

Improvements to the generation of HHO and creation of a combustion mixture for use with power generation apparatus, a system of operation.

The invention to which this application relates is to the decarbonisation of hydrocarbon internal combustion engines using hydroxyl gas. Hydroxyl Gas is known by several names including, but not limited to; Hydroxyl Gas, Brown's Gas, Di-hydrogen monoxide and HHO amongst others. For the purposes of this document, HHO is used as a convenient shorthand notation. Systems for the creation of HHO do exist, but the currently available systems are inefficient, and also lack effective safety systems. HHO is a volatile gas, and as such; systems for the safe creation and use of this valuable resource must be included.

The documented history of oxy-hydrogen gas starts with William H. Rhodes around 1964 and further developments occurred during the 1970's with disclosure of the potential use of the gas as part of a combustion system. However the applicant is not aware of any commercially successful implementation of the same. As environmental concerns have increased there is a perceived need and encouragement to reduce the use of oil based fuels and/or reduce and/or improve the type of emission gases so as to reduce the emission of those gases which are deleterious to health and the environment.

Conventional apparatus for use to create HHO include wet cell apparatus which is typically provided with electrodes which are concentric and the electrodes and electrolyte are encased in a sealed insulating cell. A second type of apparatus is referred to as a dry cell apparatus which typically utilises flat electrodes, and although there is a seal between each plate, the edges of the electrodes are open to the atmosphere and the electrolyte is circulated through the cell.

One aim of the present invention is therefore to provide apparatus and a method for the use of HHO in a safe and predictable manner and also to improve the efficiency of combustion.

In accordance with a first aspect of the invention there is provided apparatus for the creation of Hydroxyl gas, said apparatus including a substantially gas tight case which houses a sealing shield substantially surrounding a plate assembly including a plurality of electrode plates located spaced apart and substantially parallel by spacer plates and end plates located at opposing sides of the cell assembly, power supply means connected to said electrode plates to provide positive or negative potential connections to respective plates and around which cell assembly an electrolyte liquid flows and wherein said apparatus further includes an electrolyte inlet port, a hydroxyl gas collector and a hydroxyl gas and electrolyte outlet port therefrom passing to a gas concentrator.

In one embodiment the cell assembly is energised using an electrical pulse generator under the control of a programmable electronic control device.

In one embodiment the apparatus according to claim 2 wherein the apparatus includes a plurality of sensors and at least one flow meter to provide feedback which is used to alter, if required, a power pulse train used to control the provision of power to the electrode plates. In one embodiment the sensors include pressure sensors, current, voltage and temperature sensors.

In one embodiment the spacer plates are formed so as to be substantially transparent.

In one embodiment the apparatus includes one or more light sources are provided to be illuminated at one or a series of predetermined wavelengths to emit light into the casing to increase the efficiency of the hydroxyl gas production.

In one embodiment the apparatus includes a dosing pump to add a material to modify the electrolyte.

In one embodiment the sealing shield is formed by a sealing compound.

In one embodiment the sealing compound has chemical and/or electrical characteristics which create a unique detectable signature so as to allow identification of the same and prevent unauthorised modification or counterfeiting.

In one embodiment the apparatus includes connection means to supply hydroxyl gas provided from said cell assembly to be mixed with at least one hydrocarbon fuel.

In one embodiment a control system to provide a stoichiometric mix of said gas and said at least one hydrocarbon fuel that adapts the mix in response to detected requirements of a device to which the mix is supplied. Typically the said device is a combustion engine into which the said mix is introduced to power the engine.

In one embodiment the apparatus includes switching means to allow the operation of the combustion engine to be switched between using a hydrocarbon fuel and then change to using hydroxyl gas or hydroxyl gas mixed with a hydrocarbon fuel.

In one embodiment the switching means allows the transition from the use of the hydrocarbon fuel at least at the starting of the combustion process and then the hydroxyl gas or hydroxyl gas mixed with said hydrocarbon fuel as the ongoing secondary running fuel for the combustion process.

In one embodiment the apparatus includes means to allow the injection of the hydroxyl gas or HHO into a combustion chamber of the combustion engine. Typically the said injection means are piezo controlled solenoid valves.

In one embodiment the said piezo controlled solenoid valves are provided as one or more modules for location and operation with the said combustion engine.

In one embodiment the apparatus includes connection means to supply hydroxyl gas provided from said cell assembly to be mixed with at least one hydrocarbon fuel.

In a further aspect of the invention there is provided apparatus including a combustion engine with a combustion chamber, said apparatus including a control system to provide a stoichiometric mix of said HHO gas and at least one hydrocarbon fuel and wherein said control system adapts the mix in response to detected requirements of said combustion engine at that instant of time.

In one embodiment the apparatus includes switching means to allow the operation of the combustion engine to be switched between using a hydrocarbon fuel and then change to using hydroxyl gas or hydroxyl gas mixed with a hydrocarbon fuel.

In one embodiment the apparatus includes means to allow the injection of the hydroxyl gas or HHO into the combustion chamber of the combustion engine in which the HHO is mixed with the said hydrocarbon base.

In a further aspect of the invention there is provided a method of creating a multi-component fuel for a combustion engine, said method including the steps of mixing hydroxyl gas (HHO) with a hydrocarbon fuel using a mixing device wherein the hydroxyl gas (HHO) is supplied as a preformed compound and said hydrocarbon is used as a base with which said hydroxyl gas (HHO) is mixed.

In one embodiment the molecular bonds of the HHO and/or multi-component fuel are changed from a dipole-permanent bond to an SP3 hybridised bond.

In one embodiment the said mixing of the hydrocarbon base and said HHO is performed within a chamber of said combustion engine.

In one embodiment the combustion engine is designed to use diesel fuel and the multi-component fuel created in accordance with the invention is a mixture of the diesel and preformed compound.

In one embodiment the said method includes the step of blending the HHO with NO_y and/or ozone. In one embodiment the NO_y is created by passing NO_x through ozone to create NO_y:

In one embodiment the ozone used is unreacted Ozone.

