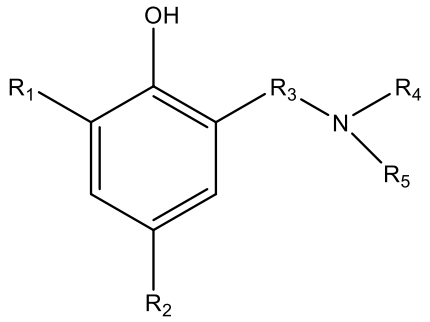
CLAIMS

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)

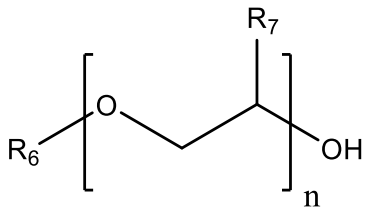
wherein R_1 is hydrogen or a C1 to C4 alkyl group, R_2 is a hydrocarbyl group having a number average molecular weight of about 500 to about 3000, R_3 is a C1 to C4 alkylene or alkenyl group, and R_4 and R_5 are, independently, hydrogen, a C1 to C12 alkyl group, or a C1 to C4 alkyl amino C1-C12 alkyl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

a quaternary ammonium salt additive having the structure of Formula II

$$[(R_{10})(R_{11})N\text{-}(CH_2)_n\text{-}X_m\text{-}(CH_2)_n\text{-}X_m\text{-}(CH_2)_n\text{-}N^{\oplus}(R_7)(R_8)(R_9)]\ M^{\ominus} \qquad \text{(Formula II)}$$

wherein each X is a bivalent moiety selected from the group consisting of -O-, -N(R_{12})-, -C(O)-, -C(O)O-, or -C(O)NR_{12}; each R_7, R_8, and R_9 are independently alkyl groups containing 1 to 8 carbon atoms; R_{10} and R_{11} are independently selected from hydrogen, an alkyl group, an acyl group, or a hydrocarbyl substituted acyl group, the hydrocarbyl substituent of one or both of R_{10} and R_{11} having a number average molecular weight of about 700 or greater; R_{12} is independently a hydrogen or a group selected from $C_{1\text{-}6}$ aliphatic, phenyl, or alkylphenyl; each m is independently an integer of 0 or 1 with at least one m being 1; each n is independently an integer of 1 to 10; and $M^{\ominus}$ is a carboxylate;

an alkoxylated alcohol, wherein a weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.8 or less, wherein the alkoxylated alcohol is a polyether having the structure of Formula Va:



(Formula Va)

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 Mannich detergent to the quaternary ammonium salt additive is about 4:1 to about 10:1; and

wherein the fuel additive package includes about 20 to about 70 weight percent of the Mannich detergent, about 1 to about 20 weight percent of the quaternary ammonium salt additive, and about 5 to about 30 weight percent of the alkoxylated alcohol.

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 R_{10} and R_{11} of the quaternary ammonium salt of Formula II, together with the nitrogen atom to which they are attached, combine to form a ring moiety.

4. The fuel additive package of claim 1, wherein the carboxylate of the quaternary ammonium salt of Formula II is oxalate, salicylate, or combinations thereof.

5. The fuel additive package of claim 4, wherein X of Formula II is –O- or –NH-.

6. The fuel additive package of claim 5, wherein the quaternary ammonium salt is derived from 3-(2-(dimethylamino)ethoxy)propylamine, N,N-dimethyldipropylenetriamine, or mixtures thereof.

7. The fuel additive package of claim 1, wherein R_{10} and R_{11} of the quaternary ammonium salt of Formula II, together with the nitrogen atom to which they are attached, combine to form a hydrocarbyl substituted succinimide.

8. The fuel additive package of claim 7, wherein the hydrocarbyl substituent has a number average molecular weight of about 700 to about 2,500.

