CLAIMS

1. A fuel additive comprised of more than one metal, metal oxide or metallic compound for improving combustion of fossil fuels, said fuel additive comprising:

a first metal, metal oxide or metallic compound of iron, wherein the first metal, metal oxide or metallic compound is capable of being dissolved in a solvent and has a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emissions of less than 0.0025 over the gap in the spectral intensity of the first metal, metal oxide or metallic compound of iron;

a second metal, metal oxide or metallic compound of magnesium, wherein the second metal, metal oxide or metallic compound is over based and is capable of forming a colloidal suspension in the solvent and has a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emissions of less than 0.0025 over the gap in spectral intensity of the second metal, metal oxide or metallic compound; and

a third metal, metal oxide or metal compound which produces total normalized spectral emissions of 0.02 or greater over the normalized spectral emissions gap of the first metal, metal oxide or metal compound or of the second metal, metal oxide or metal compound, or of both;

wherein fuel additive particles introduced into said combustion chamber of said fossil fuels are of molecular particle size wherein molecular particle size is less than one micrometer in size.

2. The fuel additive of Claim 1:

wherein at least 50% of said fuel additive particles are of molecular size; or

wherein more than one said metal, metal oxide or metallic compound are chosen from the metals consisting of aluminum, magnesium, iron, tin, cerium, manganese, copper, cobalt, nickel, palladium, and platinum; or

wherein the third metal, metal oxide or metal compound is spectrally complementary with either iron or magnesium or both over the wave length bands from 200 nm to 2500 nm.

3. The fuel additive of Claim 1 or Claim 2 wherein said solvent is chosen from one of toluene, hexanol, octanol, xylene, kerosene, fuel oil, naphtha, Aromatic 150 and petroleum spirits or their equivalents.

4. The fuel additive of any one of the preceding Claims:

wherein the concentration of said metals in the fuel is greater than about 0.1 PPM and less than about 15 PPM by weight; or

wherein said the first metallic compound includes dicyclopentadienyl Fe°, cyclopentadienyl triscarbonyl Fe° and iron salts of carboxylic acids; or

wherein said first metallic compound of iron is ferrocene; or

further comprising metallic ash content greater than about 0.5 PPM and less than about 15 PPM by weight; or

wherein said iron compound is dissolved in xylene; or

wherein said iron compound is dissolved in a naphtha solvent with a flash point between about 108 degrees F and 200 degrees F; or

wherein the over-based magnesium compound is a magnesium sulfonate or carboxylate;

wherein the fuel additive comprises magnesium in a ratio of about 3 to 8 parts iron

to about 1 part magnesium compound by weight; or

whereby said fuel additive provides an increase in fuel efficiency when combusted in said fossil fuel; or

wherein the fossil fuel is used in one of distillate fuel oil combustion processes, natural gas combustion processes, stationary natural gas turbines, natural gas-fired reciprocating engines, gasoline and diesel internal combustion engines, large stationary diesel engines and large stationary dual-fuel engines.

5. The fuel additive of any one of the preceding Claims wherein the third metal, metal oxide or metallic compound is spectrally complementary to either iron or magnesium or both over the spectral wavelength band from 200 to 2500 nm, wherein the concentration by weight of said third metal, metal oxide, or metallic compound is less than iron.

6. The fuel additive of Claim 5 wherein the third metal, metallic oxide or metallic compound is a copper compound dissolved in or forming a colloidal suspension in said solvent.

7. The fuel additive of Claim 6 wherein the concentration of copper by weight is less than that of iron.

8. The fuel additive of any one of the preceding Claims wherein the fossil fuel includes distillate fuel oil, gasoline, natural gas and coal.

9. The fuel additive of Claim 8:

wherein the distillate fuel oil for use in combustion processes includes residential

applications, commercial energy consumption, industrial applications, farm applications, electric power generation, railroad applications, vessel bunkering, military applications, and off-highway applications; or

wherein said fossil fuels include low or ultra-low sulfur content diesel fuel or distillate fuel oil.

10. The fuel additive of any one of the preceding Claims whereby said fuel additive provides a decrease in NOx emissions from the fossil fuel into which it is mixed when combusted in said fossil fuels.