In one embodiment the method includes the steps of monitoring the condition of the combustion engine with respect to any or any combination of the load, speed,

water condition and/or exhaust gasses in order to determine the optimal ratio and injection time using the said fuel.

In one embodiment the method includes the step of varying the ignition timing in response to detected NO_x, NO_y and/or N₂O content in the air induction of the combustion engine.

In one embodiment a corona discharge breakdown of NO_x is performed when injecting the HHO, or HHO and secondary gas mixture with said hydrocarbon fuel into the engine to create said multi-component fuel.

In one embodiment one or more further gases and/or liquids are mixed with the HHO and hydrocarbon base.

Typically the provision of the HHO preformed compound is used as opposed to the introduction of oxygen and hydrogen as two separate gasses.

In one embodiment the method includes the step of adding of one or more chemicals such as carbon and/or metallic compounds, to a thermosetting encapsulating compound in order to create a specific electrical and/or chemical profile or signature specifically for the fuel and measuring the signature of the said modified thermosetting encapsulating material.

In one embodiment the method incorporates the use of reactance modification to prevent unauthorised tampering with the apparatus and in particular to prevent the direct measurement of electrical characteristics and resultant analysis of the production of oxygen-hydrogen gas or the operation of the apparatus and method in general.

It is found that the gas blend produced will be extremely oxidising and this increases the efficiency of the burn.

In one embodiment the method includes the step of creating a pulse shape in conjunction with the standing wave ratio monitoring specifically applied to the production of oxygen-hydrogen gas.

Typically the provision of the stoichiometric mix that adapts to the instantaneous requirement of the engine results in a reduction or removal of environmentally harmful pollutants caused by the burning of fossil fuels.

In one embodiment the said case is insulated and hermetically sealed and allows gas production pressure therein.

In one embodiment the apparatus the series of spacer plates are typically of a minimum of Rockwell R120 specification, which are used to ensure precision spacing of the individual electrode plates.

In one embodiment of the present invention, the case is sealed by use of a sealing compound that, in one embodiment has chemical and/or electrical characteristics which create a unique detectable signature so as to allow identification of the same and prevent unauthorised modification or counterfeiting.

In one embodiment the apparatus includes at least one dosing pump incorporated in the case to modify an electrolyte used within the case to ensure the cell is returned to an authorised service centre for servicing when the working life of the cell is complete.

In one embodiment the apparatus includes a thermosetting encapsulating compound in which there is provided one or more chemicals such as carbon and/or metallic compounds, in order to create a specific electrical and/or chemical profile or signature specifically for the fuel. In one embodiment the apparatus includes a device to measure the signature of the said modified thermosetting encapsulating material.

In one embodiment the apparatus includes a series of pressure sensors and flow meters to monitor gas production and usage so as to ensure the safe operation of the entire system. In one embodiment the pressure sensors, flow meters, and current, voltage and temperature sensors are provided to monitor the gas production and allow modification of a pulse train to maximise the efficiency of the gas production.

In one embodiment of the present invention, a programmable electronic control system is used to monitor the sensors to control the safety systems. In one embodiment of the present invention, at least one pump, flow sensors and valves are used to allow automated and unattended start, stop and running of the apparatus.

In one embodiment the said piezo controlled solenoid valves are provided as one or more modules for location and operation with the said combustion engine. In one embodiment the said one or more modules may be retrofitted to existing combustion engines so as to adapt the operation of the same.

In one embodiment the hydroxyl gas is mixed with the hydrocarbon fuel using a mixing device.

Specific embodiments of the invention are now described with reference to the accompanying drawings; wherein

Figures 1 and 2 illustrate a combustion engine and combustion model in relation to which trials have been undertaken;

Figure 3 illustrates the parameters of the trial performed;

Figure 4 illustrates examples of the fuel injection parameters used in the trials;

Figures 5a-c illustrate measured flow rates at different stages of the combustion process;

Figure 6 illustrates measured flow rates during the combustion process with increased granularity;

Figure 7 illustrates temperature distribution at the same stages as illustrated in Figure 6;

Figure 8 illustrates the in-cylinder pressure during the combustion process in accordance with the trial;

Figure 9 illustrates the comparison between heat release rate and integrated heat release during the combustion process;

Figure 10 illustrates the indicated mean effective pressure (IMEP) during the combustion process of the trials;

Figure 11 illustrates a comparison between the Soot and NO_x created during the combustion process;

Figure 12 illustrates a comparison between the HC/CO and CO₂ created during the combustion process of the trials;

Figure 13 illustrates conventional electrolysis apparatus of the type used to break Hydrogen and Oxygen bonds in water;

Figures 14 and 15 illustrate one embodiment injection apparatus in accordance with the invention;

Figure 16 illustrates a flow control system for introducing the hydroxyl gas into the combustion chamber in accordance with one embodiment of the invention.

Figures 17a-i illustrate a Hybrid Hydroxyl gas generating apparatus in accordance with one embodiment of the invention; and

Figure 18 illustrates a control system in accordance with one embodiment of the invention;

Figure 19 is a pulse power control system illustration in accordance with one embodiment of the invention; and

Figure 20 illustrates an example of a Flow Meter, for use in accordance with the invention.

Conventional apparatus used to provide hydroxyl gas created from hydrogen and oxygen is shown in Figure 13. The source material for this gas is water which shows the most common hydrogen and oxygen bond, known as a dipole-permanent bond which allows for liquid water at atmospheric pressures and 'goldilocks' temperatures.

Although known as a permanent bond, this permanence can be broken by a specific application of energy. break a 'permanent' bond is electrolysis which uses electricity to separate water into separate monatomic hydrogen and oxygen. This is a very inefficient and slow process.

Figures 17a-i illustrate an embodiment of a gas generator module in the form of a Hybrid Hydroxyl Cell assembly 30, in accordance with one embodiment of the invention.

