

LUBRICATING FLUID FOR AN ELECTRIC MOTOR

TECHNICAL FIELD

[001] The present disclosure relates to methods of using a lubricating fluid and a lubricating fluid for an electric motor system. In particular, the disclosed methods and compositions relate to a lubricating fluid suitable for electric or hybrid-electric vehicles including a tolyltriazole corrosion inhibitor, an ashless dialkyl dithiophosphoric acid, and detergent that achieves copper corrosion and extreme pressure performance.

BACKGROUND

[002] A major challenge in developing electric vehicle powertrain lubricants is achieving acceptable extreme pressure performance while minimizing copper leaching for compatibility with electrical components in the electric vehicle powertrain.

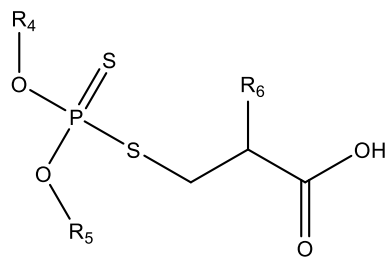
[003] Tolyltriazole compounds (e.g., methyl-benzotriazole) are effective metal deactivators that inhibit copper from leaching into the lubricant but have been discovered to negatively impact the performance of certain extreme pressure additives. For instance, combining tolyltriazole with an ashless dialkyl dithiophosphoric acid extreme pressure additive in electric vehicle powertrain lubricants leads to lower failure load stage (FLS) in FZG performance (e.g., A10/16.6R/120 scuffing test of CEC L-84-02). If the tolyltriazole is eliminated from the composition, the FZG FLS improves, but copper leaching also increases.

SUMMARY

[004] In one embodiment, an electric motor lubricating fluid suitable for electric or hybrid-electric vehicles is described herein. In one aspect of this embodiment, the electric motor lubricating fluid includes one or more base oils of lubricating viscosity; at least about 1 ppm of nitrogen provided by a tolyltriazole corrosion inhibitor; an oil-soluble phosphorus antiwear additive including an ashless dialkyl dithiophosphoric acid providing about 40 ppm to about 150 ppm of phosphorus and about 85 ppm to about 315 ppm sulfur to the electric motor lubricating fluid; a succinimide dispersant derived from a hydrocarbyl-substituted dicarboxylic acid or anhydride reacted with polyalkylene polyamines having one or more primary or secondary amines, wherein the one or more primary or secondary amines are post-treated with a capping agent; a sulfonate detergent in amounts to contribute a TBN of about 0.02 to about 1.9 (ASTM

D2896) to the electric motor lubricating fluid; and wherein the electric motor lubricating fluid contains less than about 500 ppm sulfur and at least about 70 ppm phosphorus.

[005] In other approaches or embodiments, the electric motor lubricating fluid of the previous paragraph may include other features or embodiments in any combination. These other features or embodiments may include one or more of the following: wherein the tolyltriazole corrosion inhibitor includes methyl-1H-benzotriazole; and/or wherein a ratio of the amount phosphorus (ppm) delivered from the ashless dialkyl dithiophosphoric acid to the fluid and the amount of nitrogen (ppm) delivered from the tolyltriazole corrosion inhibitor to the fluid (EP Phos + CI Nitrogen) relative to a TBN factor is about 70,000 or less and wherein the TBN factor is the TBN (ASTM D2896) delivered by the detergent to the fluid divided by the amount of metal (ppm) delivered from the detergent to the fluid (TBN/Det metal); and/or wherein the sulfonate detergent is calcium sulfonate and provides about 30 to about 600 ppm calcium to the electric motor lubricating fluid; and/or wherein the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate is made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product and (b) further reacting the reaction product with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate; and/or wherein the ashless dialkyl dithiophosphate includes a compound of Formula I, or a salt thereof:



(Formula IIa)

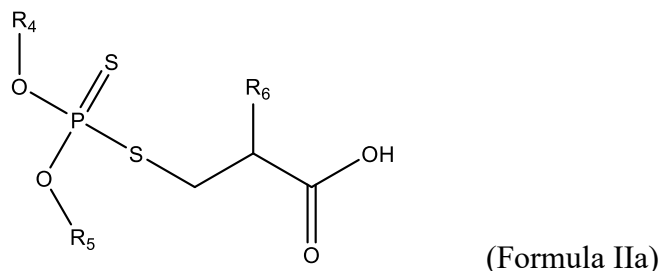
wherein R₄ and R₅ are, independently, a C₁ to C₁₀ linear or branched alkyl group, and R₆ is -H or -CH₃; and/or wherein the ashless dialkyl dithiophosphoate includes 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid; and/or wherein the succinimide dispersant is post treated with a phosphorus containing compound and/or a boron containing compound; and/or wherein the succinimide dispersant delivers about 20 to about 100 ppm phosphorus and about 5 to about 50 ppm boron to the electric motor lubricating fluid; and/or wherein the sulfonate detergent is provided in amounts to contribute a TBN of about 0.2 to about 0.6; and/or wherein the electric motor lubricating fluid exhibits about 30 ppm or less of copper leaching

pursuant to ASTM D130; and/or wherein the electric motor lubricating fluid has a failure load stage rating of 8 or higher in the FZG A10/16.6R/120 test of ASTM D5182; and/or wherein the electric motor lubricating fluid contains less than about 300 ppm of sulfur.

[006] In yet other approaches or embodiments, a method for lubricating a driveline component including an electric motor is described herein. In aspects of this approach or embodiment, the method includes lubricating the driveline component with an electric motor lubricating fluid and wherein the electric motor lubricating fluid contacts portions of the electric motor; wherein in the electric motor lubricating fluid includes (i) one or more base oils of lubricating viscosity, (ii) at least about 1 ppm of nitrogen provided by a tolyltriazole corrosion inhibitor; (iii) an oil-soluble phosphorus antiwear additive including an ashless dialkyl dithiophosphoric acid providing about 40 ppm to about 150 ppm of phosphorus and about 85 ppm to about 315 ppm sulfur to the electric motor lubricating fluid, (iv) a succinimide dispersant derived from a hydrocarbyl-substituted dicarboxylic acid or anhydride reacted with polyalkylene polyamines having one or more primary or secondary amines, wherein the one or more primary or secondary amines are post-treated with a capping agent; (v) a sulfonate detergent provided in amounts to contribute a TBN of about 0.02 to about 1.9 to the electric motor lubricating fluid; and (vi) wherein the electric motor lubricating fluid contains less than about 500 ppm sulfur and at least about 70 ppm phosphorus; and wherein the electric motor lubricating fluid exhibits about 30 ppm or less of copper leaching pursuant to ASTM D130 and has a failure load stage rating of 8 or higher in the FZG A10/16.6R/120 test of ASTM D5182.

[007] In other approaches or embodiments, the method of the previous paragraph may include other steps, approaches, embodiments, or features in any combination. These other steps, approaches, embodiments or features may include one or more of the following: wherein the triazole corrosion inhibitor includes methyl benzotriazole; and/or wherein a ratio of the amount phosphorus (ppm) delivered from the ashless dialkyl dithiophosphoric acid to the fluid and the amount of nitrogen (ppm) delivered from the tolyltriazole corrosion inhibitor to the fluid (EP Phos + CI Nitrogen) relative to a TBN factor is about 70,000 or less and wherein the TBN factor is the TBN (ASTM D2896) delivered by the detergent to the fluid divided by the amount of metal (ppm) delivered from the detergent to the fluid (TBN/Det metal); and/or wherein the sulfonate detergent is calcium sulfonate and provides about 30 to about 600 ppm calcium to the electric motor lubricating fluid; and/or wherein the oil-soluble phosphorus antiwear additive

including the ashless dialkyl dithiophosphate is made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product and (b) further reacting the reaction product with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate; and/or wherein the ashless dialkyl dithiophosphate includes a compound of Formula I, or a salt thereof:



wherein R₄ and R₅ are, independently, a C₁ to C₁₀ linear or branched alkyl group, and R₆ is -H or -CH₃; and/or wherein the ashless dialkyl dithiophosphate includes 3-[[bis(2-methylpropoxy) phosphinothiyl]thio]-2-methyl-propanoic acid; and/or wherein the succinimide dispersant is post treated with a phosphorus containing compound and/or a boron containing compound; and/or wherein the succinimide dispersant delivers about 20 to about 100 ppm phosphorus and about 5 to about 50 ppm boron to the electric motor lubricating fluid; and/or wherein the sulfonate detergent is provided in amounts to contribute a TBN of about 0.2 to about 1.6; and/or wherein the electric motor lubricating fluid contains less than about 300 ppm sulfur.

[008] In yet other embodiments, the use of any embodiment of the electric motor lubricating fluid of this Summary is also provided for lubricating the driveline component of an electric or hybrid-electric vehicle and for achieving about 30 ppm or less of copper leaching pursuant to ASTM D130 and/or for achieving a failure load stage (FLS) rating of 8 or higher in the FZG A10/16.6R/120 test of ASTM D5182.

[009] Other embodiments of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein.

BRIEF DESCRIPTION OF DRAWING FIGURE

[010] FIG. 1 is a graph of FZG failure load stage and copper leaching relative to a ratio of antiwear phosphorus, tolyltriazole nitrogen, and a detergent TBN factor as described herein.

DETAILED DESCRIPTION

[011] According to exemplary embodiments, an electric motor lubricating fluid suitable for electric or hybrid-electric vehicles is described herein that achieves low copper leaching while also providing acceptable FZG failure load stage (FLS) scuffing performance. It was discovered that tolyltriazole corrosion inhibitors negatively impact the extreme pressure performance of ashless dialkyl dithiophosphoric acids, which can lead to unacceptably low FZG Scuffing FLS as measured by the A10/16.6R/90 test of CEC L-84-02. While not wishing to be limited by theory, it is believed that the tolyltriazole compound and the ashless dialkyl dithiophosphoric acid compete for surface activity whereby the tolyltriazole compound interferes with and/or inhibits the ashless dialkyl dithiophosphoric acid from providing a sufficient protective layer on metal surface leading to decreased FZG scuffing performance.

[012] The present application relates to the discovery that lubricating fluids suitable for electric vehicle powertrains can overcome any negative impact of the tolyltriazole corrosion inhibitor on extreme pressure performance from the dialkyl dithiophosphoric acid through the addition of select TBN detergent contributions (ASTM D2896) relative to the extreme pressure agent and nitrogen content of the tolyltriazole corrosion inhibitor. The selected TBN contribution is largely provided by one or more neutral to overbased sulfonate detergents in amounts to contribute a TBN (ASTM D2896) of about 0.02 to about 1.9 to the electric motor lubricating fluid (in other approaches, about 0.04 to about 1.6, or about 0.2 to about 1.6, or about 0.2 to about 0.6). As shown by the Examples and in some embodiments, a unique relationship was discovered whereby the detergent TBN (ASTM D2896) is balanced relative to the amount of detergent metal (preferably calcium) and then further balanced relative to the phosphorus content provided by the extreme pressure additive and the nitrogen content provided by the tolyltriazole corrosion inhibitor. As discussed more below, this fluid relationship is defined by a ratio of phosphorus (in ppm) delivered from the ashless dialkyl dithiophosphoric acid and nitrogen (in ppm) delivered from the tolyltriazole corrosion inhibitor (e.g., EP phosphorus + CI nitrogen) relative to a TBN Factor of about 70,000 or less and where the TBN Factor is the amount of TBN delivered by the detergent to the fluid (ASTM D2896) divided by the amount of metal (in ppm) delivered from the detergent to the fluid (TBN/detergent metal). Preferably, the detergent metal is calcium. For instance, FIG. 1 illustrates embodiments of the lubricants herein where the ratio is about 70,000 or below and reflects desired FZG performance (e.g., FLS of 8 or higher)

and desired copper leaching performance (e.g., copper leaching of 30 ppm or less) in lubricants including both a tolyltriazole corrosion inhibitor and an ashless dialkyl dithiophosphoric acid.