11. The fuel additive of Claim 10:

used together with Selective Catalytic Reduction of NOx to provide additional improvement in NOx compared to Selective Catalytic Reduction technology alone; or

whereby the fuel additive provides at least one of a decrease of CO emissions and/or a decrease of particulate emissions when combusted in said fossil fuel; or

used in combination with exhaust gas recirculation NOx reduction technology to provide more complete combustion improvement compared to exhaust gas recirculation alone; or

wherein the fuel additive is utilized in a natural gas combustion process comprising a burner whereby the burner utilizes fuel induced exhaust gas recirculation.

12. The fuel additive of Claim 11 wherein a lubricity agent is added to said fuel additive wherein the lubricity of the fuel after addition of said lubricity agent has an ASTM D 6079 HFRR average wear scar diameter not greater than 400 microns.

13. The fuel additive of Claim 12 wherein the average wear scar diameter is not greater than 270 microns.

14. The fuel additive of Claim 13 wherein said low or ultra-low sulfur content diesel or distillate fuel oil is used in one of fuel oil combustion processes, diesel internal combustion engines, large stationary diesel engines and large stationary dual-fuel engines.

15. Steam generators, process heaters, combustion turbines, vehicles, compression ignited combustion reciprocating engines, spark ignited reciprocating engines, natural gas compressors, turbines, combined power plants used for generation of electricity, micro-turbine electrical generators, compressors and burners whose primary fuel is natural gas wherein the fuel additive of any one of the preceding Claims is added to the fuel natural gas prior to or during combustion; or

pumps using natural gas as their primary fuel to move natural gas in pipeline applications to include but not limited to gathering natural gas from the well field, moving natural gas through main pipelines and/or injecting and extracting natural gas from the gas storage facilities wherein the fuel additive of any one of the preceding Claims is added to the natural gas prior to or during combustion; or

a combustion turbine whose primary fuel is natural gas utilizing staged combustion wherein a portion of the natural gas containing the fuel additive of any one of the preceding Claims is introduced into a primary combustion zone and the remainder is introduced into at least one secondary zone where combustion is completed; or

low NOx, lean mix combustion turbines whose primary fuel is natural gas wherein the fuel additive of any one of the preceding Claims, added to the natural gas prior to or during combustion, reduces the NOx produced by said combustion turbines by 40% or

more; or

a burner whose primary fuel is natural gas utilizing fuel gas recirculation in combination with staged combustion whereby the fuel additive of any one of the preceding Claims is introduced into the natural gas prior to or during combustion; or

a low-NOx burner or combustion turbine using natural gas as a primary fuel and utilizing an SCR to reduce the amount of NOx generated by the low-NOx burner wherein the fuel additive of any one of the preceding Claims is introduced into the natural gas prior to entering the low-NOx burner or combustion turbine; or

a low-NOx burner using a primary fuel including one of coal, distillate oil, low or ultra-low sulfur diesel oil, gasified biomass, coal water slurry, or emulsion, or other than natural gas and using natural gas as a re-burn fuel added to the combustion process wherein the fuel additive of any one of the preceding Claims is introduced into the natural gas re-burn stream prior to its use as a re-burn fuel; or

a misting nozzle used to introduce the fuel additive of any one of the preceding Claims together with its carrier solvent into a conduit of flowing natural gas prior to the gas entering the combustion chamber.

16. A fuel additive comprised of a least three metals, metal oxides or metallic compounds for improving combustion of fossil fuels wherein the metal, metal oxide or metallic compound with the highest concentration by weight is iron and wherein the said at least two additional metals are chosen from the group consisting of aluminum, magnesium, tin, cerium, manganese, copper, cobalt and nickel wherein said at least two additional metals are spectrally complementary to the metal of highest concentration over the wavelength bands of 200 nm to 2500 nm by each producing total normalized spectral emissions of 0.02 or greater over a normalized spectral emissions gap of the first metal,

metal oxide or metallic compound.