Hydrogen and oxygen have other bonds which can be created by modification of the dipole-permanent bonds rather than breaking these permanent bonds. This requires far less energy, and although not 'permanent', these bonds will last more than enough time to allow the gas produced to be used to create the multi-component fuel. This increase in the efficiency of gas production, when compared to electrolysis, allows this reactive gas to be produced in large volumes for comparatively low energy input. The efficiency of the gas generation can be improved by modification and safety apparatus and methods are incorporated in order to prevent unwanted effects. The safety apparatus and method includes pressure sensors, water level sensing, water condition sensing, fluid traps, check valves and/or a rupture disk valve and monitoring means and a control means which allows the status of these valves to be, preferably constantly, monitored. The control unit also has a double redundancy communication port that receives the demand signals from the ECU as well as providing the ECU with operational status updates.

The Cell assembly 30, as shown in Figure 17a is the component where the HHO gas is created. The assembly includes an insulated, hermetically sealed external case 31 with gas tight sealing. A plurality of electrode plates 32 are provided parallel and spaced apart within the casing by spacer plates 36 and are located between end plates 42 and typically with a surface finish in which the surface finish value (Ra) is a harmonic relative wavelength proportional to the diameter of the water molecule. This relative measurement assists the nucleation of the gas, and this design of plate finish aids the release of the gas bubbles into the circulating electrolyte. This is a representative image of a Hybrid Hydroxyl Cell, with components indicated and described in which there is also shown the end plates 42 and connections 43 are provided for the electrically positive plates and connections 45 are provided for electrically negative plates.

As shown in more detail in Figures 17b-d, the electrode plate assembly is comprised of a series of electrode plates 32 and the same have a width and length dimension which is determined by the relationship between the wavelength of the pulse frequency and the harmonic resonance of the width and length of the plates. The plates also include a pattern of repeating holes 34 which create pathways for the electrolyte liquid in the cell assembly to flow through the same and so create a desired

flow pattern of the electrolyte to assist in gas removal from the surfaces of the plates. The dimension of the gap between the respective plates, the relationship of the diameter of the hole relative to the repeating pattern of holes, the pulse frequency and the plate length and width is used to tune the eccentrical resonance of the plates. The plates 32 are mutually arranged in a manner that has a number of plates with respective positive and negative and the specific arrangement is dependent upon the specific application. For example, if we use 1 to indicate a plate connected to the positive side 43 of the power source, and 0 to indicate a plate connected to the negative side 45 of the power source; possible configurations of the plates are:

0101010101...- This sequence allows maximum HHO gas output, but uses most power.

0110110110...-This configuration gives 80% of the HHO gas output above, but uses 50% less power.

As shown in Figure 17e plate spacers 36 are provided. The plate spacers do not act as act as sealing means but ensure that the gap between the adjacent plates 32 in the assembly is held at a precise distance to ensure the relationship between the plate distances are kept at harmonic values in comparison with the pulse frequency. The plate spacer 36 is also designed to ensure the combined plate impedance maintains the correct pulse voltage. As the plate spacer does not act as a sealing means, it can incorporate a gap 38 to allow gas to escape easily in a direction 90 degrees to the direction of electrolyte flow and thereby prevent gas pockets developing between the electrode plates 32. This increases the cell efficiency, and also keeps the voltage within design limits.

The plate spacers 36 can be made of an optically clear polymer, and so allow the use of directed light sources to be used to excite the hydrogen and oxygen molecules within the electrolyte to lower the amount of electrical energy required to change the bond within the H₂O molecule.

As the plate spacers 36 do not seal the gap between the plates, the entire cell assembly can be contained within a cell epoxy shield 51 as illustrated in Figure 17h. Once the epoxy shield is in place, it is filled with an optically clear epoxy. This provides the sealing properties required for both the electrolyte and also the HHO gas. Excitation lighting emitters may be embedded within the epoxy, or they may be mounted externally of the shield 51.

The end plates 42 are shown in more detail in Figure 17f and are designed to allow electrolyte to be pumped into the bottom of the cell at inlet 48 and Figure 17g illustrates the gas collector 44 which is placed over the plates 30 to allow the hydroxyl

gas which is created to be collected and then transported to a concentrator 46 which has a chamber 47 and shown in section in Figure 17i, in solution.

The electrolyte is circulated from concentrator 46 through the pump to the cell. The electrolyte / gas is returned from the cell to the concentrator 46. The separated gas is removed from the cell, and the electrolyte gas pressure and temperature is monitored using the pressure and temperature sensors 52,54. This is used to monitor waste energy which is indicated by a comparison between the temperature from the sensor, when compared to atmospheric temperature. The pressure is used to monitor gas production cycle times and provides data to the control and safety systems for efficiency turning, and safety information.

The shape of the Gas / electrolyte inlet tube 56 of the concentrator is designed to force the gas out of solution, and so minimise gas build up in the cell and maximising gas production. The electrolyte outlet tube 58 is of sufficient length to prevent gas bubbles being recirculated through the cell and there is also a gas outlet 60. The pressure and flow monitoring system is a combination of a HHO Specific flow sensor and a pressure gauge to react to on- demand requirements of HHO, as well as ensuring the output of the gas is in line with the desired volume for the specific application.

The case 31 of the cell assembly allows the HHO gas to be held in solution for the greater part of its circulation than in other systems to minimise possible ignition risk and the pulse form driving the cell is a multiplexed signal with resonant frequencies that apply to every component of the cell as illustrated in Figure 19.

A control system 72 is illustrated in Figure 18 in which the components referred to above are indicated. Typically a differential pressure system is used and controlled via regulator 74.

The water condition sensor, coupled with the control unit and the electrical input to the cell are modified and in one embodiment, moulded within the cell case as passive electronic components that modify the electrical reactance of plates which are preferably sealed within a tamper proof resin.

