

AFTERTREATMENT SYSTEM FRIENDLY ENGINE OIL FORMULATION

CROSS REFERENCE TO RELATED APPLICATIONS

[001] This application claims the priority benefit of U.S. Provisional Application No. 63/451,669, filed March 13, 2023, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

[002] This disclosure relates to engine oil formulations. More specifically, this disclosure relates to engine oil formulations designed to reduce emissions from an internal combustion engine.

BACKGROUND

[003] There are ongoing efforts to reduce emissions such as carbon monoxide (CO) and nitrogen oxide (NO_x) from compression ignited internal combustion engines. Aftertreatment system is a method or device that aims to reduce harmful exhaust emissions from internal combustion engines. Some aftertreatment systems (ATS) may employ a diesel particulate filter (DPF) which trap emission particles.

[004] Another ATS approach (which is may be used in combination with DPF) is selective catalytic reduction (SCR). SCR catalytically converts tailpipe nitrogen oxide (NO_x) to diatomic nitrogen (N₂) and water. Potential drawbacks of SCR are its susceptibility to plugging and poisoning from soot and ash. In particular, the presence of metals from engine oil can poison the catalysts used in selective catalytic reduction.

SUMMARY

[005] In one aspect, there is provided a method of reducing catalyst poisoning in a diesel engine aftertreatment system comprising a selective catalytic reduction device, the method comprising: lubricating the engine with a lubricating oil composition comprising: a major amount of oil of lubricating viscosity; and a Ca or Mg

salicylate detergent; wherein the lubricating oil composition is devoid of Ca sulfonate detergent.

[006] In yet another aspect, there is provided a use of a lubricating oil composition to reduce catalyst poisoning in a diesel engine aftertreatment system comprising a selective catalytic reduction device, the lubricating oil composition comprising: a major amount of oil of lubricating viscosity; and a Ca or Mg salicylate detergent; wherein the lubricating oil composition is devoid of sulfonate detergent.

DETAILED DESCRIPTION

[007] It is understood that when combinations, subsets, groups, etc. of elements are disclosed (e.g., combinations of components in a composition, or combinations of steps in a method), that while specific reference of each of the various individual and collective combinations and permutations of these elements may not be explicitly disclosed, each is specifically contemplated and described herein.

[008] Modern engines are often equipped with an aftertreatment system which aims to reduce harmful exhaust emissions from internal combustion engines. Aftertreatment systems may feature selective catalytic reduction which is a means of converting nitrogen oxide (NO_x) with the aid of a catalyst into diatomic nitrogen (N_2) and water (H_2O). This reduction chemistry takes place as exhaust gases pass through a catalyst chamber. Just prior to entering the chamber, a reductant is injected and mixed with the exhaust gases. The reductant (typically ammonia) or its precursors (e.g., aqueous ammonia, urea) are usually provided by diesel exhaust fluid (DEF). Catalysts include oxides of base metals (such as molybdenum and tungsten), zeolites, metals, or activated carbon.

[009] The present disclosure relates to a lubricating oil composition formulated to enhance or improve the performance of an aftertreatment system, particularly one that is equipped with selective catalytic reduction system. The specific formulation of these lubricating oil compositions is critical because metals from commonly used lubricant additives such as detergents (e.g., salicylates, sulfonates,

phenates) or anti-wear agents (e.g., zinc dithiophosphates) are considered catalyst poisoning compounds.

[010] As an advantage, the lubricating oil composition of this disclosure reduces harmful emissions by reducing the poisoning of catalysts which are used to convert harmful emissions into less harmful compounds. In another aspect, the lubricating oil composition improves the performance of the selective catalytic reduction system. Other advantages will be apparent from the disclosure herein.

[011] The present disclosure provides a method for reducing catalyst poisoning in a diesel engine equipped with an aftertreatment system comprising a selective catalytic reduction system. In some embodiments, the present disclosure provides a method for improving the performance of a diesel engine equipped with an aftertreatment system comprising a selective catalytic reduction system. In some embodiments, the present disclosure provides a use of a lubricating oil composition for a diesel engine equipped with an aftertreatment system comprising a selective catalytic reduction system.

[012] The method of this disclosure involves lubricating the engine with a lubricating composition comprising a major amount of oil of lubricating viscosity and a detergent system comprising Ca or Mg salicylate detergent(s). The lubricating oil composition is generally devoid of calcium sulfonates as it has been unexpectedly discovered that calcium sulfonates can lead to relatively higher levels of emissions. Consequently, lubricating oil composition is devoid of calcium sulfonates. In some embodiments, the lubricating oil composition contains a total of about 50 ppm or less of calcium sourced from sulfonate detergent(s).

Detergent System

[013] The lubricating oil composition of this disclosure includes a detergent system comprising one or more salicylate detergents. In some embodiments, the lubricating oil composition comprising the detergent system unexpectedly improves the ATS conversion rate or the efficiency of NO_x conversion. Detergents compatible

with this disclosure include Ca or Mg salicylate detergents. Incompatible detergents include sulfonate detergents. Optional detergents include phenate detergents.

Salicylate Detergent

[014] Salicylate detergents may be prepared by reacting a basic metal compound with at least one carboxylic acid and removing water from the reaction product.

