various engine parts and to prevent engine wear, additives such as friction modifiers, anti-wear agents, and antioxidants are incorporated into the engine oil. Antioxidants tend to lengthen the effect of the afore-mentioned additives. Further, to reduce the hydrodynamic friction in the piston/cylinder, the viscosity of engine oils has been lowered. This has resulted in an increased the dependence on friction modifiers to offset the new boundary layer regime. Hence, a vast amount of effort has focused on the interaction of oil viscosity with various friction modifiers to improve fuel economy.

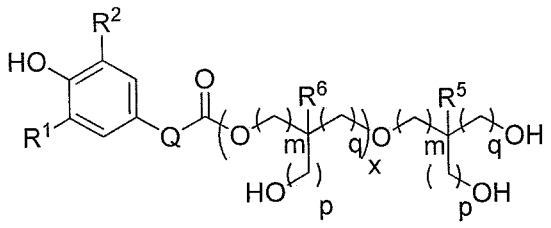
Although compounds combining boron with anti-oxidants are known in the art, as evidenced by EP 0089844, US 3,347,793, US 3,356,707, US 3,359,298, US 3,509,054, US 4,474,670, US 5,252,237, US 5,698,499, US 6,605,572, and US 6,777,378; compounds with the outstanding oxidation and friction performance of those of the invention have not been described.

Thus, herein we report borated polyol hindered phenol antioxidant/friction modifier compounds and compositions containing same. These compounds and compositions enhanced performance in engine oils when compared with industry standard hindered phenolic antioxidants.

SUMMARY OF THE INVENTION

In one aspect of the present disclosure, there is provided a compound comprising the reaction product of:

a. a phenolic ester polyol, wherein the phenolic ester polyol has the following formula (I):



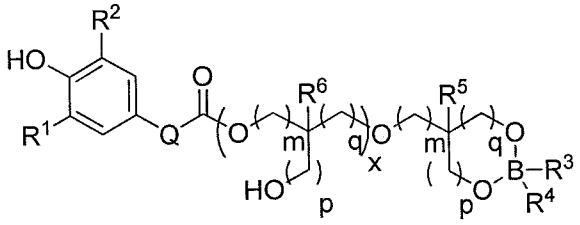
Formula (I)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol;

b. a boron containing compound, and

c. optionally, an alcohol.

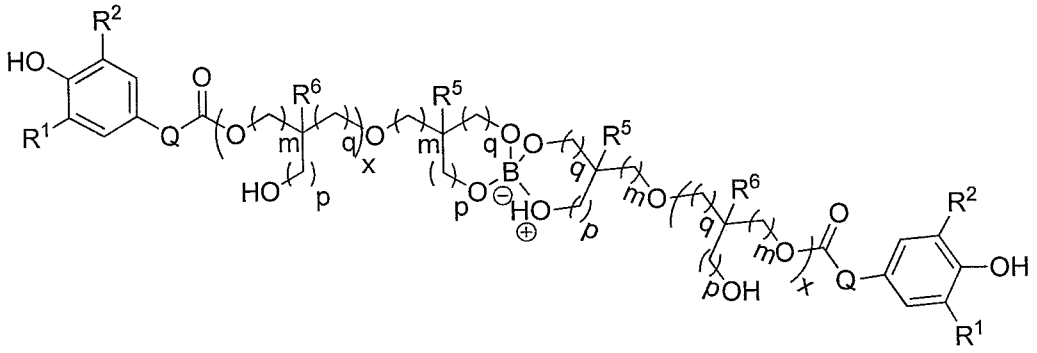
In another aspect of the present disclosure, there is provided a compound having the following formula (IV):



Formula (IV)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^3 is absent or a C_1 - C_{12} alkoxy group; R^4 is absent or a C_1 - C_{12} alkoxy group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

In another aspect of the present disclosure, there is provided a compound having the following formula (V):



Formula (V)

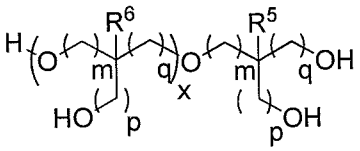
wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

In another aspect of the present disclosure, there is provided a compound comprising the reaction product of:

a. a polyol,

b. a boron containing compound, and

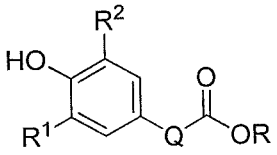
c. a phenolic acid or ester, wherein the polyol has the following formula (III):



(Formula III),

wherein each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^5 is H, a C_1 - C_{12} alkyl group,

or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and the phenolic acid or ester has the following formula (II):



(Formula II),

wherein Q is an alkylene group of 2 to 6 carbon atoms; R is H or a moiety suitable to undergo transesterification; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group.