This reactance is monitored by the control unit, and the control unit modifies the standing wave ratio to a predetermined value with feedback of the standing wave ratio provided via a coaxial cable of a precise length. This means that if extension cables are used to 'break into the circuit' for unauthorised monitoring, the standing wave ratio will be changed, and so the output is not the same as during operation. This helps to prevent a third party from easily measuring the electrical signals to the cell and therefore determining the precise electrical method of gas production.

In one embodiment a micro dosing pump and a reservoir are provided within the cell case which will allow a measured and precise addition of an amount of cerium oxide or similar semi-conducting ceramic into the cell. The addition of this material allows a precise adjustment, if necessary, of the reactance of the cell. As the cerium oxide or similar material reservoir depletes, this creates a requirement for the cells to be returned for service. In addition, the resin itself can be dosed with a substance such as carbon and very fine metal powder which will give a unique signature when tested either electrically or chemically. This allows us to check for tampering with the cell structure due to changes in the measured signature of the resin. In accordance with one embodiment, the invention utilises a method of creating and controlling a multi-component fuel by the addition of an anhydrous combined oxygen-hydrogen gas, referred to in non-limiting manner as hydroxyl gas or HHO, (along with the optional provision of other oxygen rich compounds and referred to hereon in as secondary gases) to a hydrocarbon fuel such as conventional diesel which acts as a base for the multi-component fuel. This multi-component fuel is created when the hydroxyl gas and any secondary gas products are mixed with the hydrocarbon fuel within a combustion chamber which may be in the form of a conventional internal combustion engine. When the three components are mixed at a predetermined ratio and injected at the appropriate time within the combustion cycle, there is an associated improvement of the chemical thermodynamics and chemical kinetics of the combustion process.

A flow-meter of a design suited to the current invention is illustrated in Figure 20. The flow-meter assembly comprises a flow-meter throat 80 which is typically formed of 304L stainless steel. T-pieces 82 are provided and a reducing port 84 is provided and both are formed of 304L stainless steel. The reducing port connects the throat 80 and one of the T-pieces as indicated. A pressure feed pipe 86 connects the T-piece 82' in which the inlet 89 is located and a piezo differential pressure sensor 88 and a pressure feed pipe 90 connects the pressure sensor 88 and T-piece 82 in which the outlet 92 is provided. The use of the same type of stainless steel throughout the flow meter is specifically to prevent electrolytic reaction and stainless steel to the specification 304L has been chosen for its resistance to embrittlement. The use of conductive material is so that it can be grounded to prevent any static electricity build up. The functionality of the device is based on the mathematical relationship between the inlet and outlet pressures and the known distance between the inlet port 89 and the reducing port 84.

The differential pressure sensor 88 is a very high accuracy, device capable of reading very low pressures of ± 0.0145 Bar (± 0.21 PSI). This unit is designed for a PLC based generator system, and relies on internal calculations within the PLC programme to provide real-time flow rates from 0.25LPM to 30LPM.

A safety system is provided as a stand alone module within the control system. It will cause a software and hardware shut down of the generation system, if any value is outside of prescribed limits.

The control system is a programmable controller that can use a combination of logic arithmetic or artificial intelligence created instructions to produce a stream of pulses where each pulse has a harmonic relevance to either mechanical, or electrical or chemical constants found within the system. The operating code is suitable for further intellectual protection.

The pulse train (the electrical pulses that are used to change the atomic bonds between the hydrogen and oxygen atoms in the electrolyte) are provided by the combination of a high frequency, high current switching unit; capable of switching a high current DC power supply. The pulse train is a series of pulses each corresponding to a specific resonant value. This is represented by Figure 19

The use of a combined power control pulse 62 is uncommon and the system does not use a synchronisation pulse, and therefore the waveform appears to be almost random. However it is not random, the combined pulse is created by multiplexing a continuous stream of several clocks 64,66,68,70. Each clock is referencing a separate octal harmonic relationship between a harmonic of the average pulse frequency and a specific measurement. These specific measurements can include, but are not limited to the dimensions of the plates, the diameter of a water molecule, the diameter of a hydrogen atom or the diameter of an oxygen atom. Other relationships can include, but are not limited to harmonic consistencies between individual relationships; as well as to the physical measurements of component parts. These values are shown by the use of the descriptor 'Period A', 'Period B', 'Period C; and ;Period D'; the finite limit of the number of period clocks is determined by the number of available programmable system clocks in the controller, and the highest frequency that can be generated by the pulse generator.

In one embodiment of the invention the HHO gas which is produced is mixed, with or without secondary gas products to a hydrocarbon base to create a fuel for use to power a combustion engine as is now described. The mixing ratio is precisely controlled by an ECU or engine control unit control system, along with the location of injection of the multi-component fuel in the combustion cycle in order to achieve the optimum results. The value for the actual ratio and timing will vary depending on the operating conditions of the combustion engine and may vary during the operation of the combustion engine.

In the embodiment now described the system components include the gas generator, an engine control unit (ECU), an injector system, communication hub and a

scrubber array and control and communication between each of the components is integral to the operation as a whole.

The ECU unit of the invention, in one embodiment, has a variety of functions to control the injection of the gas into the combustion cylinder of the engine in order to create and maintain the correct ratio of addition of hydroxyl gas and secondary gas products to the hydrocarbon fuel and also the correct time of injection of the gasses into the combustion cylinder. The volume of gas is dependent on variables such as load, ambient environmental conditions, exhaust analysis, engine temperature temperatures, RPM and the chemical consistency of the secondary gas. As each of these values are monitored and the results processed through an internal algorithm, the timing and volume requirements may, if required, be constantly adjusted.

In one embodiment, a communication port is used to control the electronic control module of the gas generator and typically there is no requirement for storage of flammable gas as the gas generator can produce the hydroxyl gas “on demand” for supply and addition to the combustion chamber. This communication port can be provided so as to utilise a double redundancy protocol to ensure reliability of communication, and also to detect any errors that may indicate that a service of the equipment is required. The ECU can also control the timing of the injection of the gas to ensure that this gas is always inserted at the correct ratio and timing to provide the maximum decarbonisation and energy at the specific load and engine speed.