[015] Useful salicylates include hydrocarbyl-substituted salicylic acid such as long chain alkyl salicylates. The term "hydrocarbyl" refers to a chemical group or moiety derived from hydrocarbons including saturated and unsaturated hydrocarbons. Examples of hydrocarbyl groups include alkenyl, alkyl, polyalkenyl, polyalkyl, phenyl, and the like. Hydrocarbyl-substituted salicylic acids may be prepared from phenols by the Kolbe reaction (see U.S. Patent No. 3,595,791). The metal salts of the hydrocarbyl-substituted salicylic acids may be prepared by double decomposition of a metal salt in a polar solvent such as water or alcohol.

[016] A typical detergent is an anionic material that contains a long chain hydrophobic portion of the molecule and a smaller anionic or oleophobic hydrophilic portion of the molecule. The anionic portion of a salicylate detergent is derived from carboxylic acid. The counterion is calcium or magnesium.

[017] Salts that contain stoichiometric amount of the metal are described as neutral salts and have a total base number (TBN) of from 0 to 80 mg KOH/g as measured by ASTM D-2896.

[018] Many detergents are overbased, containing large amounts of a metal base that is achieved by reacting an excess of a metal compound (e.g., a metal hydroxide or oxide) rich an acidic gas (e.g., carbon dioxide).

[019] Useful detergents can be neutral, mildly overbased, or highly overbased.

[020] In some embodiments, at least some detergent used in the detergent system may be overbased. Overbased detergents help neutralize acidic impurities produced by the combustion process and entrapped in the oil. The degree of

overbasing generally depends on the ratio of metallic ion to anionic portion of the detergent on an equivalent basis.

[021] An overbased detergent will typically have a TBN of 10 mg KOH/g or higher as measured by ASTM D-2896, such as from 15 mg KOH/g or higher, 25 mg KOH/g or higher, 50 mg KOH/g or higher, 75 mg KOH/g or higher, 100 mg KOH/g or higher, 125 mg KOH/g or higher, 150 mg KOH/g or higher, 175 mg KOH/g or higher, 200 mg KOH/g or higher, 225 mg KOH/g or higher, 250 mg KOH/g or higher, 275 mg KOH/g or higher, 300 mg KOH/g or higher, 325 mg KOH/g or higher, 350 mg KOH/g or higher, 375 mg KOH/g or higher, 400 mg KOH/g or higher, 425 mg KOH/g or higher, 450 mg KOH/g or higher, 475 mg KOH/g or higher, 500 mg KOH/g or higher, 525 mg KOH/g or higher, 550 mg KOH/g or higher, 575 mg KOH/g or higher, 600 mg KOH/g or higher and 650 mg KOH/g or higher.

[022] In some embodiments, the overbased detergent has a TBN of 10 to 650 mg KOH/g as measured by ASTM D-2896, such as 10 to 600 mg KOH/g, 10 to 550 mg KOH/g, 10 to 500 mg KOH/g, 10 to 450 mg KOH/g, 10 to 400 mg KOH/g, 10 to 350 mg KOH/g, 10 to 300 mg KOH/g, 10 to 250 mg KOH/g, 10 to 200 mg KOH/g, 10 to 150 mg KOH/g, 10 to 100 mg KOH/g, 10 to 50 mg KOH/g, 50 to 650 mg KOH/g, 50 to 600 mg KOH/g, 50 to 550 mg KOH/g, 50 to 500 mg KOH/g, 50 to 450 mg KOH/g, 50 to 400 mg KOH/g, 50 to 350 mg KOH/g, 50 to 300 mg KOH/g, 50 to 250 mg KOH/g, 50 to 200 mg KOH/g, 50 to 150 mg KOH/g, 50 to 100 mg KOH/g, 100 to 650 mg KOH/g, 100 to 600 mg KOH/g, 100 to 550 mg KOH/g, 100 to 500 mg KOH/g, 100 to 450 mg KOH/g, 100 to 400 mg KOH/g, 100 to 350 mg KOH/g, 100 to 300 mg KOH/g, 100 to 250 mg KOH/g, 100 to 200 mg KOH/g, 100 to 150 mg KOH/g, 150 to 650 mg KOH/g, 150 to 600 mg KOH/g, 150 to 550 mg KOH/g, 150 to 500 mg KOH/g, 150 to 450 mg KOH/g, 150 to 400 mg KOH/g, 150 to 350 mg KOH/g, 150 to 300 mg KOH/g, 150 to 250 mg KOH/g, 150 to 200 mg KOH/g, 200 to 650 mg KOH/g, 200 to 600 mg KOH/g, 200 to 550 mg KOH/g, 200 to 500 mg KOH/g, 200 to 450 mg KOH/g, 200 to 400 mg KOH/g, 200 to 350 mg KOH/g, 200 to 300 mg KOH/g, 200 to 250 mg KOH/g, 250 to 650 mg KOH/g, 250 to 600 mg KOH/g, 250 to 550 mg KOH/g, 250 to 500 mg KOH/g,