The Examples below demonstrate in more details how the ratio, as defined herein, is calculated.

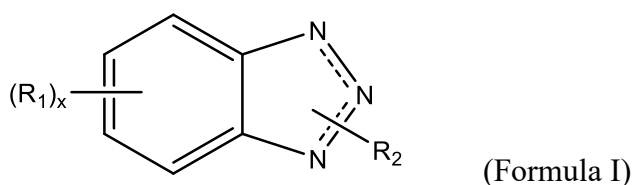
[013] Traditional driveline lubricants may also contain some active sulfur which can be harmful to copper wiring found in the electric motor or other copper componentry in proximity to the lubricant. Thus, it is often preferred to formulate low sulfur electric motor lubricating fluids to reduce corrosion of the copper componentry. In embodiments, the electric motor lubricating fluids described herein also contains less than about 500 ppm total sulfur (in other approaches, less than about 400 ppm sulfur or less than about 300 ppm sulfur and, in some approaches, about 50 ppm or more, about 100 ppm or more, or about 200 ppm or more), and at least about 50 ppm total phosphorus (in the approaches, about 50 to about 200 ppm phosphorus or about 50 to about 150 total phosphorus).

[014] Tolyltriazole Corrosion Inhibitor

[015] In approaches and embodiments herein, the electric motor lubricating fluids of the present disclosure include at least about 2 ppm of a tolyltriazole corrosion inhibitor, at least about 4 ppm of a tolyltriazole corrosion inhibitor, at least about 5 ppm of a tolyltriazole corrosion inhibitor, at least about 10 ppm of a tolyltriazole corrosion inhibitor, at least about 20 ppm of a tolyltriazole corrosion inhibitor, at least about 30 ppm of a tolyltriazole corrosion inhibitor, at least about 50 ppm of a tolyltriazole corrosion inhibitor, at least about 70 ppm of a tolyltriazole corrosion inhibitor, or at least about 90 ppm of a tolyltriazole corrosion inhibitor. In other embodiments, the electric motor lubricating fluid of the present disclosure includes about 150 ppm or less of a tolyltriazole corrosion inhibitor, about 100 ppm or less of a tolyltriazole corrosion inhibitor, or about 70 ppm or less of a tolyltriazole corrosion inhibitor, or about 40 ppm or less of a tolyltriazole corrosion inhibitor. Other ranges between such end points are also within the scope of this disclosure. Tolyltriazole compounds (e.g., methyl-1H-benzotriazole or isomers thereof) contain about 31.5 weight percent nitrogen. Thus, in the context of nitrogen contributed to the electric motor lubricating fluids of the present disclosure, the tolyltriazole is provided in other embodiments is within amounts to contribute at least about 1 ppm of tolyltriazole nitrogen, at least about at least about 2 ppm of tolyltriazole nitrogen, at least about 4 ppm of tolyltriazole nitrogen, at least about 5 ppm of tolyltriazole nitrogen, at least about 10 ppm

of tolyltriazole nitrogen, at least about 20 ppm of tolyltriazole nitrogen, or at least about 25 ppm of tolyltriazole nitrogen. In yet other embodiments, the tolyltriazole is provided in amounts to contribute about 35 ppm or less of a tolyltriazole nitrogen, about 30 ppm or less of a tolyltriazole nitrogen, or about 25 ppm or less of a tolyltriazole nitrogen, or about 15 ppm or less of a tolyltriazole nitrogen. Other ranges of nitrogen within such specified endpoints are also within the scope of this disclosure.

[016] In other embodiments, the tolyltriazole corrosion inhibitor is an hydrocarbaryl substituted benzotriazole compound having a structure of Formula I below or tribologically acceptable salts thereof:



wherein each R_1 is independently a hydrocarbaryl group having 1 to 10 carbon atoms, x is an integer of 1 to 4, and R_2 is hydrogen or a hydrocarbaryl group containing 1 to 10 carbon atoms. In other approaches, each R_1 is independently a straight or branched alkyl group or an aryl group such as phenyl, and more preferably, R_1 is independently a straight or branched alkyl group having 1 to 8 carbon atoms (in other approaches, 1 to 6 carbon atoms, and yet further approaches, 1 to 4 carbon atoms, and most preferably, a methyl group). Suitable examples for R_1 are alkyl groups including methyl, ethyl, n-propyl, i-propyl, n-butyl, i-butyl, and t-butyl. Preferably, methyl and ethyl are the alkyl groups for R_1 , and methyl is most preferred for R_1 . As noted above, x is an integer of 1 to 4. In another embodiment, the upper limit for the integer x is preferably 3, and more preferably 2. It is particularly preferred for x to be 1.

[017] In other embodiments, R_2 is preferably hydrogen or a straight or branched alkyl group or an aryl group such as phenyl. More preferably, R_2 is hydrogen or a straight or branched alkyl group. Most preferably R_2 is hydrogen. When R_2 is a hydrocarbaryl group containing 1 to 10 carbon atoms, it preferably includes 1 to 8 carbon atoms, more preferably 1 to 6 carbon atoms, and yet more preferably 1 to 4 carbon atoms. Preferred examples for R_2 in this regard are alkyl groups such as methyl, ethyl, n-propyl, i-propyl, n-butyl, i-butyl, and t-butyl, with methyl and ethyl being particularly preferred, and methyl most preferred. In yet other embodiments, R_2 is hydrogen.

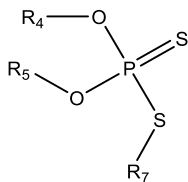
[018] In a particularly preferred embodiment, integer x is 1, R₁ is a straight or branched alkyl group comprising 1 to 4 carbon atoms such as methyl or ethyl (typically methyl), and R₂ is hydrogen or a straight or branched alkyl group comprising 1 to 4 carbon atoms such as methyl or ethyl (typically R₂ is hydrogen). Examples of preferred compounds of Formula I are tolyltriazole and a hydrocarbyl-substituted benzotriazole, with tolyltriazole (e.g., methyl benzotriazole such as methyl-1H-benzotriazole) being particularly preferred for the compositions herein.

[019] Oil-Soluble Phosphorus Extreme Pressure Additive:

[020] In approaches or embodiments, the electric motor lubricating fluids herein also include an oil-soluble phosphorus extreme pressure additive in the form of an ashless dialkyl dithiophosphoric acid extreme pressure additive.

[021] In one embodiment, the ashless dialkyl dithiophosphoric acid extreme pressure additive provides about 40 ppm to about 150 ppm of phosphorus (in other approaches, about 45 to about 100 ppm phosphorus or about 50 to about 80 ppm phosphorus) and about 85 ppm to about 315 ppm sulfur (in other approaches, about 80 to about 300 ppm sulfur, or about 95 to about 210 ppm sulfur, or about 95 to about 170 ppm sulfur) to the electric motor lubricating fluid. As shown by the Examples below, when electric motor lubricating fluids included the above-described tolyltriazole compound as a corrosion inhibitor combined with an ashless dialkyl dithiophosphoric acid, there was a negative impact on FZG extreme pressure performance.

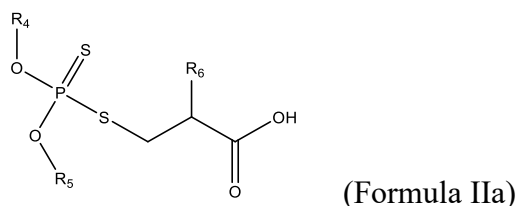
[022] In an embodiment, the ashless dialkyl dithiophosphoric acid has a structure of the compounds shown in Formula II or a salt thereof



(Formula II)

wherein R₄ and R₅ of Formula II above are each, independently, a linear or branched C₁ to C₁₀ hydrocarbyl group and R₇ of Formula II above is a C₁ to C₁₀ linear or branched carboxylic group or a C₁ to C₁₀ linear or branched alkyl alkanoate group. Preferably, R₄ and R₅ of Formula II above are each a C₃ to C₈ linear or branched alkyl group and R₇ of Formula II above is derived from 2-methyl propanoic acid such that the phosphorus product (or a salt thereof) has the

structure of Formula IIa below:



wherein R₄ and R₅ of Formula IIa are defined as noted with respect to Formula II above and are, independently, a C₁ to C₁₀ or a C₃ to C₈ linear or branched alkyl group (preferably, a branched C₄ group), and R₆ of Formula IIa above is -H or -CH₃. In some approaches or embodiments, the oil-soluble phosphorus antiwear additive of the compositions and methods herein is preferably 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid.

[023] In some approaches, the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphoric acid is made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide (in some forms, a monomer or a dimer thereof) to form a reaction product and (b) further reacting the reaction product with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate.

[024] Suitable organic hydroxy compounds may include normal straight chain alcohols, branched chain alcohols, hydroxy aryl compounds, such as phenol and naphthol, substituted aryl hydroxy compounds, such as diamyl phenol, or any other hydroxy organic material in which the hydroxy group will react with the phosphorus pentasulfide. In one approach, the starting alcohols are saturated alcohols or substituted aryl hydroxy compounds such as aryl hydroxy compounds substituted by saturated alkyl radicals. In some approaches, the organic hydroxy compound may be a C₁ to C₁₀ (in other approaches, a C₁ to C₆) linear or branched alcohols, a hydroxy aryl compound, or mixtures thereof such as one or more of methyl alcohol, ethyl alcohol, propyl alcohol, isopropyl alcohol, butyl alcohol, isobutyl alcohol, tert-butyl alcohol, sec-butyl alcohol, phenol, naphthol, an amyl alcohol, hexyl alcohol, iso-hexyl alcohol, octyl alcohol, decyl alcohol, dodecyl alcohol, octadecyl alcohol, 2-ethylhexyl alcohol, 4-methyl-2-pentyl alcohol, phenyl alcohol, butylphenyl alcohol, cyclohexyl alcohol, methylcyclopentyl alcohol, propenyl alcohol, butenyl alcohol, or combinations thereof. Preferred organic hydroxy compounds herein include C₁ to C₄ alcohols such as ethyl alcohol, propyl alcohol, or isopropyl alcohol, and most preferably, the organic hydroxy compound is isobutyl alcohol.

[025] Suitable unsaturated carboxylic acids to form the oil-soluble phosphorus antiwear additives of the present disclosure may include a wide variety of unsaturated carboxylic acids or fatty acids. Preferred unsaturated carboxylic acids may include C₁ to C₂₀ unsaturated fatty acids such as acrylic acid, methacrylic acid, 2-ethyl acrylic acid, or combinations thereof and, most preferably, is methacrylic acid. (As used herein, (meth)acrylic acid refers to either acrylic acid or methacrylic acid.)

[026] Succinimide Dispersant:

[027] The electric motor lubricating fluids herein also contain a dispersant system with at least one oil-soluble ashless dispersant that is a succinimide dispersant derived from a hydrocarbyl-substituted dicarboxylic acid or anhydride reacted with polyalkylene polyamines having one or more primary or secondary amines and wherein the one or more primary or secondary amines of the dispersant are post-treated with a capping agent. Suitable succinimide dispersants and their preparation are disclosed in at least US 7,897,696 and/or US 4,234,435, which are incorporated herein by reference.

