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(58) Field of Search:  
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(54) Title of the Invention: **Aqueous metal nanofluid fuel additive**  
 Abstract Title: **Aqueous metal nanofluid fuel additive**

(57) The present invention relates to a composition for a fuel containing fine metal particles (e.g. iron) and a method for producing the composition, and more particularly to a composition for a fuel in the form of a metal particle, wherein the composition comprises metal particles providing in an alkaline aqueous solution, the metal particles being dispersed within that solution and having a size in the range of several nanometres to several micrometres.

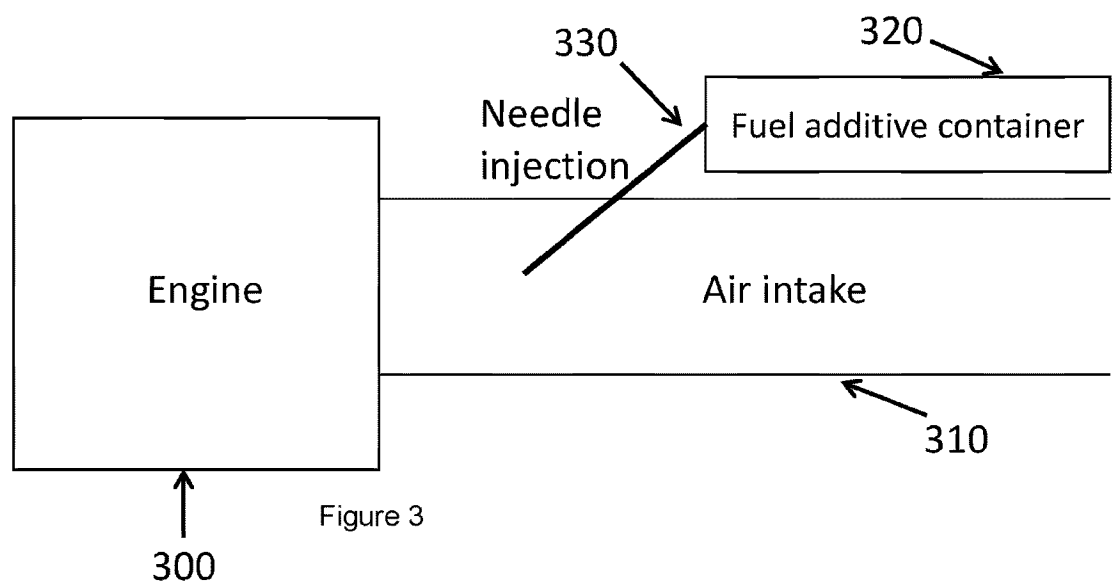


Figure 3

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

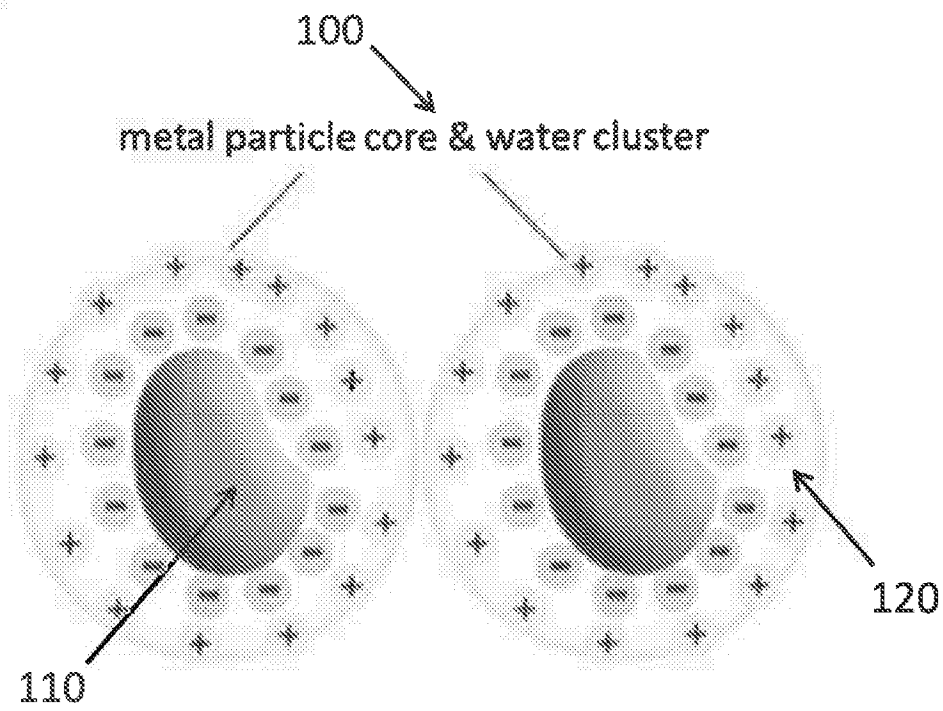


Figure 1A

17 12 19

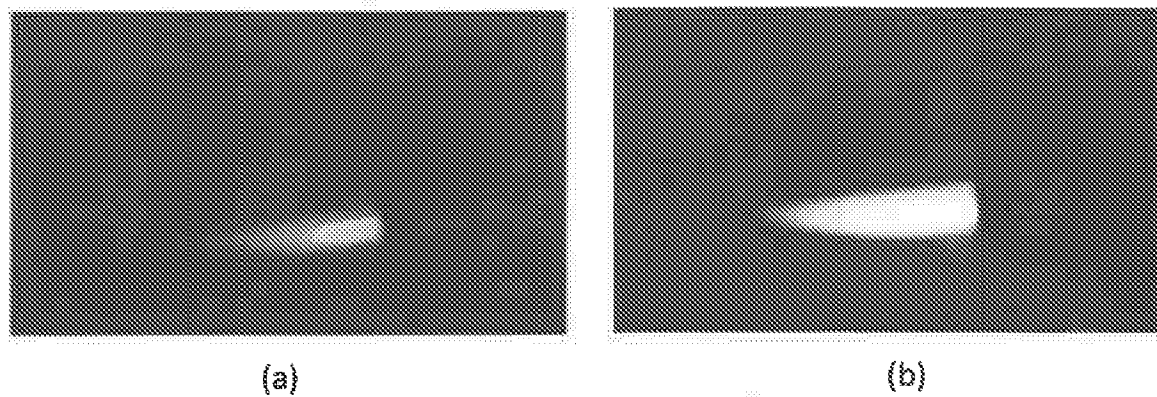


Figure 1B

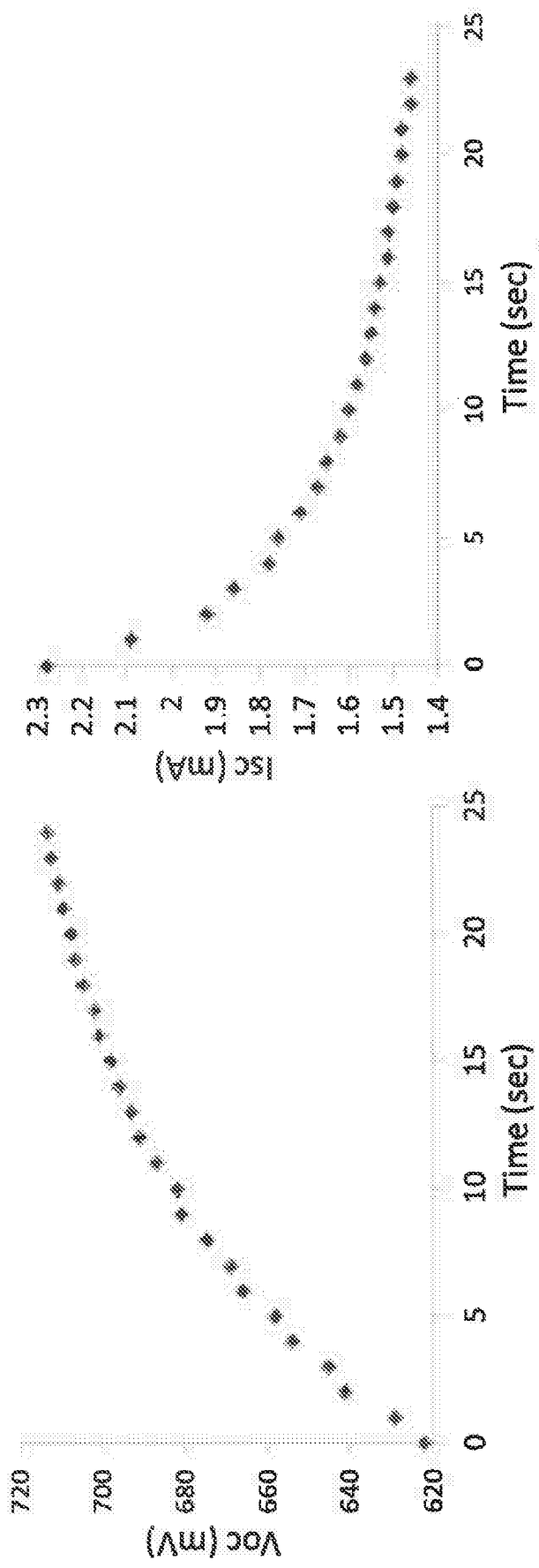


Figure 2

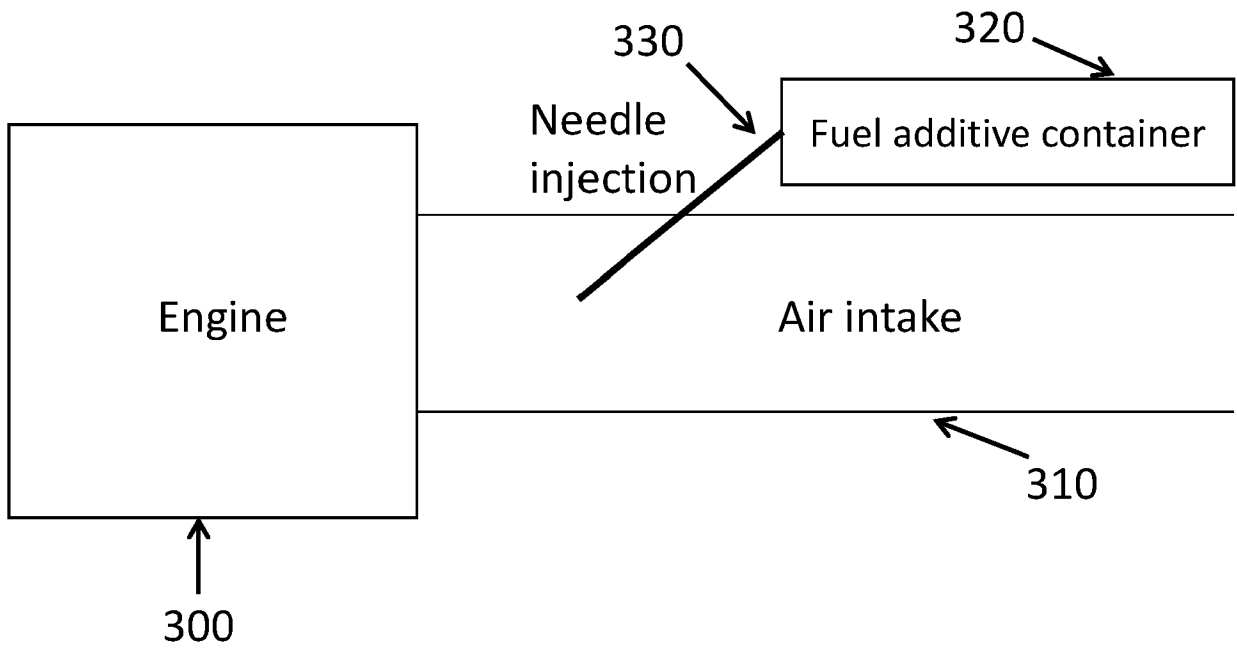


Figure 3

25 06 20

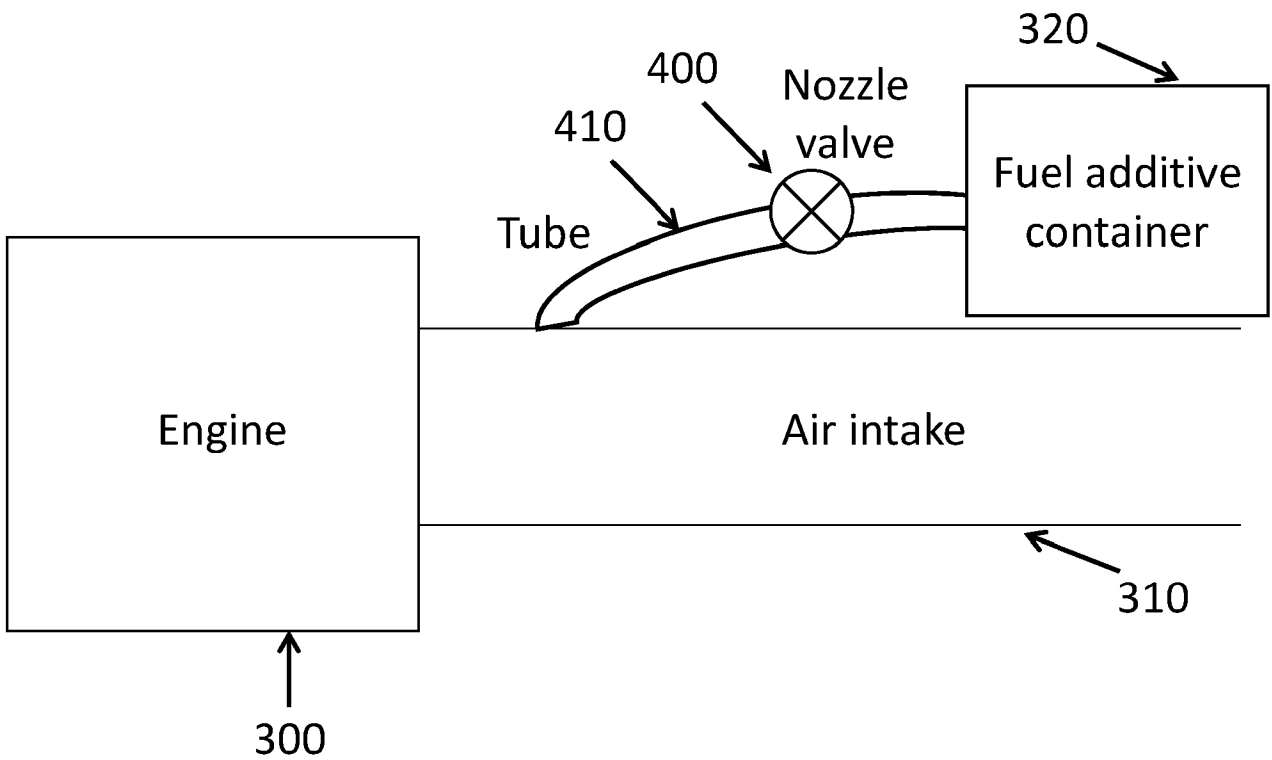


Figure 4

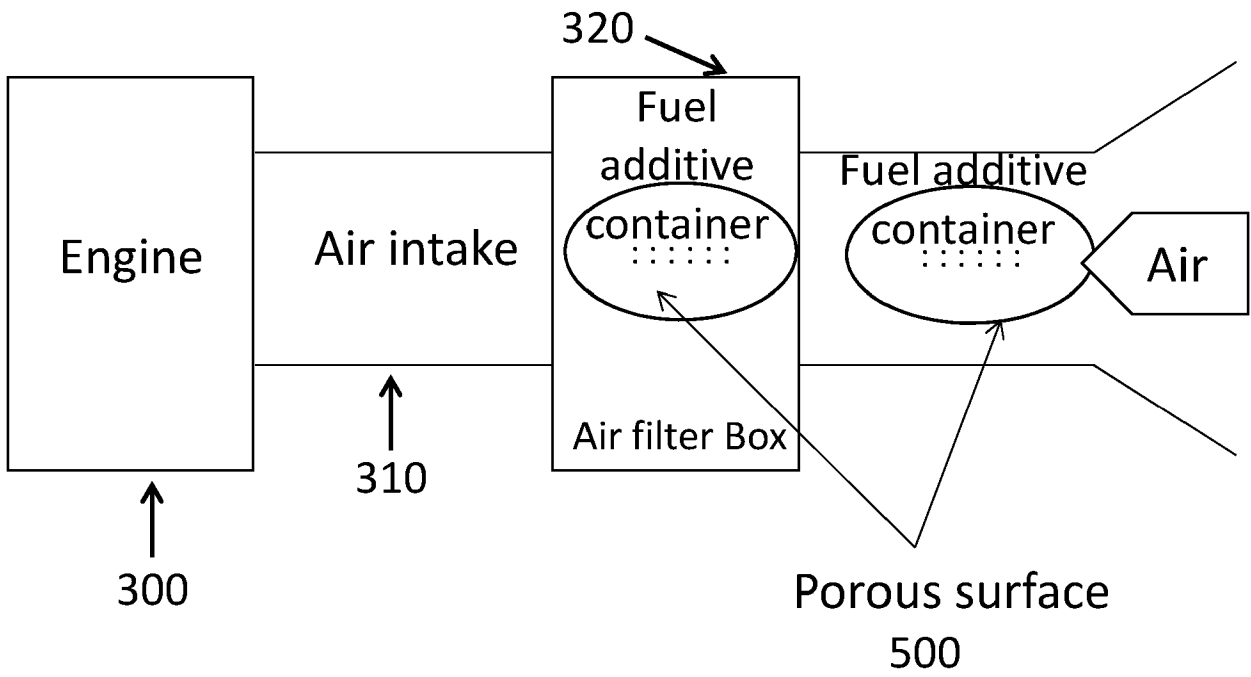


Figure 5

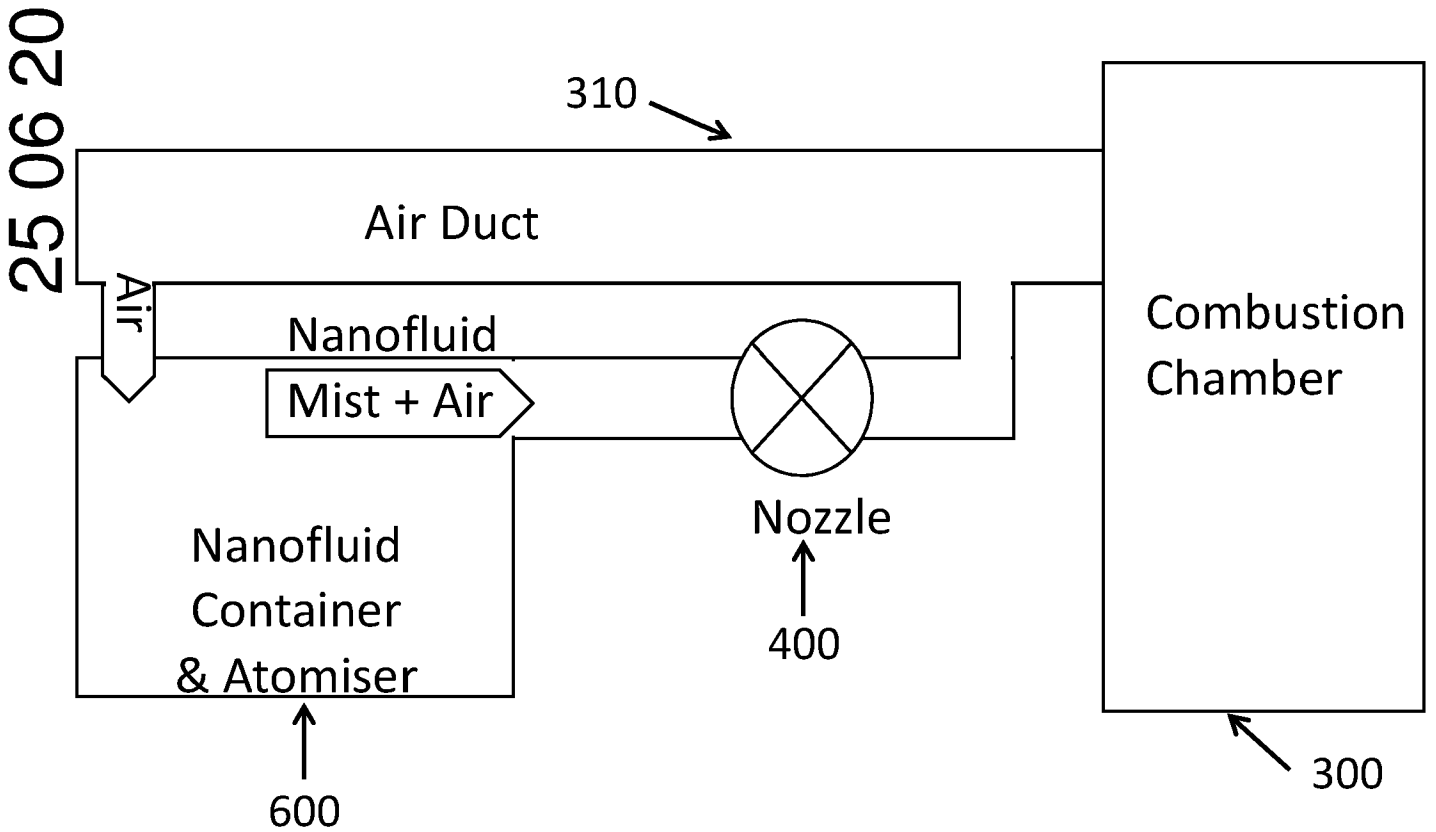


Figure 6

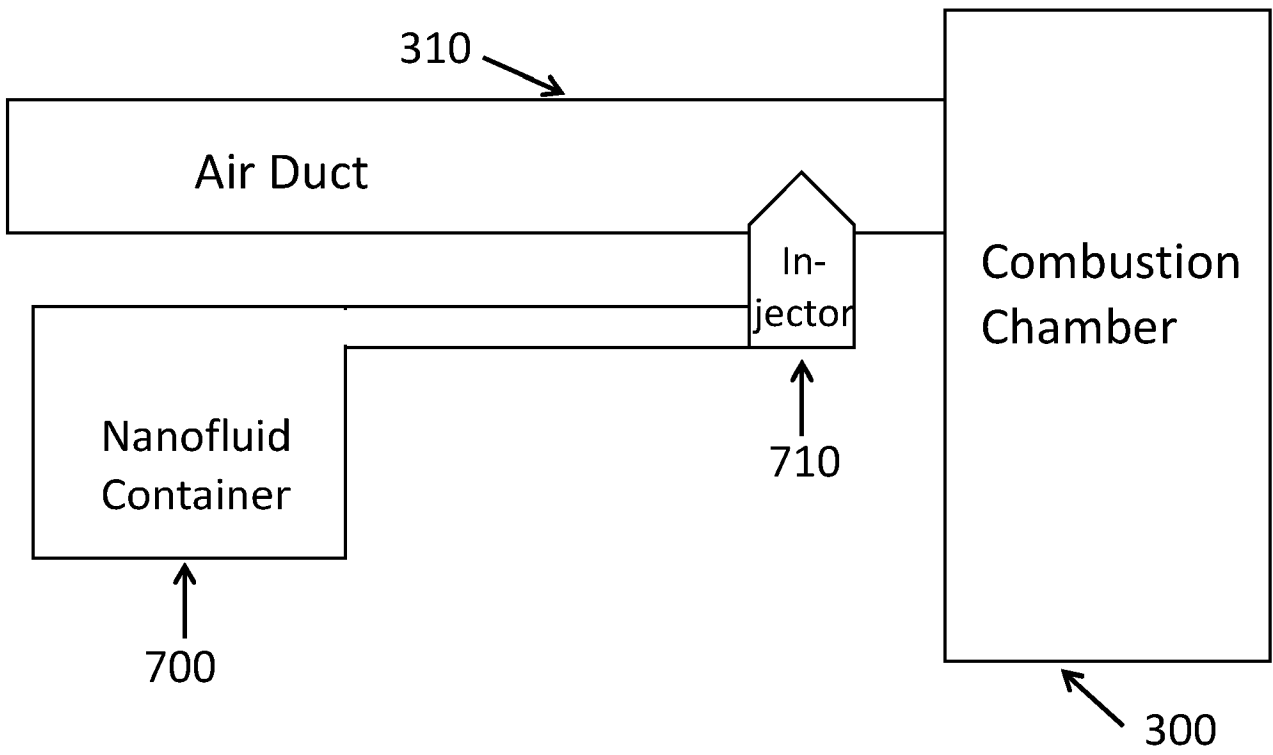


Figure 7

25 06 20

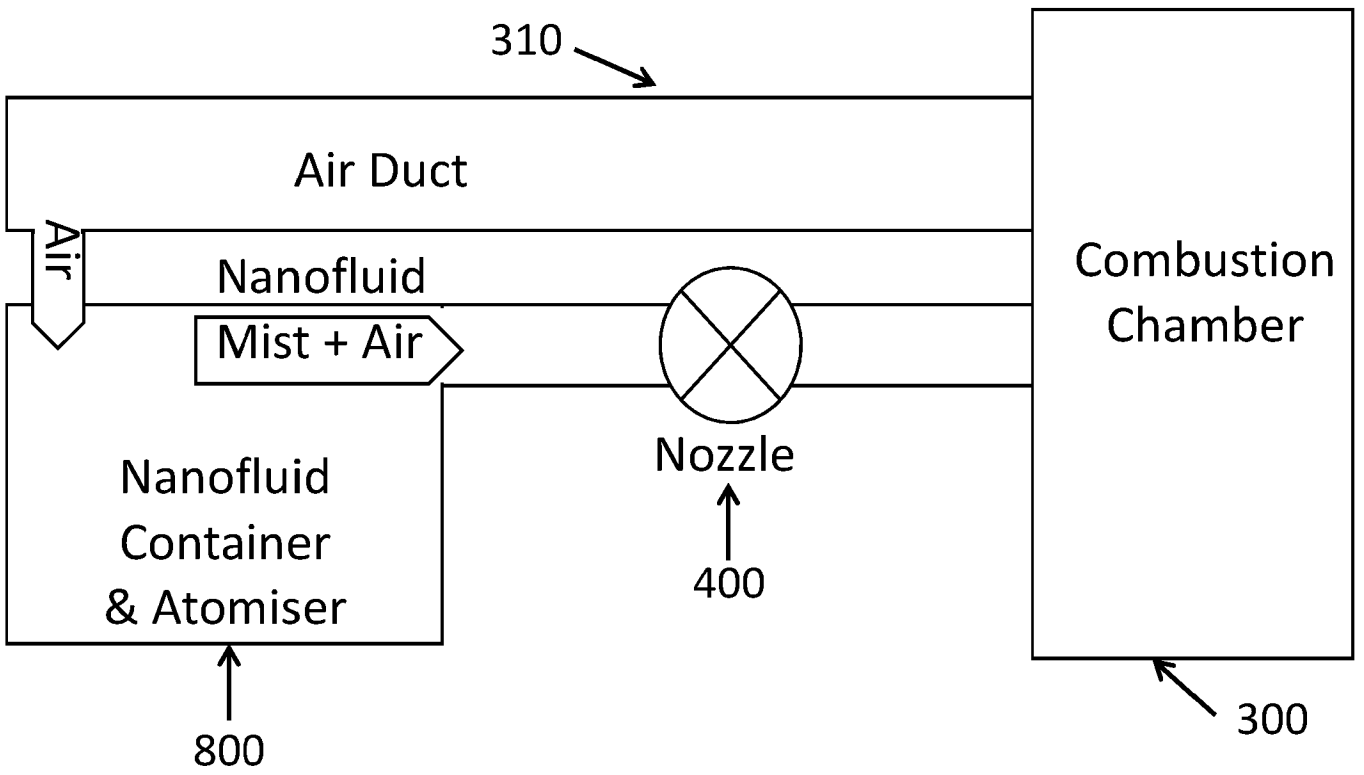


Figure 8

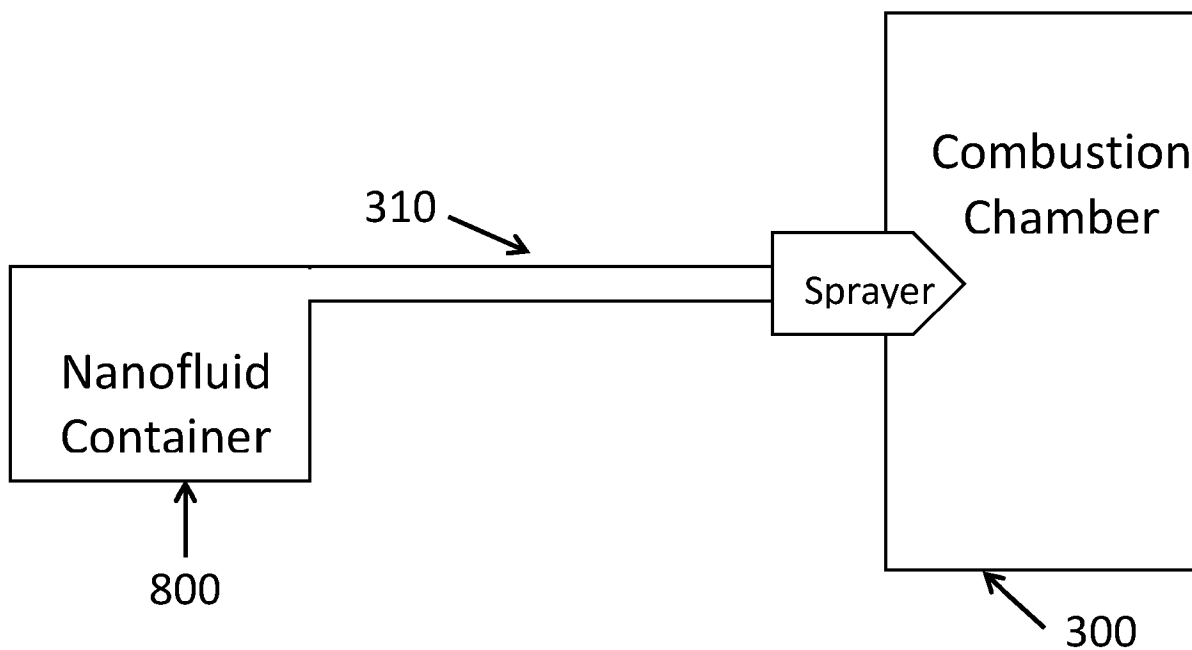


Figure 9

25 06 20

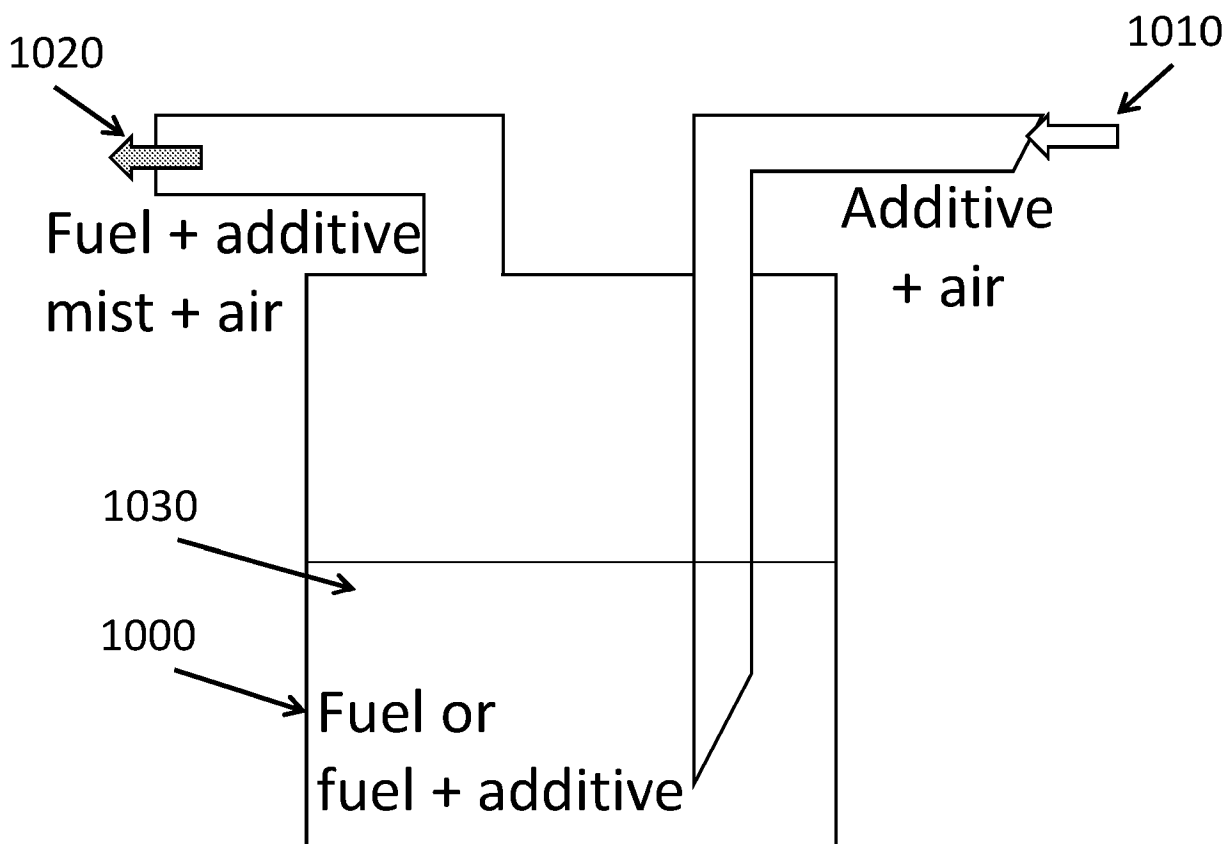


Figure 10

17 12 19

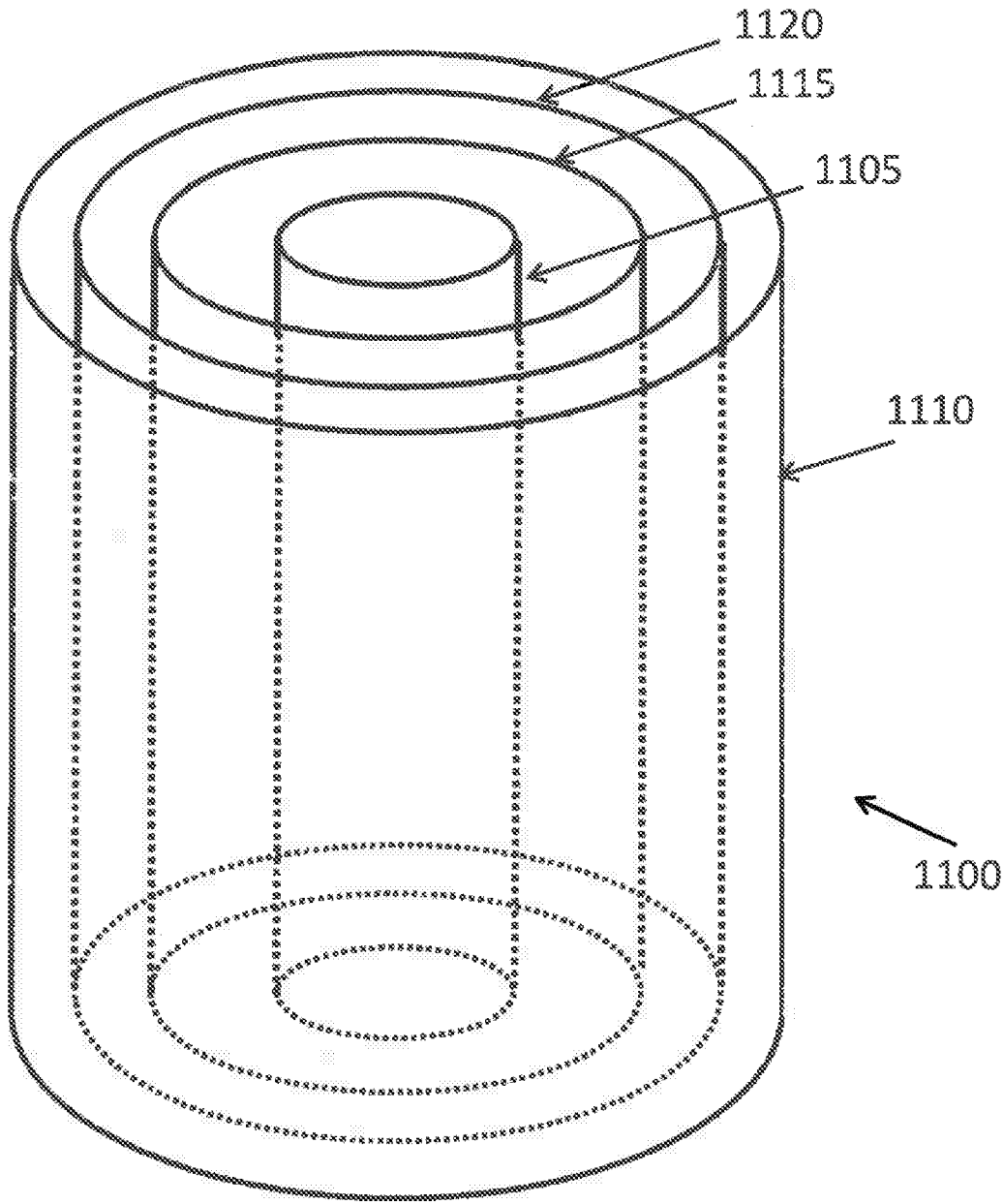


Figure 11



## **TECHNICAL FIELD**

The present invention relates to a composition for a fuel containing fine metal particles and a method of preparing the same, and more particularly, to a fuel additive  
5 comprising an alkaline aqueous solution, in which metal particles of several nanometres to several micrometres are dispersed. The present teaching also relates to a method and apparatus for introducing fuel additives into the combustion cycle so as to improve the efficacy of engines that are using the fuel additive.

