

**ADDITIVE FOR LIQUID OR LIQUIFIED HYDROCARBON FUELED  
DIRECT FIRED BURNERS, OPEN FLAMES AND RELATED PROCESSES**

Related Applications

[0001] This patent application claims priority to U.S. Provisional Patent Application  
5 Serial No. 60/613,699 filed on September 28, 2004, which is incorporated by  
reference in its entirety.

Technical Field of the Invention

[0002] The present invention relates to the field of fuel additives, in particular, to an  
additive for hydrocarbon fueled burners and flames to enhance efficiency and/or  
10 reduce undesirable emissions, such as pollutants.

Background of the Invention

[0003] Many hydrocarbon fuels have been used, each with their own advantages and  
drawbacks. Examples of such fuels include diesel, kerosene, heavy distillates and  
bunker fuels. Chemical compounds have been used as combustion improvers to  
15 enhance combustion efficiency, of these types of fuels. Many of these additives  
contain metallic elements such as manganese, iron, copper, cerium, calcium and  
barium. Each of these elements has advantages and disadvantages in particular  
applications. Drawbacks of certain iron compounds include limited solubility in fuels,  
toxicity, and expense as an additive. Interaction with sulfur and creation of sulfide  
20 precipitate may also occur, which is undesirable.

[0004] In addition to the goal of improved combustion efficiency, smoke emissions  
reduction is also a concern, particularly for heavier fuels in direct fired applications.  
The industry has not made substantial progress on development of a fuel additive for  
reducing smoke and particulate emissions in these applications.

25 [0005] A fuel additive that includes a combustion catalyst to reduce smoke and  
particulate emissions from open flame burners and other direct-fired applications  
would be advantageous. A fuel additive that increases efficiency and/or decreases  
pollutants for diesel and heavier fuels used in these applications would be particularly  
advantageous. It would also be advantageous to reduce smoke, particulate and

nitrogen emissions from fuel applications. In addition to reduction of  $\text{NO}_x$ , reduction or elimination of HCN emissions is highly desirable.

[0006] An additive that does not result in the formation of precipitates and burns clean during the combustion process would be desirable.

## 5 Summary of the Invention

[0007] The present invention includes a fuel additive and a method of using the additive in relation to hydrocarbon fuel.

[0008] The fuel additive of the invention includes a phosphorus-containing parent solution containing  $[\text{Y}]_x\text{H}_2\text{PO}_4$ ,  $[\text{Y}]_{x+1}\text{HPO}_4$ , where Y is a cation. Y does not have to be  
10 the same cation in both salt compounds. The cationic portion of the salt components can be any cation, with potassium being a preferred cation. In this case, the preferred components would be  $\text{KH}_2\text{PO}_4$ ,  $\text{K}_2\text{HPO}_4$ . These salts are at least partially dispersed and/or dissolved in water or other appropriate solvent to create the phosphorus-containing parent solution. Advantageously, this embodiment of the fuel additive is  
15 an ammonia-free solution. One preferred embodiment includes adding these components, in the presence of water, to create the phosphorus-containing parent solution as an aqueous parent solution. The water acts as the solvent. Other preferred parent solution solvents include alcohols. Another group of preferred cations would be the alkali metals or Group 1A elements. While  $\text{NH}_4$  used as Y creates a fuel  
20 additive that enhances fuel performance, there are instances when it is preferred to avoid ammonium and thereby ammonia altogether.

[0009] The phosphorus-containing parent solution is added or mixed with a dispersion fluid. The dispersion fluid is a fluid that is operable to maintain the salts within the dispersion fluid in at least a partially dispersed state and that is miscible, or capable of  
25 being maintained in solution, in the hydrocarbon fuel. In a preferred embodiment, the solvent is largely removed from the phosphorus-containing parent solution in the dispersion fluid through thermal means to create the fuel additive. The fuel additive is operable to enhance combustion when placed into contact with fuel in a direct fired burner or open flame and combusted. Enhanced combustion means that fuel

efficiency is increased when compared to fuel without the fuel additive, or that pollutant output in an exhaust gas from the combustion is decreased or a combination of these effects. Typical pollutants can include NO<sub>x</sub>, HCN, SO<sub>2</sub> particulate matter, carbon monoxide and other recognized pollutants resulting from the combustion of hydrocarbon fuel. It is noted that different geographical areas focus on minimizing a particular pollutant depending on air characteristics. Reduction of a target pollutant or a combination of pollutants, such as NO<sub>x</sub> and HCN is highly advantageous. Alternately, increased fuel efficiency results in a total lower volume of pollutants, as well as economic advantage.