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[023] In some embodiments, the overbased detergent has a TBN of 10 to 150 mg KOH/g, such as from 10 to 140 mg KOH/g, 10 to 130 mg KOH/g, 10 to 120 mg KOH/g, 10 to 110 mg KOH/g, 10 to 100 mg KOH/g, 10 to 90 mg KOH/g, 10 to 80 mg KOH/g, 10 to 70 mg KOH/g, 10 to 60 mg KOH/g, 10 to 50 mg KOH/g, 10 to 40 mg KOH/g, 10 to 30 mg KOH/g, 10 to 20 mg KOH/g, 20 to 150 mg KOH/g, 20 to 140 mg KOH/g, 20 to 130 mg KOH/g, 20 to 120 mg KOH/g, 20 to 110 mg KOH/g, 20 to 100 mg KOH/g, 20 to 90 mg KOH/g, 20 to 80 mg KOH/g, 20 to 70 mg KOH/g, 20 to 60 mg KOH/g, 20 to 50 mg KOH/g, 20 to 40 mg KOH/g, 20 to 30 mg KOH/g, 30 to 150 mg KOH/g, 30 to 140 mg KOH/g, 30 to 130 mg KOH/g, 30 to 120 mg KOH/g, 30 to 110 mg KOH/g, 30 to 100 mg KOH/g, 30 to 90 mg KOH/g, 30 to 80 mg KOH/g, 30 to 70 mg KOH/g, 30 to 60 mg KOH/g, 30 to 50 mg KOH/g, 30 to 40 mg KOH/g, 40 to 150 mg KOH/g, 40 to 140 mg KOH/g, 40 to 130 mg KOH/g, 40 to 120 mg KOH/g, 40 to 110 mg KOH/g, 40 to 100 mg KOH/g, 40 to 90 mg KOH/g, 40 to 80 mg KOH/g, 40 to 70 mg KOH/g, 40 to 60 mg KOH/g, 40 to 50 mg KOH/g, 50 to 150 mg KOH/g, 50 to 140 mg KOH/g, 50 to 130 mg KOH/g, 50 to 120 mg KOH/g, 50 to 110 mg KOH/g, 50 to 100 mg KOH/g, 50 to 90 mg KOH/g, 50 to 80 mg KOH/g, 50 to 70 mg KOH/g, 50 to 60 mg KOH/g, 60 to 150 mg KOH/g, 60 to 140 mg KOH/g, 60 to 130 mg KOH/g, 60 to 120 mg KOH/g, 60 to 110 mg KOH/g, 60 to 100 mg KOH/g, 60 to 90 mg KOH/g, 60 to 80 mg KOH/g, 60 to 70 mg KOH/g, 80 to 150 mg KOH/g, 80 to 140 mg KOH/g, 80 to 130 mg KOH/g, 80 to 120 mg KOH/g, 80 to 110 mg KOH/g, 80 to 100 mg KOH/g, 80

to 90 mg KOH/g, 90 to 150 mg KOH/g, 90 to 140 mg KOH/g, 90 to 130 mg KOH/g, 90 to 120 mg KOH/g, 90 to 110 mg KOH/g, 90 to 100 mg KOH/g, 100 to 150 mg KOH/g, 100 to 140 mg KOH/g, 100 to 130 mg KOH/g, 100 to 120 mg KOH/g, 100 to 110 mg KOH/g, 110 to 150 mg KOH/g, 110 to 140 mg KOH/g, 110 to 130 mg KOH/g, 110 to 120 mg KOH/g, 120 to 150 mg KOH/g, 120 to 140 mg KOH/g, 120 to 130 mg KOH/g, 130 to 150 mg KOH/g, 130 to 140 mg KOH/g, or 140 to 150 mg KOH/g,

[024] The salicylate may be a calcium or magnesium containing salicylate. In some embodiments, the detergent system includes a mixture of Ca and Mg salicylates.

[025] The calcium salicylate may be present in an amount to provide about 500 to about 5000 ppm of calcium to the lubricating oil composition, such as from about 500 to about 4500 ppm, 500 to 4000 ppm, 500 to 3500 ppm, 500 to 3000 ppm, 500 to 2500 ppm, 500 to 2000 ppm, 500 to 1500 ppm, 500 to 1000 ppm, 1000 to 5000 ppm, 1000 to 4500 ppm, 1000 to 4000 ppm, 1000 to 3500 ppm, 1000 to 3000 ppm, 1000 to 2500 ppm, 1000 to 2000 ppm, 1000 to 1500 ppm, 1500 to 5000 ppm, 1500 to 4500 ppm, 1500 to 4000 ppm, 1500 to 3500 ppm, 1500 to 3000 ppm, 1500 to 2500 ppm, 1500 to 2000 ppm, 2000 to 5000 ppm, 2500 to 4500 ppm, 2500 to 4000 ppm, 2500 to 3500 ppm, 2500 to 3000 ppm, 3000 to 5000 ppm, 3000 to 4500 ppm, 3000 to 4000 ppm, 3000 to 3500 ppm, 3500 to 5000 ppm, 3500 to 4500 ppm, 3500 to 4000 ppm, 4000 to 5000 ppm, 4000 to 4500 ppm, or 4500 to 5000 ppm.