In one embodiment of the present disclosure, there is provided an additive concentrate comprising:

a. major amount of base oil of lubricating viscosity; and

b. a compound comprising the reaction product of a boron containing compound, a phenolic ester polyol, and optionally, an alcohol.

In another emboidment of the present disclosure, there is provided a lubricating oil composition comprising:

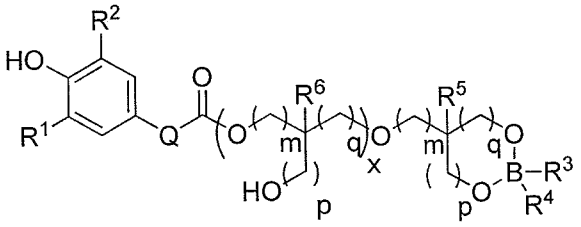
a. a major amount of base oil of lubricating viscosity; and

b. a compound comprising the reaction product of a boron containing compound, a phenolic ester polyol, and optionally, an alcohol.

In another embodiment of the present disclosure, there is provided a lubricating oil composition comprising:

a. a major amount of base oil of lubricating viscosity; and

b. a compound having the following formula (IV):



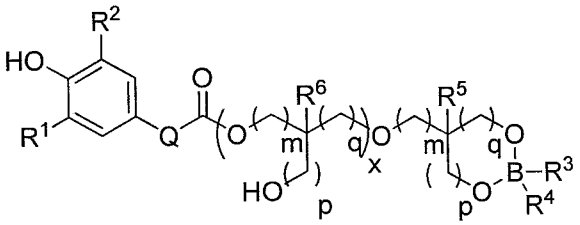
Formula (IV)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^3 is absent or a C_1 - C_{12} alkoxy group; R^4 is absent or a C_1 - C_{12} alkoxy group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

In another embodiment of the present disclosure, there is provided a method for operating an internal combustion engine comprising lubricating said engine with a lubricating oil composition comprising:

a. a major amount of base oil of lubricating viscosity; and

b. a compound having the following formula (IV):



Formula (IV)

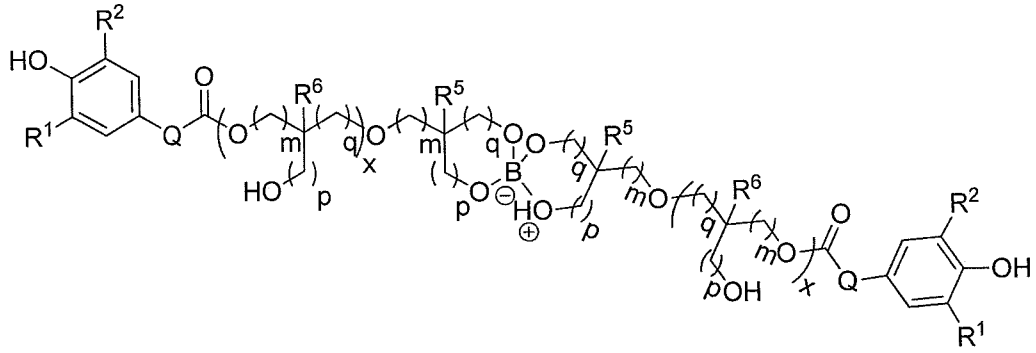
wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^3 is absent or a C_1 - C_{12} alkoxy group;

R^4 is absent or a C_1 - C_{12} alkoxy group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

In another embodiment of the present disclosure, there is provided a lubricating oil composition comprising:

a. a major amount of base oil of lubricating viscosity; and

b. a compound having the following formula (V):



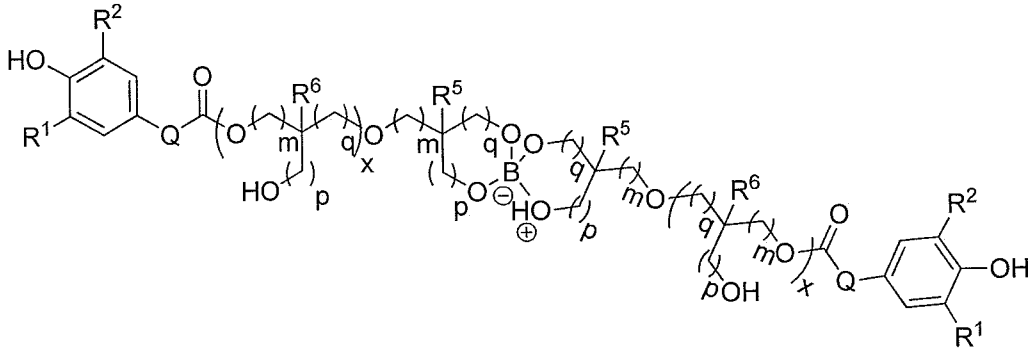
Formula (V)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

