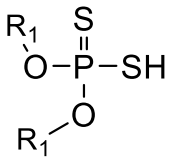
(a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product; (b) distilling the reaction product and recovering a condensate; and (c) reacting the condensate with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive; wherein

the reaction product comprises diesters of dithiophosphoric acids having the structure of Formula 1 below; and

the condensate includes the diesters of dithiophosphoric acids having the structure of Formula 1 below and having a content of phosphorus polysulfides derived from the reaction product of less than 1 wt%



Formula 1

wherein R_1 is a residue derived from the organic hydroxy compound.

[0004] In another approach or example, the lubricating composition described in the previous paragraph may include optional features and/or examples in any combination. These optional features or examples may include one or more of the following: wherein the distillation occurs at one or more of a temperature of at least about 50°C, a pressure of at least about 0.1 torr, or combinations thereof; and/or wherein the condensate is recovered at a temperature of about 10°C or less; and/or wherein the distillation occurs in a falling-film

[0005a] In one aspect, the present disclosure refers to a method of preparing an oil-soluble phosphorus antiwear additive, the method comprising:

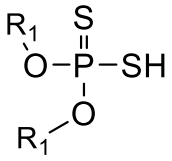
reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product;

distilling the reaction product and recovering a condensate therefrom; and

reacting the condensate with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive; wherein

the reaction product comprises diesters of dithiophosphoric acids having the structure of Formula 1 below; and

the condensate includes the diesters of dithiophosphoric acids having the structure of Formula 1 below and having a content of phosphorus polysulfides derived from the reaction product of less than 1 wt%



Formula 1

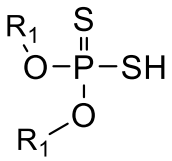
wherein R_1 is a residue derived from the organic hydroxy compound.

[0006] In other approaches or examples, the method of the previous paragraph may include optional features, steps, or examples in any combination. These optional features,

any of the optional features or examples as described by any example of the lubricant or method herein. In one aspect, the present disclosure refers to an oil-soluble phosphorus antiwear additive made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product; (b) distilling the reaction product and recovering a condensate therefrom; and (c) reacting the condensate with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive; wherein

the reaction product comprises diesters of dithiophosphoric acids having the structure of Formula 1 below; and

the condensate includes the diesters of dithiophosphoric acids having the structure of Formula 1 below, having the content of phosphorus polysulfides derived from the reaction product of less than 1 wt%



Formula 1

wherein R_1 is a residue derived from the organic hydroxy compound.

[0008] In yet further approaches or examples, the use of evaporation or distillation to recover a condensate from the reaction product of an organic hydroxy compound reacted with phosphorus pentasulfide is described herein and wherein the condensate is further reacted with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive. The use herein may include any further example as described in this Summary

[0009] Other examples of the present disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure disclosed herein. The following definitions of terms are provided in order to clarify the meanings of certain terms as used herein.

CLAIMS

WHAT IS CLAIMED IS

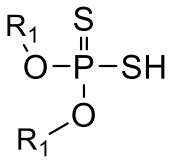
1. A lubricating composition comprising:

a majority of one or more base oils of lubricating viscosity; and

an oil-soluble phosphorus antiwear additive made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product; (b) distilling the reaction product and recovering a condensate; and (c) reacting the condensate with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive; wherein

the reaction product comprises diesters of dithiophosphoric acids having the structure of Formula 1 below; and

the condensate includes the diesters of dithiophosphoric acids having the structure of Formula 1 below and having a content of phosphorus polysulfides derived from the reaction product of less than 1 wt%



Formula 1

wherein R_1 is a residue derived from the organic hydroxy compound.

2. The lubricating composition of claim 1, wherein the distillation occurs at one or more of a temperature of at least 50° C., a pressure of at least 0.1 torr, or combinations thereof; and/or wherein the condensate is recovered at a temperature of 10° C. or less.

3. The lubricating composition of claim 1, wherein the distillation occurs in a falling-film evaporator, a wiped-film evaporator, a thin-film evaporator, a short-path evaporator, or combinations thereof.

4. The lubricating composition of claim 1, wherein the condensate includes a dialkyl dithiophosphoric acid.

5. The lubricating composition of claim 4, wherein the dialkyl dithiophosphoric acid is dipropyl dithiophosphoric acid, diisopropyl dithiophosphoric acid, dibutyl dithiophosphoric acid, diisobutyl dithiophosphoric acid, or combinations thereof.

6. The lubricating composition of claim 1, wherein the unsaturated carboxylic acid is an C1 to C20 fatty acid.

7. The lubricating composition of claim 6, wherein the unsaturated fatty acid is acrylic acid, methacrylic acid, 2-ethyl acrylic acid, or combinations thereof.