[026] The magnesium salicylate may be present in an amount to provide about 500 to about 5000 ppm of magnesium to the lubricating oil composition, such as from about 500 to about 4500 ppm, 500 to 4000 ppm, 500 to 3500 ppm, 500 to 3000 ppm, 500 to 2500 ppm, 500 to 2000 ppm, 500 to 1500 ppm, 500 to 1000 ppm, 1000 to 5000 ppm, 1000 to 4500 ppm, 1000 to 4000 ppm, 1000 to 3500 ppm, 1000 to 3000 ppm, 1000 to 2500 ppm, 1000 to 2000 ppm, 1000 to 1500 ppm, 1500 to 5000 ppm, 1500 to 4500 ppm, 1500 to 4000 ppm, 1500 to 3500 ppm, 1500 to 3000 ppm, 1500 to 2500 ppm, 1500 to 2000 ppm, 2000 to 5000 ppm, 2500 to 4500 ppm, 2500 to 4000 ppm, 2500 to 3500 ppm, 2500 to 3000 ppm, 3000 to 5000 ppm, 3000 to 4500 ppm, 3000 to

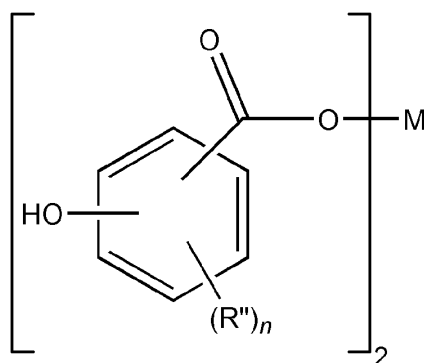
4000 ppm, 3000 to 3500 ppm, 3500 to 5000 ppm, 3500 to 4500 ppm, 3500 to 4000 ppm, 4000 to 5000 ppm, 4000 to 4500 ppm, or 4500 to 5000 ppm.

[027] In some embodiments, the total amount of calcium salicylate and magnesium salicylate is such that the total amount of calcium and magnesium in the lubricating oil composition is from about 500 to about 5000 ppm, such as from about 500 to about 4500 ppm, 500 to 4000 ppm, 500 to 3500 ppm, 500 to 3000 ppm, 500 to 2500 ppm, 500 to 2000 ppm, 500 to 1500 ppm, 500 to 1000 ppm, 1000 to 5000 ppm, 1000 to 4500 ppm, 1000 to 4000 ppm, 1000 to 3500 ppm, 1000 to 3000 ppm, 1000 to 2500 ppm, 1000 to 2000 ppm, 1000 to 1500 ppm, 1500 to 5000 ppm, 1500 to 4500 ppm, 1500 to 4000 ppm, 1500 to 3500 ppm, 1500 to 3000 ppm, 1500 to 2500 ppm, 1500 to 2000 ppm, 2000 to 5000 ppm, 2500 to 4500 ppm, 2500 to 4000 ppm, 2500 to 3500 ppm, 2500 to 3000 ppm, 3000 to 5000 ppm, 3000 to 4500 ppm, 3000 to 4000 ppm, 3000 to 3500 ppm, 3500 to 5000 ppm, 3500 to 4500 ppm, 3500 to 4000 ppm, 4000 to 5000 ppm, 4000 to 4500 ppm, or 4500 to 5000 ppm.

[028] The ppm values are based on total weight of the lubricating oil composition.

[029] In general, the total amount of Ca and Mg present in the lubricating oil composition is about 5000 ppm or less.

[030] In one embodiment, the hydrocarbyl-substituted salicylate is a long chain alkyl salicylate represented by the following generalized structure:



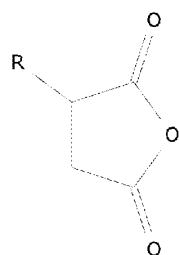
wherein R" is a C1 to C30 (e.g., C13 to C30) alkyl group; n is an integer from 1 to 4; and M is an alkaline earth metal (e.g., Ca or Mg).

[031] In one aspect of the present disclosure, the salicylate is derived from C10-C40 isomerized normal alpha olefins (NAO) and is made from an alkylphenol with an alkyl group derived from an isomerized NAO having an isomerization level (i) from about 0.10 to about 0.40, from about 0.10 to about 0.35, preferably from about 0.10 to about 0.30, from about 0.12 to about 0.30, from about 0.12 to about 0.25, from about 0.12 to about 0.23, from about 0.12 to about 0.22, from about 0.12 to about 0.20, from about 0.13 to about 0.19, from about 0.14 to about 0.18, from about 0.15 to about 0.17.

Succinimides

[032] The lubricating oil composition of the present invention may optionally include nitrogen-containing dispersants. These include polyalkenyl succinimide dispersants such as those described herein. In general, the nitrogen content from the nitrogen-containing dispersant based on the lubricating oil composition is from about 0.010 wt % to about 0.30 wt % such as from about 0.050 to about 0.25 wt %, about 0.050 to about 0.20 wt %, and about 0.050 to about 0.15 wt %.

[033] In one embodiment, a polyalkenyl bis-succinimide can be obtained by reacting a polyalkenyl-substituted succinic anhydride below



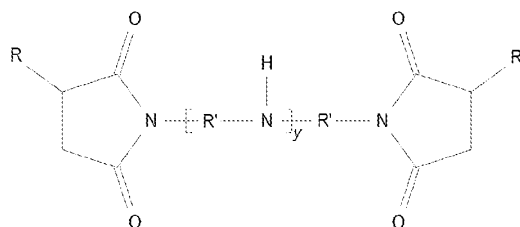
wherein R is a polyalkenyl substituent is derived from a polyalkene group having a number average molecular weight of from about 500 to about 3000, with a polyamine. In one embodiment, R is a polyalkenyl substituent derived from a polyalkene group having a number average molecular weight of from about 1000 to about 2500. In one

embodiment, R is a polyisobutenyl substituent derived from a polyisobutene having a number average molecular weight of from about 500 to about 3000. In another embodiment, R is a polyisobutenyl substituent derived from a polyisobutene having a number average molecular weight of from about 1000 to about 2500.