In another embodiment of the present disclosure, there is provided a method for operating an internal combustion engine comprising lubricating said engine with a lubricating oil composition comprising:

a. a major amount of base oil of lubricating viscosity; and

b. compound having the following formula (V):



Formula (V)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

In another embodiment of the present disclosure, there is provided an additive concentrate comprising:

a. major amount of base oil of lubricating viscosity; and

b. a compound comprising the reaction product of a polyol, a boron containing compound, and a phenolic acid or ester.

In another embodiment of the present disclosure, there is provided a lubricating oil composition comprising:

a. a major amount of base oil of lubricating viscosity; and

b. a compound comprising the reaction product of a polyol, a boron containing compound, and a phenolic acid or ester.

Also provided are lubricating oil compositions and additive concentrates comprising above compounds, and methods for operating an internal combustion engine using said lubricating oil compositions.

Definitions:

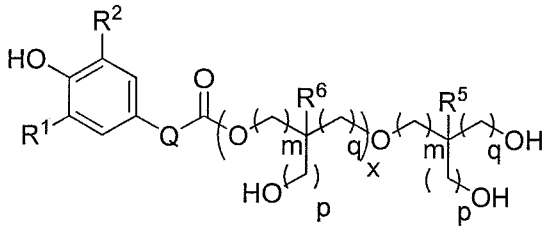
The following terms will be used throughout the specification and will have the following meanings unless otherwise indicated.

The term "a major amount" of a base oil refers to where the amount of the base oil is at least 40 wt. % of the lubricating oil composition. In some embodiments, "a major amount" of a base oil refers to an amount of the base oil more than 50 wt.%, more than 60 wt.%, more than 70 wt.%, more than 80 wt.%, or more than 90 wt.% of the lubricating oil composition.

WHAT IS CLAIMED IS:

1. A compound comprising the reaction product of:

a. a phenolic ester polyol, wherein the phenolic ester polyol has the following formula (I):



Formula (I)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol;

b. a boron containing compound; and

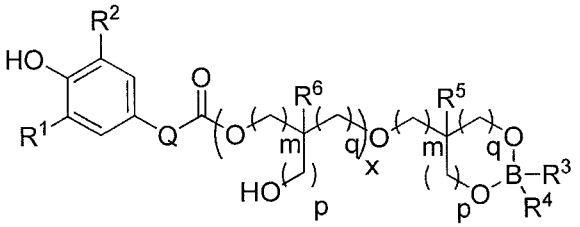
c. optionally, an alcohol.

2. The compound of claim 1, wherein the phenolic ester polyol is selected from the group consisting of a glycerol ester of a propionate phenol, diglycerol ester of a propionate phenol, pentaerythritol ester of a propionate phenol, and a trimethylolethane ester of a propionate phenol.

3. The compound of claim 1, wherein the alcohol is a linear or branched aliphatic alcohol.

4. The compound of claim 1, wherein the alcohol is a monool or polyol.

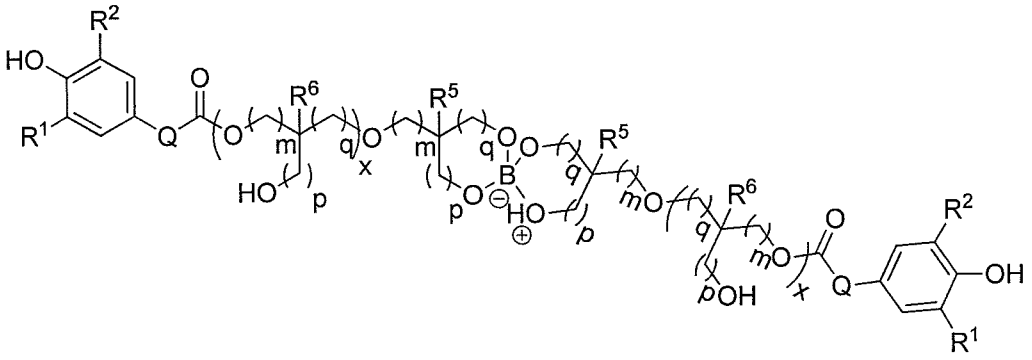
5. A compound having the following formula (IV):