[028] In one embodiment, the hydrocarbyl-substituent of the succinimide dispersants herein has a number average molecular weight of about 500 to about 5000, about 800 to about 2500 and, in one approach of this embodiment, is preferably derived from a polyisobutylene having a number average molecular weight of about 1000 or lower and, in another approach of this embodiment is preferably derived from a polyisobutylene having a number average molecular weight of about 2000 to about 3000. In either approach or embodiment, the hydrocarbyl moiety of the hydrocarbyl-dicarboxylic acid or anhydride of may be derived from butene polymers, for example, polymers of isobutylene. Suitable polyisobutylenes for use herein include those formed from conventional polyisobutylene or highly reactive polyisobutylene having at least 60%, such as 70% to 90% and above, terminal vinylidene content. Suitable polyisobutylenes may include those prepared using BF₃ catalysts. In preferred embodiments, the dispersants herein have a relatively low molecular weight, and as such, the number average molecular weight of the polyisobutylene substituent of the dispersants herein may be about 1,000 and lower and, in some instances, about 500 to about 1000 or about 700 to about 1000, as determined by gel permeation chromatography (GPC) using polystyrene (with a number average molecular weight of 180 to about 18,000) as the calibration reference. In other preferred embodiments, the

dispersants herein have a relatively high molecular weight, and as such, the number average molecular weight of the polyisobutylene substituent of the dispersants herein may be at least about 2,000 and, in some instances, about 2,000 to about 5,000 or about 2,000 to about 3,000, as determined by gel permeation chromatography (GPC) using polystyrene (with a number average molecular weight of 180 to about 18,000) as the calibration reference. The GPC method additionally provides average weight molecular weight distribution information; see, for example, W. W. Yau, J. J. Kirkland and D. D. Bly, "Modern Size Exclusion Liquid Chromatography", John Wiley and Sons, New York, 1979, also incorporated herein by reference.

[029] The polyisobutylene moiety of any embodiment in the dispersants herein may also have a molecular weight distribution (MWD), also referred to as polydispersity index (PDI), as determined by the ratio of weight average molecular weight (M_w) to number average molecular weight (M_n). In some approaches or embodiments, suitable polyisobutylene moieties may have a M_w/M_n of less than about 3.0, or less than about 2.8, or less than about 2.5, and in other approaches, suitable polyisobutylene substituents have a polydispersity of from about 1.5 to about 3.0, or from about 2.0 to about 3.0.

[030] The dicarboxylic acid or anhydride suitable to form the dispersants herein may be selected from carboxylic reactants such as maleic anhydride, 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 C_1 - C_4 aliphatic esters. In some approaches, a mole ratio of dicarboxylic acid or anhydride to hydrocarbyl moiety in a reaction mixture used to make the hydrocarbyl-dicarboxylic acid or anhydride may vary widely. Accordingly, the charge mole ratio may vary from 5:1 to 1:5, for example from 3:1 to 1:3. In some embodiments, a particularly suitable molar ratio of acid or anhydride to hydrocarbyl moiety is from 1:1 to less than 1.6:1. In other embodiments, another useful charge molar ratio of dicarboxylic acid or anhydride to hydrocarbyl moiety may be 1:1 to 1.5:1, or 1:1 to 1.4:1, or 1.1:1 to 1.3:1, or 1:1 to 1.2:1.

[031] Any of numerous polyalkylene polyamines can be used as in preparing the dispersant additives herein. Non-limiting exemplary polyamines may include aminoguanidine bicarbonate (AGBC), diethylene triamine (DETA), triethylene tetramine (TETA), tetraethylene

pentamine (TEPA), pentaethylene hexamine (PEHA) and heavy polyamines. A heavy polyamine may comprise a mixture of polyalkylenepolyamines having small amounts of polyamine oligomers such as TEPA and PEHA, but primarily oligomers having seven or more nitrogen atoms, two or more primary amines per molecule, and more extensive branching than conventional polyamine mixtures. Typically, these heavy polyamines have an average of 6.5 nitrogen atoms per molecule. Additional non-limiting polyamines which may be used to prepare the hydrocarbyl-substituted succinimide dispersant are disclosed in US 6,548,458, the disclosure of which is incorporated herein by reference in its entirety. In some embodiments, the charge molar ratio of hydrocarbyl-dicarboxylic acid or anhydrides to polyalkylene polyamines may be from about 1:1 to about 3.0:1. In one embodiment, the dispersants in the present disclosure described herein may be the reaction product of a polyisobutenyl succinic anhydride (PIBSA), and a polyamine, for example heavy polyamines wherein the charge molar ratio of the polyisobutenyl-substituted succinic anhydride to the polyamine of about 1.7:1 to about 2.5:1.

[032] As noted above, embodiments of the succinimide dispersants suitable for the electric motor lubricating fluids herein are post treated with a capping agent and, in particular, wherein the one or more primary or secondary amines of the succinimide dispersants are post-treated with the capping agent. As shown in the Examples below, non-capped succinimide dispersants also do not provide suitable performance in the context of corrosion and extreme pressure performance. Suitable post-treat capping agents include, but are not limited to, boron compounds, urea compounds, thiourea compounds, dimercaptothiadiazole compounds, carbon disulfide, aldehydes, ketones, lactones, carboxylic acids, hydrocarbon-substituted succinic anhydrides, maleic anhydride, naphthalic anhydride, nitriles, epoxides, carbonates, ethylene carbonate, cyclic carbonates, aromatic glycidyl ethers, acidic acids, hindered phenolic esters, and/or phosphorus compounds. (See, e.g., US 7,645,726; US 7,214,649; US 8,048,831; and US 5,241,003, which are all incorporated herein by reference in their entireties.) Preferably, the post-treat capping agent is one or more boron compounds, one or more phosphorus compounds, or both boron compounds and phosphorus compounds.

[033] In one embodiment, suitable boron compounds useful as capping agents in forming the dispersants herein include any boron compound or mixtures of boron compounds capable of introducing boron-containing species into the ashless dispersant. Any boron compound, organic or inorganic, capable of undergoing such reaction can be used. Accordingly, use can be made

of boron oxide, boron oxide hydrate, boron trifluoride, boron tribromide, boron trichloride, HBF_4 boron acids such as boronic acid (e.g. alkyl-B(OH)_2 or aryl-B(OH)_2), boric acid, (i.e., H_3BO_3), tetraboric acid (i.e., $\text{H}_2\text{B}_5\text{O}_7$), metaboric acid (i.e., HBO_2), ammonium salts of such boron acids, and esters of such boron acids. The use of complexes of a boron trihalide with ethers, organic acids, inorganic acids, or hydrocarbons is a convenient means of introducing the boron reactant into the reaction mixture. Such complexes are known and are exemplified by boron trifluoride-diethyl ether, boron trifluoride-phenol, boron trifluoride-phosphoric acid, boron trichloride-chloroacetic acid, boron tribromide-dioxane, and boron trifluoride-methyl ethyl ether.

[034] In other embodiments, suitable phosphorus compounds useful as capping agents for forming the dispersants herein include any phosphorus compound or mixtures of phosphorus compounds capable of introducing a phosphorus-containing species into the ashless dispersant. Any phosphorus compound, organic or inorganic, capable of undergoing such reaction can thus be used. Accordingly, use can be made of such inorganic phosphorus compounds as the inorganic phosphorus acids, and the inorganic phosphorus oxides, including their hydrates. Typical organic phosphorus compounds include full and partial esters of phosphorus acids, such as mono-, di-, and tri esters of phosphoric acid, thiophosphoric acid, dithiophosphoric acid, trithiophosphoric acid and tetrathiophosphoric acid; mono-, di-, and tri esters of phosphorous acid, thiophosphorous acid, dithiophosphorous acid and trithiophosphorous acid; trihydrocarbyl phosphine oxide; trihydrocarbyl phosphine sulfide; mono- and dihydrocarbyl phosphonates, $(\text{RPO}(\text{OR}')(\text{OR}''))$ where R and R' are hydrocarbyl and R'' is a hydrogen atom or a hydrocarbyl group), and their mono-, di- and trithio analogs; mono- and dihydrocarbyl phosphonites, $(\text{RP}(\text{OR}')(\text{OR}''))$ where R and R' are hydrocarbyl and R'' is a hydrogen atom or a hydrocarbyl group) and their mono- and dithio analogs; and the like. Thus, use can be made of such compounds as, for example, phosphorous acid (H_3PO_3 , sometimes depicted as $\text{H}_2(\text{HPO}_3)$, and sometimes called ortho-phosphorous acid or phosphonic acid), phosphoric acid (H_3PO_4 , sometimes called orthophosphoric acid), hypophosphoric acid ($\text{H}_4\text{P}_2\text{O}_6$), metaphosphoric acid (HPO_3), pyrophosphoric acid ($\text{H}_4\text{P}_2\text{O}_7$), hypophosphorous acid (H_3PO_2 , sometimes called phosphinic acid), pyrophosphorous acid ($\text{H}_4\text{P}_2\text{O}_5$, sometimes called pyrophosphonic acid), phosphinous acid (H_3PO), tripolyphosphoric acid ($\text{H}_5\text{P}_3\text{O}_{10}$), tetrapolyphosphoric acid ($\text{H}_5\text{P}_4\text{O}_{13}$), trimetaphosphoric acid ($\text{H}_3\text{P}_3\text{O}_9$), phosphorus trioxide, phosphorus tetraoxide, phosphorus pentoxide, and the like. Partial or total sulfur analogs such as phosphorotetrathioic

acid (H_3PS_4) acid, phosphoromonothioic acid ($\text{H}_3\text{PO}_3\text{S}$), phosphorodithioic acid ($\text{H}_3\text{PO}_2\text{S}_2$), phosphorotrithioic acid (H_3POS_3), phosphorus sesquisulfide, phosphorus heptasulfide, and phosphorus pentasulfide (P_2S_5 , sometimes referred to as P_4S_{10}) can also be used in forming dispersants for this disclosure. Also usable, are the inorganic phosphorus halide compounds such as PCl_3 , PBr_3 , POCl_3 , PSCl_3 , etc.

[035] In other embodiments, organic phosphorus compounds can be used as the capping agent. Exemplary organic phosphorus compounds include, but are not limited to, mono-, di-, and triesters of phosphoric acid (*e.g.*, trihydrocarbyl phosphates, dihydrocarbyl monoacid phosphates, monohydrocarbyl diacid phosphates, and mixtures thereof), mono-, di-, and triesters of phosphorous acid (*e.g.*, trihydrocarbyl phosphites, dihydrocarbyl hydrogen phosphites, hydrocarbyl diacid phosphites, and mixtures thereof), esters of phosphonic acids (both “primary”, $\text{RP}(\text{O})(\text{OR})_2$, and “secondary”. $\text{R}_2\text{P}(\text{O})(\text{OR})$), esters of phosphinic acids, phosphoryl halides (*e.g.*, $\text{RP}(\text{O})\text{Cl}_2$ and $\text{R}_2\text{P}(\text{O})\text{Cl}$), halophosphites (*e.g.*, $(\text{RO})\text{PCl}_2$ and $(\text{RO})_2\text{PCl}$), halophosphates (*e.g.*, $\text{ROP}(\text{O})\text{Cl}_2$ and $(\text{RO})_2\text{P}(\text{O})\text{Cl}$), tertiary pyrophosphate esters (*e.g.*, $(\text{RO})_2\text{P}(\text{O})\text{-O-P}(\text{O})(\text{OR})_2$), and the total or partial sulfur analogs of any of the foregoing organic phosphorus compounds, and the like wherein each hydrocarbyl group contains up to 100 carbon atoms, preferably up to 50 carbon atoms, more preferably up to 24 carbon atoms, and most preferably up to 12 carbon atoms. Also, suitable as capping agents are the halophosphine halides (*e.g.*, hydrocarbyl phosphorus tetrahalides, dihydrocarbyl phosphorus trihalides, and trihydrocarbyl phosphorus dihalides), and the halophosphines (mono halophosphines and dihalophosphines).