## **BACKGROUND**

10 Metal additives such as aluminium have been used in solid form for rockets for many years as a way of increasing the performance, since they have the ability to increase the volumetric heat release of the propellants. Fine particles and microparticles of aluminium, as well as boron and zinc, have also been numerously investigated as a potential fuel additive. Cerium oxide is known to behave as an oxygen-storing agent  
15 in the diesel exhaust catalyser. In addition to aluminium or cerium oxide, it is also known that adding various kinds of fine metal particles into fuel can help decomposition of unburnt hydrocarbon and soot, thus reducing the amount of these pollutants emitted in the exhaust and reducing the amount of fuel used.

20 Metal oxide nanoparticles work as good combustion catalysers when the oxide layer is thin, since the heat expansion of the core metal should break the oxide layer easily in the combustion. For this purpose, it would be preferable if the nanoparticles are created and kept in a less corrosive atmosphere and the exposure time of metal nanoparticles to the air is short before the combustion.

25 On the contrary, the metal in the fuel additive can be accumulated in the combustion system, which may be harmful to the system. The environmental safety of the metal nanoparticles is in question at this time. There is therefore a need for fuel additives that can actively assist in the combustion cycle yet are not contributing adversely to environmental effects.

30 Water injection or a mixture of water and ethanol/methanol injection has been attempted to improve the engine performances. Gasoline engines mainly show an improved octane number with this technology, with the result that there is an improved anti-knocking and a power enhancement effect achieved. Diesel engines mainly show a reduction of the combustion temperature with this technology, and this assists in a reduction of NO<sub>x</sub> exhaustion.

