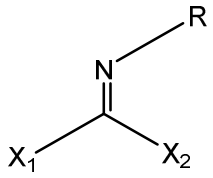
## ]CLAIMS

1. A fuel composition comprising:

(1) greater than 50 wt % of a hydrocarbon fuel boiling in the gasoline or diesel range;

(2) a minor amount of one or more of:

a primary low-speed pre-ignition (LSPI)-reducing additive comprising (i) an amino additive, (ii) an amine additive, (iii) a triazole additive, (iv) a benzamidinium additive, (v) a benzoxazole additive, or (vi) a N=C-X motif additive having a structure of




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wherein R is H, monovalent organic group, or monovalent heterorganic group;

wherein $X_1$ and $X_2$ are independently H, C, N, O, or S; and

wherein $X_1$ or $X_2$ independently includes one or more $C_1$-$C_{20}$ alkyl group or one or more aromatic group; and

(3) a secondary LSPI-reducing additive comprising an acid additive, a phenol additive, a 1,3 dicarbonyl additive, a hydroxamide additive, antioxidant additive, or salicylate additive,

wherein the primary LSPI-reducing additive and the secondary LSPI-reducing additive form a salt.

2. The fuel composition of claim 1, wherein the amino additive is a beta-amino alkanol, an amino acid, or an amino ester.

3. The fuel composition of claim 1 or 2, wherein the amine additive is aromatic amine or aliphatic amine.

4. The fuel composition of any one of claims 1 to 3, wherein the triazole additive is 5,6-dimethylbenzotriazole.

5. The fuel composition of any one of claims 1 to 4, wherein the primary LSPI-reducing additive is prolinol, aliquat, morphguam, 2-aminobenzimidazole, N-(2,3-dihydroxypropyl)heptan-2-aminium ("AHPD"), N,N-dimethyl-N-octylbenzamidinium-2-oxide, benzoxazole, 2-methylquinolin-8-amine, or 2-aminobenzoxazole.

6. The fuel composition of any one of claims 1 to 5, wherein the N=C-X motif additive is an amidine, a guanidine, an imidazole, a benzamidine, a benzimidazole, or an amino benzimidazole.

7. The fuel composition of claim 6, wherein the amidine is 1,4,5,6-tetrahydropyrimidine, 1,2-dimethyl-1,4,5,6-tetrahydropyrimidine, 1,2-diethyl-1,4,5,6-tetrahydropyrimidine, 1,5-diazabicyclo[4.3.0]non-5-ene (DBN), 2-phenyl-1H-benzo[d]imidazole, or 1,8-diazabicyclo[5.4.0]-undece-7-ene (DBU).

8. The fuel composition of claim 6, wherein the guanidine is 1,1,3,3-tetramethylguanidine (TMG), 2-tert-butyl-1,1,3,3-tetramethylguanidine(BTMG), 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD), 1,2-diphenylguanidine, or 7-methyl-1,5,7-triazabicyclo[4.4.0]dec-5-ene (MTBD).

9. The fuel composition of any one of claims 1 to 8, wherein the acid additive is an aliphatic acid, an unsaturated acid, an alkylaromatic acid, an aromatic acid, a hydroxy acid, or an amino acid.

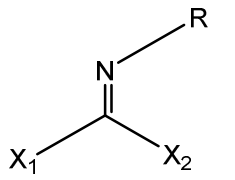
10. The fuel composition of any one of claims 1 to 9, wherein the secondary LSPI-reducing additive is 2-ethylhexanoate, isostreate, proline, diketone, oleate, toluene,

tetraline carboxylate, phenoxide, phenol carboxylate, hydroxy acid, 2-hydroxy-5-(tetracosa-1,3,5,7,9,11,13,15,17,19,21,23-dodecayn-1-yl)benzoic acid--dihydrogen or ketoester.

11. A fuel concentrate comprising:

(1) from 90 to 30 wt % of an organic solvent boiling in a range of from 65°C to 205°C;

(2) from 10 to 70 wt % of an additive component selected from one or more of (i) an amino additive, (ii) an amine additive, (iii) a triazole additive, (iv) a benzamidinium additive, (v) a benzoxazole additive, or (vi) a N=C-X motif additive having a structure of



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wherein R is H, monovalent organic group, or monovalent heterorganic group;

wherein $X_1$ and $X_2$ are independently H, C, N, O, or S; and

wherein $X_1$ or $X_2$ independently includes one or more $C_1$-$C_{20}$ alkyl group or one or more aromatic group; and

(3) a secondary LSPI-reducing additive comprising an acid additive, a phenol additive, a 1,3 dicarbonyl additive, a hydroxamide additive, antioxidant additive, or salicylate additive,

wherein the primary LSPI-reducing additive and the secondary LSPI-reducing additive form a salt.