10 [0010] Another preferred embodiment of the phosphorus-containing parent solution includes the addition of [NH<sub>4</sub>]<sub>2</sub>HPO<sub>4</sub> to the [Y]<sub>x</sub>H<sub>2</sub>PO<sub>4</sub>, [Y]<sub>x+</sub>HPO<sub>4</sub>, and water. Yet another embodiment includes the addition of NH<sub>4</sub>C<sub>2</sub>H<sub>3</sub>O<sub>2</sub> where C<sub>2</sub>H<sub>3</sub>O<sub>2</sub><sup>-</sup> ion is an acetate group such that the solution contains [Y]<sub>x</sub>H<sub>2</sub>PO<sub>4</sub>, [Y]<sub>x+</sub>HPO<sub>4</sub>, [NH<sub>4</sub>]<sub>2</sub>HPO<sub>4</sub>, NH<sub>4</sub>C<sub>2</sub>H<sub>3</sub>O<sub>2</sub> and water. When the fuel additive is prepared using ammonium compounds, ammonium compounds being defined as those compounds containing NH<sub>x</sub> groups, the nitrogen in the solution is essentially all in the form of ammonium ions. There is at most a negligible amount of free ammonia. In a preferred embodiment, the solution has a pH between about 6.0 and 8.0.

[0011] Another preferred embodiment of the phosphorus-containing parent solution includes the addition of [Y]<sub>x</sub>PO<sub>4</sub> to the [Y]<sub>x</sub>H<sub>2</sub>PO<sub>4</sub>, and [Y]<sub>x+</sub>HPO<sub>4</sub>.

[0012] While orthophosphoric acids have been described, also called phosphoric acids, this includes pyrophosphoric acids, which are the condensed analogs of orthophosphoric acid. The difference being that, through the process to condense the orthophosphoric acid, the PO<sub>4</sub><sup>3-</sup> becomes P<sub>2</sub>O<sub>7</sub><sup>2-</sup> or other condensed phosphates. Therefore, [Y]<sub>x</sub>H<sub>2</sub>PO<sub>4</sub>, and [Y]<sub>x+</sub>HPO<sub>4</sub> are precursors to pyrophosphoric acids. The use of the pyrophosphoric and other condensed forms is therefore encompassed within the definition of the orthophosphate form.

[0013] The phosphorus-containing parent solution of one embodiment of the invention can be used in any type of environment, either hydrophilic or hydrophobic

environments. In the case of a hydrophobic environment, it may be necessary that a carrier fluid or fluids be selected to allow for proper dispersion. A dispersant used in conjunction with the carrier fluids to create the fuel additive is also encompassed in a preferred embodiment. For liquid hydrocarbon fuel applications, at least one carrier  
5 fluid can preferably be a fluid with a least some hydrophilic character that is miscible with the fuel to act as compatibilizing agent in conjunction with dispersant..

[0014] The fuel additive of the invention is useful to enhance combustion such that more complete combustion is achieved with increased combustion to CO<sub>2</sub> and H<sub>2</sub>O as compared to the combustion of the fuel without the fuel additive. The outcome is the  
10 reduction of products of partial combustion as well as NO<sub>x</sub> and SO<sub>2</sub>, thereby increasing fuel efficiency.

[0015] The fuel additive is used by adding this additive to the fuel in an amount sufficient to increase fuel efficiency or to reduce pollutants. The terms enhanced and enhanced combustion refer to either of these effects. An example of reduced  
15 pollutants is a reduction of NO<sub>x</sub> and HCN in an exhaust gas produced from a direct fired burner or open flame. Advantageously, both of these effects are observed though the addition of the fuel additive of the current invention. A preferred embodiment includes the addition of between about 50 and 150 ppm phosphorus into the fuel though the addition of the fuel additive. Increased amounts of phosphorus are  
20 effective as well. It is notable that a very cost-effective solution can be prepared with low weight percent of phosphorus. Another preferred target is around 1 ppm phosphorus to 150 ppm phosphorus. Positive test results have been generated as low as 0.25 ppm phosphorus.