9. The fuel additive package of claim 1, wherein X moiety of the quaternary ammonium salt of Formula II is an oxygen atom and wherein R_{10} and R_{11} of the quaternary ammonium salt, together with the nitrogen atom to which they are attached, combine to form a hydrocarbyl substituted succinimide with the hydrocarbyl substituent having a number average molecular weight of about 700 to about 1,500 as measured by GPC using polystyrene as a calibration reference.

10. The fuel additive package of claim 1, wherein the fuel additive package includes about 20 to about 60 weight percent of the Mannich detergent.

11. 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.

12. The fuel additive package of claim 11, wherein the fuel additive package includes about 0.1 to about 10 weight percent of the succinimide detergent.

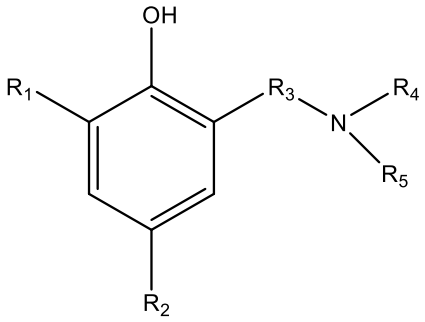
13. The fuel additive package of claim 12, wherein the succinimide detergent is a hydrocarbyl substituted mono-succinimide detergent, a hydrocarbyl substituted bis-succinimide detergent, or a combination thereof.

14. The fuel additive package of claim 12, 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.

15. A gasoline fuel composition comprising

about 55 to about 125 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)

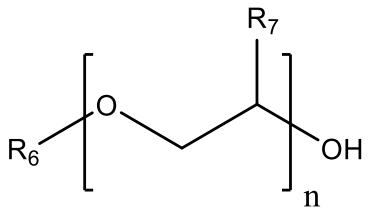
wherein R_1 is hydrogen or a C1 to C4 alkyl group, R_2 is a hydrocarbyl group having a number average molecular weight of about 500 to about 3000, R_3 is a C1 to C4 alkylene or alkenyl group, and R_4 and R_5 are, independently, hydrogen, a C1 to C12 alkyl group, or a C1 to C4 alkyl amino C1-C12 alkyl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

about 4 to about 15 ppmw of a quaternary ammonium salt additive has the structure of Formula II

$$[(R_{10})(R_{11})N\text{-}(CH_2)_n\text{-}X_m\text{-}(CH_2)_n\text{-}X_m\text{-}(CH_2)_n\text{-}N^{\oplus}(R_7)(R_8)(R_9)]\ M^{\ominus} \qquad \text{(Formula II)}$$

wherein each X is a bivalent moiety selected from the group consisting of -O-, -N(R_{12})-, -C(O)-, -C(O)O-, or -C(O)NR_{12}; each R_7, R_8, and R_9 are independently alkyl groups containing 1 to 8 carbon atoms; R_{10} and R_{11} are independently selected from hydrogen, an alkyl group, an acyl group, or a hydrocarbyl substituted acyl group, the hydrocarbyl substituent of one or both of R_{10} and R_{11} having a number average molecular weight of about 700 or greater; R_{12} is independently a hydrogen or a group selected from $C_{1\text{-}6}$ aliphatic, phenyl, or alkylphenyl; each m is independently an integer of 0 or 1 with at least one m being 1; each n is independently an integer of 1 to 10; and $M^{\ominus}$ is a carboxylate; and

about 15 to about 40 ppmw of an alkoxylated alcohol, wherein a weight ratio of the alkoxylated alcohol to the Mannich detergent is about 0.8 or less, wherein the alkoxylated alcohol is a polyether having the structure of Formula Va:



(Formula Va)

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

wherein a weight ratio of the Mannich detergent to the quaternary ammonium salt additive is about 4:1 to about 10:1.

16. 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.

17. The method of claim 16, wherein the improved injector performance is one of improved fuel flow, improved fuel economy, improved engine efficiency, or combinations thereof.

18. The method of claim 17, wherein the improved injector performance is measured by one of injector pulse width, injection duration, injector flow, or combinations thereof.