However, at the same time it is also known that water injection is generally known to enhance CO exhaustion and may reduce the fuel efficiency unless it is optimised accurately. The water aerosol size is a critical factor in this technology, since water aerosols of a big size can hinder the uniform air-fuel mixture in the combustion chamber.

WO2015003678A1 describes a method of operating an internal combustion engine, a turbine or jet engine and a means for introducing a fuel additive into the air passage of an internal combustion engine, a turbine or jet engine. In the method, the additive is transferred from a liquid to a droplet state and is then introduced into the fuel through an air channel during actual use of the fuel in the combustion process. As a result of directly passing a droplet form of the additive into the passage its dosage in the ppm range can be effectively controlled. This differs from other fuel additive arrangements where the additive is mixed directly into the fuel – either before being dispensed from retail fuel pump into the vehicle or mixed into the fuel within the fuel tank of the vehicle.

Despite these approaches there continues to be a need to develop a fuel additive that can improve the efficacy of the fuel combustion process.

## **SUMMARY**

The present invention has been made in order to solve the problems of the prior art as described above, and in accordance with the present teaching there is provided a fuel additive formed from an aqueous alkaline solution comprising metal nanoparticles, a nanofluid composition, dispersed therein. The present teaching then provides a fuel injection system whereby the fuel additive is actively injected into the fuel stream during the combustion process.

The nanofluid composition preferably comprises water as a main component.

The metal particles of the nanofluid composition preferably include an iron component as a main component.

The nanofluid composition preferably further comprises a sodium ion component as a main alkali metal ion component.

It is preferable that the nanofluid composition has an ammonia/ammonium value of 3 to 10 mg/L when fabricated.