[0016] Included in the invention is a process for enhancing fuel performance of a  
25 hydrocarbon fuel in a combustion system including the steps of providing the fuel additive described above in an amount effective to enhance fuel performance to the hydrocarbon fuel and combusting the hydrocarbon fuel with the fuel additive. The combustion system can be any means known to those with ordinary skill in the art for combusting hydrocarbon. The combustion system can include one or more direct  
30 fired burners or open flames. In a preferred embodiment, this process is used with a

liquid or liquefied hydrocarbon fuel. The result of adding the additive to the hydrocarbon fuel is an enhanced fuel that has a substantial amount of hydrocarbon fuel suitable for combustion, and an amount of the fuel additive operable to enhance combustion. Preferably, the enhanced fuel contains phosphorus in an amount  
5 operable to reduce emissions upon combustion of the enhanced fuel as compared to the combustion of the hydrocarbon fuel without the fuel additive. More preferably, the enhanced fuel contains phosphorus of between about 1 and 150 ppm by weight.

[0017] An alternate embodiment of the invention includes a process for enhancing fuel performance of a hydrocarbon fuel in a combustion system including the steps of  
10 adding a chemical addition composition to the hydrocarbon fuel in an amount effective to enhance fuel performance. The chemical addition composition is created by creating an intermediate solution by (i) mixing in an aqueous medium a source of reactive  $\text{NH}_2$  groups with one of the following:

1. (a) an alkali metal hydroxide to raise the pH of the intermediate solution above  
15 12 to form an aqueous ammonium/alkali metal hydroxide; or
2. (b) a source of phosphoric acid to lower the pH of the intermediate solution to about 0 to form an acidic ammonium mixture.
3. The next step includes either combining the intermediate solution of step (i.a.) with the source of phosphoric acid; or the intermediate solution of (i.b.) with the  
20 hydroxide at a rate sufficient to create a highly exothermic reaction. This results in reactive  $\text{NH}_2$  groups being contained in solution during the formation of the chemical addition composition. This chemical addition composition is added to the hydrocarbon fuel.

[0018] The parent solution, or the chemical addition composition of the invention, can  
25 be added into or include a combustion fuel. Again, it can be advantageous to include dispersants to promote dispersion in fuels that are hydrocarbon based. Exemplary fuels kerosene, diesel fuel and residual fuels.

[0019] An enhanced fuel is created when a substantial amount of a fuel suitable for combustion is combined with an amount of the phosphorus-containing parent solution or the chemical addition composition sufficient to reduce emissions or to increase efficiency upon combustion of the enhanced fuel. In certain circumstances, the dispersion fluid is a quantity of a target fluid, that is, a fluid that contains the desired fuel.

[0020] A composition of phosphoric acid, alkali metal hydroxide and a source of reactive  $\text{NH}_2$  groups has been explored in U.S. Patent No. 5,540,788 for the creation of a conversion surface, the disclosure of the patent being incorporated herein by reference. The current invention includes the use of the conversion surface composition as a fuel additive. In one embodiment the fuel additive is chemical addition composition for the enhancement of hydrocarbon fuels where the chemical addition composition has the composition disclosed in U.S. Patent No. 5,540,788. This embodiment is unique in the use of the source of reactive  $\text{NH}_2$  groups, which can be advantageous under certain circumstances. While the chemical composition including reactive  $\text{NH}_2$  groups has certain advantages, it can result in the presence of free ammonia. Various other embodiments of the fuel additive of this invention avoid the production of free ammonia and the related issues.

#### Detailed Description

[0021] The fuel additive of the invention is believed to perform a gas phase conversion of hydrocarbon fuels to achieve more complete combustion to  $\text{CO}_2$  and  $\text{H}_2\text{O}$  in the process. Preferably, the fuel additive is provided as a dispersion in the dispersion fluid. Preparation preferably includes forming the aqueous parent solution that is emulsified and then added into base oils. Dispersion can be aided through the use of emulsifiers and dispersants. In a preferred embodiment, a dispersant with a total base number of from 30 to 160 on an oil-free basis is used. Tests run using infrared and other testing techniques confirm the reduction of CO from the offgas from the combustion of hydrocarbon fuels with the fuel additive of the invention.

[0022] U.S. Patent No. 5,540,788 (the Defalco patent) teaches a process for creating an iron-phosphorus surface through the formation of a conversion surface on iron

substrates by delivering a phosphatizing compound in a lubricating fluid. The present invention also includes the use of the composition of DeFalco as a fuel additive for introduction into a burner or open-flame. The composition includes a source of phosphoric acid, an alkali metal hydroxide and a source of reactive NH<sub>2</sub> groups.

