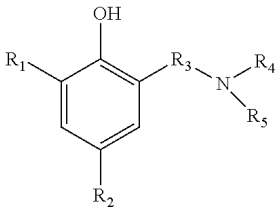
CLAIMS

WHAT IS CLAIMED IS:

1. 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:

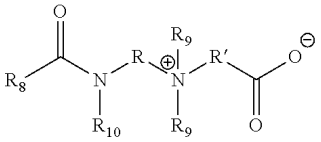
(Formula I)



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

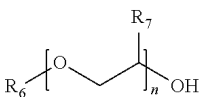
(Formula II)



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.

2. The fuel additive package of claim 1, 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.

3. The fuel additive package of claim 1, wherein a weight ratio of the Mannich detergent to the quaternary ammonium internal salt is about 20:1 to about 80:1.

4. The fuel additive package of claim 1, wherein the fuel additive package includes about 1 to about 15 weight percent of the quaternary ammonium internal salt.

5. The fuel additive package of claim 1, 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.

6. The fuel additive package of claim 4, wherein the fuel additive package includes about 0.1 to about 10 weight percent of the succinimide detergent.

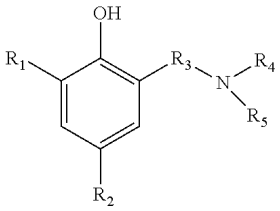
7. The fuel additive package of claim 6, wherein the succinimide detergent is a hydrocarbyl substituted mono-succinimide detergent, a hydrocarbyl substituted bis-succinimide detergent, or a combination thereof.

8. The fuel additive package of claim 6, 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.

9. 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:

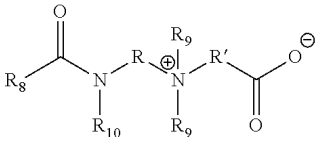
(Formula I)



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

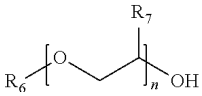
(Formula II)



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.

10. 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 of claim 1; and

wherein the fuel additive package in the gasoline fuel improves the injector performance of the gasoline direct injection engine.

11. The method of claim 10, wherein the improved injector performance is one of improved fuel flow, improved fuel economy, improved engine efficiency, or combinations thereof.

12. The method of claim 11, wherein the improved injector performance is measured by one of injector pulse width, injection duration, injector flow, or combinations thereof.

13. The fuel additive package of claim 1, wherein the weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.5 or less.

14. The gasoline fuel composition of claim 9, wherein the weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.5 or less.

15. The method of claim 10, wherein the weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.5 or less.