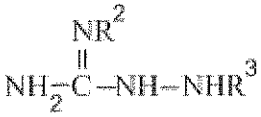
example, because of the need for additional friction modifiers and/or corrosion inhibitors in the low sulfur fuels.

[0005] Conventional quaternary ammonium compounds have been found effective in cleaning up certain fuels but are not effective in other fuels. In addition, such compounds have non-covalently bound anions that may lead to other problems such as deposit formation in the fuel from the anionic part of the compound.

[0006] Certain quaternary ammonium internal salts have been found to be effective where conventional quaternary ammonium salts lack the performance. However quaternary ammonium internal salts may be ineffective in certain petroleum fuels. Accordingly, there is a need for fuel additives, additive concentrates and fuel compositions that provide improved engine performance in a variety of fuels and engines.

[0007] In accordance with the disclosure, exemplary embodiments provide a fuel additive concentrate, a method for cleaning fuel injectors, a method for restoring power to a diesel fuel injected engine, a fuel composition, and a method of operating a fuel injected diesel engine. The additive concentrate includes (a) a hydrocarbyl substituted quaternary ammonium internal salt; and (b) a hydrocarbyl substituted dicarboxylic anhydride derivative selected from a diamide, acid/amide, acid/ester, diacid, amide/ester, diester, and imide. The hydrocarbyl substituent of component (b) has a number average molecular weight ranging from about 450 to about 1500. A weight ratio of (a) to (b) in the additive concentrate ranges from about 20:1 to about 1:2. The additive concentrate is devoid of a reaction product of a hydrocarbyl substituted dicarboxylic acid, anhydride or ester and an amine compound of the formula



wherein R^2 is selected from hydrogen and a hydrocarbyl group containing from about 1 to about 15 carbon atoms, and R^3 is selected from hydrogen and a hydrocarbyl group containing from about 1 to about 20 carbon atoms.

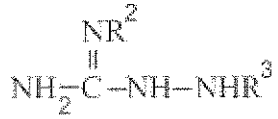
[0007a] In one aspect, there is provided an additive concentrate for a fuel for use in a injected fuel engine comprising

(a) a hydrocarbyl substituted quaternary ammonium internal salt; and

(b) a hydrocarbyl substituted dicarboxylic anhydride derivative selected from the group

consisting of a diamide, acid/amide, acid/ester, diacid, amide/ester, diester, and imide, wherein the hydrocarbyl substituent of component (b) has a number average molecular weight ranging from about 450 to about 1500,

wherein a weight ratio of (a) to (b) in the additive concentrate ranges from about 20:1 to about 1:2, and wherein the additive concentrate is devoid of a reaction product of a hydrocarbyl substituted dicarboxylic acid, anhydride or ester and an amine compound of the formula



wherein R^2 is selected from the group consisting of hydrogen and a hydrocarbyl group containing from about 1 to about 15 carbon atoms, and R^3 is selected from the group consisting of hydrogen and a hydrocarbyl group containing from about 1 to about 20 carbon atoms.

[0007b] In another aspect, there is provided a diesel fuel composition comprising a major amount of a low sulfur diesel fuel and a minor amount of the additive concentrate as defined above.

[0007c] In another aspect, there is provided a method of cleaning up internal components of a fuel injector for a diesel engine comprising operating a fuel injected diesel engine on a fuel composition as defined above.

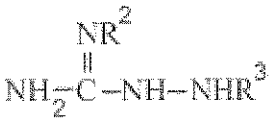
[0007d] In another aspect, there is provided a method of restoring power to a diesel fuel injected engine after an engine dirty-up phase comprising combusting in the engine a diesel fuel composition as defined above, wherein the power restoration is measured by the following formula:

Percent Power recovery = (DU-CU)/DU x 100

wherein DU is a percent power loss at the end of a dirty-up phase without the additive, CU is the percent power loss at the end of a clean-up phase with the fuel additive, and said power restoration is about 49% or greater.