5 Notably, the source of the reactive NH<sub>2</sub> groups produces the reactive NH<sub>2</sub> groups as a result of the highly exothermic reaction that is described in the Defalco patent. Testing indicates that the same compounds that act as a source of reactive NH<sub>2</sub> groups in the above reaction do not produce reactive NH<sub>2</sub> groups under different physical conditions since they follow a different reaction path. This specific

10 chemistry results from the highly exothermic reaction described in the DeFalco patent. It is also noted that the physical conditions of high pH results in the production of free ammonia.

[0023] Both the new composition disclosed herein and the previously described composition of Defalco can be used to produce the enhanced fuel performance.

15 [0024] The invention includes the use of the fuel additive in the direct-fired burners and open flames. This is believed to be particularly valuable for burners using heavy fuels such as bunker fuels, including bunker C. Use in the burner or flame appears to provide combustion benefits allowing for a reduction in particulate and other emissions. The process of the invention is effective at the high temperatures produced

20 as part of the combustion process such that the fuel additive is contained or present in the flame with the fuel. The fuel additive acts as a catalyst to enhance combustion.

[0025] One example of a preferred formulation of the invention includes the following ratios: 1.597 mols KH<sub>2</sub>PO<sub>4</sub>, 0.693 mol K<sub>2</sub>HPO<sub>4</sub>, 0.315 mol [NH<sub>4</sub>]<sub>2</sub>HPO<sub>4</sub> and water. The pH of the solution can be controlled through manipulation of the

25 ratios of these components. By manipulating the ratios of the resulting H<sub>2</sub>PO<sub>4</sub><sup>-</sup> and HPO<sub>4</sub><sup>2-</sup> ions, the solution can be created in a preferred pH range of about 6.0 to about 8.0.

[0026] In a preferred embodiment, KH<sub>2</sub>PO<sub>4</sub>, K<sub>2</sub>HPO<sub>4</sub>, [NH<sub>4</sub>]<sub>2</sub>HPO<sub>4</sub> and water are created into the phosphorus containing parent solution that is added to a dispersion

fluid, such as a refined oil dispersion fluid, and mixed with dispersants. Exemplary dispersants include polyalkenyl succinimides such as Texaco TFA 4690C, Oronite ODA 78012 and Ethyl Hitec 646. It may also be advantageous to include certain carrier fluids. Exemplary carrier fluids include polyoxpropylene monols, diols and polyols, polyoxybutylene monols, diols and polyols, particularly Bayer Actaclear ND17. The phosphorus containing parent solution is added in at approximately 10 wt. % of the refined oil dispersion fluid. This is heated to drive off a significant amount of the solvent, in this case, water. The mixture can be described at this point as a colloid. When the resulting solution is mixed into the fuel, an effective amount of the phosphorus in the solution can be dilute. One example of a preferred embodiment is 0.3 wt% phosphorus in the solution. Upon addition to the fuel, the phosphorus content can be in the range of 5–100 ppb and still be effective. Preferably, 1–250 ppm phosphorus is used in the fuel. Higher amounts are also effective. More preferably, 1-150 ppm phosphorus by weight is in the fuel with the fuel additive.

[0027] An example of an alternate embodiment of the phosphorus-containing parent solution that is for use in fuel includes mixing about 2.6 molar (M) orthophosphate with alkali metal and ammonium cations, the resulting aqueous parent solution having a pH of 7 at ambient temperatures. A measured volume of this aqueous parent solution is suspended in a mixture of refined oil dispersion fluid and dispersant, most of the water of the aqueous parent solution is removed thermally, and diluted to about 0.3 weight % P. This mixture is used, with further dilution, as an additive to fuels. The dilution is preferably achieved with the same refined oil dispersion fluid. A Group II base oil is preferred. Other preferred dispersion fluids include light hydrocarbons, gasoline, polygas, kerosene, diesel, naphtha light oils, Group I, III, IV, V or VI base oils as defined by API, aromatic oils, polybutenes, polyglycols, heavier oils or combinations of the same. When added to fuel, the aqueous parent solution prepared in this fashion acts to diminish the emission of pollutant molecules under normal operating conditions. An example of an alternate embodiment includes the use of phosphoric acid, potassium hydroxide, ammonium hydroxide in water. Acetic acid

can also be added. The amounts of the components can be adjusted to reach the desired pH.