[034] Suitable polyamines for use in preparing the bis-succinimide dispersants include polyalkylene polyamines. Such polyalkylene polyamines will typically contain about 2 to about 12 nitrogen atoms and about 2 to 24 carbon atoms. Particularly suitable polyalkylene polyamines are those having the formula: $\text{H}_2\text{N}-(\text{R}'\text{NH})_x-\text{H}$ wherein R' is a straight- or branched-chain alkylene group having 2 or 3 carbon atoms and x is 1 to 9. Representative examples of suitable polyalkylene polyamines include ethylenediamine, diethylenetriamine, triethylenetetraamine, tetraethylenepentamine, pentaethylene hexamine, and heavy polyamines (e.g., Ethyleneamine E-100, available from Huntsman Company).

[035] Generally, the polyalkenyl-substituted succinic anhydride is reacted with the polyamine at a temperature of about 130°C to about 220°C (e.g., 145°C to 175°C). The reaction can be carried out under an inert atmosphere, such as nitrogen or argon. Generally, a suitable molar charge of polyamine to polyalkenyl-substituted succinic anhydride is from about 0.35:1 to about 0.6:1 (e.g., 0.4:1 to 0.5:1). As used herein, the "molar charge of polyamine to polyalkenyl-substituted succinic anhydride" means the ratio of the number of moles of polyamine to the number of succinic groups in the succinic anhydride reactant.

[036] One class of suitable polyalkenyl succinimides may be represented by the following:



wherein R and R' are as described herein above and y is 1 to 11.

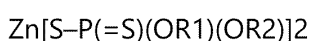
Post-Treatment of Polyalkenyl Succinimide

[037] In some embodiments, the succinimide dispersant may be post-treated by a reactive boron compound or organic carbonate.

[038] Suitable boron compounds that can be used as a source of boron include, for example, boric acid, a boric acid salt, a boric acid ester, and the like. Representative examples of a boric acid include orthoboric acid, metaboric acid, paraboric acid, and the like. Representative examples of a boric acid salt include ammonium borates, such as ammonium metaborate, ammonium tetraborate, ammonium pentaborate, ammonium octaborate, and the like. Representative examples of a boric acid ester include monomethyl borate, dimethyl borate, trimethyl borate, monoethyl borate, diethyl borate, triethyl borate, monopropyl borate, dipropyl borate, tripropyl borate, monobutyl borate, dibutyl borate, tributyl borate, and the like.

Anti-wear Agents

[039] The lubricating oil composition disclosed herein may optionally comprise one or more anti-wear agent. Antiwear agents reduce wear of metal parts. Suitable anti-wear agents include dihydrocarbyl dithiophosphate metal salts such as zinc dihydrocarbyl dithiophosphates (ZDDP) of the following structure:



wherein R1 and R2 may be the same or different hydrocarbyl radicals having from 1 to 18 (e.g., 2 to 12) carbon atoms and including radicals such as alkyl, alkenyl, aryl, arylalkyl, alkaryl and cycloaliphatic radicals. Particularly preferred as R1 and R2 groups are alkyl groups having from 2 to 8 carbon atoms (e.g., the alkyl radicals may be ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, n-pentyl, isopentyl, n-hexyl, isohexyl, 2-ethylhexyl). In order to obtain oil solubility, the total number of carbon atoms (i.e., R1+R2) will be at least 5. The zinc dihydrocarbyl dithiophosphate can therefore comprise zinc dialkyl dithiophosphates. The zinc dialkyl dithiophosphate is a primary, secondary zinc dialkyl dithiophosphate, or a combination thereof. ZDDP may be

present at 3 wt. % or less (e.g., 0.1 to 1.5 wt. %, or 0.5 to 1.0 wt %) of the lubricating oil composition.

Antioxidants

[040] In one embodiment, the lubricating oil composition may optionally comprise an antioxidant compound. In one embodiment, the antioxidant is an aromatic amine antioxidant. Typical aromatic amine antioxidants have at least two aromatic groups attached directly to one amine nitrogen. Typical aromatic amine antioxidants have alkyl substituent groups of at least 6 carbon atoms.

[041] Examples of aromatic amine antioxidants useful herein include 4,4'-dioctyldiphenylamine, 4,4'-dinonyldiphenylamine, N-phenyl-1-naphthylamine, N-(4-tert-octylphenyl)-1-naphthylamine, and N-(4-octylphenyl)-1-naphthylamine. Antioxidants may be present at 0.01 to 5 wt. % (e.g., 0.1 to 2 wt. %) of the lubricating oil composition.

Lubricating Oil

[042] The oil of lubricating viscosity (sometimes referred to as "base stock" or "base oil") is the primary liquid constituent of a lubricant, into which additives and possibly other oils are blended, for example to produce a final lubricant (or lubricant composition). A base oil, which is useful for making concentrates as well as for making lubricating oil compositions therefrom, may be selected from natural (vegetable, animal or mineral) and synthetic lubricating oils and mixtures thereof.