8. The lubricating composition of claim 1, wherein the organic hydroxy compound is a C1 to C6 linear or branched alcohol, a hydroxyl aryl compound, or mixtures thereof.

9. The lubricating composition of claim 8, wherein the organic hydroxy compound is 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.

10. The lubricating composition of claim 1, wherein the organic hydroxy compound is isobutyl alcohol, the reaction product comprises diisobutyl dithiophosphoric acid and one or more phosphorus polysulfides, the condensate includes the diisobutyl dithiophosphoric acid and is substantially free of the one or more phosphorus polysulfides, and the condensate is further reacted with methacrylic acid to form the oil-soluble phosphorus antiwear additive.

11. The lubricating composition of claim 1, wherein the lubricating composition includes 0.1 to 5 weight percent of the oil-soluble phosphorus antiwear additive.

12. The lubricating composition of claim 1, wherein the organic hydroxy compound is provided in a molar ratio relative to the phosphorus pentasulfide of 4:1 to 10:1.

13. The lubricating composition of claim 12, wherein the unsaturated carboxylic acid is provided in a molar ratio relative to the organic hydroxy compound of 0.01:1 to 0.5:1.

14. A method of preparing an oil-soluble phosphorus antiwear additive, the method comprising:

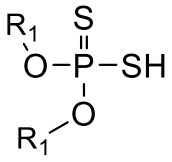
reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product;

distilling the reaction product and recovering a condensate therefrom; and

reacting the condensate with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive; wherein

the reaction product comprises diesters of dithiophosphoric acids having the structure of Formula 1 below; and

the condensate includes the diesters of dithiophosphoric acids having the structure of Formula 1 below and having a content of phosphorus polysulfides derived from the reaction product of less than 1 wt%



Formula 1

wherein R_1 is a residue derived from the organic hydroxy compound.

15. The method of claim 14, wherein the distillation occurs at a temperature of at least 50°C.

16. The method of claim 15, wherein the distillation occurs at a pressure of at least 0.1 torr.

17. The method of claim 14, wherein the condensate is recovered at a temperature of 10° C. or less.

18. The method of claim 14, wherein the distillation occurs in a falling-film evaporator, a wiped-film evaporator, a thin-film evaporator, a short-path evaporator, or combinations thereof.

19. The method of claim 14, wherein the condensate includes a dialkyl dithiophosphorus acid.

20. The method of claim 19, wherein the dialkyl dithiophosphoric acid is dipropyl dithiophosphoric acid, diisopropyl dithiophosphoric acid, dibutyl dithiophosphoric acid, diisobutyl dithiophosphoric acid, or combinations thereof.

21. The method of claim 19, wherein the unsaturated carboxylic acid is an C1 to C20 fatty acid.

22. The method of claim 21, wherein the fatty acid is acrylic acid, methacrylic acid, 2-ethyl acrylic acid, or combinations thereof.

23. The method of claim 14, wherein the organic hydroxy compound is a C1 to C6 linear or branched alcohol, a hydroxy aryl compound, or mixtures thereof.

24. The method of claim 23, wherein the organic hydroxy compound is 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.

25. The method of claim 14, wherein the organic hydroxy compound is isobutyl alcohol, the reaction product comprises diisobutyl dithiophosphoric acid and one or more phosphorus polysulfides, the condensate includes the diisobutyl dithiophosphoric acid and is substantially free of the one or more phosphorus polysulfides, and the condensate is further reacted with methacrylic acid to form the oil-soluble phosphorus antiwear additive.

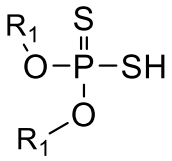
26. The method of claim 14, wherein the organic hydroxy compound is provided in a molar ratio relative to the phosphorus pentasulfide of 4:1 to 10:1.

27. The method of claim 26, wherein the unsaturated carboxylic acid is provided in a molar ratio relative to the organic hydroxy compound of 0.01:1 to 0.5:1.

28. An oil-soluble phosphorus antiwear additive made by a process comprising the steps of (a) reacting an organic hydroxy compound with phosphorus pentasulfide to form a reaction product; (b) distilling the reaction product and recovering a condensate therefrom; and (c) reacting the condensate with an unsaturated carboxylic acid to form the oil-soluble phosphorus antiwear additive; wherein

the reaction product comprises diesters of dithiophosphoric acids having the structure of Formula 1 below; and

the condensate includes the diesters of dithiophosphoric acids having the structure of Formula 1 below, having the content of phosphorus polysulfides derived from the reaction product of less than 1 wt%



Formula 1

wherein R_1 is a residue derived from the organic hydroxy compound.