Example 1

1. Prepare a Phosphoric Acid/ Acetic Acid solution [ $\text{H}_3\text{PO}_4/\text{HOAc}$  Solution]. For  
5 this run, the  $\text{H}_3\text{PO}_4/\text{HOAc}$  Solution is about 90% mole of  $\text{H}_3\text{PO}_4$  and 10% mole of  $\text{HOAc}$ .
2. Prepare for reaction De-ionized water
3. 2,736.39 lbs of the Potassium Hydroxide is added to the water
4. Add to this aqueous solution 1315.14 lbs of the Ammonium Hydroxide (29%)
- 10 5. Into the resulting solution, add the  $\text{H}_3\text{PO}_4/\text{HOAc}$  Solution and allow for reaction.
6. After reaction, adjust pH with acetic acid to a pH of about 7.0. The resulting product of this reaction is useful as the chemical addition component to enhance hydrocarbon fuel.

15 Example 2

- [0028] Laboratory tests with the fuel additive of  $\text{KH}_2\text{PO}_4$ ,  $\text{K}_2\text{HPO}_4$ ,  $[\text{NH}_4]_2\text{HPO}_4$  in refined oil dispersion fluid as an additive in diesel fuels show major improvements in fuel efficiency. Sodium has also been evaluated for use as a cation in this formulation. Group IA metals are also preferred cations. Factors related to selection  
20 of the cation include commercial expense and corrosion resistance.

Example 3:

- [0029] Use of the fuel additive described in Example 2 in combination with a low sulfur diesel fuel provided a 74% reduction in CO emissions in the exhaust gas as compared to diesel without the fuel additive, 34% reduction in  $\text{SO}_2$ , and 55%  
25 reduction in particulates.

Example 4:

[0030] Use of the fuel additive described above in combination with natural gas showed an 87% reduction in the formation of carbon monoxide as compared to combustion of the natural gas without the fuel additive, and an 18% reduction in NO<sub>x</sub>.

5 Example 5:

| Component                                   | lbs    | Unit Ratio<br>weight |
|---------------------------------------------|--------|----------------------|
| -----                                       | -----  | -----                |
| Phosphoric Acid                             | 2,583  | 0.25                 |
| Potassium Hydroxide                         | 2,736  | 0.26                 |
| Ammonium Hydroxide                          | 1,315  | 0.13                 |
| Acetic Acid                                 | 672    | 0.06                 |
| Deionized Water                             | 3,105  | 0.30                 |
|                                             | =====  | =====                |
| Total Phosphorus-Containing Parent Solution | 10,411 | 1.00                 |

Example 6:

| Component                                         | Input<br>Lbs | Unit Ratio<br>weight |
|---------------------------------------------------|--------------|----------------------|
| -----                                             | -----        | -----                |
| Star 4 Base Oil                                   | 8,544        | 0.79                 |
| Kerosene                                          | 1,282        | 0.12                 |
| ODA 78012                                         | 205          | 0.02                 |
| Hitec 646                                         | 205          | 0.02                 |
| Actaclear ND 17                                   | 85           | 0.01                 |
| Phosphorus-Containing Parent Solution (Example 5) | 273          | 0.03                 |
|                                                   | =====        | =====                |
| Total                                             | 10,748       | 1.00                 |

[0031] This is further diluted in base oil to adjust to desired concentration of phosphorus in fuel additive. The solvent is removed from the solution in order to create the fuel additive. In this case, the solvent is water and dehydration is accomplished thermally.

- 5 [0032] An alternate embodiment includes the use of  $[\text{NH}_4]\text{H}_2\text{PO}_4$ ,  $[\text{NH}_4]_2\text{HPO}_4$  and water. In a preferred embodiment, the solvent is one that is defined by solubility or dispersability of the salts in the solvent as well as the volatility of the solvent. For example, the salts are preferably dispersed throughout the solvent but the solvent is of such volatility that it can be boiled out of solution and preferably recovered for reuse
- 10 without affecting the resulting product.

- [0033] While the invention has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention. For example, introduction of the salts into the fuel or the dispersion fluid can be accomplished
- 15 through high speed shear mixing without the creation of an intermediate solution and the subsequent thermal removal of the solvent. Regarding the salts,  $[\text{Y}]_x\text{H}_2\text{PO}_4$ ,  $[\text{Y}]_{x+}\text{HPO}_4$  also encompasses  $[\text{Y}]_x[\text{H}_2\text{PO}_4]_z$ ,  $[\text{Y}]_{x+}[\text{HPO}_4]_z$  where x and z are variable integers.

