In another aspect of the disclosure, there is provided a fuel composition comprising as an additive one or more quaternary ammonium compounds wherein the quaternary ammonium compound is the reaction product of

i) a cyclic tertiary amine of formula R==NR^1 having less than 19 carbon atoms, which is an N-alkyl heterocyclic amine having 5 to 7 atoms in the heterocyclic ring
ii) an epoxide having less than 8 carbon atoms; and
iii) a carboxylic acid of formula R^5COOH, wherein R^5COOH is the residue of an optionally substituted phthalic acid or succinic acid derivative.

In yet another aspect of the disclosure, there is provided a method of preparing a fuel composition comprising preparing a quaternary ammonium salt by reacting (a) a cyclic tertiary amine of formula R==NR^1 having less than 19 carbon atoms which is an N-alkyl heterocyclic amine having 5 to 7 atoms in the heterocyclic ring; with (b) an epoxide in the presence of (c) a carboxylic acid of formula R^5COOH; wherein R^5COOH is the residue of an optionally substituted phthalic acid or succinic acid derivate; and mixing the quaternary ammonium salt into the fuel.

The quaternary ammonium salts of the present invention include cations of formula R==$N^+R^1R^2$, wherein each of R^1 and R^2 is independently an optionally substituted alkyl, alkenyl or aryl group having less than 8 carbon atoms, and R together with N forms a heterocycle having less than 12 carbon atoms.

For the avoidance of doubt, the structure R==$N^+R^1R^2$ is used to indicate that the group R forms 2 bonds to N, not that it forms a double bond.

In this specification, unless otherwise stated references to optionally substituted alkyl groups may include aryl-substituted alkyl groups and references to optionally-substituted aryl groups may include alkyl-substituted or alkenyl-substituted aryl groups.

R^1 and R^2 may be the same or different. In some embodiments they are the same. In some embodiments they are different.

Preferably R^1 is an optionally substituted alkyl, alkenyl or aryl group having from 1 to 7 carbon atoms, preferably from 1 to 5 carbon atoms, more preferably from 1 to 4 carbon atoms.

R^1 may be optionally substituted with one or more groups selected from halo (especially chloro and fluoro), hydroxy, alkoxy, keto, acyl, cyano, mercapto, alkylmercapto, dialkylamino, nitro, nitroso, and sulphoxy. The alkyl groups of these substituents may be further substituted.

Preferably R^1 is an optionally substituted alkyl or alkenyl group. Preferably R^1 is an optionally substituted alkyl group. Preferably R^1 is an optionally substituted alkyl or alkenyl group having from 1 to 7 carbon atoms, preferably from 1 to 6 carbon atoms, more preferably from 1 to 5 carbon atoms, suitably from 1 to 4 carbon atoms, preferably from 1 to 3 carbon atoms, more preferably from 1 to 2 carbon atoms.

Preferably R^1 is an optionally substituted alkyl or alkenyl group, preferably having from 1 to 6, preferably from 1 to 4 carbon atoms. Preferably R^1 is an alkyl group. It may be a substituted alkyl group, for example a hydroxy substituted alkyl group. Preferably R^1 is an unsubstituted alkyl group or a hydroxy alkyl group. More Preferably R^1 is an unsubstituted alkyl group. The alkyl chain may be straight-chained or branched. Preferably R^1 is selected from methyl, ethyl, propyl and butyl, including isomers thereof. Most preferably R^1 is methyl.

In some embodiments R^1, R and N together form an aromatic ring and the quaternary ammonium salt may have the structure:

Claims

1. A fuel composition comprising as an additive one or more quaternary ammonium compounds wherein the quaternary ammonium compound is the reaction product of
   i) a cyclic tertiary amine of formula R==NR^1 having less than 19 carbon atoms, which is an N-alkyl heterocyclic amine having 5 to 7 atoms in the heterocyclic ring;
   ii) an epoxide having less than 8 carbon atoms; and
   iii) a carboxylic acid of formula R^5COOH, wherein R^5COOH is the residue of an optionally substituted phthalic acid or succinic acid derivative.

