions can contain at least one additional lubricating oil or hydraulic fluid additive, which include, but not limited to, viscosity and viscosity index improvers such as polyalkylene or polyolefin viscosity index improvers, metal deactivators such as triazoles and thiadiazoles, extreme pressure and antiwear additives such as phosphate ester, amine phosphate and sulfurized olefins, antirust agents such as carboxylic acids, dispersants such as succinimides, antifoamants and dyes to mention a few. The amount of such other additives included in the formulation will be the amount typically used in formulated oils.

[059] Typical end use applications for the compositions of the invention include, but are not limited to, circulating oils, hydraulic fluids, greases, gear oils, metal working fluids, engine oils and automatic transmission fluids.

[060] The following non-limiting examples are provided to illustrate the

invention.

EXAMPLES

[061] A series of compositions were formulated and evaluated for antioxidative properties. The unadditized base oils used were a GTL base oil with a kV at 100°C of 6 mm²/s and an unsaturated PAO oil with a kV at 100°C of 6 mm²/s. The antioxidants used in the formulated compositions were a commercially available alkylated diphenyl amine sold by Ciba under the trade name Irganox L57 and a N,N'-bis(2,6-dimethylphenyl)-*m*-phenylenediamine (*m*-PDA) of the present invention.

[062] The data was collected using a DuPont DSC Model 2920 pressure differential scanning calorimeter. The results reported in following tables are for isothermal oxidation runs carried out in air (100 psig) at 180°C using open aluminum pans and 6.5mg of sample. The samples were heated from room temperature to 180°C at 10°C/min and then held isothermally to monitor the time taken for oxidation exotherm to occur. The oxidation induction time (OIT) for each run is shown in tables. OIT is calculated as the extrapolation tangent to the exotherm from a plot of heat flow versus time. The OIT is defined as the amount of time taken for the depletion of the antioxidant. In other words, the OIT is the amount of time before oxidation of the lubricant or hydraulic fluid occurs.

Comparative Examples 1 and 2 and Example 3

[063] The base oil used was a GTL base oil. The results are shown in Table 1.

Table 1

	Additive, wt%	Oxidation Induction Time, Minutes
Comp. 1	None	4.2
Comp. 2	L57, 0.5 wt%	42.5
Example 3	<i>m</i> -PDA, 0.1 wt%	58.6

[064] As is shown in Table 1, the *m*-PDA antioxidant of the invention provided the GTL base oil with better antioxidative properties at lower concentrations as measured by the OIT as compared with the commercially available antioxidant, L57.

Comparative Examples 4 and 5 and Example 6

[065] The procedure in Examples 1 to 3 was followed except the base oil used was a PAO base oil. The results are shown in Table 2.

Table 2

	Additive, wt%	Oxidation Induction Time, Minutes
Comp. 4	None	2.7
Comp. 5	L57, 0.1 wt%	5.1
Example 6	<i>m</i> -PDA, 0.1 wt%	14.6

[066] As can be seen in Table 2, the *m*-PDA antioxidant of the present invention provided the PAO base oil with better anti-oxidative properties as measured by the OIT as compared with the commercially available antioxidant, L57.

[067] In the following examples, Examples 7 to 9, the substituted N, N'-diaryl-*m*-phenylenediamine antioxidant is synthesized using different raw materials as well as different catalysts.

Example 7

Synthesis of N,N'-bis(2,6-dimethylphenyl)-*m*-phenylenediamine from 1,3-dibromobenzene and 2,6-dimethylaniline in the presence of palladium acetate/tri-*t*-butylphosphine catalyst