It is preferable that the nanofluid composition has a pH value of 8.5 to 12.5 in the state after the fabrication process.

The nanofluid composition preferably has a Total Dissolved Solid (TDS) value of 1800 to 3500 ppm in the state after the fabrication process.

5 The total amount of the metal ion and the dispersed metal particles within the nanofluid composition after finishing the fabrication process is preferably 10 to 100 mg/L. The metal particles within the nanofluid composition preferably have a size range of several nanometres to several micrometres.

The present invention also provides a method for preparing a nanofluid composition for a fuel additive, wherein the metal particles are eluted from electrodes and dispersed in an alkaline aqueous solution.

10 The fabrication process desirably comprises an electrolysis step whereby metal particles are eluted from an electrode and are then filtered to remove excess sized particles.

It is preferred that the electrolysis process is performed using power of 1 to 3 W per 5 L of the composition.

15 The present invention also provides a method for using the nanofluid composition as a fuel additive, wherein the composition or its mixture with water and/or water miscible solvents is injected through an air inlet or added directly to a fuel.

20 The injection method is preferably via an air intake path or is achieved by directly spraying the additive into the combustion system. The fuel additive injection amount can be controlled via one or more nozzles and/or the atomiser power. The nanofluid composition or its mixture with water/solvent can be atomised via a carburettor or an ultrasonic vibrator or an air bubbler or a sprayer or other droplet methods. The nanofluid or its mixture with water/solvent can be used with commercial water or water/solvent injection devices. The injection devices may comprise a temperature  
25 controller and an ioniser.

The dosing ratio of water insoluble fuel: additive is typically 100:1 to 1,000:1 and can vary outside this range according to the combustion system and the purpose of fuel additive.