12. The fuel concentrate of claim 11, wherein the amino additive is a beta-amino alkanol, an amino acid, or an amino ester.

13. The fuel concentrate of claim 11 or 12, wherein the amine additive is aromatic amine or aliphatic amine.

14. The fuel concentrate of any one of claims 11 to 13, wherein the triazole additive is 5,6-dimethylbenzotriazole.

15. The fuel concentrate of any one of claims 11 to 14, wherein the primary LSPI-reducing additive is prolinol, aliquat, morphguam, 2-aminobenzimidazole, AHPD, N,N-dimethyl-N-octylbenzamidinium-2-oxide, benzoxazole, 2-methylquinolin-8-amine, or 2-aminobenzoxazole.

16. The fuel concentrate of any one of claims 11 to 15, wherein the N=C-X motif additive is an amidine, a guanidine, an imidazole, a benzamidine, a benzimidazole, or an amino benzimidazole.

17. The fuel concentrate of claim 16, wherein the amidine is 1,4,5,6-tetrahydropyrimidine, 1,2-dimethyl-1,4,5,6-tetrahydropyrimidine, 1,2-diethyl-1,4,5,6-tetrahydropyrimidine, 1,5-diazabicyclo[4.3.0]non-5-ene (DBN), 2-phenyl-1H-benzo[d]imidazole, or 1,8-diazabicyclo[5.4.0]-undece-7-ene (DBU).

18. The fuel concentrate of claim 16, wherein the guanidine is 1,1,3,3-tetramethylguanidine (TMG), 2-tert-butyl-1,1,3,3-tetramethylguanidine(BTMG), 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD), 1,2-diphenylguanidine, or 7-methyl-1,5,7-triazabicyclo[4.4.0]dec-5-ene (MTBD).

19. The fuel concentrate of claim 11, wherein the acid additive is an aliphatic acid, an unsaturated acid, an alkylaromatic acid, an aromatic acid, a hydroxy acid, or an amino acid.

20. The fuel concentrate of claim 11, wherein the secondary LSPI-reducing additive is 2-ethylhexanoate, isostreate, proline, diketone, oleate, toluene, tetraline carboxylate, phenoxide, phenol carboxylate, hydroxy acid, or ketoester.

21. A method for preventing or reducing low speed pre-ignition events in a spark-ignited internal combustion engine, the method comprising supplying to the engine the fuel composition of any one of claims 1 to 10.

22. The method of claim 21, wherein the spark-ignited internal combustion engine is operated at a speed of less than 3000 rpm.

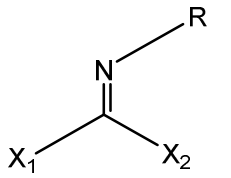
23. The method of claim 21 or 22, wherein the spark-ignited internal combustion engine is operated under a load with a brake mean effective pressure of at least 10 bar (1 MPa).

24. Use of the fuel composition of any one of claims 1 to 10 to prevent or reduce low speed pre-ignition events in a spark-ignited internal combustion engine, wherein the fuel composition is supplied to the engine.

25. Use in a fuel composition comprising greater than 50 wt.% of a hydrocarbon fule boiling in the gasoline or diesel range of:

(1) a minor amount of one or more of:

a primary low-speed pre-ignition (LSPI)-reducing additive comprising (i) an amino additive, (ii) an amine additive, (iii) a triazole additive, (iv) a benzamidinium additive, (v) a benzoxazole additive, or (vi) a N=C-X motif additive having a structure of




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wherein R is H, monovalent organic group, or monovalent heterorganic group;

wherein $X_1$ and $X_2$ are independently H, C, N, O, or S; and

wherein $X_1$ or $X_2$ independently includes one or more $C_1$-$C_{20}$ alkyl group or one or more aromatic group; and

(2) a secondary LSPI-reducing additive comprising an acid additive, a phenol additive, a 1,3 dicarbonyl additive, a hydroxamide additive, antioxidant additive, or salicylate additive,

wherein the primary LSPI-reducing additive and the secondary LSPI-reducing additive form a salt, to prevent or reduce low speed pre-ignition events in a spark-ignited internal combustion engine, wherein the fuel composition is supplied to the engine.