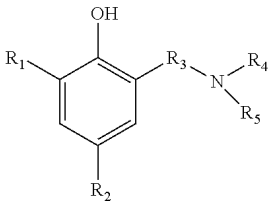
SUMMARY

[0004] In one example, a method of providing improved engine performance is provided herein. In one example or approach, a fuel additive package for a spark-ignition engine is described herein to provide the improved engine performance and includes (i) a Mannich detergent including the reaction product of a hydrocarbyl-substituted phenol, one or more aldehydes, and one or more amines and (ii) a quaternary ammonium internal salt obtained from amines or polyamines that is substantially devoid of any free anion species.

[0004a] In one aspect, the disclosure provides a fuel additive package for a spark-ignition engine comprising:

a Mannich detergent including the reaction product of a hydrocarbyl-substituted phenol, one or more aldehydes, and one or more amines, wherein the Mannich detergent has the structure of Formula I:

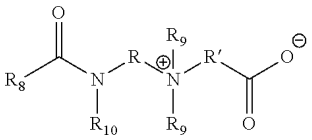
(Formula I)



wherein R_1 is hydrogen or a C1 to C4 alkyl group, R_2 is a hydrocarbyl group having a number average molecular weight of about 500 to about 3000, R_3 is a C1 to C4 alkylene or alkenyl group, and R_4 and R_5 are, independently, hydrogen, a C1 to C12 alkyl group, or a C1 to C4 alkyl amino C1-C12 alkyl group;

a quaternary ammonium internal salt obtained from amines or polyamines that is substantially devoid of any free anion species, wherein the quaternary ammonium internal salt has the structure of Formula II

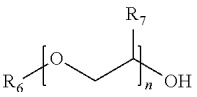
(Formula II)



wherein R and R′ are, independently, alkylene linkers having 1 to 10 carbon atoms; R_8 is a C12 to C100 alkylene, alkene, or hydrocarbyl group or an aryl group or optionally substituted aryl group; each R_9 is, independently, a linear or branched C1 to C4 alkyl group; and R_{10} is a hydrogen atom or a C1 to C4 alkyl group;

an alkoxylated alcohol, wherein the alkoxylated alcohol is a polyether having the structure of Formula III:

(Formula III)

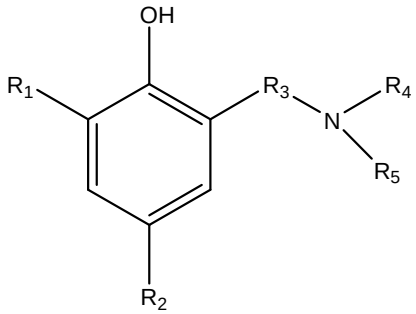


wherein R_6 is an aryl group or a linear, branched, or cyclic aliphatic group having 5 to 50 carbons, R_7 is a C1 to C4 alkyl group, and n is an integer from 5 to 100;

wherein a weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.8 or less;

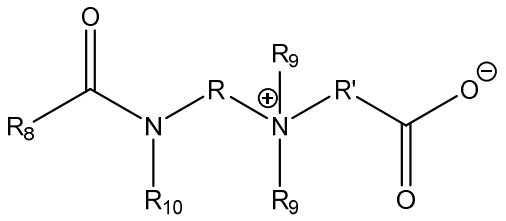
wherein the fuel additive package includes about 20 to about 60 weight percent of the Mannich detergent and about 5 to about 30 weight percent of the alkoxylated alcohol; and wherein a weight ratio of the Mannich detergent to the quaternary ammonium internal salt is about 5:1 to about 100:1.

[0005] In other approaches or examples, the fuel additive package described above may include one or more optional features or examples in any combination. These optional features or examples may include one or more of the following: wherein the fuel additive package further includes an alkoxylated alcohol; and/or wherein a weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.8 or less; and/or wherein the alkoxylated alcohol is a polyether prepared by reacting an alkyl alcohol or an alkylphenol with an alkylene oxide selected from ethylene oxide, propylene oxide, butylene oxide, copolymers thereof, or combinations thereof; and/or wherein a weight ratio of the Mannich detergent to the quaternary ammonium internal salt is about 5:1 to about 100:1; and/or wherein the Mannich detergent has the structure of Formula I:



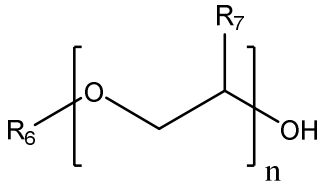
(Formula I)

wherein R_1 is hydrogen or a C1 to C4 alkyl group, R_2 is a hydrocarbyl group having a number average molecular weight of about 500 to about 3000, R_3 is a C1 to C4 alkylene or alkenyl group, and R_4 and R_5 are, independently, hydrogen, a C1 to C12 alkyl group, or a C1 to C4 alkyl amino C1-C12 alkyl group; and/or wherein the quaternary ammonium internal salt has the structure of Formula II



(Formula II)

wherein R and R' are, independently, alkylene linkers having 1 to 10 carbon atoms; R_8 is a C12 to C100 alkylene, alkene, or hydrocarbyl group or an aryl group or optionally substituted aryl group; each R_9 is, independently, a linear or branched C1 to C4 alkyl group; and R_{10} is a hydrogen atom or a C1 to C4 alkyl group; and/or wherein the alkoxylated alcohol is a polyether having the structure of Formula III:



(Formula III)