30 The sludge by-product may be filtered out of the nanofluid as the last step of the fabrication process and can be preferably utilised as a constituent of a mineral fertiliser, a raw material for electrets (constant voltage capacitor), a photo-sensitive material of solar cells, a raw material for photo-sensitive capacitors and a catalyser material of fuel cells.

These and other features will be better understood with reference to the following exemplary arrangements which are useful for a better understanding of the present teaching.

## 5 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic showing a nanofluid composition in accordance with the present teaching.

10 FIG. 1B is a schematic showing changes in intensity of a flame generated when a nanofluid composition prepared according to an embodiment of the present invention is sprayed onto a butane gas flame.

FIG. 2 is a graph showing the results of measurement of the voltage-current characteristics of the nanofluid composition prepared by the method of the present invention. The electrodes used for this test are the same as the electrolytic cell used for preparing the nanofluid composition.

15 FIG. 3 is a schematic view showing a method of injecting a fuel additive prepared according to an embodiment of the present invention into an air injection port of a combustion system using a tubular body such as an injection needle or a tube.

20 FIG. 4 is a schematic view showing a method of injecting a fuel additive by connecting a fuel additive prepared according to an embodiment of the present invention to a fuel additive vessel (fuel additive container) through a nozzle into an air inlet port.

FIG. 5 is a schematic view showing that a fuel additive prepared according to an embodiment of the present invention is accommodated in a container having micropores and is installed on one side of an air inlet.

25 FIG. 6 shows an injection system schematic configured to provide a mixing of air and the fuel additive vapour/aerosol/mist prior to introduction to the combustion chamber.

FIG. 7 shows a variant injection system schematic configured to provide a mixing of air and the fuel additive vapour/aerosol/mist prior to introduction to the combustion chamber.

30 FIG. 8 shows an injection system schematic similar to FIG. 6 but configured to provide a mixed air and the fuel additive vapour/aerosol/mist directly into the combustion chamber.

FIG. 9 shows an injection system schematic similar to FIG. 7 but configured to provide a mixed air and the fuel additive vapour/aerosol/mist directly into the combustion chamber.

5 FIG. 10 is a schematic view showing a method of injecting a fuel additive prepared according to an embodiment of the present invention into an engine by mixing the fuel with a bubbler method.

FIG. 11 is a schematic diagram showing a typical electrolytic cell that may be used to fabricate a nanofluid composition in accordance with the present teaching.

## 10 DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, the present invention will be described in more detail based on preferred embodiments and drawings.

15 The present invention discloses an alkaline aqueous solution in which nanometal is dispersed as a fuel additive and a method of electrolysing an aqueous solution in which nanometal is dispersed to produce such a fuel additive is also described. The aqueous solution exhibits unique electrostatic charging behaviour and high catalytic behaviour upon combustion.

20 Per the present teaching, and as shown in the exemplar arrangement of Fig. 1A, the fuel additive comprises a nanoparticle 110 that forms the core of a combined nanoparticle and water 120 cluster 100. In this arrangement the metal nanoparticles and water cluster 100 can be delivered in a vapour/aerosol/mist phase and desirably exhibit a charged exterior surface.

25 The water cluster 100 is desirably formed using an alkaline base and this alkaline aqueous base provides a suppressed growth rate of metal oxide layer, which is an advantage for a fine metal particle. The metal nanoparticles 110 maintain a thin oxide layers since they are generated in an alkaline solution through an electrolysis methodology and are kept in an optimally alkaline solution before they are delivered into the combustion environment.

30 As a result of the charged effect of the composition, and due to the Coulomb repulsion effects, the charged cluster does not agglomerate and stays as a fine mist form and mixes with air uniformly when it is atomised. The electrostatic characteristic of the cluster prevents water from entrapping the fuel, therefore air/fuel ratio stays the same which has no detrimental effect on the expected combustion process or efficiency.

Once introduced into a combustion chamber, such as the combustion chamber exemplified by the engines 300 of Figures 3 to 5 or the more generically described chambers 300 of Figures 6 to 9, as the temperature and pressure of the combustion chamber increases, an explosive breaking of the cluster prior to the main explosion will spread the water and metal nanoparticles in the chamber uniformly. This explosive migration and collision will enhance the uniformity of air-fuel mixture in the chamber. Therefore combustion is catalysed.

In this cluster breaking process, some water molecule can create hydrogen, which will assist with clean burning. Concurrently with this explosive breaking, the resultant heat is absorbed by the water or the cluster. Therefore the combustion temperature would be lower, while the mechanical movement in the combustion chamber is not reduced.

The presence of the metal nanoparticles inside the combustion chamber augments the heat transfer to fuel and shortens the ignition delay through an acceleration of the burning process. Since smaller particles have a greater surface area per unit mass, they will ignite more readily and burn faster. When a fine particle is heated to its own ignition temperature, other neighbouring particles will ignite together. The smaller the particle, the faster the entire particle can heat up and for some metals reach its ignition temperature.

Further, the metal oxide nanoparticles act as an oxygen donor, and provide oxygen for the oxidation of CO, or absorb oxygen for the reduction of NO<sub>x</sub>. This oxygen storage capability can be combined with hydrocarbon fuels and reduce soot formation.

Furthermore, the alkali metal ions remove particle precursors. The alkali metals inhibit the nucleation of particle precursors showing detergent effects.

### <Examples>

In order to prepare the nanometal aqueous solution according to the present invention, an electrolysis method in an alkaline aqueous solution was introduced, and erosion of the metal electrode was induced so that the metal nanoparticles are contained in the aqueous solution.

In the apparatus for electrolysis, such as the apparatus 1100 referenced in Figure 11, the electrode 1105, 1115, 1110, 1120 contains an iron component, and is preferably non-magnetic (food grade) stainless steel. In other words, the nanometals that are produced include the components of the stainless steel. The electrolytic cell 1100 is in the form of a cylinder, and the electrodes are stacked to form a multi-layered structure.

An inner electrode 1105 is desirably dimensioned smaller than the outer most

electrode 1110, and the smaller-sized electrode 1105 is located inside the larger-sized electrode 1120. The inner electrode 1105 is typically coupled to a negative pole and to ground. The outermost electrode 1110 is connected to a plus pole. In this exemplary arrangement, intermediary electrodes 1115, 1120 are provided between the inner  
5 1105 and outer 1110 electrodes and their potential is a floating potential. Spacers which are chemically inactive in the electrolysis process are provided between the electrodes to maintain their relative separation.

The gap between the electrodes is 5 to 15 mm, and the spacers/separator provided between the electrodes must be chemically inert or durable in the electrolysis process.

10 In addition, the electrode 1105 of the deepest portion is connected to the cathode and the ground respectively, and the outermost electrode 1110 is connected to the anode. Other electrodes are electrically insulated between the positive electrode and the negative electrode.

The use of electrolysis is a well-known technology, and a detailed description of the  
15 configuration of the electrolytic cell will be omitted. That notwithstanding it will be seen that the structure of the electrode cell of Figure 11 is preferably cylinder. If it is dimensioned to receive about 5L of water, it is desirable to place the 2 neutral cylinders 1115, 1120 between the anode 1105 and the cathode 1110. The main erosion happens in anode cylinder 1105 and the eluded material becomes dispersed as  
20 nanoparticles. Using such an arrangement with stainless steel electrodes an exemplary electrolysis process will now be described.

A solution comprising water, ethanol and ammonia/ammonium is introduced into the electrolytic cell. The main electrolyte is NaCl and the minor electrolyte can be  
25 comprised of various metal salts. The solution can contain powder of various quartz minerals. The solution can contain Mg and Zn. Ethanol mixture to the water is preferably 0.5 to 1.5 % by volume.

To supply ammonia/ammonium to the solution, human or any similar animal urine can be used. If the urine is used, the pH value is preferably 5 to 6 and mixed into water at 0.5 to 2 % by volume. The urine can be replaced by an urea solution.

30 Mg and Zn can be added to the solution as a salt form. Mg is added 100 to 300 mg/L and Zn is added 0 to 100 mg/L of the solution.

The electrolyte is added at a ratio of 2 to 8 g/L of the solution. One can use a ready-made mixture of various salts and quartz minerals, e.g. an alkaline salt such that sold under the trade mark MeineBase salt.

In a preferred arrangement, the TDS value before starting the electrolysis process varies 1500 to 2500 mg/L and after finishing the fabrication process, 1800 to 3500 mg/L at 20 °C measured through its conductivity.

5 Total amount of the metal ion and the dispersed metal particle after finishing the fabrication process can vary 10 to 100 mg/L measured by Inductive Coupled Plasma Optical Spectroscopy.

The ammonia/ammonium value before starting the electrolysis process can vary from 2 to 5 mg/L before the fabrication process and from 3 to 10 mg/L after finishing the process.

10 Having introduced the electrolyte solution into the electrolytic cell, the electrolysis uses on/off DC current with on time of 5 sec and off time of 10 sec, or the frequency can be adjusted keeping the duty ratio fixed. The current at on time is preferably 0.4 to 0.8 A and the voltage should be controlled to have the desirable power consumption of 3 to 9 W at on time per 5 L of solution, therefore the averaged power consumption is 1 to 15 3 W per 5 L of solution. In this case, it is difficult to generate nanometal when the lower limit is exceeded, and excessive electrode corrosion occurs when the upper limit is exceeded.

20 The electrolysis solution temperature is preferably maintained at 30 to 45 °C. It is desirable to prevent the evaporated solution does not flow back to the electrolyzing bath. The electrolysis process continues preferably for 22 days.

25 Post processing, the sludge of the electrolysis process must be filtered out by a filter paper with pore size of 2 to 8 micron. As discussed below, the sludge may be advantageously used for other applications. When 5 L of water was used in the beginning, 2.5 to 3.5 L of solution remains after finishing the process due to evaporation and filtering process.

During the fabrication process the alcohol is evaporated and a nitrogen constituent of the urea and/or uric acid is retained in its ammoniac form ( $\text{NH}_3 / \text{NH}_4^+$ ).

30 If salt is out of the upper limit, there is a problem of excessive corrosion of the electrode, and the powder material such as quartz should be added in the upper range to help the nano-sized metal do not agglomerate and to corrode in the nano size. Within the conductivity range, the substances induce biochemical phenomena appropriately.

35 The electrolytic solution has a pH value of 8.5 to 9.5 in the prepared state in which the metal particles are not contained. The above pH value is an important factor that must be controlled in order to maintain the surface oxide film of the nanometal to be formed



thinly. The pH value should be alkaline. If the above range is exceeded, the electrolysis reaction becomes excessively rapid. Within the above range, the alkalinity is optimal to suppress oxidation of metal particles such as iron. The pH value thus has a critical significance in this range.