A water condition sensing means is provided to allow, typically several, functions to be performed. A first function is to check the incoming water supply to ensure that the chemical composition is within acceptable parameters for the source being used and if required to remove potential contaminants prior to entering the gas generator process. As the system works by changing the molecular bonds of the hydrogen and oxygen, rather than by heating, electrolysis or other reaction, any contamination that passes through the filters would not be affected by the reaction and therefore not affect the purity of the hydroxyl gas. The water in the cell is checked to ensure the filters are working to the specified level.

A further function is to check the level of micro-dosing of cerium oxide is at the correct level and a third purpose is to give a live reading of the cell's electrical reactivity in order to allow the correct electrical output to be supplied. The use of a high precision rotary encoder connected to the crank shaft is one method to allow adjustment of the timing of the injection of the gasses by fractions of a degree.

The hydroxyl gas generated by the gas generator is, as stated, selectively injected via an injection system into the combustion chamber to mix with the hydrocarbon fuel and the injection system, in the embodiment described herein, is an electrically

controlled solenoid valve, or an electrically controlled solenoid/spring valve. The valve opening duration, and the valve opening time is controlled by the ECU. This opening duration and time varies depending on factors including the speed, load and any pre-existing carbon build up.

In one embodiment the gas generator, injection means and other components may be provided as modules which can be fitted as part of new engines, to refurbished engines or engines currently in service.

In the case of in-service engines, there will be a level of pre-existing carbon build-up. The injection of the gas as described provided a Multi Stage Heat Release (MSHR) which is found to reduce the carbon compounds inherent in the combustion process, and can remove solid carbon that has built up over the operational period of the engine prior to the installation of the modules in accordance with the invention.

Typically the hydroxyl gas is not required to be created or injected at high pressure and in certain conditions the lowest production pressure required in many applications would be anything over 14.5 PSIG or 1 Bar at sea level. Depending on the distance which the generated gas is to be transported to the ignition location in the engine, the diameter of the piping and also the volume of gas required at the demand side of the pipe, pressure may be increased to supply the correct volume required at the point of demand. For applications above sea level, the pressure can be reduced by a value roughly equivalent to 1.2kPa per 100mtrs above sea level.

At the location of injection, the system uses the vacuum typically created in the manifold of the engine to draw the gas into the engine. This creates a safer working condition and can also mean that the energy required to 'inject' the gas is limited to a relatively small electrical pulse required to open and close the injection valve, without energy being used to compress the gas and so efficiency is further increased. If Piezo solenoid valves are used the advantages includes even lower operating energy requirements, and more rapid response times which, in turn, allow improved precision of the injection time within the combustion cycle and it is believed greater energy release from the multi-component fuel.

Due to the high energy density of the hydroxyl gas, and the very low energy required to initiate combustion, the gas needs to be released in a controlled manner. As it is lighter than air, a system comprising of both oxygen and hydrogen gas sensors is used at various points around the apparatus, at a height above the apparatus and also within 'chimneys' and vertical pockets created by the surrounding structure of the engine. Should the oxygen and/or hydrogen content rise above ambient atmospheric conditions, then the generation of hydroxyl gas can be stopped and, if necessary, an alarm sounded.

Typically the supply channel that delivers the gas to the point of injection is designed to be a double wall construction with the cavity between the walls vented to atmosphere at a safe point with a venturi action to create a negative pressure with reference to atmospheric pressure. At intervals along the channel, sensors can be provided and used in order to check for any gas leakage through the inner wall of the pipe and again shut down the production of gas in the event of uncontrolled or unexpected release from the inner pipe to a bund.

In one embodiment the supply channel is formed of a carbon fibre composite to allow for the pipework to be grounded and therefore dissipate build up of static charges. Furthermore, the resin used in the creation of the pipework itself and used in the jointing of sections can be used to form an impermeable barrier to the gas flowing through the pipe. The use of carbon fibre composite also allows for an ease of creation of shapes to envelope the injectors, bulkhead transitions and other irregular features which may be provided along the channel along the entire delivery system so as to create a completely bunded containment of the hydroxyl gas from the gas generator to the point of use at the combustion engine.

Furthermore, the structural strength of the carbon fibre matrix used to form the channel walls, coupled with the bunded nature of the channel walls protects the internal transmission path of the gas from damage caused by external impact.

In one embodiment the valve construction used to introduce the hydroxyl gas and, if provided, secondary gas products, into the combustion chamber is provided in the form of a tapered orifice with a mating plug, in order to allow variation in the flow of the gas while providing a relatively large thermally conductive area to facilitate the removal of heat caused by the gas passing over the surfaces of the flow valve. The valve and valve body are also electrically conductive so that an electrical bonding can be provided in order to maintain an equal electrical potential between all surfaces to prevent the build-up of an electrical charge (static electricity).

Typically the arrangement is used to provide flow control for a single gas introduction and a plurality of these valves are used, each providing a flow controlled supply of a gas to a chamber at which the gases are mixed and then provided with an overall flow control of the final mixture.

Figure 14 shows a needle 2 of an injector in accordance with the invention with a rounded tip 4 which is required to prevent the valve acting as a spiculum. The large surface area of the two valve surfaces is required to allow dissipation of heat. Figure 15 shows the valve assembly 6 with a body 8 and that the hydroxyl gas is introduced through the gas inlet port 10 and the Gas Flow Pocket 12 prevents a natural trap forming within the valve body 8. O-rings 14 are provided to provide a gas-tight seal

16 and the gas exits through the gas exit port 18 either to the engine, or to be blended with a secondary gas.

Figure 16 illustrates the provision of a Primary inlet flow control valve 20 used in conjunction with the secondary gas flow control valve 22 to provide an optimally blended gas for injection into the engine. This assembly can be paralleled and then a tertiary flow control added to provide a complex mix of gases. Typically a motor 24 with encoder sets the position of the valve. This is geared down in order to increase the effective number of encoder pulses per linear distance.