[036] In yet other approaches, carboxylic acid may also be used as a post-treating reagent and, in such embodiment, can be saturated or unsaturated mono-, di-, or poly-carboxylic acid. Examples of carboxylic acids include, but are not limited to, maleic acid, fumaric acid, succinic acid, and naphthalic diacid (*e.g.*, 1,8-naphthalic diacid). Anhydrides can also be used as a post-treating reagent and can be selected from the group consisting of mono-unsaturated anhydride (*e.g.*, maleic anhydride), alkyl or alkylene-substituted cyclic anhydrides (*e.g.*, succinic anhydride or glutamic anhydride), and aromatic carboxylic anhydrides (including naphthalic anhydride, *e.g.*, 1,8-naphthalic anhydride).

[037] In embodiments, the process of post-treating any embodiment of the dispersants herein includes first forming the succinimide product, as described above, and then further

reacting the succinimide product with the post treating agent. In some cases, the dispersants herein may be post-treated with more than one post-treatment agents. For example, the dispersant may be post-treated with a boron compound, such as boric acid and also a phosphorus compounds, such as a phosphoric acid.

[038] In one embodiment, when one or more of the dispersants is post treated (such as with one or both of a boron compound and/or a phosphorus compound), the dispersants are post treated to provide at least about 5 ppm of boron and up to 50 ppm of boron to the lubricating composition and/or to provide at least about 20 ppm of phosphorus and up to about 100 ppm phosphorus to the lubricating composition. In other approaches, the dispersant may be used in the lubricating composition in amounts from about 0.1 weight percent to about 10 weight percent, or about 0.1 weight percent to about 5 weight percent, about 0.1 weight percent to 3 weight percent, or about 0.5 weight percent to about 2 weight percent, or about 0.5 weight percent to about 1.5 weight percent based upon the final weight of the lubricating oil composition. In yet another embodiment, the succinimide dispersants of the electric motor lubricating fluids herein preferably includes at least a polyisobutenyl moiety having a number average molecular weight of 1000 or less, and in other approaches, about 500 to about 1000, or in yet further approaches, about 700 to about 1000, and has about 0.5 to about 2.5 wt% of nitrogen, about 0.1 to about 0.7 wt% boron, and about 0.20 to about 1.0 wt% phosphorus, or in yet further embodiments, includes at least a polyisobutenyl moiety having a number average molecular weight of between 800 and 1000 and has about 1.0 to about 2.0 wt% nitrogen, about 0.2 to about 0.6 wt% boron, and about 0.6 to about 0.9 wt% phosphorus, or in yet further embodiments includes at least a polyisobutenyl moiety having a number average molecular weight of between 2000 and 3000 and has about 0.5 to about 1.0 wt% nitrogen, about 0.1 to about 0.3 wt% boron, and about 0.2 to about 0.6 wt% phosphorus.

[039] Detergent

[040] The electric motor lubricating fluids herein also include one or more detergents selected to facilitate effective performance of the tolyltriazole corrosion inhibitor combined with the oil-soluble phosphorus extreme pressure additive in the context of electric motor lubricating fluids. In one embodiment, the detergent is one or more neutral, low-based, or overbased sulfonate detergents (preferably calcium sulfonate detergents) having a total base number (TBN)

of about 450 or less (preferably about 0 to about 450) and provided in amounts to the electric motor lubricating fluids to contribute a TBN of about 0.02 to about 1.9 to the electric motor lubricating fluid (in other approaches, a TBN of about 0.02 to about 1.6, about 0.04 to about 1.6, about 0.04 to about 0.6, or about 0.2 to about 0.6) and with TBN measured pursuant to ASTM D2896. Suitable detergents and their methods of preparation are described, for instance, in greater detail in numerous patent publications, including US 7,732,390; US 4,165,291, and/or US 4,206,062 (and references cited therein), which are incorporated herein by reference.

[041] As used herein, a low-based to neutral detergent additive may have a total base number (TBN) of less than about 200 mg KOH/gram, and an overbased detergent may have a total base number (TBN) of about 200 mg KOH/gram or greater, or about 250 mg KOH/gram or greater, or about 350 mg KOH/gram or greater, or about 375 mg KOH/gram or greater, or about 400 mg KOH/gram or greater (with TBN measured by ASTM D2896). In other embodiments, an overbased detergent may have a metal to substrate ratio of from 1.1:1 or less, or from 2:1 or less, or from 4:1 or less, or from 5:1 or less, or from 7:1 or less, or from 10:1 or less, or from 12:1 or less, or from 15:1 or less, or from 20:1 or less.

[042] As shown in the Examples below, detergent selection to facilitate effective performance of the combined tolyltriazole corrosion inhibitor and oil-soluble phosphorus extreme pressure additive needs to be correctly balanced relative to, for instance, the amount detergent metal (e.g., calcium) and, in other embodiments, also balanced relative to the phosphorus from the oil-soluble antiwear compound and the nitrogen from the tolyltriazole corrosion inhibitor. As shown in the Examples, the selected sulfonates are provided in amounts to deliver a TBN (ASTM D2896) of about 0.02 to about 1.9 (or about 0.02 to about 1.6, or about 0.2 to about 0.6 or other ranges as noted above) to the electric motor lubricating fluid and, when the detergent TBN is correctly balanced relative to the detergent metal (e.g., calcium), antiwear phosphorus, and tolyltriazole nitrogen, such detergent selection surprisingly facilitates effective performance of both the tolyltriazole corrosion inhibitor and the oil-soluble ashless dialkyl dithiophosphoric acid extreme pressure additive.

[043] As shown in the Examples and in some embodiments, the detergent TBN is first balanced relative to detergent metal content (e.g., calcium) to create a TBN Factor of about 0.0011 to about 0.0025 where the TBN Factor is TBN measured by ASTM D2896 divided by detergent metal in ppm and reflects the amount of TBN provided per each ppm of detergent

metal. Preferably, the detergent metal is calcium. To facilitate performance of the oil-soluble phosphorus antiwear additive combined with the tolyltriazole corrosion inhibitor, the amount of detergent is also further balanced relative to the phosphorus content provided by the extreme pressure additive and the nitrogen content provided by the tolyltriazole corrosion inhibitor. That is, an effective fluid relationship was discovered whereby a ratio of phosphorus (in ppm) delivered from the ashless dialkyl dithiophosphoric acid and nitrogen (in ppm) delivered from the tolyltriazole corrosion inhibitor (e.g., EP phosphorus + CI nitrogen) relative to the TBN Factor of about 70,000 or less surprisingly achieved both low copper leaching (ASTM D130 as modified herein) and high FZG performance (ASTM D5182) and, in other embodiments, a ratio of about 65,000 or less, about 60,000 or less or, in yet other embodiments, a ratio of about 20,000 to about 70,000 or about 30,000 to about 70,000 (or in other embodiments any other range between such endpoints). For instance, FIG. 1 illustrates embodiments of the lubricants herein where the fluid ratio is about 70,000 or below and reflects desired FZG performance (e.g., FLS of 8 or higher) and desired copper leaching performance (e.g., copper leaching of 30 ppm or less) in lubricants including both a tolyltriazole corrosion inhibitor and an ashless dialkyl dithiophosphoric acid. The Examples below also demonstrate in more details how the ratio, as defined herein, is calculated.

[044] In embodiments, suitable detergent substrates (e.g., sulfonates) may be salted with an alkali or alkaline earth metal, which are preferably calcium and/or magnesium and most preferably calcium. Thus, suitable detergents herein may include alkali or alkaline earth metal salts of petroleum sulfonic acids and long chain mono- or di-alkylarylsulfonic acids with the aryl group being benzyl, tolyl, and xylyl. Examples of suitable detergents discovered to facilitate effective performance of the tolyltriazole corrosion inhibitor and the oil-soluble ashless dialkyl dithiophosphoric acid extreme pressure additive include calcium sulfonates, and/or magnesium sulfonates, and preferably calcium sulfonates.

[045] Overbased detergent additives are well known in the art and generally include alkali or alkaline earth metal overbased detergent additives. Such detergent additives may be prepared by reacting a metal oxide or metal hydroxide with a substrate and carbon dioxide gas. The substrate is typically an acid, for example in the context of the lubricants herein, an acid such as an aliphatic substituted sulfonic acid. The terminology “overbased” relates to metal salts, such as metal salts of sulfonates for the fluids herein, wherein the amount of metal present exceeds the

stoichiometric amount. Such salts may have a conversion level in excess of 100% (i.e., they may comprise more than 100% of the theoretical amount of metal needed to convert the acid to its “normal,” “neutral” salt). The expression “metal ratio,” often abbreviated as MR, is used to designate the ratio of total chemical equivalents of metal in the overbased salt to chemical equivalents of the metal in a neutral salt according to known chemical reactivity and stoichiometry. In a normal or neutral salt, the metal ratio is one and in an overbased salt, MR, is greater than one. They are commonly referred to as overbased, hyperbased, or superbased salts and may be salts of organic sulfur acids.

[046] As used herein, an overbased detergent of the electric motor lubricating fluids herein may have, in one embodiment, a total base number (TBN) of about 200 mg KOH/gram or greater, about 290 mg KOH/gram or greater, or about 300 mg KOH/gram or greater. As used herein, total base number or TBN is determined using ASTM D2896. When such detergent compositions are formed in an inert diluent, e.g. a process oil, usually a mineral oil, the total base number reflects the basicity of the overall composition including diluent, and any other materials (e.g., promoter, etc.) that may be contained in the detergent composition. TBN of overbased detergents may be about 450 or less or about 400 or less.

[047] Preferably, detergents herein are neutral, low-based, or overbased calcium sulfonate detergents and wherein the detergents provide about 30 to about 600 ppm of calcium (in other embodiments, about 30 to about 300 ppm of calcium, about 30 to about 100 ppm of calcium or about 100 or about 200 ppm of calcium). As noted above, the amount of calcium is factored relative to the TBN contribution which is then balanced relative to the antiwear phosphorus and tolyltriazole nitrogen.

[048] Base Oil:

[049] The electric motor lubricating fluids herein include one or more base oils having a lubricating viscosity. Base oils suitable for use in formulating the electric motor lubricating fluids for use in electric and/or hybrid-electric motor vehicles according to the disclosure may be selected from any of suitable synthetic or natural oils or mixtures thereof having a suitable lubricating viscosity. Natural oils may include animal oils and vegetable oils (e.g., castor oil, lard oil) as well as mineral 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 may also be suitable. Further, oil derived from a gas-to-liquid process is also suitable. The base oil may have a kinematic viscosity at 100°C (e.g. kV100) of about 2 to about 15 cSt, as measured by ASTM D2270-10.