- 5 In addition, it is preferable that the pH of the nanometal aqueous solution after the fabrication process is completed has a value of 8.5 to 12.5, meaning that the upper limit is set to 12.5 so as to prevent the reoxidation of the metal particles. That is, when the pH exceeds 12.5, the metal particles (for example, iron) may start to be oxidized again. Therefore, the pH should not exceed 12.5.
- 10 The pH value of the aqueous solution is closely related to the pH value of the starting electrolyte. In order to maintain the pH of the upper limit 12.5, the pH value of the starting electrolyte should be maintained within the range described above. Therefore, the pH value of the nanometal aqueous solution has its critical significance in the above range.
- 15 As a result of carrying out the electrolysis process, by-products are generated separately from the production of the fuel composition, and these by-products are of value for recycling. This by-product sludge can be utilised as mineral fertiliser, electret (constant voltage capacitor), photo-sensitive material for solar cells, photo-sensitive capacitor and the catalyser for fuel cells.
- 20 The characteristic of the aqueous metal nanofluid is highly sensitive to the temperature and/or pressure for operation and also for storage. The finished nanofluid should be kept sealed in the dark with the preferred temperature of 5 to 25 °C. Outside the range, the nanoparticles and ions agglomeration rate and fungi growth rate increase therefore the nanofluid degrades quickly. When the nanofluid is atomised, the
- 25 vapour/aerosol/mist has to be generated at 10 to 25 °C. Below the lower limit, the cluster disturbs the heat expansion in the combustion cycle and above the upper limit, it the cluster will not be formed ideally.

30 Once the nanometal solution is formed, it can be mixed with water, organic water miscible solvents and/or inorganic water soluble solvents, where the mixing ratio of the added component is preferably less than 40 % by volume of the nanofluid.

### **<Evaluation examples>**

Table 1 shows the composition of the main metal added in an amount of 1 mg/L or more in the aqueous solution of the nanometal dispersed according to the present invention which can be used as a fuel additive. The composition was measured by

35 Inductively Coupled Plasma Optical Spectroscopy and it may vary depending on the electrode material and additives used in electrolysis.

[Table 1]

Element	Aluminium	Chromium	Iron	Sodium	Nickel
mg/L	5.4	5.1	20.4	22.9	6.4

5 Since stainless steel was used as the electrolytic cell and sodium chloride was used a main electrolyte, the main constituents are iron and sodium. In a preferred arrangement as the metal particles are eluted from a stainless steel electrode through this electrolysis process.

Table 2 below shows the characteristics of the nanometal aqueous solution prepared according to the present invention using Laser Doppler Micro-Electrophoresis. The ambient temperature is 25 °C. For this measurement, the nanofluids were filtered by a 450 nm radius filter paper.

10 [Table 2]

Zeta Potential (mV)	-2 to -20
Conductivity (mS / cm)	12 to 15
Average particle radius (nm)	40 to 150
Polydispersity Index	0.1 to 1

15 Despite the high pH value of 11 or higher, the relatively low zeta potential is indicative of the ability of the composition according to the invention to accumulate charge. The value of the conductivity is correlated with the high pH, However, since it is the conductivity data by the optical method, the result may differ slightly from the method of flowing the current directly. The average size of the nanoparticles is 40 to 150 nm, but high polydispersity index shows high diversity of the particles.

FIG. 1B is a schematic showing changes in intensity of a flame generated when a nanometal aqueous solution prepared according to an embodiment of the present invention is sprayed onto a flame.

20 As shown in FIG. 1B, the butane gas flame intensity of the lighter differs between (a) before applying the nanometal aqueous solution of the present invention and (b) the supply of the atomised nanofluid, respectively.

25 The brightness of the flame became brighter as the atomised aqueous solution was supplied. At this time, the nanometal and the metal ions of the aqueous solution were burned, and the colour change to yellow occurred.

FIG. 2 shows the electrical behaviour of the nanometal aqueous solution prepared in accordance with an embodiment of the present invention in an open state and in a short circuit state without supplying an external current.

The nanometal in the aqueous solution draws the electric charge around it, and when the electrode is connected, an electrostatic potential is formed on the electrodes. As shown in FIG. 2 (a), in the open, an electrostatic potential is formed in the system. As shown in FIG. 2 (b), when the short circuit current  $I_{sc}$  starts from a maximum of 2.3 mA, and approaching a balanced point where the charge is drawn from the periphery and consumed by the short circuit. This operating state can be repeated.

The principle of operation when a nanometal aqueous solution is used as a fuel additive is as follows.

When an aqueous solution of nanometal is introduced into an internal combustion engine, the aqueous solution heats up, the water-nanometal cluster breaks explosively, spreading uniformly in the combustion chamber. When the metal particles are dispersed in an appropriate level in the air, the ignition of the fuel is uniformly spread in the chamber or the cylinder, thereby increasing the combustion efficiency. Also, the charge generated in the aqueous solution and generated during atomisation is discharged in the chamber or the cylinder to help the ignition process. Taking this into consideration, the amount of energy required for combustion can be reduced by introducing nanofluid. When the nanometal aqueous solution is supplied in an injected manner through the air inlet or directly into the chamber, it becomes more energy-efficient than when it is mixed directly into the fuel tank, which makes it easier to contact the metal particles in the air with higher degrees of freedom thus the reaction can proceed more actively.

FIGs. 3 to 5 illustrate a method of supplying a nanometal aqueous solution or its mixture with water/solvent as a fuel additive to an internal combustion engine in embodiments.

A combustion system, such as an automobile, a ship, an aircraft, a generator, a boiler, etc., may be equipped with a dosing system for allowing the fuel additive of the present invention to mix with fuel through an air inlet. At this time, it is possible to provide a control unit for controlling the amount of injection according to temperature, fuel injection rate, air flow rate, torque, and number of revolutions per minute (rpm) of the engine or the like, or use a tubular body such as a needle for main use connected to the air inlet.

FIG. 3 is a schematic view showing a method of injecting a fuel additive prepared according to an embodiment of the present invention into an air injection port 310 and then into an engine 300 of a combustion system using a main body of a needle 330,

tube, or the like. The fuel additive is initially provided in a container 320. In order to precisely adjust the addition ratio of the additive, the diameter of the tubular body should be properly adjusted. The diameter of the tube is related to the flow rate. If there is no space in the container 320 within which the fuel additive is provided, a connection tube may be interposed between the container and the tube.

In a variation where similar components are described with the same reference numerals, FIG. 4 is a schematic view showing a method of injecting a fuel additive of the present invention by connecting a fuel additive prepared according to an embodiment of the present invention with a tube 410 through a flow control valve 400 from a fuel additive container 320 (nanofluid composition container) to an air inlet port 310. The tubular body may be composed of a tube, a pipe, or the like. In addition, a control unit for controlling the flow rate control valve may be separately provided.

The mixing ratio of the air and the fuel additive can be varied by adjusting the flow control valve 400 between the fuel additive container 320 and the air inlet 310. The flow control valve or controller is connected via a tubular body, but may also be connected directly to the vessel.

It can also be controlled by a temperature controller, and/or an ultrasonic vibrator and/or a pressure regulator that keeps the atomisation rate constant. In the context of temperature controller, the present inventor has identified keeping the temperature of the introduced composition in the range 10 to 25 °C is particularly advantageous. During storage i.e. pre-introduction to the air stream, it is desirable to have a temperature controller of the liquid container configured to maintain the liquid at the range of 5 to 40 °C to avoid a rapid degradation of the nanofluid.

This mixing ratio is determined by considering the positive catalytic effect of the nanometal and the negative effect of the water vapour/aerosol/mist which disturbs air-fuel mixture. The dosing ratio of water insoluble fuel : additive can vary 100 : 1 to 1,000 : 1 initially. As the fuel additive effect settles in the combustion system, the dosing ratio can be reduced to 50,000 : 1. In case of using water soluble fuel as the main fuel, the mixing ratio can vary more flexibly and purposefully, and it can go up to 1 : 4, where the nanofluid is consumed more than the fuel itself.

The conditioning system may be installed in the fuel additive container portion. This stabilizes the air/fuel mixing ratio and the aerosol (mist) size. In this way, the fuel additive injection amount can be controlled via one or more nozzles and/or the atomiser power according to the amount of the air flow and the fuel injection. In other configurations, its rate of introduction can be varied in accordance with sensed variation in engine performance such as engine rpm and/or the torque.

FIG. 5 is a schematic view showing that a fuel additive prepared according to an embodiment of the present invention is accommodated in a container 320 having micropores 500 and is simply installed at one side of the air inlet.

As shown, the fuel additive of the present invention can be discharged through the micropores from the vessel by the pressure in the air injection tube, from which nanofluid can be supplied to the fuel.

More specifically, the method of injecting the fuel additive of the present invention through the air inlet comprises providing a housing 320 having a fine pore channel 500 on one side of the air inlet, housing the composition in the housing, and applying the vibration to the composition. Subsequent to the vibration to effect on dispersion of the nanometal within the aqueous alkaline solution, the container can be pressurised through the introduction of air which causes a subsequent discharge of the fuel additive through the air inlet 310 and into the fuel channel. Here, the vibration is, for example, a vibration generated by an engine or a vehicle, but it is not necessarily limited thereto, and the vibration may be artificially applied.

Meanwhile, the method of injecting an atomised fuel additive through the air inlet may be performed by a water mist generating device or an air bubbler or an aerosol spraying device other than the enclosure, and the enclosure, the mist generating device or the air bubbler or the aerosol spraying device can be installed in the air filter box of the air inlet.

The mist generator or the air bubbler or the aerosol spraying device itself is a known technology, so a detailed description thereof will be omitted.

FIGs. 6 and 7 show alternatives to that of FIG. 3 to FIG. 5 where the fuel additive is provided into the air duct 310. In both configurations, the composition is injected into the air duct, preferably after a lambda probe 400 and nearest to the combustion chamber 300. In Fig. 6 the fuel additive container and the atomiser can be separated or embedded in a bottle 600. The method of how to achieve the necessary atomisation can be for example through use of a carburettor, an ultrasonic vibrator or a bubbler, where fine size mist or aerosol is created under a low temperature. A part of the air from the air duct flows through the atomiser and mixes with the fuel additive vapour/aerosol/mist. The temperature controller can be embedded in the atomiser and the container. The ioniser can be embedded in the atomiser.

In FIG. 7, the injection method can be pressure driven spray, ultrasonic vibration, capillary motion driven droplet via a porous material or weight driven droplet via a needle 710. The injector 710 can have an ioniser, which functions similarly to electrostatic spray guns. In this scheme, the temperature controller can be installed in the container 700 or in the line between the container and the injector

FIGs. 8 and 9 show two further variations, where in FIG. 8 there is detailed an injection system that facilitates a mixing of the air and the fuel additive vapour/aerosol/mist 800 prior to injecting the mixture directly into the combustion chamber 300 via a nozzle 400. FIG. 9 uses a similar mechanism to that of FIG. 7 in that the injection method can be pressure driven spray, ultrasonic vibration but differs in that it injects the fuel additive directly into the combustion chamber.