The hydrocarbon fuel injectors are used to inject the hydrocarbon component of the multi-component gas into the combustion chamber at high pressure. The most common methods of injection system are individual fuel system and common rail. The common rail system is primarily used on smaller capacity diesel engines and is very similar to the EFI system used on petrol engines in as far as two pumps are used. A low pressure pump is used to take the fuel from the storage tank to the fuel line and a high pressure pump which feeds a number of injectors. In large capacity compression ignition engines, an individual fuel system is typically used. In this configuration, each injector is served by an individual pump. It is very common practice that these injectors are be mechanically controlled. They are driven by a camshaft with a lobe, for each injector. This means that in order to effect a change in the timing, the lobe must be adjusted mechanically. This makes it impossible to change the hydrocarbon injection timing whilst the engine is running.

Common rail injectors are triggered electrically either using electromagnetic actuators or the more modern Piezo injectors. The advantage of these injectors over mechanical injectors is that being electrically triggered, the injection timing can be modified by the ECU whilst the engine is running. This ability to adjust the timing during the combustion cycle means that the overall efficiency of the engine can be increased. If we look at the difference between electromagnetic and Piezo injectors, we find that Piezo injectors are more responsive than electromagnetic injectors to the point that multiple injections of the hydrocarbon fuel can be used in a single compression stroke if required. When using a multiple injection process, very small injection durations are used through the compression cycle to maximise the efficiency of the ignition. This has the potential to reach a higher stage of heat release and therefore extract more energy from the same hydrocarbon content of the multi-component fuel.

One way to increase the lifespan of older in-service engines would be to move away from mechanical injectors to increase efficiency, and so reduce the amount of hydrocarbon fuel used. Rather than requiring significant modification to the engine which would not be cost effective, it would be possible to create a 'drop-in' Piezo actuator. This retrofit upgrade would have to take place in a re-manufacturing

facility, this is not an upgrade that could be carried out on-site. There would be a requirement for some machining of the injectors, and the spray pattern would need to be checked and any remedial work required would need to be carried out. This retrofit upgrade would allow us to recycle older injectors. Our ECU modules already have the control capability to control these Piezo controlled injectors. This increases the already significant benefits of our multi-component fuel system. It would give the precision of new injection technology and even greater fuel savings to older engine models while extending their lifespan and adding further saving over the entire lifecycle of the vessel, vehicle or stationary engine.

A current trend with fuel for both spark and compressive ignition engines is to use what are referred to as enhanced fuels. Even a visual inspection will show the difference between fuels. Enhanced fuels are clearer than its conventional counterpart, this is due to the addition of Gas-to-Liquid fuels (GTL). Gas to Liquid fuels are created by the conversion of methane rich gasses or other gaseous hydrocarbons into longer chain hydrocarbons. However the energy density is lower than that of the equivalent conventional fuel. This leads to higher usage of the enhanced fuel when compared to the equivalent conventional fuel. The energy density of a multi-component fuel using hydrocarbon fuel and hydroxyl gas has been proven by an independent body to be significantly greater than that of a single component fuel, be that conventional or enhanced. This leads to a raft of benefits a position sensor. The motor is controlled by an electronic circuit that uses a software algorithm to determine the correct flow setting of each of the gases. As well as mixing the hydroxyl gas and secondary gas products the components are most typically operated in conjunction with hydrocarbon fuel injectors, which may be electronically controlled injectors, so that the fuel inlet can be advanced and retarded independently of the advance and retardation of the hydroxyl gas injection. This advance and retardation can also be independent to each cylinder. The algorithm used to control this is a function of the required gas supply and the required mixing of the gasses as well as the primary fuel in cases where the hydroxyl gas and any secondary gases are used as a fuel additive.

The requirement and components of the gas supply is responsive to data from feedback sensors which measure various parameters of the combustion engine performance, including any, or any combination of, Exhaust constituents, including gaseous and particular constituents; engine load which is of particular value where an engine speed is fixed, but the load varies; Revolutions per minute (RPM) which is of particular value where the load is more constant, but the RPM varies; cylinder head temperature which gives an indication of effective combustion, carbon build up around valve seats; exhaust temperature which gives an indication of the content of unburned fuel, and can also indicate the presence of excessive particulate matter; valve Timing as where the timing is variable it is necessary to know the ideal point

of the cycle to inject the gas as the stoichiometric burn rate is different for the gas when used as a fuel additive and/or pressure sensors which can include, but are not limited to the inlet boost pressure and the gas supply pressures.

A control algorithm used as part of the control unit can also use a series of equations known as 'The Gas Laws'. These laws can be roughly given as:-

Gas Law	Formula	Description
Charle’s Law	$V1/T1=V2/T2$	At constant P, as the volume increases the temperature also increases.
Boyle’s Law	$P1V1=P2V2$	At constant T, if pressure increases then volume decreases.
Gay- Lussac Law	$P1/T1=P2/T2$	At constant V as pressure increases the temperature also increases.
Avogadro’s Law	$V / n = \text{constant}$	When the amount of gas increases, the volume of the gas also increases.
Ideal Gas Law	$PV=nRT$	

By the use of these laws the hydroxyl gas and any secondary gases can be blended with the fuel, depending on the combustion engine requirement at any given time to provide a stoichiometrically ideal mix that adapts to the instantaneous requirement of the engine to reduce or remove environmentally harmful pollutants caused by the burning of fossil fuels.

The effects of the creation of a multi-component fuel comprised of a hydrocarbon base and the hydroxyl gas has significant environmental and economy benefits and an analysis of these are provided as a result of trials which have been undertaken and as are described below and with reference to Figures 1-12 and which shows very positive results across several metrics when the hydroxyl gas is injected at the correct time in the combustion cycle and at the correct ratio.