[050] The base oil as used in the invention described herein may be a single base oil or may be a mixture of two or more base oils. The one or more base oil(s) may be selected from any of the base oils in Groups III or IV as specified in the American Petroleum Institute (API) Base Oil Interchangeability Guidelines. Such base oil groups are shown in Table 1 as follows:

[051] Table 1

Base oil Category	Sulfur (%)		Saturates (%)	Viscosity Index
API Group I	> 0.03	and/or	<90	80 to 120
API Group II	≤0.03	and	≥90	80 to 120
API Group III	≤0.03	and	≥90	≥120
API Group IV	All polyalphaolefins (PAOs)			
API Group V	All others not included in Groups I, II, III, or IV			

[052] In one embodiment, the base oil may be selected from an API GII base oil, an API Group III base oil, or an API Group IV base oil, or a mixture of these base oils. Alternatively, the base oil may be a mixture of two or more of an API Group II base oils, two or more API GIII base oils, or two or more of an API Group IV base oils.

[053] API Group III base oils may include oil derived from Fischer-Tropsch synthesized hydrocarbons. Fischer-Tropsch synthesized hydrocarbons are made from synthesis gas containing H₂ and CO using a Fischer-Tropsch catalyst. Such hydrocarbons typically require further processing in order to be useful as the base oil. These types of oils are commonly referred to as gas-to-liquids (GTLs). For example, the hydrocarbons may be hydroisomerized using processes disclosed in U.S. Pat. No. 6,103,099 or 6,180,575; hydrocracked and hydroisomerized using processes disclosed in U.S. Pat. No. 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.

[054] API Group IV base oils, PAOs, are typically derived from monomers having from 4 to 30, or from 4 to 20, or from 6 to 16 carbon atoms. Examples of PAOs that may be used in the present invention include those derived from octene, decene, mixtures thereof, and the like. PAOs may have a kinematic viscosity of from 2 to 15, or from 3 to 12, or from 4 to 8 cSt at

100°C, as measured by ASTM D2270-10. Examples of PAOs include 4 cSt at 100°C PAOs, 6 cSt at 100°C PAOs, and mixtures thereof.

[055] The base oil(s) are combined with an additive composition as disclosed in embodiments herein to provide a lubricating and cooling fluid for use in an electric motor system having an electric motor, gears, and clutches. Accordingly, the base oil may be present in the lubricating and cooling fluid in an amount greater than about 80 wt % based on the total weight of the lubricating and cooling fluid. In some embodiments, the base oil may be present in the lubricating and cooling fluid in an amount greater than about 85 wt % based on the total weight of the lubricating and cooling fluid.

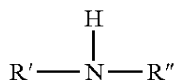
[056] Other Additives

[057] The electric motor lubricating fluid described herein may also include other additives of the type used in transmission fluid compositions in addition to the components described above. Such additives include, but are not limited to, antioxidant(s), viscosity modifier(s), phosphorus-containing components, detergent(s), corrosion inhibitor(s), antirust additives, antifoam agent(s), demulsifier(s), pour point depressant(s), seal swell agent(s), and additional dispersant(s), additional friction modifier(s), and additional sulfur-containing component(s).

[058] **ANTIOXIDANTS:** In some embodiments, the electric motor lubricating fluid contains one or more antioxidants. Suitable antioxidants include phenolic antioxidants, aromatic amine antioxidants, sulfur containing antioxidants, and organic phosphites, among others.

[059] 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-methyl-6-tert-butylphenol), and 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.

[060] Aromatic amine antioxidants include, but are not limited to diarylamines having the formula:



wherein R' and R'' each independently represents a substituted or unsubstituted aryl group having from 6 to 30 carbon atoms. Illustrative of substituents for the aryl group include aliphatic hydrocarbon groups such as alkyl having from 1 to 30 carbon atoms, hydroxy groups, halogen radicals, carboxylic acid or ester groups, or nitro groups.

[061] The aryl group is preferably substituted or unsubstituted phenyl or naphthyl, particularly wherein one or both of the aryl groups are substituted with at least one alkyl having from 4 to 30 carbon atoms, preferably from 4 to 18 carbon atoms, most preferably from 4 to 9 carbon atoms. It is preferred that one or both aryl groups be substituted, e.g. mono-alkylated diphenylamine, di-alkylated diphenylamine, or mixtures of mono- and di-alkylated diphenylamines.

[062] Examples of diarylamines that may be used include, but are not limited to: diphenylamine; various alkylated diphenylamines, 3-hydroxydiphenylamine, N-phenyl-1,2-phenylenediamine, N-phenyl-1,4-phenylenediamine, monobutyldiphenyl-amine, dibutyl diphenylamine, monooctyldiphenylamine, dioctyldiphenylamine, monononyl diphenylamine, dinonyldiphenylamine, monotetradecyldiphenylamine, ditetradecyl diphenylamine, phenyl-alpha-naphthylamine, monooctyl phenyl-alpha-naphthylamine, phenyl-beta-naphthylamine, monoheptyldiphenylamine, diheptyl-diphenylamine, p-oriented styrenated diphenylamine, mixed butyloctyldi-phenylamine, and mixed octylstyryldiphenylamine.

[063] The sulfur containing antioxidants include, but are not limited to, sulfurized olefins that are characterized by the type of olefin used in their production and the final sulfur content of the antioxidant. High molecular weight olefins, i.e., those olefins having an average molecular weight of 168 to 351 g/mole, are preferred. Examples of olefins that may be used include alpha-olefins, isomerized alpha-olefins, branched olefins, cyclic olefins, and combinations of these.

[064] Alpha-olefins include, but are not limited to, any C₄ to C₂₅ alpha-olefins. Alpha-olefins may be isomerized before the sulfurization reaction or during the sulfurization reaction. Structural and/or conformational isomers of the alpha olefin that contain internal double bonds and/or branching may also be used. For example, isobutylene is a branched olefin counterpart of the alpha-olefin 1-butene.

[065] Sulfur sources that may be used in the sulfurization reaction of olefins include: elemental sulfur, sulfur monochloride, sulfur dichloride, sodium sulfide, sodium polysulfide, and mixtures of these added together or at different stages of the sulfurization process.

[066] Unsaturated oils, because of their unsaturation, may also be sulfurized and used as an antioxidant. Examples of oils or fats that may be used include corn oil, canola oil, cottonseed oil, grapeseed oil, olive oil, palm oil, peanut oil, coconut oil, rapeseed oil, safflower seed oil, sesame seed oil, soybean oil, sunflower seed oil, tallow, and combinations of these.

[067] The total amount of antioxidant in the lubricating and cooling fluid described herein may be present in an amount to deliver up to about 200 ppm nitrogen, or up to about 150 ppm nitrogen, or about 100 to about 150 ppm nitrogen.

[068] **FRICITION MODIFIERS:** In some embodiments, the electric motor lubricating fluid contains additional friction modifiers other than those contained in the friction modifier system described above. Suitable additional friction modifiers may comprise metal containing and metal-free friction modifiers and may include, but are not limited to, imidazolines, amides, amines, succinimides, alkoxylated amines, alkoxylated ether amines, amine oxides, amidoamines, nitriles, betaines, quaternary amines, imines, amine salts, amino guanidine, alkanolamides, phosphonates, metal-containing compounds, glycerol esters, sulfurized fatty compounds and olefins, sunflower oil other naturally occurring plant or animal oils, dicarboxylic acid esters, esters or partial esters of a polyol and one or more aliphatic or aromatic carboxylic acids, and the like.

[069] Suitable friction modifiers may contain hydrocarbyl groups that are selected from straight chain, branched chain, or aromatic hydrocarbyl groups or mixtures thereof, and such hydrocarbyl groups may be saturated or unsaturated. The hydrocarbyl groups may be composed of carbon and hydrogen or hetero atoms such as sulfur or oxygen. The hydrocarbyl groups may range from 12 to 25 carbon atoms. In some embodiments the friction modifier may be a long chain fatty acid ester. In another embodiment the long chain fatty acid ester may be a mono-ester, or a di-ester, or a (tri)glyceride. The friction modifier may be a long chain fatty amide, a long chain fatty ester, a long chain fatty epoxide derivative, or a long chain imidazoline.

[070] Other suitable friction modifiers may include organic, ashless (metal-free), nitrogen-free organic friction modifiers. Such friction modifiers may include esters formed by reacting carboxylic acids and anhydrides with alkanols and generally include a polar terminal group (e.g.

carboxyl or hydroxyl) covalently bonded to an oleophilic hydrocarbon chain. An example of an organic ashless nitrogen-free friction modifier is known generally as glycerol monooleate (GMO) which may contain mono-, di-, and tri-esters of oleic acid. Other suitable friction modifiers are described in U.S. Pat. No. 6,723,685.

[071] Aminic friction modifiers may include amines or polyamines. Such compounds can have hydrocarbyl groups that are linear, either saturated or unsaturated, or a mixture thereof and may contain from 12 to 25 carbon atoms. Further examples of suitable friction modifiers include alkoxyated amines and alkoxyated ether amines. Such compounds may have hydrocarbyl groups that are linear, either saturated, unsaturated, or a mixture thereof. They may contain from about 12 to about 25 carbon atoms. Examples include ethoxyated amines and ethoxyated ether amines.

[072] The amines and amides may be used as such or in the form of an adduct or reaction product with a boron compound such as a boric oxide, boron halide, metaborate, boric acid or a mono-, di- or tri-alkyl borate. Other suitable friction modifiers are described in U.S. Pat. No. 6,300,291.

[073] If the additional friction modifiers contain nitrogen, such additional friction modifiers may be present in the lubricating and cooling fluid in any amount as long as the performance requirements are not compromised.

[074] DETERGENTS: Metal detergents that may be included in the electric motor lubricating fluid described herein may generally comprise a polar head with a long hydrophobic tail where the polar head comprises a metal salt of an acidic organic compound. The salts may contain a substantially stoichiometric amount of the metal, in which case they are usually described as normal or neutral salts, and would typically have a total base number or TBN (as measured by ASTM D2896) of from 0 to less than 150. Large amounts of a metal base may be included by reacting an excess of a metal compound such as an oxide or hydroxide with an acidic gas such as carbon dioxide. The resulting overbased detergent comprises micelles of neutralized detergent surrounding a core of inorganic metal base (e.g., hydrated carbonates). Such overbased detergents may have a TBN of 150 or greater, such as from 150 to 450 or more.

[075] Detergents that may be suitable for use in the present embodiments include oil-soluble overbased, low base, and neutral sulfonates, phenates, sulfurized phenates, and salicylates of a metal, particularly the alkali or alkaline earth metals, e.g., sodium, potassium,

lithium, calcium, and magnesium. More than one metal may be present, for example, both calcium and magnesium. Mixtures of calcium and/or magnesium with sodium may also be suitable. Suitable metal detergents may be overbased calcium or magnesium sulfonates having a TBN of from 150 to 450 TBN, overbased calcium or magnesium phenates or sulfurized phenates having a TBN of from 150 to 300 TBN, and overbased calcium or magnesium salicylates having a TBN of from 130 to 350. Mixtures of such salts may also be used.

[076] The metal-containing detergent may be present in the lubricating and cooling fluid in an amount sufficient to improve the anti-rust performance of the fluid. The metal-containing detergent may be present in the fluid in an amount sufficient to provide up to 90 ppm alkali and/or alkaline earth metal based on a total weight of the lubricating and cooling fluid. In one example, the metal-containing detergent may be present in an amount sufficient to provide from about 20 to about 50 ppm alkali and/or alkaline earth metal. In another embodiment, the metal-containing detergent may be present in an amount sufficient to provide from about 30 to about 40 ppm alkali and/or alkaline earth metal.