FIG. 10 is a schematic view illustrating a method of mixing a fuel 1030 with a bubbler 1000 by atomising an aqueous nanometal solution 1010 prepared according to an embodiment of the present invention. This type of fuel injection can replace the fuel carburettor, especially for mixing with ethanol/methanol fuel. The bubbler can be equipped with a thermostat and a device that stabilizes the mixing ratio by maintaining the height of the fuel. The output of the bubbler is a mixed fuel, and additive mist and air combination 1020.

In this way it will be appreciated that the present teaching provides the composition into the fuel as an aerosol/mist. The nanofluid or its mixture with water/solvent can be atomised via one or more of a carburettor or ultrasonic vibrator or air bubbler or sprayer or droplet or any other aerosol delivery method. Indeed, the injection system can incorporate an ioniser and ionisation of the fluid concurrent with its introduction into the fuel system can be achieved through corona discharge or electrostatic induction. This principle of ionisation is the same as commercial air ionisers or electrostatic spray guns but heretofore has not been used in the context of fuel additives for combustion engines. The advantages of using an ioniser is that the mobility and the catalytic activity of the vapour/mist/aerosol are enhanced and the aerosol size and the spraying angle can be adjust.

The air entering the upper right inlet 1010 of FIG. 10 causes a turbulence in the bubbler due to a strong flow rate as the mixed vapour/aerosol/mist enters the fuel (or may be mixed with the fuel additive) container. The bubbles are mixed with the fuel additive, air, and fuel, and are sucked into the engine cylinder through the outlet 1020 at the upper left of FIG 10. When a bubbler of this structure 1000 is installed instead of a fuel tank, it is usually possible to connect the output end of the bubbler to the air inlet of the engine, and to lock the fuel inlet of the engine, and to optimize the bubbler without special modification of the engine. This scheme is advantageous when ethanol or methanol is used as the main fuel instead of gasoline, because an optimisation of air/fuel mixture is easily obtained.

When the nanometal aqueous solution or its mixture with water/solvent is directly mixed with the fuel, the fuel may be mixed in the pre-stage or the injection stage before being injected into the fuel tank of the combustion system. That is, the fuel additive of the present invention can be mixed into the fuel at a more varied point in time, which

can be mixed immediately in the oil refinery to produce the additive in the refinery. This is because the injection amount of the fuel additive can be freely adjusted according to the customer's needs or the quality of the product to be sold. The fuel additive of the present invention may also be injected at gas stations using a commercial emulsification method.

Besides, in addition to the main object to be achieved from the nanometal aqueous solution itself of the present invention, it is possible to regenerate the diesel particulate filter when the metal nanoparticles are present in the fuel. The aqueous solution serves to enable such regeneration to occur at a lower temperature.

In another embodiment of the present teaching and as shown in Table 3, a nanofluid prepared by the present invention is added to the fuel as a fuel additive and compared with the fuel consumption before the addition. The test was performed by an independent exhaust emission analysis lab in South Korea. The tested car was Hyundai NF Sonata Gasoline 2.0 L, manual transmission and 92,000 km driven. The test condition was analysing the exhaustion gas on a dyno with 1591 kg inertia weight. After evaluating the initial condition, the nanofluid was injected and the car was driven by 300 km for 1 week on the road. After the field aging, the nanofluid was injected and performed evaluation. The nanofluid was injected through air duct through a needle.

[Table 3]

Speed (km/h)	40	50	60	60	70	70	80	90	100	110	120
Gear	4	4	4	5	4	5	5	5	5	5	5
(a) Fuel Efficiency Baseline (km/L)	16.9	16.0	15.1	16.5	14.2	15.6	14.6	13.5	12.4	11.1	9.8
(b) Fuel Efficiency Fuel Additive (km/L)	19.4	17.8	16.7	17.6	15.3	16.8	15.7	14.6	13.2	12.4	11.3
difference % = (b-a)/a	<b>+14.6</b>	<b>+11.4</b>	<b>+10.6</b>	<b>+6.8</b>	<b>+7.9</b>	<b>+7.8</b>	<b>+7.9</b>	<b>+8.2</b>	<b>+7.0</b>	<b>+11.4</b>	<b>+15.4</b>

As can be seen from the above table, when the nanofluid of the present invention is used as a fuel additive, the effect of improving the fuel economy as described above has been proved.

As shown in the table, there is a speed region in which the effect of the fuel additive is prominent, and the effect of the fuel economy improvement according to the present

invention can be proved. However, the speed range may be variable depending on the type of vehicle and the environment.

5 In Table 4, the nanofluid prepared according to the present invention is added to the fuel as a fuel additive, and tested by CVS 75 mode, which is a Korean standard testing method at this time, and the degree of generation of toxic substances before and after addition is compared. The test was performed by an independent exhaust emission analysis lab in South Korea. The tested car was Kia Soul Gasoline 1.6 L, automatic transmission and 20,000 km driven. The nanofluid was injected through air duct through a needle.

10 [Table 4]

	CO (mg/Km)	NOx (mg/Km)
Baseline (a)	134	7
Fuel Additive Injection (b)	114	3
Difference % = (b-a)/a	<b>-15</b>	<b>-57</b>

As can be seen from the above table, when the nanofluid of the present invention is used as a fuel additive, the effect of improving the emission of harmful substances as described above has been proved.

15 In Table 5, the nanofluid was added to a diesel generator in a mist form through the air duct as a fuel additive. The tested generator is Senci SC6000C, 5.5KW. A 3KW heater was connected to the generator as a load and the produced electricity (Wh) was measured with a power consumption meter by using 500mL of diesel. The exhaust gas was analysed with Kane Auto 3-7 device. The test was repeated and  
20 the value was averaged for 5 times for the initial condition and 5 times for the fuel additive provided condition.

[Table 5]

Condition	Generated Power (Wh)	CO (ppm)	NOx (ppm)
Baseline (a)	1214	1143	464
Fuel Additive Injection (b)	1290	960	411
Difference % = (b-a)/a	<b>+5.9</b>	<b>-16.0</b>	<b>-11.4</b>



As seen in the above table, a more power is produced with the nanofluid of the present invention and the harmful emissions are reduced. This test proves that the nanofluid makes a positive effect on diesel engine operation as well.

5 By immersing the fuel additive containing the metal particles in the reducing solution, an action effect that can cope with the oxidation phenomenon occurring during the process until the fuel additive actually reaches the fuel is expected to be maximised. This process can create nanoparticles with relatively thin metal oxide layers, therefore the particles can be used as catalysers easily, while nanoparticles with thick oxide layers would stay inactive in the combustion process. The nanoparticles are dispersed  
10 in a alkaline solution to prevent the metal oxide layer growth.

Further, as a result of improving the reactivity of the metal particles, it is possible to derive a higher burning rate of the fuel containing the fuel, and thus it is expected that the effect of suppressing the generation of harmful emissions due to the incomplete combustion of the fuel can be minimised.

15 Further, as a result of improving the reactivity of the metal particles, it is possible to burn the fuel even though using less fuel, thereby improving the combustion efficiency and improving the fuel efficiency.

In addition, the main effect of nanofluid or its water/solvent mixed fuel additive injection is enhancing uniformity of combustion. In other words, fuel has a better chance to be  
20 mixed with air through the migration of the nanofluid vapour/aerosol/mist. This will enhance the fuel efficiency and reduce CO, HC and soot creation. The key factor that enables high catalytic effect with a low concentration of nanoparticles is clustering of water-nanoparticle and its breaking creates charged water molecules with a higher migration-mobility than the normal water vapour.

25 Since the presence of water will reduce the combustion temperature, it reduces NOx creation.

This fabrication method has an advantage of making water-nanoparticle clusters since the particles are directly disintegrated from the electrode in the electrolysis process.

30 The shown electrolysis process for metal nanoparticle inclusion has a merit of simplicity and low energy consumption of the fabrication process.

In addition, by-products obtained in the electrolysis and filtering process can be recycled as electrets (capacitor with constant voltage recovery behaviour) raw materials, fuel cell catalyser, photo-sensitive raw material for solar cells or photo-sensitive capacitor, high mineral fertilizers, and the like, thereby reducing the  
35 occurrence of waste and improving the environment.

In addition, the aqueous solution acts as a catalyst to reduce the toxic exhaust gases in the combustion process. The diesel system generally includes a trap for filtering the dust generated from the combustion of the diesel fuel, and introducing metal nanoparticles into the trap, it is expected that a beneficial effect is obtained in incineration of the dust accumulated in the combustion chamber.

The alkali metal ions contained in the nanofluid make detergent effect in combustion preventing soot deposition in the chamber.

The air intake injection method has an advantage of keeping the property of the nanofluid without being affected by the chemicals in the main fuel, since the clustering of the water-nanofluid plays an important role.

The air intake injection method has an advantage of controlling the temperature and the electrical charge of the vapour/aerosol/mist separately from the fuel.

[Claims]

1. A fuel additive nanofluid comprising an alkaline aqueous solution in which metal particles having a size in the range of several nanometres to several micrometres are dispersed.
- 5 2. The nanofluid of claim 1, wherein the metal particles of the composition comprise iron.
3. The nanofluid of claim 1 or 2 comprising sodium as a main alkali metal ion component.
- 10 4. The nanofluid according to any one of claims 1 to 3, wherein the total metal composition value shows 10 to 100 mg/L measured by Inductive Coupled Plasma Optical Spectroscopy.
- 15 5. The nanofluid according to any one of claims 1 to 4, comprising ammonia/ammonium constituents having a concentration of 3 to 10 mg/L, the composition further exhibiting a pH value in the range 8.5 to 12.5, and wherein a Total Dissolved Solid, TDS, value is in the range 1800 to 3500 ppm, all when measured at 20 °C.
6. A fuel additive comprising the nanofluid of any preceding claim in combination with a water and/or organic water miscible solvent and/or inorganic water soluble solvents.
- 20 7. A method of forming the nanofluid of any one of claims 1 to 5 or the mixture of claim 6, the method comprising:
  - providing an alkaline aqueous solution in an electrode bath, the electrode bath comprising a plurality of non-magnetic stainless steel electrodes, and
  - 25 eluting the metal particles from the one or more of the electrodes using electrolysis to form the nanofluid, wherein the electrolysis is performed using electric power in the range of 1 to 3 W with respect to 5 L of a fluid solution.
8. The method of claim 7 wherein the electrolysis uses a cyclical on/off DC current with on-time of 5 sec and off-time of 10 sec, or wherein a frequency is adjusted with a fixed duty ratio maintained.
- 30 9. The method of claim 8 wherein the current at an on-time is in the range 0.4 to 0.8 A and the voltage is controlled to provide power consumption in the range of 3 to 9 W at on-time per 5 L of fluid solution.