The results included below and in Figures 1-12 show that the combustion is made up of stages known as multi stage heat release, and the bandwidth of the stages is quite narrow, shown as a sharp peak on the graphs. The results detail a two stage heat release. The addition of the gases ozone and nitrous oxide into the combustion cycle have the effect of increasing the heat release of both stages as well as increasing the bandwidth of both of these stages. This increase of bandwidth has the immediate result of increasing the energy release in both stages one and two. The next effect of

increasing the bandwidth of heat stages one and two, is the increasing of the bandwidth of stage 3 heat release which is not dealt with in the trial described herein due to the extremely narrow bandwidth due to the original vagaries of the test equipment which would require the injection timing to be controlled to small fractions of a degree of crank angle. The addition of O³ will increase the bandwidth of stage 3 heat release and so make it simpler to access. This will release more energy and increase the efficiency of the combustion cycle by a significant percentage. At the same time, this energy release could reduce the NO_x compounds and release more unreacted O³ from a scrubber. This then opens the pathway to achieving 50/50 mixture.

The trials were performed by an independent body (University of Huddersfield in association with the National Physics Laboratory (NPL)) and the following results have been determined with respect to trials undertaken in relation to a combustion engine, an example of which is shown in Figure 1 and the specifics of which are indicated in Table 1 below:-

Table 1

Items	Value
Engine Type	QCH1122
Number Of Cylinders	1
Combustion System	Direct Injection, Toroidal Combustion Chamber
Bore/Stroke	122/115mm
Displacement Volume	1.344 L
Compression Ratio	17.5:1
Rated Power	18/2300 kW – 2300 r/min
Overall Dimensions (L*W*H)	510*410*735 mm

For combustion simulation, the following materials are necessary: piston top profile, intake and exhaust ports and valve model, compression ratio, valve-cam profile, injection pressure. A preliminary simulation analysis of the effect of different hydrogen injection parameters on combustion performance has been carried out based on a well-calibrated model as illustrated in Figure 2.

To investigate the effect of hydrogen substitution rate and injection angle on the combustion, the simulation parameters are set as shown in Figure 3. The benchmarking case burns diesel fuel. The engine speed for all cases is 1600 rpm. The

amount of in-cylinder hydrogen injection was calculated based on the target substitution rate and the calorific value of hydrogen and the different configurations of the trials are as indicated in Figure 4.

Figures 5a-c illustrates the flow rate in the cylinder at critical moments during the operation of the internal combustion engine at the intake as shown in Figure 5a, the compression ignition stage as shown in Figure 5b and the exhaust stage as shown in Figure 5c. As the hydrogen substitution rate increases, so the peak flow rate region at the moment of compression ignition rises progressively from the base of the combustion chamber to near the bottom of the cylinder head. Different injection angles can cause distinct effects on the flow rate distribution in the cylinder of the engine and as illustrated in Figure 6.

With regard to the distribution of temperature, differences in the in-cylinder temperature distribution caused due to the changes in hydrogen substitution rate and/or injection angle are difficult to distinguish visually as is illustrated in Figure 7. However an indication of the differences can be identified as a result of the comparisons of the pressure and IMEP

Referring now to Figure 8 the in -cylinder pressure can be analysed at operating conditions of 1600 r/min-30Nm (Diesel 100%) The pre-injection of the hydrogen is found to allow the cylinder to reserve a portion of the premixed combustible mixture before the diesel fuel is compression-ignited, and thus the in-cylinder pressure curve for the dual-fuel cases exhibit an advance in the combustion onset point (from 353 to 349o CA) and causes higher combustion pressures up to 18.63%-21.36%, which subsequently results in higher heat release and in-cylinder temperatures.

The difference in combustion is more pronounced in the heat release rate (HRR) curves, as illustrated in Figure 9 where the hydrogen is ignited by the diesel and burns quickly, and the premixed combustion accelerates the combustion process, resulting in the HRR peak being advanced by 5 degrees compared to the diesel only combustion process, with the amplitude increasing by 210.2% and 7.78% without releasing more heat. The integrated heat release values for the dual fuels were lower than that of the diesel (1289 J), with a decrease between 3.36% and 7.78%.

Figure 10 shows that cylinder pressure data can be used to calculate the work transfer from the gas to the piston. This is generally expressed as the indicated mean effective pressure (IMEP) and is a measure of the work output for the swept volume of the engine. In comparison to the IMEP of a diesel only combustion (281022Pa), a decrease (2.63%-15.20%) in the values occurred for all the dual fuels, with H20D-330-320 showing the smallest decrease (2.63%), indicating better combustion

efficiency and indicates that optimising the injection angle and substitution rate are important factors.

Figure 11 illustrates a comparison between the generation of Soot and NO_x emissions from the combustion process. High in cylinder temperatures caused by the dual fuel combustion result in a fuller burnout of soot compared to diesel with a 97.5-98.8% reduction in soot, and also result in more NO_x production, with a 49.6%-177.3% increase.

Figure 12 indicates a comparison of the HC, CO and CO₂ and it is found that compared to diesel fuel only combustion, the dual fuel combustion as herein described produces fewer unburned hydrocarbons (83.6-97.8%) and carbon monoxide (78.6-96.7%). The CO₂ emissions of the dual fuel with low hydrogen substitution rate (H10D) are higher than that of diesel (7.59-9.49%), while the CO₂ emissions of the dual fuel with high hydrogen substitution rate (H30D) are significantly lower than that of diesel. (-15.1%-17.7%).

In conclusion, this preliminary simulation analysis of the effect of different hydrogen injection parameters on combustion performance on the basis of a well-calibrated model indicates that as the hydrogen substitution rate increases, the peak flow rate region at the moment of compression ignition rises progressively from the bottom of the combustion chamber to near the bottom of the cylinder head. Different injection angles caused distinct effects on the flow rate distribution in the cylinder.