[043] Oils used as the base oil will be selected or blended depending on the desired end use and the additives in the finished oil to give the desired grade of engine oil, e.g. a lubricating oil composition having an Society of Automotive Engineers (SAE). In one embodiment, the lubricating oil composition is a multi-grade oil for heavy duty or passenger car. The multi-grade oil may have a viscosity grade SAE of 0W-8, 0W-12, 0W-16, 0W-20, 0W-30, 0W-40, 0W-50, 0W-60, 5W, 5W-20, 5W-30, 5W-40, 5W- 50, 5W-60, 10W, 10W-20, 10W-30, 10W-40, 10W-50, 15W, 15W-20, 15W-30, or 15W-40.

[044] Definitions for the base stocks and base oils in this disclosure are the same as those found in American Petroleum Institute (API) Publication 1509 Annex E

("API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils," December 2016). Group I base stocks contain less than 90% saturates and/or greater than 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1. Group II base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 80 and less than 120 using the test methods specified in Table E-1. Group III base stocks contain greater than or equal to 90% saturates and less than or equal to 0.03% sulfur and have a viscosity index greater than or equal to 120 using the test methods specified in Table E-1. Group IV base stocks are polyalphaolefins (PAO). Group V base stocks include all other base stocks not included in Group I, II, III, or IV.

[045] Natural oils include animal oils, vegetable oils (e.g., castor oil and lard oil), and mineral oils. Animal and vegetable oils possessing favorable thermal oxidative stability can be used. Of the natural oils, mineral oils are preferred. Mineral oils vary widely as to their crude source, for example, as to whether they are paraffinic, naphthenic, or mixed paraffinic-naphthenic. Oils derived from coal or shale are also useful. Natural oils vary also as to the method used for their production and purification, for example, their distillation range and whether they are straight run or cracked, hydrorefined, or solvent extracted.

[046] Synthetic oils include hydrocarbon oil. Hydrocarbon oils include oils such as polymerized and interpolymerized olefins (e.g., polybutylenes, polypropylenes, propylene isobutylene copolymers, ethylene-olefin copolymers, and ethylene-alphaolefin copolymers). Polyalphaolefin (PAO) oil base stocks are commonly used synthetic hydrocarbon oil. By way of example, PAOs derived from C₈ to C₁₄ olefins, e.g., C₈, C₁₀, C₁₂, C₁₄ olefins or mixtures thereof, may be utilized.

[047] Other useful fluids for use as base oils include non-conventional or unconventional base stocks that have been processed, preferably catalytically, or synthesized to provide high performance characteristics.

[048] Non-conventional or unconventional base stocks/base oils include one or more of a mixture of base stock(s) derived from one or more Gas-to-Liquids (GTL) materials, as well as isomerase/isodewaxate base stock(s) derived from natural wax or waxy feeds, mineral and or non-mineral oil waxy feed stocks such as slack waxes, natural waxes, and waxy stocks such as gas oils, waxy fuels hydrocracker bottoms, waxy raffinate, hydrocrackate, thermal crackates, or other mineral, mineral oil, or even non-petroleum oil derived waxy materials such as waxy materials received from coal liquefaction or shale oil, and mixtures of such base stocks. Other base oils include Coal to liquid (CTL) products and alkyl-naphthalene.

[049] Base oils for use in the lubricating oil compositions of present disclosure are any of the variety of oils corresponding to API Group I, Group II, Group III, Group IV, and Group V oils, and mixtures thereof, preferably API Group II, Group III, Group IV, and Group V oils, and mixtures thereof, more preferably the Group III to Group V base oils due to their exceptional volatility, stability, viscometric and cleanliness features.

[050] The lubricating oil composition may have a high temperature shear (HTHS) viscosity at 150° C of 3.7 cP or less, such as 3.6 cP or less, 3.5 cP or less, 3.4 cP or less, 3.3 cP or less, 3.2 cP or less, 3.1 cP or less, 3.0 cP or less, 2.9 cP or less, 2.8 cP or less, 2.7 cP or less, 2.6 cP or less, 2.5 cP or less, 2.4 cP or less, 2.3 cP or less, 2.2 cP or less, 2.1 cP or less, 2.0 cP or less, 1.9 cP or less, 1.8 cP or less, 1.7 cP or less, 1.6 cP or less, 1.5 cP or less, 1.4 cP or less, 1.3 cP or less, 1.2 cP or less, 1.1 cP or less, 1.0 cP or less, 1.0 to 2.9 cP, 1.3 to 2.9 cP) 1.0 to 2.6 cP, 1.3 to 2.6 cP, 1.0 cP to 2.3 cP, 1.3 cP to 2.3 cP, 1.0 cP to 2.0 cP, 1.3 cP to 2.3 cP, 1.0 cP to 1.7 cP, or 1.3 cP to 1.7 cP.

[051] The lubricating oil composition may have a viscosity index of at least 135 (e.g., 135 to 400, or 135 to 250), at least 150 (e.g., 150 to 400, 150 to 250), at least 165 (e.g., 165 to 400, or 165 to 250), at least 190 (e.g., 190 to 400, or 190 to 250), or at least 200 (e.g., 200 to 400, or 200 to 250). If the viscosity index of the lubricating oil composition is less than 135, it may be difficult to improve fuel efficiency while maintaining the HTHS viscosity at 150° C. If the viscosity index of the lubricating oil composition exceeds 400, evaporation properties may be reduced, and deficits due to

insufficient solubility of the additive and matching properties with a seal material may be caused.