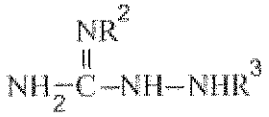
[0008] ~~Another embodiment of the disclosure provides~~In another aspect, there is provided a method of improving the injector performance of a fuel injected diesel engine. ~~The method includes~~ comprising operating the engine on a fuel composition ~~that includes~~ comprising a major amount of fuel and from about 5 to about 500 ppm by weight based on a total weight of the fuel of a synergistic fuel additive. ~~The synergistic fuel additive includes~~ comprising (a) a hydrocarbyl substituted quaternary ammonium internal salt; and (b) a

hydrocarbyl substituted dicarboxylic anhydride derivative selected from the group consisting of a diamide, acid/amide, acid/ester, diacid, amide/ester, diester, and imide. The, wherein the hydrocarbyl substituent of component (b) has a number average molecular weight ranging from about 450 to about 1500. A, wherein a weight ratio of (a) to (b) in the fuel additive ranges from about 20:1 to about 1:2. When wherein when the synergistic additive(s) is present in the fuel, at least about 49 % of the power lost during a dirty up phase of a CEC F98-08 DW10 test conducted in the absence of the synergistic additive(s) is recovered and wherein. In another embodiment, at least 70% of the lost power is recovered. In still another embodiment at least 100% of the lost power is recovered. The the additive concentrate is devoid of a reaction product of a hydrocarbyl substituted dicarboxylic acid, anhydride or ester and an amine compound of the formula



wherein R^2 is selected from hydrogen and a hydrocarbyl group containing from about 1 to about 15 carbon atoms, and R^3 is selected from hydrogen and a hydrocarbyl group containing from about 1 to about 20 carbon atoms. In another embodiment, at least 70% of the lost power is recovered. In still another embodiment at least 100% of the lost power is recovered.

[0009] A further embodiment aspect of the disclosure provides a method of operating a fuel injected engine. The method includescomprising combusting in the engine a fuel composition containing a major amount of fuel and from about 5 to about 500 ppm by weight based on a total weight of the fuel of a synergistic fuel additive. The synergistic fuel additive includescomprising (a) a hydrocarbyl substituted quaternary ammonium internal salt; (b) a reaction product derived from (i) a hydrocarbyl substituted dicarboxylic acid, anhydride, or ester, wherein the hydrocarbyl substituent of component (b) has a number average molecular weight ranging from about 450 to about 1500 and (ii) a polyamine of the formula H_2N-((CHR^1-$(CH_2)_n$-$NH)_m$-H, wherein R^1 is hydrogen, n is 1 and m is 4, wherein a molar ratio of (i) reacted with (ii) ranges from about 0.5:1 to about 2:1; and (c) a metal deactivator selected from the group consisting of tolyltriazole and N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine. A, wherein a weight ratio of (a) to (b) in the fuel additive ranges from about 20:1 to about 1:2 and a weight ratio of (b) to (c) ranges from 0.5:1 to 5:1. The, and wherein fuel additive is devoid of a reaction product of a hydrocarbyl substituted dicarboxylic acid, anhydride or ester and an amine compound of the formula



wherein R^2 is selected from hydrogen and a hydrocarbyl group containing from about 1 to about 15 carbon atoms, and R^3 is selected from hydrogen and a hydrocarbyl group containing from about 1 to about 20 carbon atoms.

[00010] Another ~~embodiment~~ aspect of the disclosure provides a fuel additive composition that includes a) an oleyl amidopropyl dimethylamino internal salt, (b) a reaction product derived from (i) a hydrocarbyl substituted succinic anhydride, wherein the hydrocarbyl substituent of component (b) has a number average molecular weight of about 950, and (ii) a tetraethyelene pentamine, wherein a molar ratio of (i) reacted with (ii) is about 1.6:1, and c) a metal deactivator selected from tolyltriazole and N,N-bis(2-ethylhexyl)-ar-methyl-1H-benzotriazole-1-methanamine.

[00011] It was surprisingly found the hydrocarbyl substituted anhydrides and derivatives in combination with certain hydrocarbyl quaternary ammonium internal salts may be synergistically more effective for improving injector performance and power recovery (power restoration) than each of the components (a) and (b) alone in the fuel. Hydrocarbyl substituted anhydride derivatives may include among others diacid, mono acid/ester, mono acid/amide, amide, ester, imide, and mixtures.

[00012] An advantage of the fuel additive described herein is that the additive may not only reduce the amount of deposits forming on fuel injectors, but the additive may also be effective to clean up dirty fuel injectors sufficient to provide improved power recovery to the engine. The combination of components (a) and (b) may also be effective for improving the fuel delivery system including, but not limited to, reducing fuel filter blockage.

[00013] Additional embodiments and advantages of the disclosure will be set forth in part in the detailed description which follows, and/or can be learned by practice of the disclosure. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure, as claimed.