2. A method of preparing a fuel composition comprising preparing a quaternary ammonium salt by reacting (a) a cyclic tertiary amine of formula R==NR^1 having less than 19 carbon atoms which is an N-alkyl heterocyclic amine having 5 to 7 atoms in the heterocyclic ring; with (b) an epoxide in the presence of (c) a carboxylic acid of formula R^5COOH; wherein R^5COOH is the residue of an optionally substituted phthalic acid or succinic acid derivate; and mixing the quaternary ammonium salt into the fuel.

3. A composition or method according to claim 1 or claim 2 wherein component (a) comprises an amine of formula R==NR^1 in which R^1 is an optionally substituted hydrocarbyl group and R and N together form a heterocycle having less than 12 carbon atoms.

4. A composition or method according to any preceding claim wherein the N-alkyl heterocycle is an N-methyl heterocycle.

5. A composition or method according to any preceding claim wherein the heterocycle is selected from pyrrolidine, piperidine, morpholine, piperazine, pyrrole, imidazole and dihydropyrrole.

6. A composition or method according to any preceding claim wherein the epoxide is selected from 1,2-epoxybutane and isopropyl glycidyl ether.

7. A composition or method according to any preceding claim wherein component (c) comprises a hydrocarbyl substituted or succinic acid derivative wherein the hydrocarbyl substituent has a molecular weight of from 100 to 5000.

8. A fuel composition according to any preceding claim wherein the fuel is diesel fuel and which optionally comprises one or more further detergents selected from:

(i) an additional quaternary ammonium salt additive which is not a quaternary ammonium compound of claim 1;

(ii) the product of a Mannich reaction between an aldehyde, an amine and an optionally substituted phenol;

(iii) the reaction product of a carboxylic acid-derived acylating agent and an amine;

(iv) the reaction product of a carboxylic acid-derived acylating agent and hydrazine;

(v) a salt formed by the reaction of a carboxylic acid with di-n-butylamine or tri-n-butylamine;

(vi) the reaction product of a hydrocarbyl-substituted dicarboxylic acid or anhydride and an amine compound or salt which product comprises at least one amino triazole group; and

(vii) a substituted polyaromatic detergent additive.

9. A fuel composition according to any of claims 1 to 7 wherein the fuel is gasoline fuel and which optionally comprises one or more gasoline detergents selected from .

(p) hydrocarbyl-substituted polyoxyalkylene amines or polyetheramines;
(q) acylated nitrogen compounds which are the reaction product of a carboxylic acid-derived acylating agent and an amine;
(r) hydrocarbyl-substituted amines wherein the hydrocarbyl substituent is substantially aliphatic and contains at least 8 carbon atoms;
(s) Mannich base additives comprising nitrogen-containing condensates of a phenol, aldehyde and primary or secondary amine;
(t) aromatic esters of a polyalkylphenoxyalkanol;
(u) an additional quaternary ammonium salt additive which is not a quaternary ammonium compound of claim 1; and
(v) tertiary hydrocarbyl amines having a maximum of 30 carbon atoms.

10. A method of preparing a fuel composition as claimed in any of claims 2 to 9, the method comprising adding the quaternary ammonium salt additive to the fuel after the fuel has left the distribution terminal.

11. A method of improving the performance of an engine, the method comprising combusting in said engine a fuel composition comprising as an additive one or more quaternary ammonium compounds as claimed in any of claims 1 to 7.

12. A method according to claim 11 wherein the engine is a gasoline engine and the fuel is a gasoline fuel.

13. A method according to claim 11 wherein the engine is a diesel engine having a fuel injection system which comprises a high pressure fuel injection (HPFI) system with fuel pressures greater than 1350 bar.

14. A method according to claim 11 or claim 13 wherein improvement in performance is achieved by combating deposits in the engine.

15. A method according to claim 14 which combats internal diesel injector deposits and/or which combats external diesel injector deposits, including injector nozzle deposits and/or which combats fuel filter deposits.

16. A method according to claim 11 or claim 13 wherein the improvement in performance is a power gain compared to when combusting an unadditised base fuel and with clean injectors.

17. The use of an additive in a fuel composition to improve the performance of an engine combusting said fuel composition wherein the additive is a quaternary ammonium salt as claimed in any of claims 1 to 7.

18. The use according to claim 17 to achieve "keep clean" performance or to achieve "clean up" performance.