17. The fuel additive of Claim 16 wherein the fossil fuel is used in one of fuel oil combustion processes, natural gas combustion processes, stationary natural gas turbines, natural gas-fired reciprocating engines, gasoline and diesel internal combustion engines, large stationary diesel engines and large stationary dual-fuel engines,

wherein the fuel oil combustion processes may comprise: the use of distillate fuel oil which processes include residential applications, commercial energy consumption, industrial applications, farm applications, electric power generation, railroad applications, vessel bunkering military applications, and off-highway applications.

18. A combustion fuel composition comprising:

(a) a combustion fuel; and

(b) a combustion catalyst additive which comprises:

(i) an oil-soluble organometallic iron compound having a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emissions of less than 0.0025 over the gap in spectral intensity of the first metal, metal oxide or metal compound;

(ii) an over-based oil-soluble organometallic magnesium compound having a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emissions of less than 0.0025 over the gap in spectral intensity of the second metal, metal oxide or metal compound; and

(iii) a third oil-soluble organometallic compound selected from the group consisting of organic compounds of cerium, copper, platinum, palladium, cobalt, nickel and manganese,

wherein iron from the oil-soluble organometallic iron compound is present in an amount equal to or less than 8 ppm by weight, based on the total weight of the combustion fuel composition and

wherein the third oil-soluble organometallic compound produces total normalized spectral emissions of 0.02 or greater over the normalized spectral emissions gap of the first metal, metal oxide or metal compound or of the second metal, metal oxide or metal compound, or of both.

19. The combustion fuel composition of Claim 18:

wherein 100% of the particulate size of the material is less than 0.02×10^{-6} meters and 50% is less than 0.0075×10^{-6} meters;

wherein the third metal is spectrally complementary with either or both of iron (III) and magnesium (II) over the wavelength bands from 200 nanometers (2,000 Å) and 2,500 nanometers (25,000 Å);

wherein the total concentration of metals from (i), (ii) and (iii) in the combustion catalyst additive is from 0.1% to 10% by weight, based on the total weight of the combustion catalyst additive;

wherein the total concentration of metals from (i), (ii) and (iii) in the combustion fuel composition is from 0.1 ppm to 10 ppm by weight, based on the total weight of the combustion fuel composition;

wherein the oil-soluble organometallic iron compound is selected from the group consisting of dicyclopentadienyl Fe(0) and the salt of a C9 to C12 alkyl carboxylic acid;

wherein the over-based oil-soluble organometallic magnesium compound is an over-based magnesium sulfonate or carboxylate having a maximum particle size less than 0.02×10^{-6} meters;

wherein the third oil-soluble organometallic compound is selected from the group consisting of oil-soluble salts of an organic acid;

wherein the fuel is a fossil fuel;

wherein the fuel further comprises one or more selected from the group consisting of ethanol, bio-ethanol, fatty acid methyl esters (FAME) and ligno-cellulosic ethanol.

20. A method for formulating a combustion fuel comprising:

(a) selecting one or more oil-soluble organo-metallic compounds;

(b) determining or measuring the atomic emission spectrum of the metals in the one or more oil-soluble organometallic compounds;

(c) comparing the atomic emission spectrum from step (b) to atomic emission spectra of iron (III) and magnesium (II);

(d) if the atomic emission spectrum from step (b) contains peaks not present in the atomic emission spectra of at least one of iron (III) and magnesium (II) such that the normalized spectral emission from step (b) is 0.02 or greater over that of at least one of iron (III) and magnesium (II), formulating a combustion catalyst fuel additive which comprises an oil-soluble organometallic iron compound, an over-based oil-soluble organometallic magnesium compound and the oil-soluble organometallic compound, wherein the third oil-soluble organometallic compound is spectrally complementary either with the oil-soluble organometallic iron compound or with the over-based oil-soluble organometallic magnesium compound or with both;

(e) adding the combustion catalyst fuel additive to a combustion fuel,

wherein the oil-soluble organometallic iron compound is present in the fuel at an amount equal to or less than 8 ppm by weight.