[077] In one approach, preferred detergents may be neutral to low base sulfonates, and in some approaches, calcium sulfonates. Suitable detergents may be calcium sulfonates having a TBN of 50 or less (such as about 25 to about 30) and providing no more than about 50 ppm of calcium to the lubricant. In other approaches, the detergents may provide about 25 to about 40 ppm of calcium, about 30 to about 40 ppm of calcium, or about 30 to about 38 ppm of calcium to the finished electric motor lubricating fluid or composition. In terms of an additive concentrate, the detergent may provide to more than about 950 ppm of calcium to an additive concentrate, or about 500 to about 950 ppm of calcium, about 550 to about 900 ppm of calcium, about 600 to about 800 ppm of calcium, or about 600 to about 700 ppm of calcium to an additive concentrate.

[078] CORROSION INHIBITORS: Other rust or corrosion inhibitors may also be included in the electric motor lubricating fluid described herein. 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.

[079] Another useful type of rust inhibitor may be 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 8 to 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. Mixtures of such rust or corrosion inhibitors may be used. The total amount of corrosion inhibitor, when present in the lubricating composition described herein may range up to 2.0 wt% or from 0.01 to 1.0 wt% based on the total weight of the lubricating composition.

[080] VISCOSITY MODIFIERS: The electric motor lubricating fluid may optionally contain one or more viscosity modifiers. Suitable viscosity modifiers may include polyolefins, olefin copolymers, ethylene/propylene copolymers, polyisobutenes, hydrogenated styrene-isoprene polymers, styrene/maleic ester copolymers, hydrogenated styrene/butadiene copolymers, hydrogenated isoprene polymers, alpha-olefin maleic anhydride copolymers, polymethacrylates, polyacrylates, polyalkyl styrenes, hydrogenated alkenyl aryl conjugated diene copolymers, or mixtures thereof. Viscosity modifiers may include star polymers and suitable examples are described in US Publication No. 2012/0101017 A1.

[081] The electric motor lubricating fluid described herein also may optionally contain one or more dispersant viscosity modifiers in addition to a viscosity modifier or in lieu of a viscosity modifier. Suitable dispersant viscosity modifiers may include functionalized polyolefins, for example, ethylene-propylene copolymers that have been functionalized with the reaction product of an acylating agent (such as maleic anhydride) and an amine; polymethacrylates functionalized with an amine, or esterified maleic anhydride-styrene copolymers reacted with an amine.

[082] The total amount of viscosity modifier and/or dispersant viscosity modifier, when present, may be up to about 1.0 wt%, or up to about 0.5 wt%, or up to about 0.3 wt% based on the total weight of the lubricating and cooling fluid.

[083] DEMULSIFIERS: Demulsifiers include trialkyl phosphates, and various polymers and copolymers of ethylene glycol, ethylene oxide, propylene oxide, or mixtures thereof, including polyethylene oxides, polypropylene oxides and (ethylene oxide-propylene oxide) polymers. When present, the amount of demulsifier in the lubricating and cooling fluid may be

up about 0.05 wt, or up to about 0.02 wt%, or below about 0.015 wt% based on the total weight of the lubricating and cooling fluid.

[084] ANTIFOAM AGENTS: Antifoam agents used to reduce or prevent the formation of stable foam include silicones, polyacrylates, or organic polymers. Foam inhibitors that may be useful in the compositions of the disclosed invention include polysiloxanes, copolymers of ethyl acrylate and 2-ethylhexylacrylate and optionally vinyl acetate. When present, the amount of antifoam in the lubricating and cooling fluid may be up about 0.1 wt, or up to about 0.05 wt%, or below about 0.04 wt% based on the total weight of the lubricating and cooling fluid.

[085] POUR POINT DEPRESSANTS: The electric motor lubricating fluid may optionally contain one or more pour point depressants. Suitable pour point depressants may include esters of maleic anhydride-styrene, polymethacrylates, polymethylmethacrylates, polyacrylates or polyacrylamides or mixtures thereof. Pour point depressants, when present, may be present in amount from about 0.001 wt% to about 0.04 wt%, based upon the total weight of the lubricant.

[086] In general terms, a lubricating and cooling fluid described herein may include additive components in the ranges listed in Table 2.

[087] TABLE 2

Component	(Suitable Embodiments)	(Preferred Embodiments)
Tolyltriazole Corrosion Inhibitor, ppm N	1 – 50	1.5 - 40
Oil-soluble Phosphorus Extreme Pressure Additive, wt%	0.045 - 0.17	0.05 - 0.09
Succinimide Dispersant(s), wt%	0.3 - 1.5	0.8 - 1.5
Sulfonate Detergent(s), wt%	0.05 - 0.5	0.1 - 0.3
Antioxidant(s), wt%	0.1 - 0.6	0.3 - 0.5
Antifoaming agent(s), wt%	0 - 0.05	0.1 - 0.04
Viscosity index improver(s), wt%	0 - 7.0	0 - 5.0
Base oil(s)	Balance	Balance
Total	100	100

[088] The percentages of each component above represent the weight percent of each component, based upon the total weight of the lubricating and cooling fluid containing the recited component. Additives used in formulating the compositions described herein may be blended into the base oil individually or in various sub-combinations. However, it may be 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.

[089] The electric motor lubricating fluids herein achieve a FLS of at least 8 in the FZG A10/16.6R/90 scuffing test of CEC L-84-02 and have about 30 ppm or less of copper leaching when measured pursuant to ASTM D130-19 (e.g., a half-submerged copper strip heated to 150°C for 168 hours). It was surprising that fluids herein having combinations of the tolyltriazole and the oil-soluble phosphorus extreme pressure additive, having low copper leaching performance, could also achieve the above acceptable performance in the FZG A10/16.6R/90 scuffing test of CEC L-84-02. Such performance is achieved when the detergent TBN is correctly balanced relative to the antiwear phosphorus and the tolyltriazole nitrogen.

[090] Unless the context of discussion herein suggests otherwise, the following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

[091] The terms “lubricating oil,” “lubricant composition,” “lubricating composition,” “lubricant” and “lubricating and cooling fluid” refer to a finished lubrication product comprising a major amount of a base oil plus a minor amount of an additive composition. As used herein, a major amount includes at least 50 weight percent or more and a minor amount includes less than 50 weight percent.

[092] As used herein, the terms “additive package,” “additive concentrate,” and “additive composition,” refer the portion of the lubricating oil composition excluding the major amount of base oil.

[093] As used herein, the term "hydrocarbyl substituent" or "hydrocarbyl group" 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 the molecule and having a predominantly hydrocarbon character. Each hydrocarbyl group is independently selected from hydrocarbon substituents, and substituted hydrocarbon substituents containing one or more of halo groups, hydroxyl groups, alkoxy groups, mercapto groups, nitro groups, nitroso groups, amino groups, pyridyl groups, furyl groups, imidazolyl groups, oxygen and nitrogen, and wherein no more than two non-hydrocarbon substituents are present for every ten carbon atoms in the hydrocarbyl group.

[094] As used herein, the term "percent by weight" or "wt%", unless expressly stated otherwise, means the percentage the recited component represents to the weight of the entire composition.

[095] The terms "soluble," "oil-soluble," or "dispersible" used herein may, but does not necessarily, indicate that the compounds or additives are soluble, dissolvable, miscible, or capable of being suspended in the oil in all proportions. The foregoing terms do mean, however, that they are, for instance, soluble, suspendable, dissolvable, or stably dispersible in oil to an extent sufficient to exert their intended effect in the environment in which the oil is employed. Moreover, the additional incorporation of other additives may also permit incorporation of higher levels of a particular additive, if desired.

[096] The term "alkyl" as employed herein refers to straight, branched, cyclic, and/or substituted saturated chain moieties from about 1 to about 200 carbon atoms.

[097] The term "alkenyl" as employed herein refers to straight, branched, cyclic, and/or substituted unsaturated chain moieties from about 3 to about 30 carbon atoms.

[098] The term "aryl" as employed herein refers to single and multi-ring aromatic compounds that may include alkyl, alkenyl, alkylaryl, amino, hydroxyl, alkoxy, halo substituents, and/or heteroatoms including, but not limited to, nitrogen, and oxygen.

[099] As used herein, the "average number molecular weight" or "Mn" is determined by gel permeation chromatography (GPC) using commercially available polystyrene standards (with a Mn of about 180 to about 18,000 as the calibration reference).

[0100] Total Base Number (TBN) is measured pursuant to ASTM D2896.

[0101] It is to be understood that throughout the present disclosure, the terms "comprises," "includes," "contains," etc. are considered open-ended and include any element, step, or ingredient not explicitly listed. The phrase "consists essentially of" is meant to include any expressly listed element, step, or ingredient and any additional elements, steps, or ingredients that do not materially affect the basic and novel aspects of the invention. The present disclosure also contemplates that any composition described using the terms, "comprises," "includes," "contains," is also to be interpreted as including a disclosure of the same composition "consisting essentially of" or "consisting of" the specifically listed components thereof.

EXAMPLES

[0102] A better understanding of the present disclosure and its many advantages may be clarified with the following example. The following examples are illustrative and not limiting thereof in either scope or spirit. Those skilled in the art will readily understand that variations of the components, methods, steps, and devices described in these examples can be used. Unless noted otherwise or apparent from the context of discussion in the Example below and throughout this disclosure, all percentages, ratios, and parts noted in this disclosure are by weight. Any standardized test method noted in the Examples, disclosure, or claims, unless apparent from the context of its use, refers to the version of the test method publicly available at the time of the filing of the present disclosure.

[0103] FZG Scuffing was used to evaluate the scuffing load capacity of lubricants and was performed according to the A10/16.6R/90 test of CEC L-84-02. Results are reported in failure load stage (FLS), and better results are obtained for samples with a higher FLS. Preferably a FLS of 8 or above is desired.

[0104] Copper leaching into the lubricating composition was determined via ICP using a modified procedure of ASTM D130-19 (using a half-submerged copper strip and heated to about 150°C for about 168 hours). It is preferred that less than 30 ppm copper is leached into the fluid after testing.