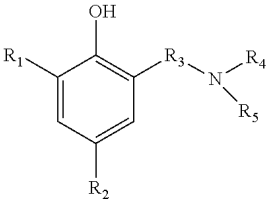
wherein R_6 is an aryl group or a linear, branched, or cyclic aliphatic group having 5 to 50 carbons, R_7 is a C1 to C4 alkyl group, and n is an integer from 5 to 100; and/or wherein the fuel additive package includes about 20 to about 60 weight percent of the Mannich detergent, about 1 to about 15 weight percent of the quaternary ammonium internal salt, and about 5 to about 30 weight percent of the alkoxylated alcohol; and/or further comprising a succinimide detergent prepared by reacting a hydrocarbyl-substituted succinic acylating agent with an amine, polyamine, or alkyl amine having one or more primary, secondary, or tertiary amino groups; and/or wherein the fuel additive package includes about 0.1 to about 10 weight percent of the succinimide detergent; and/or wherein the succinimide detergent is a hydrocarbyl substituted mono-succinimide detergent, a hydrocarbyl substituted bis-succinimide detergent, or a combination thereof; and/or further comprising one or more of a demulsifier, a corrosion inhibitor, an antiwear additive, an antioxidant, a metal deactivator, an antistatic additive, a dehazer, an antiknock additive, a lubricity additive, and/or a combustion improver.

[0006] In other approaches or examples, the disclosure herein also describes a gasoline fuel composition comprising about 40 to about 750 ppmw of a fuel additive package as described in any of the examples from the previous two paragraphs and including about 15 to about 300 ppmw of the Mannich detergent, about 0.1 to about 10 ppmw of the quaternary ammonium internal salt, and about 2 to about 90 ppmw of the alkoxylated alcohol.

[0006a] In one aspect, the disclosure provides a gasoline fuel composition comprising:

about 55 to about 190 ppmw of a Mannich detergent including the reaction product of a hydrocarbyl-substituted phenol, one or more aldehydes, and one or more amines, wherein the Mannich detergent has the structure of Formula I:

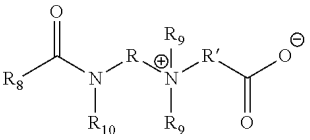
(Formula I)



wherein R_1 is hydrogen or a C1 to C4 alkyl group, R_2 is a hydrocarbyl group having a number average molecular weight of about 500 to about 3000, R_3 is a C1 to C4 alkylene or alkenyl group, and R_4 and R_5 are, independently, hydrogen, a C1 to C12 alkyl group, or a C1 to C4 alkyl amino C1-C12 alkyl group;

about 0.1 to about 3 ppmw of a quaternary ammonium internal salt obtained from amines or polyamines that is substantially devoid of any free anion species, wherein the quaternary ammonium internal salt has the structure of Formula II

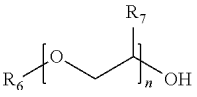
(Formula II)



wherein R and R′ are, independently, alkylene linkers having 1 to 10 carbon atoms; R_8 is a C12 to C100 alkylene, alkene, or hydrocarbyl group or an aryl group or optionally substituted aryl group; each R_9 is, independently, a linear or branched C1 to C4 alkyl group; and R_{10} is a hydrogen atom or a C1 to C4 alkyl group;

about 15 to about 50 ppmw of an alkoxylated alcohol, wherein the alkoxylated alcohol is a polyether having the structure of Formula III:

(Formula III)



wherein R_6 is an aryl group or a linear, branched, or cyclic aliphatic group having 5 to 50 carbons, R_7 is a C1 to C4 alkyl group, and n is an integer from 5 to 100;

wherein a weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.8 or less; and

wherein a weight ratio of the Mannich detergent to the quaternary ammonium internal salt is about 5:1 to about 100:1.

[0007] The gasoline fuel composition of the previous paragraph may also include other optional features or examples in any combination. These optional feature or examples of the gasoline fuel composition may include one or more of the following: wherein intake valve deposits, as measured pursuant to one of ASTM D6201, or

ASTM D5500 are reduced when the gasoline fuel composition is combusted in a spark-ignition engine as compared to combusting a gasoline fuel composition including the aminophenol detergent and/or the alkoxylated alcohol and being devoid of the quaternary ammonium internal salt; and/or wherein the spark-ignition engine is a gasoline direct or port fuel injection engine.

[0008] In yet other approaches or examples, a method of improving the injector performance of a gasoline direct injection (GDI) engine is described herein. The method includes operating the gasoline direct injection engine on a fuel composition containing a major amount of a gasoline fuel and a minor amount of the fuel additive package as described by any example set forth in this Summary, and wherein the fuel additive package in the gasoline fuel improves the injector performance of the gasoline direct injection engine. In one aspect, the disclosure provides a method of improving the injector performance of a gasoline direct injection (GDI) engine, the method comprising: operating the gasoline direct injection engine on a fuel composition containing a major amount of a gasoline fuel and a minor amount of the fuel additive package as disclosed herein; and wherein the fuel additive package in the gasoline fuel improves the injector performance of the gasoline direct injection engine. Also provided herein is the use of a fuel additive package as described by any example herein or any example of a fuel composition herein for improving the injector performance of a gasoline direct injection engine.

[0009] The method or the use of the previous paragraph may include optional steps, features, or limitations in any combination thereof. Approaches or examples of the method or use may include one or more of the following: wherein the improved injector performance is one of improved fuel flow, improved fuel economy, improved engine efficiency, or combinations thereof; and/or wherein the improved injector performance is measured by one of injector pulse width, injection duration, injector flow, or combinations thereof.

BRIEF DESCRIPTION OF DRAWING FIGURES

[00010] FIG. 1 is a graph showing percent of injector fouling in a base fuel and an additized fuel;

[00011] FIG. 2 is a graph showing Long Term Fuel Trim (LTFT) of a base fuel and an additized fuel; and

[00012] FIG. 3 is a graph showing Long Term Fuel Trim (LTFT) of Inventive 5 and Comparatives 3 and 4.