21. A natural gas fuel composition comprising:

(a) natural gas;

(b) a natural gas combustion catalyst additive which comprises:

(i) an oil-soluble organometallic iron compound having a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emission of less than 0.0025 over the gap in spectral intensity of the oil-soluble organometallic iron compound,

(ii) an over-based oil-soluble organometallic magnesium compound having a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emissions of less than 0.0025 over the gap in spectral intensity of the over-based oil-soluble organometallic magnesium compound, and

(iii) a third oil-soluble organometallic compound selected from the group consisting of cerium, copper, platinum, palladium, cobalt, nickel and manganese, wherein the third oil-soluble organometallic compound is spectrally complementary either with the oil-soluble organometallic iron compound or with the over-based oil-soluble organometallic magnesium compound or with both, wherein the iron from the oil-soluble organometallic iron compound is present in an amount equal to or less than 8 ppm by weight, based on the total weight of the natural gas fuel composition; and

wherein the third oil-soluble organometallic compound produces total normalized spectral emissions of 0.02 or greater over the normalized spectral emissions gap of the oil-soluble organometallic iron compound or of the over-based oil-soluble organometallic magnesium compound, or both.

22. The natural gas fuel composition of Claim 21, wherein 100% of the particulate size of the material is less than 0.02 x 10^{-6} meters and 50% is less than 0.0075 x 10^{-6}

meters.

23. The natural gas fuel composition of Claim 22:

wherein the third metal is spectrally complementary with either or both of iron (III) and magnesium (II) over the wavelength bands from 200 nanometers (2,000 Å) and 2,500 nanometers (25,000 Å); or

wherein the total concentration of metals from (a), (b) and (c) in the fuel additive is from 0.1% to 10% by weight, based on the total weight of the combustion catalyst additive; or

wherein the oil-soluble organometallic iron compound is selected from the group consisting of dicyclopentadienyl Fe(0) and the salt of a C9 to C12 alkyl carboxylic acid; or

wherein the oil-soluble organometallic magnesium compound is an over-based magnesium sulfonate or carboxylate having a maximum particle size less than 0.02×10^{-6} meters; or

wherein the third oil-soluble organometallic compound is selected from the group consisting of oil-soluble salts of an organic acid.

24. A method of making a natural gas fuel composition comprising:

(a) selecting a natural gas combustion catalyst additive which comprises an oil-soluble organometallic iron compound, having a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emission of less than 0.0025 over the gap in the spectral intensity of the oil-soluble organometallic iron compound, an over-based oil-soluble organometallic magnesium compound having a spectral intensity with at least one continuous gap that is at least 25 nm wide in wavelengths and a total normalized spectral emissions of less than 0.0025 over the

gap in spectral intensity of the over-based organometallic magnesium, a third oil-soluble organometallic compound selected from the group consisting of organic compounds of cerium, copper, platinum, palladium, cobalt, nickel and manganese, and a solvent selected from the group consisting of xylene, toluene, benzene and combinations thereof, wherein the oil-soluble iron (III) compound is present in an amount equal to or less than 8 ppm by weight and wherein the third oil-soluble organometallic compound is spectrally complementary either with the oil-soluble organometallic iron compound or with the over-based oil-soluble organometallic magnesium compound or with both and wherein the third oil-soluble organometallic compound produces total normalized spectral emissions of 0.02 or greater over the normalized spectral emissions gap of the oil-soluble organometallic iron compound or of the over-based organometallic magnesium compound, or of both;

(b) providing natural gas in a container; and

(c) atomizing the natural gas combustion catalyst additive into the container.

25. A fuel additive for improving combustion of fossil fuels comprises:

a first metal, metal oxide or metallic compound which is of iron, and

a solvent in which said first metal, metal oxide or metallic compound is dissolved,

a second metal, metallic oxide or metallic compound which forms a colloidal suspension in said solvent, said second metal, metal oxide or metallic compound being of an over based magnesium; and

wherein the concentration of iron and magnesium in the fuel additive is from 0.1 to 15 ppm by weight;

said additive comprising a third metal, metal oxide or metal compound which is spectrally complementary with either iron or magnesium or both over the wavelength

bands from 200 nm to 2500 nm, said third metal oxide or metal compound being selected from the group consisting of aluminum, magnesium, iron, tin, cerium, manganese, copper, cobalt, nickel, palladium and platinum;

wherein fuel additive particles introduced into the combustion chamber of said fossil fuels are of molecular particle size wherein molecular particle size is less than one micrometer in size.