[052] The base oil may have a kinematic viscosity at 100°C (ASTM D445) in a range of 1.4 to 20 mm²/s such as 3 to 12 mm²/s, such as 3 to 11 mm²/s, 3 to 10 mm²/s, 3 to 9 mm²/s, 3 to 8 mm²/s, 3 to 7 mm²/s, 3 to 6 mm²/s, 3 to 5 mm²/s, 3 to 4 mm²/s, 4 to 12 mm²/s, 4 to 11 mm²/s, 4 to 10 mm²/s, 4 to 9 mm²/s, 4 to 8 mm²/s, 4 to 7 mm²/s, 4 to 6 mm²/s, 4 to 5 mm²/s, 5 to 12 mm²/s, 5 to 11 mm²/s, 5 to 10 mm²/s, 5 to 9 mm²/s, 5 to 8 mm²/s, 5 to 7 mm²/s, 5 to 6 mm²/s, 6 to 12 mm²/s, 6 to 11 mm²/s, 6 to 10 mm²/s, 6 to 9 mm²/s, 6 to 8 mm²/s, 6 to 7 mm²/s, 7 to 12 mm²/s, 7 to 11 mm²/s, 7 to 10 mm²/s, 7 to 9 mm²/s, 7 to 10 mm²/s, 7 to 9 mm²/s, 7 to 8 mm²/s, 8 to 12 mm²/s, 8 to 11 mm²/s, 8 to 10 mm²/s, 8 to 9 mm²/s, 9 to 12 mm²/s, 9 to 11 mm²/s, 9 to 10 mm²/s, 10 to 12 mm²/s, 10 to 11 mm²/s, or 11 to 12 mm²/s.

[053] In some embodiments, the lubricating oil composition contains 0.8 to 1.5 wt% of ash, such as 0.8 to 1.4 wt%, 0.8 to 1.3 wt%, 0.8 to 1.2 wt%, 0.8 to 1.1 wt%, 0.8 to 1.0 wt%, 0.8 to 0.9 wt%, 0.9 to 1.5 wt%, 0.9 to 1.4 wt%, 0.9 to 1.3 wt%, 0.9 to 1.2 wt%, 0.9 to 1.1 wt%, 0.9 to 1.0 wt%, 1.0 to 1.5 wt%, 1.0 to 1.4 wt%, 1.0 to 1.3 wt%, 1.0 to 1.2 wt%, 1.0 to 1.1 wt%, 1.1 to 1.5 wt%, 1.1 to 1.4 wt%, 1.1 to 1.3 wt%, 1.1 to 1.2 wt%, 1.2 to 1.5 wt%, 1.2 to 1.4 wt%, 1.2 to 1.3 wt%, 1.3 to 1.5 wt%, 1.3 to 1.4 wt%, and 1.4 to 1.5 wt%.

[054] In some embodiments, the lubricating oil composition contains greater than 600 ppm of phosphorus, such as greater than 650 ppm, greater than 700 ppm, greater than 750 ppm, greater than 800 ppm, greater than 850 ppm, greater than 900 ppm, greater than 950 ppm, and greater than 1000 ppm.

Other Additives

[055] The present lubricating oil compositions may also contain conventional lubricant additives for imparting auxiliary functions to give a finished lubricating oil composition in which these additives are dispersed or dissolved. For example, the lubricating oil compositions can be blended with antioxidants, ashless dispersants, anti-wear agents, rust inhibitors, dehazing agents, demulsifying agents, friction

modifiers, metal deactivating agents, pour point depressants, viscosity modifiers, antifoaming agents, co-solvents, package compatibilizers, corrosion-inhibitors, dyes, extreme pressure agents and the like and mixtures thereof. A variety of the additives are known and commercially available. These additives, or their analogous compounds, can be employed for the preparation of the lubricating oil compositions of the invention by the usual blending procedures.

[056] Each of the foregoing additives, when used, is used at a functionally effective amount to impart the desired properties to the lubricant. Thus, for example, if an additive is an ashless dispersant, a functionally effective amount of this ashless dispersant would be an amount sufficient to impart the desired dispersancy characteristics to the lubricant. Generally, the concentration of each of these additives, when used, may range, unless otherwise specified, from about 0.001 to about 20 wt. %, such as about 0.01 to about 10 wt. %.

[057] The following non-limiting examples are illustrative of the present invention. Brief descriptions of how the examples were prepared are provided.

EXAMPLES

Baseline Formulation

[058] All samples (Examples 1-7) include the following baseline formulation: SAE 10-30W viscosity grade heavy duty diesel lubricating oil composition prepared by blending the following components:

- a) mixture of borated and non-borated succinimide
- b) diphenylamine antioxidant
- c) mixture of primary and secondary ZnDTP
- d) detergent system comprising Ca/Mg sulfonate, Ca phenate, and/or Ca/Mg salicylate

[059] The remainder of the lubricating oil composition includes base oil, viscosity index improver, and pour point depressant. Each sample was subjected to NOx conversion bench test as described below.

NOx Conversion Bench Test

[060] This test measures the reduction of the NOx conversion rate in a SCR catalyst after contamination with a lubricating oil. Before the SCR tests can be performed, the catalyst must be prepared, which involves taking solid vanadium EU6 catalyst monolith and crushing, filtering, hydrothermallyaging, and impregnating/calcinating the material.