[068] In an argon glove box, 0.80 mmol palladium acetate, Pd(OAc)₂, and 2.2 mmol of solid tri-*t*-butylphosphine, P^{*t*}Bu₃, were combined in 20mL of toluene. The mixture was stirred until the Pd(OAc)₂ dissolved. Twenty-five (25) mmol of 1,3-dibromobenzene was added to the mixture followed by 74 mmol of 2,6-dimethylaniline and 75 mmol of sodium tert-butoxide, NaO^{*t*}Bu. The reaction mixture was heated to about 110°C and maintained at about 110 °C for approximately 14 h. After approximately 14 h, the argon glove box was opened and the reaction mixture was quickly quenched with aqueous ammonium chloride (40 g NH₄Cl in 80 ml H₂O). The toluene layer was separated from the aqueous layer and washed twice with 80 mL with deionized water. The toluene layer was dried over magnesium sulfate, MgSO₄, and filtered. The toluene layer was concentrated on a rotary evaporator until crystals began to form. The toluene layer with crystals was cooled to about -10 °C and maintained at this temperature for 24 hours. The crystals were isolated by filtration and dried under vacuum. The yield of isolated N,N'-diaryl-*m*-phenylenediamine was 6.28 grams, GC yield of 100%. The GC/MS spectrum suggests that the product is a single compound having a mass of m/e316.

Example 8**Synthesis of N,N'-diaryl-*m*-phenylenediamine from 1,3-dibromobenzene and 2,6-dimethylaniline in the presence of preformed palladium complex coupling catalyst**

[069] In an argon glove box, 0.168 mmol of dichlorobis(di-*tert*-butylphenylphosphine)palladium (II) was combined with 40mL of toluene and stirred for about 5 minutes. To the mixture, 8.5 mmol of 1,3-dibromobenzene was added followed by 25 mmol of 2,6-dimethylaniline and 25 mmol of sodium *tert*-butoxide, NaO^tBu. The reaction mixture was heated to about 110°C and maintained at about 110°C for approximately 14 h. After approximately 14 h, the argon glove box was opened and the reaction mixture was quickly quenched with aqueous ammonium chloride (10 g NH₄Cl in 25 ml H₂O). The toluene layer was separated from the aqueous layer and washed twice with 80 mL deionized water. The toluene layer was dried over magnesium sulfate, MgSO₄, and filtered. The toluene layer was concentrated on a rotary evaporator until crystals began to form. The solution was cooled to about -10 °C and maintained at this temperature for 24 hours. The crystals were isolated by filtration and dried under vacuum. The yield of isolated N,N'-diaryl-*m*-phenylenediamine was 1.44 g. The GC/MS spectrum suggests that the product is a single compound and has mass of m/e 316.

Example 9**Synthesis of N,N'-Bis(2,6-diisopropylphenyl)-*m*-phenylenediamine from 1,3-dibromobenzene and 2,6-diisopropylaniline in the presence of preformed palladium complex coupling catalyst**

[070] In an argon glove box, 0.168 mmol of dichlorobis(di-*tert*-butylphenylphosphine)palladium (II) was combined with 40mL of toluene and stirred for about 5 minutes. To the mixture, 8.5 mmol of 1,3-dibromobenzene was added followed by 25 mmol of 2,6-diisopropylaniline and 25 mmol of

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sodium tert-butoxide, NaO^tBu . The reaction mixture was heated to about 110°C and maintained at about 110°C for approximately 14h. After approximately 14h, the argon glove box was opened and the reaction mixture was quickly quenched with aqueous ammonium chloride (10 g NH_4Cl in 25 ml H_2O). The toluene layer was separated from the aqueous layer and washed twice with 80 mL deionized water. The toluene layer was dried over magnesium sulfate, MgSO_4 , and filtered. The toluene layer was concentrated on a rotary evaporator until crystals began to form. The solution was cooled to about -10°C and maintained at this temperature for 24 hours. The crystals were isolated by filtration and dried under vacuum. The yield of isolated N,N'-diaryl-*m*-phenylenediamine was 1.995 g. The GC/MS spectrum suggests that the product is a single compound and has mass of m/e 428.

[071] It is also understood that the following claims are intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention, which as a matter of language, might be said to fall therebetween.

CLAIMS

1. A catalytic antioxidant comprising N,N'-bis (2,6-dimethylphenyl)-m-phenylenediamine or N,N'-bis (2,6-diisopropylphenyl)-m-phenylenediamine.