[0105] The Inventive and Comparative Examples all contained varying amounts of phosphorus extreme pressure additives, detergent, and dispersants as set forth in in the tables of each Example. Each finished fluid included the same base additive package which contained the same antioxidant and antifoam. The antioxidant and antifoam were added to each fluid at identical treat rates. Process oil in the base package varied slightly to account for treat rate changes in the phosphorus extreme pressure additives, detergent, and dispersants. The inventive and comparative formulations were tested in the same base oil blend of Group II/III with treat rates to obtain finished fluids having a kV100 of approximately 3.5 cSt. The inventive formulations contain similar additives to the comparative formulations but balanced the delivery of the phosphorus from the extreme pressure additive, nitrogen from the corrosion inhibitor and combined with selected sulfonate detergents to achieve surprisingly improved extreme pressure and corrosion performance in compositions that also included tolyltriazole corrosion inhibitors. Details of these components are described below:

- Dispersant 1 (Disp-1): phosphorylated and borated succinimide dispersant additive made from a polyisobutylene having a Mn of approximately 1000 and a PDI of less than 2.5, maleic anhydride, and a mixture of polyalkylene polyamines having an average of 6.5 nitrogen atoms per molecule. The dispersant was post treated with phosphorous acid, and boric acid. This dispersant had approximately 0.8 wt% phosphorus, approximately 0.4 wt% boron, and approximately 1.8% nitrogen.
- Dispersant 2 (Disp-2): phosphorylated and borated succinimide dispersant additive obtained from a polyisobutylene having a Mn of approximately 2000 and a PDI of less than 3.0, maleic anhydride, and a mixture of polyalkylene polyamines having an average of 6.5 nitrogen atoms per molecule. The dispersant was post treated with phosphorous acid, and boric acid. The dispersant had approximately 0.8 wt% nitrogen, about 0.2 wt% boron, and about 0.4 wt% phosphorus.
- Dispersant 3 (Disp-3): succinimide dispersant additive obtained from a polyisobutylene having a Mn of approximately 1000 and a PDI of less than 2.5, maleic anhydride, and a mixture of polyalkylene polyamines having an average of 6.5 nitrogen atoms per molecule. This dispersant had approximately 2.1 wt% nitrogen. The dispersant was not post treated with any capping agents.
- Phosphorus EP Additive 1 (EP-1): ashless dialkyl dithiophosphate additive including at least 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid having about 9.5 wt% phosphorus and 19.5 wt% sulfur.
- Detergent Additive 1 (Det-1): overbased calcium sulfonate detergent having a TBN of about 300 (as measured by ASTM D2896) and about 11.9 wt% calcium.
- Detergent Additive 2 (Det-2): low-based to neutral calcium sulfonate detergent having a TBN of about 28 (as measured by ASTM D2896) and about 2.7 wt% calcium.
- Detergent Additive 3 (Det-3): calcium phenate detergent having a TBN of about 250 (as measured by ASTM D2896) and about 9.25 wt% calcium.
- Corrosion Inhibitor 1 (CI-1): tolyltriazole additive having about 31.5 wt% nitrogen.
- Corrosion Inhibitor 2 (CI-2): Commercially available as Cuvan 313™ and primarily includes N-((1H-1,2,4-triazol-1-yl)methyl)-2-ethyl-N-(2-ethylhexyl)hexan-1-amine and has 17.6% nitrogen.
- Corrosion Inhibitor 3 (CI-3): Commercially available as Irgamet 39™ and primarily includes N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine and has 14.5% nitrogen.

[0106] COMPARATIVE EXAMPLES 1-4

[0107] Comparative Examples 1 and 2 are electric motor lubricating fluids prepared without a corrosion inhibitor. While the compositions of Comparative Examples 1 and 2 achieved acceptable FZG Scuffing performance, the compositions exhibited poor copper leaching performance. Comparative Example 3 was an electric motor lubricating fluid prepared similar to Comparative Example 1, but with the addition of a tolyltriazole corrosion inhibitor (CI-1). While the composition showed improved copper leaching performance, its FZG Scuffing performance suffered. Comparative Example 4 was an electric motor lubricating fluid prepared similar to Comparative Example 3 but with a higher treat rate of the extreme pressure additive. However, as shown in this fluid, even doubling the treat rate of the extreme pressure additive did not provide acceptable FZG Scuffing performance when used in combination with the tolyltriazole corrosion inhibitor. The fluid compositions are summarized in Table 3, elemental calculations are provided in Table 4, and results are provided in Table 5.

[0108] Table 3: Comparative Fluid Compositions

	<i>Comp 1</i>	<i>Comp 2</i>	<i>Comp 3</i>	<i>Comp 4</i>
EP-1 (wt%)	0.06	0.06	0.06	0.12
Disp-1 (wt%)	1.0	1.0	1.0	1.0
Det-1 (wt%)	-	0.13	-	-
Det-2 (wt%)	0.13	-	0.13	0.13
CI-1 (wt%)	-	-	0.01	0.01

[0109] Table 4: Elemental Analysis of Fluids (calculated)

	<i>Comp 1</i>	<i>Comp 2</i>	<i>Comp 3</i>	<i>Comp 4</i>
Phosphorus from EP-1, ppm	57	57	57	114
Sulfur from EP-1, ppm	117	117	117	234
Nitrogen from Disp-1, ppm	180	180	180	180
Boron from Disp-1, ppm	40	40	40	40
Phosphorus from Disp-1, ppm	80	80	80	80
Calcium from Det-1, ppm	-	155	-	-
Calcium from Det-2, ppm	35	-	35	35
Nitrogen from CI-1, ppm	-	-	31.5	31.5
Total phosphorus in lubricating composition, ppm	137	137	137	194
TBN delivered to the lubricating composition by the detergent, mg KOH/g	0.04	0.40	0.04	0.04
TBN Factor [TBN/Ca]	-	-	0.001143	0.001143
Ratio [(EP P) + (CI N)]/TBN Factor	-	-	77,428	127,297

-Ratio [(EP P) + (CI N)]/TBN Factor is calculated by adding the total phosphorus from the EP-1 (in ppm) and the total nitrogen provided by the CI-1 (in ppm) and then dividing by the TBN Factor of the detergent. For Comp 3, the ratio is (57 + 31.5)/0.001143

[0110] Table 5: Fluid Performance (Failing Results underlined)

	<i>Comp 1</i>	<i>Comp 2</i>	<i>Comp 3</i>	<i>Comp 4</i>
FZG Scuffing, Failure Load Stage**	9	9	<u>4</u>	<u>7</u>
Copper Leaching, ppm ***	<u>44</u>	<u>51</u>	14	13
	FAIL	FAIL	FAIL	FAIL

** CEC L-84-022 (A10/16.6R/90)

*** modified procedure of ASTM D130-19 (half submerged copper strip heated to 150°C for 168 hours)

[0111] INVENTIVE EXAMPLES 1-8

[0112] Inventive Examples 1-8 included selected amounts of an overbased calcium sulfonate detergent or a low-based to neutral calcium sulfonate detergent (e.g., Det-1 or Det-2) that surprisingly facilitated effective performance of the tolyltriazole corrosion inhibitor and the oil-soluble phosphorus extreme pressure additive to achieve acceptable copper leaching performance and FZG Scuffing performance. Fluid compositions are provided in Table 6, elemental calculations are provided in Table 7, and testing results are provided in Table 8. All Inventive Examples were low sulfur formulations containing less than 300 ppm sulfur.

[0113] Table 6: Inventive Fluid Compositions

	<i>Inv 1</i>	<i>Inv 2</i>	<i>Inv 3</i>	<i>Inv 4</i>	<i>Inv 5</i>	<i>Inv 6</i>	<i>Inv 7</i>	<i>Inv 8</i>
EP-1 (wt%)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Disp-1 (wt%)	1.0	1.0	-	-	1.0	1.0	1.0	
Disp-2 (wt%)	-	-	1.0	2.0				1.0
Det-1 (wt%)	0.13	0.5	0.13	0.13				
Det-2 (wt%)					0.13	0.13	0.13	0.13
CI-1 (wt%)	0.01	0.01	0.004	0.008	.005	.0025	.0005	.0013

[0114] Table 7: Elemental Analysis of Fluids (calculated)

	<i>Inv 1</i>	<i>Inv 2</i>	<i>Inv 3</i>	<i>Inv 4</i>	<i>Inv 5</i>	<i>Inv 6</i>	<i>Inv 7</i>	<i>Inv 8</i>
Phosphorus from EP-1, ppm	57	57	57	57	57	57	57	57
Sulfur from EP-1, ppm	117	117	117	117	117	117	117	117
Nitrogen from Disp-1, ppm	180	180	-	-	180	180	180	
Nitrogen from Disp-2, ppm	-	-	80	160				80
Boron from Disp-1, ppm	40	40	-	-	40	40	40	
Boron from Disp-2, ppm			20	40				20
Phosphorus from Disp-1, ppm	80	80	-	-	80	80	80	
Phosphorus from Disp-2, ppm	-	-	40	80				40
Calcium from Det-1, ppm	155	595	155	155				
Calcium from Det-2, ppm					35	35	35	35
Nitrogen from CI-1, ppm	31.5	31.5	12.6	25.2	15.8	7.9	1.6	4.1
Total phosphorus in lubricating composition, ppm	137	137	97	137	137	137	137	97
TBN delivered to the lubricating composition by the Detergent, mg KOH/g	0.4	1.5	0.4	0.4	0.04	0.04	0.04	0.04
TBN Factor [TBN/Ca]	0.002581	0.002581	0.002581	0.002581	0.001143	0.001143	0.001143	0.001143
Ratio [(EP P) + (CI N)]/TBN Factor	34,289	35,105	26,966	31,848	63,692	56,780	51,269	56,456

-Ratio [(EP P) + (CI N)]/TBN Factor is calculated by adding the total phosphorus from the EP-1 (in ppm) and the total nitrogen provided by the CI-1 (in ppm) and then dividing by the TBN Factor of the detergent. For Inv 1, the ratio is (57 + 31.5)/0.002581

[0115] Table 8: Fluid Performance

	<i>Inv 1</i>	<i>Inv 2</i>	<i>Inv 3</i>	<i>Inv 4</i>	<i>Inv 5</i>	<i>Inv 6</i>	<i>Inv 7</i>	<i>Inv 8</i>
FZG, Failure Load stage**	8	9	8	9	8	9	9	9
Copper Leaching, ppm ***	10	6	13	15	29	25	27	30

** CEC L-84-022 (A10/16.6R/90)

*** modified procedure of ASTM D130-19 (half submerged copper strip heated to 150°C for 168 hours)

[0116] COMPARATIVE EXAMPLES 5-10

[0117] Comparative Example 5 was similar to Inventive Example 1 but with increased amounts of the EP-1 and Det-1 additives. As can be seen in the testing results in Table 11, this example illustrates that too much EP-1, even with the higher treat rate of Det-1, had a negative impact on copper leaching. Comparative Example 6 was similar to Comparative Example 3 but with increased amount of Det-2 and illustrates that increasing the TBN contribution from the low-based to neutral calcium sulfonate detergent Det-2 while maintaining the high treat rate of CI-1 did not facilitate effective performance to achieve acceptable copper leaching performance and FZG Scuffing performance. Comparative Example 7 illustrates that a calcium phenate Det-3, does not facilitate effective performance to achieve acceptable copper leaching performance and FZG Scuffing performance. Comparative Example 8 illustrates that an uncapped dispersant (Disp-3) was also ineffective at achieving the desired performance. Finally, Comparative Examples 9 and 10 were similar to Inventive Example 1 but include different corrosion inhibitors. As can be seen in the testing results, these combinations of additives do not achieve the desired performance with failing results underlined.