We Claim:

1. A fuel additive comprising a mixture of salts and a dispersion fluid, the mixture of salts comprising:

(a)  $[Y]_xH_2PO_4$ ; and

5 (b)  $[Y]_{x+}HPO_4$ , wherein  $[Y]$  is a cation, the dispersion fluid being operable to maintain the salts within the dispersion fluid in at least a partially dispersed state, the fuel additive being operable to enhance combustion when placed into contact with fuel in a direct fired burner or open flame and combusted, the enhanced combustion being measurable by increased fuel  
10 efficiency or decreased pollutant output in an exhaust gas resulting from the combustion of the fuel and the fuel additive.

2. The fuel additive of claim 1 further comprising  $[NH_4]_2HPO_4$ .

3. The fuel additive of claim 2 further comprising  $NH_4C_2H_3O_2$  where  $C_2H_3O_2$  is an acetate group.

15 4. The fuel additive of claim 1 wherein the pH of the solution is between about 6.0 and 8.0.

5. A process for enhancing fuel performance of a hydrocarbon fuel in a combustion system having a direct fired burner or open flame comprising the steps of providing the fuel additive of in an amount effective to enhance fuel performance to  
20 the direct fired burner or open flame and combusting the hydrocarbon fuel with the fuel additive, the fuel additive comprising:

(a)  $[Y]_xH_2PO_4$ ; and

- (b)  $[Y]_x\text{-HPO}_4$ , wherein  $[Y]$  is a cation, the dispersion fluid being operable to maintain the salts within the dispersion fluid in at least a partially dispersed state, the fuel additive being operable to enhance combustion when placed into contact with fuel in a direct fired burner or open flame and combusted, the enhanced combustion being measurable by increased fuel efficiency or decreased pollutant output in an exhaust gas resulting from the combustion of the fuel and the fuel additive.
- 5
6. The process of enhancing fuel performance of claim 5 wherein the fuel additive further comprises  $[\text{NH}_4]_2\text{HPO}_4$ .
- 10
7. The process of enhancing fuel performance of claim 5 wherein the fuel additive further comprises  $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$ , where  $\text{C}_2\text{H}_3\text{O}_2$  is an acetate group.
8. The process of enhancing fuel performance of claim 5 wherein the hydrocarbon fuel is a liquid hydrocarbon fuel.
9. An enhanced fuel comprising
- 15
- (a) a substantial amount of hydrocarbon fuel suitable for combustion, and
- (b) an amount of fuel additive of claim 1 operable to enhance combustion.
10. The enhanced fuel of claim 9 wherein phosphorus is present in the hydrocarbon fuel in an amount of between about 1 and 150 ppm by weight.
11. The enhanced fuel of claim 9 wherein the amount of fuel additive is the amount operable to reduce emissions upon combustion of the enhanced fuel as compared to the combustion of the hydrocarbon fuel without the fuel additive.
- 20

12. A process for creating an enhanced hydrocarbon fuel for use in a combustion system comprising the step of:

5 (a) Adding an amount effective to enhance fuel performance to the hydrocarbon fuel of a chemical addition composition, the chemical addition composition comprising reaction products from mixing of a source of phosphoric acid, an alkali metal hydroxide, ammonium hydroxide and water.

13. The process of claim 12 for creating an enhanced hydrocarbon fuel wherein the chemical addition composition further comprises acetic acid.

10 14. A process for creating a fuel additive for enhancing combustion of a hydrocarbon fuel, the process comprising the steps of:

(a) Mixing the salts  $[Y]_xH_2PO_4$  and  $[Y]_{x+}HPO_4$ , wherein  $[Y]$  is a cation, in a solvent to at least partially disperse the salts in the solvent to create an phosphorus-containing parent solution;

15 (b) Mixing the phosphorus-containing parent solution with dispersion fluid such that the phosphorus-containing parent solution is generally dispersed in the dispersion fluid;

(c) Removing a substantial portion of the solvent from the mixture of the phosphorus-containing parent solution with the dispersion fluid to create a fuel additive that is operable to enhance combustion when added to a direct fired burner or open flame in the presence of a hydrocarbon fuel and combusted.

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