[061] Once the catalyst material has been crushed & filtered, it is soaked in the oil samples and hot filtered until there is no visible oil. The oil impregnated catalyst is calcinated under positive airflow to remove hydrocarbons. The SCR tests were performed in typical diesel exhaust conditions (temperature ramped from 175 to 550°C). More specifically, the SCR catalyst materials came into contact with a simulated gas feed which is a mixture of NO (500ppm), NH₃ (500ppm), H₂O (5%), O₂ (10%) and balancing amount of N₂.

[062] The SCR runs were performed at 10 different temperature steps (200, 220, 240, 260, 280, 300, 320, 350, 400, 500°C). ATS conversion (NOx conversion efficiency) was evaluated from the outflow based on ICP analysis.

Ex.	Ca from Sulfonate	Mg from Sulfonate	Ca from Phenate	Ca from Salicylate	Mg from Salicylate	TBN	ATS conversion %
1	2845 ppm (71 mM)		1162 ppm (29 mM)			10.6	55
2	2004 ppm (50 mM)	50 mM				10.5	76
3	2004 ppm (50 mM)				1215 ppm (50 mM)	11.4	77
4			4008 ppm (100 mM)			11.2	68
5	4008 ppm (100 mM)					10.5	61

6				4008 ppm (100 mM)		11.4	91
7					2430 ppm (100 mM)	11.4	90

[063] While lubricants with lower TBN may show better ATS performance in some instances, the tradeoff is that lower TBN may result in poor detergency and not suitable for engine lubrication. From a formulation perspective, it is important to carefully balance TBN and ATS.

[064] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited. Additionally, within a range includes every point or individual value between its end points even though not explicitly recited. Thus, every point or individual value may serve as its own lower or upper limit combined with any other point or individual value or any other lower or upper limit, to recite a range not explicitly recited.

[065] Likewise, the term "comprising" is considered synonymous with the term "including." Likewise whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising," it is understood that we also contemplate the same composition or group of elements with transitional phrases "consisting essentially of," "consisting of," "selected from the group of consisting of," or "is" preceding the recitation of the composition, element, or elements and vice versa.

[066] The terms "a" and "the" as used herein are understood to encompass the plural as well as the singular.

[067] Various terms have been defined above. To the extent a term used in a claim is not defined above, it should be given the broadest definition persons in the

pertinent art have given that term as reflected in at least one printed publication or issued patent. Furthermore, all patents, test procedures, and other documents cited in this application are fully incorporated by reference to the extent such disclosure is not inconsistent with this application and for all jurisdictions in which such incorporation is permitted.

[068] The foregoing description of the disclosure illustrates and describes the present disclosure. Additionally, the disclosure shows and describes only the preferred embodiments but, as mentioned above, it is to be understood that the disclosure is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the concept as expressed herein, commensurate with the above teachings and/or the skill or knowledge of the relevant art. While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

[069] It is understood that when combinations, subsets, groups, etc. of elements are disclosed (e.g., combinations of components in a composition, or combinations of steps in a method), that while specific reference of each of the various individual and collective combinations and permutations of these elements may not be explicitly disclosed, each is specifically contemplated and described herein.

[070] The embodiments described hereinabove are further intended to explain best modes known of practicing it and to enable others skilled in the art to utilize the disclosure in such, or other, embodiments and with the various modifications required by the particular applications or uses. Accordingly, the description is not intended to limit it to the form disclosed herein. Also, it is intended that the appended claims be construed to include alternative embodiments.

CLAIMS

1. A method of reducing catalyst poisoning in a diesel engine aftertreatment system comprising a selective catalytic reduction device, the method comprising:
lubricating the engine with a lubricating oil composition comprising:
a major amount of oil of lubricating viscosity; and
a Ca or Mg salicylate detergent;
wherein the lubricating oil composition is devoid of Ca sulfonate detergent.
2. The method of claim 1, wherein the lubricating oil composition contains 500 to 5000 ppm of Ca from the Ca salicylate detergent.
3. The method of claim 1, wherein the lubricating oil composition contains 500 to 5000 ppm of Mg from the Mg salicylate detergent.
4. The method of claim 1, wherein the lubricating oil composition contains 0.8 to 1.5 wt% of ash.
5. The method of claim 1, wherein the lubricating oil composition contains greater than 600 ppm of phosphorus.
6. The method of claim 1, wherein the lubricating oil composition contains 500 to 5000 ppm of Ca and Mg.
7. The method of claim 1, wherein the lubricating oil composition contains 50 ppm or less of Ca or Mg sourced from a sulfonate detergent.
8. Use of a lubricating oil composition to reduce catalyst poisoning in a diesel engine aftertreatment system comprising a selective catalytic reduction device, the lubricating oil composition comprising:

a major amount of oil of lubricating viscosity; and
a Ca or Mg salicylate detergent;
wherein the lubricating oil composition is devoid of sulfonate detergent.

9. The use of claim 8, wherein the lubricating oil composition contains 500 to 5000 ppm of Ca from Ca salicylate detergent.

10. The use of claim 8, wherein the lubricating oil composition contains 500 to 5000 ppm of Mg from Mg salicylate detergent.

11. The use of claim 8, wherein the lubricating oil composition contains 0.8 to 1.5 wt% of ash.

12. The use of claim 8, wherein the lubricating oil composition contains greater than 600 ppm of phosphorus.

13. The use of claim 8, wherein the lubricating oil composition contains 500 to 5000 ppm of Ca and Mg.

14. The use of claim 8, wherein the lubricating oil composition contains 50 ppm or less of Ca or Mg sourced from a sulfonate detergent.