[0118] Table 9: Comparative Fluid Compositions 5-10

	<i>Comp 5</i>	<i>Comp 6</i>	<i>Comp 7</i>	<i>Comp 8</i>	<i>Comp 9</i>	<i>Comp 10</i>
EP-1 (wt%)	0.3	0.06	0.06	0.06	0.06	0.06
Disp-1 (wt%)	1.0	1.0	1.0	-	1.0	1.0
Disp-3 (wt%)	-	-	-	1.0	-	-
Det-1 (wt%)	0.5	-	-	0.13	0.13	0.13
Det-2 (wt%)	-	0.45	-	-	-	-
Det-3 (wt%)	-	-	0.16	-	-	-
CI-1 (wt%)	0.01	0.01	0.01	0.01	-	-
CI-2 (wt%)	-	-	-	-	0.024	-
CI-3 (wt%)	-	-	-	-	-	0.03

[0119] Table 10: Elemental Analysis of Fluids (calculated)

	<i>Comp 5</i>	<i>Comp 6</i>	<i>Comp 7</i>	<i>Comp 8</i>	<i>Comp 9</i>	<i>Comp 10</i>
Phosphorus from EP-1, ppm	285	57	57	57	57	57
Sulfur from EP-1, ppm	585	117	117	117	117	117
Nitrogen from Dispersant, ppm	180	180	180	210	180	180
Boron from Dispersant, ppm	40	40	40	-	40	40
Phosphorus from Dispersant, ppm	80	80	80	-	80	80
Calcium from Det-1, ppm	595	-	-	155	155	155
Calcium from Det-2, ppm	-	122	-	-	-	-

Calcium from Det-3, ppm	-	-	148	-	-	-
Nitrogen from CI-1, ppm	31.5	31.5	31.5	31.5	-	-
Nitrogen from CI-2, ppm	-	-	-	-	42	-
Nitrogen from CI-3, ppm	-	-	-	-	-	44
Total phosphorus in lubricating composition, ppm	365	137	137	57	137	137
TBN delivered to the lubricating composition by the Detergent, mg KOH/g	1.5	0.13	0.4	0.4	0.4	0.4
TBN Factor [TBN/Ca]	0.002521	0.001066	-	-	-	-
Ratio [(EP P) + (CI N)]/TBN Factor	125,545	83.021				

-Ratio [(EP P) + (CI N)]/TBN Factor is calculated by adding the total phosphorus from the EP-1 (in ppm) and the total nitrogen provided by the CI-1 (in ppm) and then dividing by the TBN Factor of the detergent. For Comparative 5, the ratio is (285 + 31.5)/0.002581

[0120] Table 11: Fluid Performance

	<i>Comp 5</i>	<i>Comp 6</i>	<i>Comp 7</i>	<i>Comp 8</i>	<i>Comp 9</i>	<i>Comp 10</i>
FZG, Failure Load stage**	9	<u>4</u>	<u>4</u>	<u>4</u>	<u>6</u>	<u>4</u>
Copper Leaching, ppm ***	<u>52</u>	-	10	6	9	8

** CEC L-84-022 (A10/16.6R/90)

*** modified procedure of ASTM D130-19 (half submerged copper strip heated to 150°C for 168 hours)

[0121] FIG. 1 graphically shows embodiments including the correctly balanced detergent TBN relative to the antiwear phosphorus and tolyltriazole nitrogen in fluid compositions also including the capped succinimide dispersants. FIG. 1 shows that a ratio of [(EP Phos) + (CI Nitrogen)] / TBN Factor of about 70,000 or less achieved both a FZG failure load stage of 8 or higher and copper leaching of 30 ppm or less. FIG. 1 includes data from Tables 4-5, 7-8, and 10-11.

[0122] It is to be understood that while the lubricating composition and compositions of this disclosure have been described in conjunction with the detailed description thereof and summary herein, the foregoing description is intended to illustrate and not limit the scope of the disclosure, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the claims. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims.

[0123] Other embodiments of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the embodiments disclosed herein. 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 are to be understood as being modified in all instances by the term "about," whether or not the term

"about" is present. Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification are approximations that may vary depending upon the desired properties sought to be obtained by the present disclosure. 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 disclosure 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.

[0124] It is to be understood that each component, compound, substituent or parameter disclosed herein is to be interpreted as being disclosed for use alone or in combination with one or more of each and every other component, compound, substituent or parameter disclosed herein.

[0125] It is further understood that each range disclosed herein is to be interpreted as a disclosure of each specific value within the disclosed range that has the same number of significant digits. Thus, a range of from 1 to 4 is to be interpreted as an express disclosure of the values 1, 2, 3 and 4 as well as any range of such values such as 1 to 4, 1 to 3, 1 to 2, 2 to 4, 2 to 3 and so forth.

[0126] It is further understood that each lower limit of each range disclosed herein is to be interpreted as disclosed in combination with each upper limit of each range and each specific value within each range disclosed herein for the same component, compounds, substituent or parameter. Thus, this disclosure is to be interpreted as a disclosure of all ranges derived by combining each lower limit of each range with each upper limit of each range or with each specific value within each range, or by combining each upper limit of each range with each specific value within each range.

[0127] Furthermore, specific amounts/values of a component, compound, substituent or parameter disclosed in the description or an example is to be interpreted as a disclosure of either a lower or an upper limit of a range and thus can be combined with any other lower or upper limit of a range or specific amount/value for the same component, compound, substituent or

parameter disclosed elsewhere in the application to form a range for that component, compound, substituent or parameter.

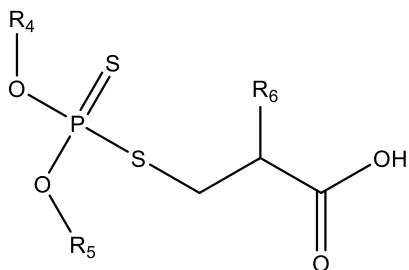
CLAIMS

WHAT IS CLAIMED IS:

1. An electric motor lubricating fluid suitable for electric or hybrid-electric vehicles, the electric motor lubricating fluid comprising:
 - one or more base oils of lubricating viscosity;
 - at least about 1 ppm of nitrogen provided by a tolyltriazole corrosion inhibitor;
 - an oil-soluble phosphorus antiwear additive including an ashless dialkyl dithiophosphoric acid providing about 40 ppm to about 150 ppm of phosphorus and about 85 ppm to about 315 ppm sulfur to the electric motor lubricating fluid;
 - a succinimide dispersant derived from a hydrocarbyl-substituted dicarboxylic acid or anhydride reacted with polyalkylene polyamines having one or more primary or secondary amines, wherein the one or more primary or secondary amines are post-treated with a capping agent;
 - a sulfonate detergent in amounts to contribute a TBN of about 0.02 to about 1.9 (ASTM D2896) to the electric motor lubricating fluid; and
 - wherein the electric motor lubricating fluid contains less than about 500 ppm sulfur and at least about 70 ppm phosphorus.
2. The electric motor lubricating fluid of claim 1, wherein the tolyltriazole corrosion inhibitor includes methyl-1H-benzotriazole.
3. The electric motor lubricating fluid of claim 1, wherein a ratio of the amount phosphorus (ppm) delivered from the ashless dialkyl dithiophosphoric acid to the fluid and the amount of nitrogen (ppm) delivered from the tolyltriazole corrosion inhibitor to the fluid (EP Phos + CI Nitrogen) relative to a TBN factor is about 70,000 or less and wherein the TBN factor is the TBN (ASTM D2896) delivered by the detergent to the fluid divided by the amount of metal (ppm) delivered from the detergent to the fluid (TBN/Det metal).

4. The electric motor lubricating fluid of claim 3, wherein the sulfonate detergent is calcium sulfonate and provides about 30 to about 600 ppm calcium to the electric motor lubricating fluid.

5. The electric motor lubricating fluid of claim 1, wherein the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate is made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product and (b) further reacting the reaction product with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate; and/or wherein the ashless dialkyl dithiophosphate includes a compound of Formula I, or a salt thereof:



(Formula IIa)

wherein R₄ and R₅ are, independently, a C₁ to C₁₀ linear or branched alkyl group, and R₆ is -H or -CH₃; and/or wherein the ashless dialkyl dithiophosphate includes 3-[[bis(2-methylpropoxy) phosphinothioyl]thio]-2-methyl-propanoic acid.

6. The electric motor lubricating fluid of claim 1, wherein the succinimide dispersant is post treated with a phosphorus containing compound and/or a boron containing compound; and/or wherein the succinimide dispersant delivers about 20 to about 100 ppm phosphorus and about 5 to about 50 ppm boron to the electric motor lubricating fluid.

7. The electric motor lubricating fluid of claim 1, wherein the sulfonate detergent is provided in amounts to contribute a TBN of about 0.2 to about 0.6; and/or wherein the electric motor lubricating fluid exhibits about 30 ppm or less of copper leaching pursuant to ASTM D130; and/or wherein the electric motor lubricating fluid has a failure load stage rating of 8 or higher in the FZG A10/16.6R/120 test of ASTM D5182; and/or wherein the electric motor lubricating fluid contains less than about 300 ppm of sulfur.

8. A method for lubricating a driveline component including an electric motor, the method comprising:

lubricating the driveline component with an electric motor lubricating fluid and wherein the electric motor lubricating fluid contacts portions of the electric motor;

wherein in the electric motor lubricating fluid includes (i) one or more base oils of lubricating viscosity, (ii) at least about 1 ppm of nitrogen provided by a tolyltriazole corrosion inhibitor; (iii) an oil-soluble phosphorus antiwear additive including an ashless dialkyl dithiophosphoric acid providing about 40 ppm to about 150 ppm of phosphorus and about 85 ppm to about 315 ppm sulfur to the electric motor lubricating fluid, (iv) a succinimide dispersant derived from a hydrocarbyl-substituted dicarboxylic acid or anhydride reacted with polyalkylene polyamines having one or more primary or secondary amines, wherein the one or more primary or secondary amines are post-treated with a capping agent; (v) a sulfonate detergent provided in amounts to contribute a TBN of about 0.02 to about 1.9 to the electric motor lubricating fluid; and (vi) wherein the electric motor lubricating fluid contains less than about 500 ppm sulfur and at least about 70 ppm phosphorus; and

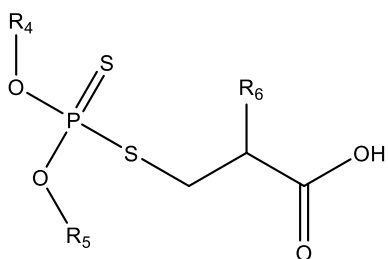
wherein the electric motor lubricating fluid exhibits about 30 ppm or less of copper leaching pursuant to ASTM D130 and has a failure load stage rating of 8 or higher in the FZG A10/16.6R/120 test of ASTM D5182.

9. The method of claim 8, wherein the triazole corrosion inhibitor includes methyl benzotriazole.

10. The method of claim 8, wherein a ratio of the amount phosphorus (ppm) delivered from the ashless dialkyl dithiophosphoric acid to the fluid and the amount of nitrogen (ppm) delivered from the tolyltriazole corrosion inhibitor to the fluid (EP Phos + CI Nitrogen) relative to a TBN factor is about 70,000 or less and wherein the TBN factor is the TBN (ASTM D2896) delivered by the detergent to the fluid divided by the amount of metal (ppm) delivered from the detergent to the fluid (TBN/Det metal); and/or wherein the sulfonate detergent is calcium sulfonate and provides about 30 to about 600 ppm calcium to the electric motor lubricating fluid.

11. The method of claim 8, wherein the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate is made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product and (b) further reacting the reaction product with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive including the ashless dialkyl dithiophosphate.

12. The method of claim 8, wherein the ashless dialkyl dithiophosphate includes a compound of Formula I, or a salt thereof:



(Formula IIa)

wherein R₄ and R₅ are, independently, a C₁ to C₁₀ linear or branched alkyl group, and R₆ is -H or -CH₃; and/or wherein the ashless dialkyl dithiophosphate includes 3-[[bis(2-methylpropoxy)phosphinothioyl]thio]-2-methyl-propanoic acid.

13. The method of claim 8, wherein the succinimide dispersant is post treated with a phosphorus containing compound and/or a boron containing compound; and/or wherein the succinimide dispersant delivers about 20 to about 100 ppm phosphorus and about 5 to about 50 ppm boron to the electric motor lubricating fluid.

14. The method of claim 8, wherein the sulfonate detergent is provided in amounts to contribute a TBN of about 0.2 to about 1.6.

15. The method of claim 8, wherein the electric motor lubricating fluid contains less than about 300 ppm sulfur.