Formula (IV)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^3 is absent or a C_1 - C_{12} alkoxy group; R^4 is absent or a C_1 - C_{12} alkoxy group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

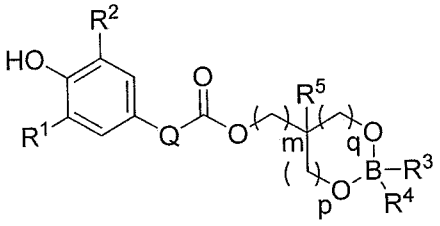
6. A compound having the following formula (V):



Formula (V)

wherein Q is an alkylene group of 2 to 6 carbon atoms; each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol.

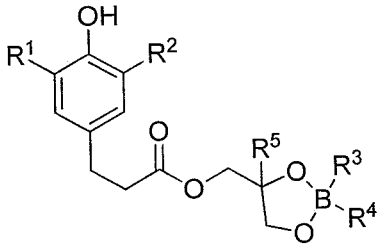
7. The compound of claim 5, wherein the compound has the following formula (VI):



Formula (VI)

wherein R^1, R^2, R^3, R^4, R^5, m, p, and q are as defined in claim 5.

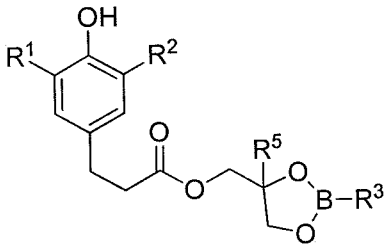
8. The compound of claim 5, wherein the compound has the following formula (VII):



Formula (VII)

wherein R^1, R^2, R^3, R^4, and R^5 are as defined in claim 5.

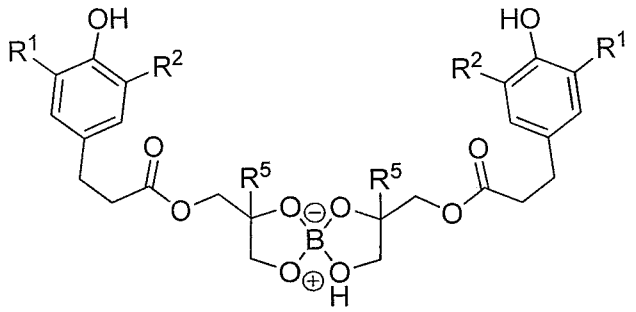
9. The compound of claim 5, wherein the compound has the following structure (VIII):



Formula (VIII)

wherein R^1, R^2, R^3, and R^5 are as defined in claim 5.

10. The compound of claim 6, wherein the compound has the structure of formula (IX):



Formula (IX)

wherein R^1, R^2, and R^5 are as defined in claim 6.

11. The compound of claim 5, wherein R^1 and R^2 are both t-butyl groups.

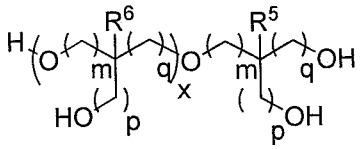
12. The compound of claim 6, wherein R^1 and R^2 are both t-butyl groups.

13. A compound comprising the reaction product of:

a. a polyol,

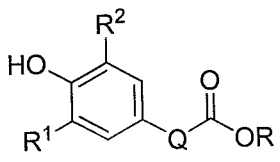
b. a boron containing compound, and

c. a phenolic acid or ester, wherein the polyol has the following formula (III):



(Formula III),

wherein each m is independently 1, 2, or 3; each p is independently 0, 1, 2, or 3; each q is independently 0, 1, 2, or 3; x is 0, 1, or 2; R^5 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and R^6 is H, a C_1 - C_{12} alkyl group, or a C_1-C_3 alkanol; and the phenolic acid or ester has the following formula (II):



(Formula II),

wherein Q is an alkylene group of 2 to 6 carbon atoms; R is H or a moiety suitable to undergo transesterification; R^1 and R^2 are each independently a C_1 - C_{12} alkyl group.

14. The compound of claim 13, wherein the molar ratio of boron containing compound: polyol: phenolic acid or ester is about 1:2:2.

15. The compound of claim 13, wherein the molar ratio of boron containing compound: polyol: phenolic acid or ester is about 1:2:1.