10. The method of any one of claims 7 to 9 wherein the aqueous solution temperature is maintained in the range of 30 to 45 °C.
11. The method of any one of claims 7 to 10 wherein the electrolysis process time is at least 20 days, preferably 22 days.
- 5 12. The method of any one of claims 7 to 11 comprising a filtration step, the filtration step being conducted after the electrolysis and being directed to filter out particles having diameters greater than 2 to 8 micrometres.
13. The method of any one of claims 7 to 12 wherein the fluid solution is water based having an alcohol, desirably ethanol, constituent in the range 0.5 to 1.5 % by volume, the solution further comprising a urine or urea solution constituent added by 0.5 to 10 2% by volume, a salt constituent in the amount of 2 to 8 g/L, a magnesium constituent in the amount of 100 to 300 mg/L, a zinc constituent in the amount of 0 to 100 mg/L, and a quartz powder constituent in the amount of 0 to 100 mg/L.
14. The method of claim 13 wherein the salt constituent is provided by sodium 15 chloride either alone or in a mixture of sodium chloride in the ratio by 70 to 100% with other salts in the ratio by 0 to 30%.
15. The method of claim 13 wherein the magnesium and zinc are provided in water soluble form.
16. The method of any one of claims 7 to 15 wherein the prepared solution before 20 electrolysis has a pH value in the range 8.5 to 9.5, a TDS value in the range 1500 to 2500 ppm, and an ammonia/ammonium value in the range 2 to 5 ppm, all when measured at 20 °C.
17. The method of any one of claims 7 to 16 further comprising mixing the formed nanofluid with water and/or organic water miscible solvent and/or inorganic water 25 soluble solvents to form a fuel additive mixture.
18. The method of claim 17 wherein a mixing ratio of the formed fuel additive mixture with the water and/or organic water miscible solvent and/or inorganic water soluble solvents is less than 40% by volume of the nanofluid.
19. A method of introducing the fuel additive of claim 6 into a fuel, the method 30 comprising injecting the fuel additive directly into an air inlet of a combustion system or directly into a combustion chamber where it mixes with the fuel at the combustion cycle.

20. The method of claim 19 wherein the fuel additive is atomised prior to mixing with the fuel, the atomising being effected using at least one of a carburettor, an ultrasonic vibrator, an air bubbler, and/or a sprayer.

5 21. The method of claim 19 or 20 further comprising providing a housing with a microporous channel on a first side of the air inlet, providing the fuel additive in droplet form within the housing, and vibrating the composition prior to introducing the fuel additive into the fuel.

22. The method of claim 21, comprising providing the housing in an air filter box of the air inlet.

10 23. The method of any one of claims 19 to 22, comprising providing a flow control valve connected to a control unit, the control unit being configured for controlling a rate of introduction of the fuel additive into the fuel, the control unit being configured to monitor one or more parameters selected from:

a flow rate of the fuel into the engine,

15 a flow rate of the air into the engine,

a revolution per minute (rpm) of the engine,

a torque of the engine,

a speed of a vehicle being powered by the engine,

20 and wherein the volume of the fuel additive introduced is further controlled by at least one of the temperature of the atomised fuel additive or the temperature of the air in the air duct.

24. The method of claim 23 wherein the flow rate is controlled by controlling the strength of atomising the fuel additive.

25 25. The method of any one of claims 19 to 24, further comprising providing a fuel injector with a temperature controller and injecting the fuel additive into the air duct or the combustion chamber at a temperature within the range 10 to 25 °C.

26. The method of any one of claims 19 to 25, comprising maintaining the fuel additive in the container at a temperature range of 5 to 40 °C.

30 27. The method of any one of claims 19 to 26, wherein the injecting the fuel additive is provided by an injection system comprising an ioniser using corona discharge or electrostatic induction.

28. The method of claim 19 further comprising incorporating the formed nanofluid or its mixture with water/solvent directly into a fuel through emulsification or simple mixing with the fuel.

5 29. The method of any one of claims 7 to 18 further comprising filtering a sludge and using the filtered sludge as one of: a mineral fertilizer; a raw material for an electrets; a photo-sensitive material for solar cells; a raw material for photo-sensitive capacitors; and/or a catalyser material for fuel cells.

Amendments have been filed as follows:-

[Claims]

1. A fuel additive nanofluid comprising an alkaline aqueous solution with a pH in the range 8.5 to 12.5, in which metal particles having a size in the several nanometre to several micrometre range are dispersed at a concentration of 10 to 100mg/L.
- 5 2. The nanofluid of claim 1, wherein the metal particles of the composition comprise stainless steel.
3. The nanofluid of claim 1 or 2 comprising sodium as a main alkali metal ion component.
4. The nanofluid according to any one of claims 1 to 3, wherein the total metal  
10 composition value shows 10 to 100 mg/L measured by Inductive Coupled Plasma Optical Spectroscopy.
5. The nanofluid according to any one of claims 1 to 4, comprising ammonia/ammonium constituents having a concentration of 3 to 10 mg/L, , and wherein a Total Dissolved Solid, TDS, value is in the range 1800 to 3500 ppm, all  
15 when measured at 20 °C.
6. A fuel additive comprising the nanofluid of any preceding claim in combination with a water and/or organic water miscible solvent and/or inorganic water soluble solvents.
7. A method of forming the nanofluid of any one of claims 1 to 5 or the mixture of claim 6, the method comprising:  
20 providing an alkaline aqueous solution in an electrode bath, the electrode bath comprising a plurality of non-magnetic stainless steel electrodes, and  
eluting the metal particles from the one or more of the electrodes using electrolysis to form the nanofluid, wherein the electrolysis is performed using electric power in the range of 1 to 3 W with respect to 5 L of a fluid solution.
- 25 8. The method of claim 7 wherein the electrolysis uses a cyclical on/off DC current with on-time of 5 sec and off-time of 10 sec, or wherein a frequency is adjusted with a fixed duty ratio maintained.
9. The method of claim 8 wherein the current at an on-time is in the range 0.4 to 0.8 A and the voltage is controlled to provide power consumption in the range of 3 to 9  
30 W at on-time per 5 L of fluid solution.
10. The method of any one of claims 7 to 9 wherein the aqueous solution temperature is maintained in the range of 30 to 45 °C.

25 06 20

11. The method of any one of claims 7 to 10 wherein the electrolysis process time is at least 20 days, preferably 22 days.
12. The method of any one of claims 7 to 11 comprising a filtration step, the filtration step being conducted after the electrolysis and being directed to filter out particles having diameters greater than 2 to 8 micrometres.
13. The method of any one of claims 7 to 12 wherein the fluid solution is water based having an alcohol, desirably ethanol, constituent in the range 0.5 to 1.5 % by volume, the solution further comprising a urine or urea solution constituent added by 0.5 to 2% by volume, a salt constituent in the amount of 2 to 8 g/L, a magnesium constituent in the amount of 100 to 300 mg/L, a zinc constituent in the amount of 0 to 100 mg/L, and a quartz powder constituent in the amount of 0 to 100 mg/L.
14. The method of claim 13 wherein the salt constituent is provided by sodium chloride either alone or in a mixture of sodium chloride in the ratio by 70 to 100% with other salts in the ratio by 0 to 30%.
15. The method of claim 13 wherein the magnesium and zinc are provided in water soluble form.
16. The method of any one of claims 7 to 15 wherein the prepared solution before electrolysis has a pH value in the range 8.5 to 9.5, a TDS value in the range 1500 to 2500 ppm, and an ammonia/ammonium value in the range 2 to 5 ppm, all when measured at 20 °C.
17. The method of any one of claims 7 to 16 further comprising mixing the formed nanofluid with water and/or organic water miscible solvent and/or inorganic water soluble solvents to form a fuel additive mixture.
18. The method of claim 17 wherein a mixing ratio of the formed fuel additive mixture with the water and/or organic water miscible solvent and/or inorganic water soluble solvents is less than 40% by volume of the nanofluid.
19. A method of introducing the fuel additive of claim 6 into a fuel, the method comprising injecting the fuel additive directly into an air inlet of a combustion system or directly into a combustion chamber where it mixes with the fuel at the combustion cycle.
20. The method of claim 19 wherein the fuel additive is atomised prior to mixing with the fuel, the atomising being effected using at least one of a carburettor, an ultrasonic vibrator, an air bubbler, and/or a sprayer.



21. The method of claim 19 or 20 further comprising providing a housing with a microporous channel on a first side of the air inlet, providing the fuel additive in droplet form within the housing, and vibrating the composition prior to introducing the fuel additive into the fuel.

5 22. The method of claim 21, comprising providing the housing in an air filter box of the air inlet.

23. The method of any one of claims 19 to 22, comprising providing a flow control valve connected to a control unit, the control unit being configured for controlling a rate of introduction of the fuel additive into the fuel, the control unit being configured  
10 to monitor one or more parameters selected from:

a flow rate of the fuel into the engine,

a flow rate of the air into the engine,

a revolution per minute (rpm) of the engine,

a torque of the engine,

15 a speed of a vehicle being powered by the engine,

and wherein the volume of the fuel additive introduced is further controlled by at least one of the temperature of the atomised fuel additive or the temperature of the air in the air duct.

20 24. The method of claim 23 wherein the flow rate is controlled by controlling the strength of atomising the fuel additive.

25. The method of any one of claims 19 to 24, further comprising providing a fuel injector with a temperature controller and injecting the fuel additive into the air duct or the combustion chamber at a temperature within the range 10 to 25 °C.

26. The method of any one of claims 19 to 25, comprising maintaining the fuel  
25 additive in the container at a temperature range of 5 to 40 °C.

27. The method of any one of claims 19 to 26, wherein the injecting the fuel additive is provided by an injection system comprising an ioniser using corona discharge or electrostatic induction.

30 28. The method of claim 19 further comprising incorporating the formed nanofluid or its mixture with water/solvent directly into a fuel through emulsification or simple mixing with the fuel.

29. The method of any one of claims 7 to 18 further comprising filtering a sludge and using the filtered sludge as one of: a mineral fertilizer; a raw material for an electrets; a photo-sensitive material for solar cells; a raw material for photo-sensitive capacitors; and/or a catalyser material for fuel cells.



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## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X,Y	1, 2, 19	US 2006/0141149 A1 Chen - see e.g. claims 1, 5, 11, 13 and the abstract and examples
X,Y	1, 2, 6, 19	WO 2013/177512 A1 Cerion - see e.g. the examples, especially example 7c
Y	19	WO 2015/003678 A1 MTR Energy - see e.g. the abstract and figures 1-4
A	-	US 6471506 B1 Zamansky - see e.g. figure 1
A	-	US 9822320 B1 Wright - see e.g. the abstract and figure 1
A	-	US 2986456 A Toulmin - see e.g. the figure

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup> :

Worldwide search of patent documents classified in the following areas of the IPC

C10L

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI



**International Classification:**

<b>Subclass</b>	<b>Subgroup</b>	<b>Valid From</b>
C10L	0001/12	01/01/2006
C10L	0010/00	01/01/2006