Furthermore, the pre-injection of hydrogen allows the cylinder to reserve a portion of the premixed combustible mixture before the diesel fuel is compression-ignited, and thus the in-cylinder pressure curve for the dual-fuel cases exhibit an advance in the combustion onset point and causes higher combustion pressures up to 18.63%-21.36%.

The premixed combustion accelerates the combustion process, resulting in the HRR peak being advanced by 5 degrees compared to the diesel, with the amplitude increasing by 210.2%-338.9%.

Compared to diesel fuel, dual fuel produces fewer unburned hydrocarbons (83.6%-97.8%) and carbon monoxide (78.6%-96.7%).

There may be a need to remove NO_x produced as a result of the increased chemical kinetics. NO_x is scientific shorthand for Nitric Oxide (NO) and Nitrogen Dioxides which are the reactive oxides of nitrogen that are responsible for atmospheric pollution. These chemicals are responsible for acid rain, smog and also the greenhouse effect in the tropospheric layer of the atmosphere. However, nitrous oxide (N₂O) is a greenhouse gas and is often called 'the forgotten greenhouse gas'. Nitrous oxide is produced during the burning of hydrocarbon fuels including GTL

fuels and as a greenhouse gas, its effect should not be ignored. The baseline unit for comparison of greenhouse gasses is carbon dioxide and to put the effect of nitrous oxide into perspective, one tonne of methane released into the atmosphere is equivalent to 34 tonnes of carbon dioxide. One tonne of nitrous oxide released into the atmosphere is equivalent to 298 tonnes of carbon dioxide. Nitrous oxide is believed to remain active in the atmosphere as a greenhouse gas for around 116 years and its breakdown by UV light in the troposphere has a negative impact on the ozone layer.

There are several methods available for the removal of NO_x in the emissions of the engine, and so using existing technology they are simple to remove. This means that all the benefits of injection of the correct ratio of hydroxyl gas at the correct time in the combustion cycle remain, but the one negative result of this injection is simple to remove. The most common method would be the use of a chemical scrubber such as sulphuric acid and hydrogen peroxide. The use of a chemical scrubber would lead to the required disposal/reprocessing of the waste material. However, there is another option with distinct advantages as outlined below.

If the exhaust gas is passed through a high energy corona discharge unit the NO_x is converted to NO_y. NO_y is made up of all the reactive oxides of nitrogen including N₂O and this is primarily made up of Dinitrogen Pentoxide (N₂O₅). N₂O₅ is a very strong oxidiser and so exhaust gas recirculation (EGR) can be used initially to reduce this value when the engine has an exhaust gas recirculation valve. Again, this would have the benefit of increasing the MSHR values during combustion due to the strong oxidising properties of N₂O₅. As N₂O₅ is highly soluble in water any remaining N₂O₅ can be scrubbed by passing the exhaust gas through water. This water scrubbing would also be effective in removing N₂O₅ on older engines that do not have EGR capabilities. This process would fix the remaining N₂O₅ in an aqueous solution and prevent its release as a greenhouse gas and so by passing the treated exhaust gasses through water, this is safely removed from the emissions. This aqueous form of N₂O₅ could then be used within industry for several purposes. A corona discharge unit produces O₃ which is most commonly referred to as ozone. Although ozone released at ground level is considered to be a greenhouse gas, this apparent negative is actually a significant positive. As most engines incorporate an exhaust gas recirculation valve as part of the emission control system, any unreacted ozone from the NO_x neutralisation can be fed back into the engine through EGR. With newer engines that have EGR capability, or older engines that do not have EGR capability, any unreacted ozone could be mixed with the hydroxyl gas and used to create multi-component fuel. As the ozone molecule is comprised of three oxygen atoms rather than the two atoms found in oxygen (O₂) it is a far better oxidiser. This increase in oxidation efficiency directly results in a cleaner and more energetic burn of the multi-

component fuel. Nitrous oxide is also a very effective oxidiser at high temperatures. So, the recirculation of any remaining nitrous oxide remaining in the exhaust gasses would increase the efficiency of combustion, and this would further enhance the results of the entire multi-component fuel system.

Furthermore the gasses used in the proposed decarbonisation process has at least two benefits. The first benefit allows protection of a specific process to create the gas to be injected into the combustion chamber(s) of a hydrocarbon internal combustion engine, as well as the protection of a specific gas created to increase the reduction, or oxidation, of the hydrocarbon fuel used within the engine.

An overview of the gas composition, pending laboratory analysis would be as follow

$\{(\text{NO}) + (\text{NO}^2) + (\text{NO}^3) + (\text{O}^2\text{N-O-O}) + (\text{N}^2\text{O}^2) + (\text{NO}_4)\} + (\text{O}^3)$

The combination above of the first compound as a component within the engine exhaust and the O^3 as a result of high energy discharge takes place in a closed environment. This closed environment has the effect of mixing the two component gasses, with the high energy not only creating the O^3 but converting this mixture into a compound gas.

Thus, in one embodiment, the system allows the creation of a gas to be created from available resources, without the requirement of externally sourced chemicals, to be used in the decarbonisation of hydrocarbon fuelled internal combustion engines to increase the efficiency of said engines with a concurrent reduction of both carbon and NO_x . The addition of this gas in controlled proportions would reduce the requirement of conventional fuels thus creating a greener operating condition with a reduction of fuel costs.

CLAIMS

1. Apparatus for the creation of Hydroxyl gas, said apparatus including a substantially gas tight case which houses a sealing shield substantially surrounding a plate assembly including a plurality of electrode plates located spaced apart and substantially parallel by spacer plates and end plates located at opposing sides of the cell assembly, power supply means connected to said electrode plates to provide positive or negative potential connections to respective plates and around which cell assembly an electrolyte liquid flows and wherein said apparatus further includes an electrolyte inlet port, a hydroxyl gas collector and a hydroxyl gas and electrolyte outlet port therefrom passing to a gas concentrator.
2. Apparatus according to claim 1, the cell assembly is energised using an electrical pulse generator under the control of a programmable electronic control device.
3. Apparatus according to claim 2 wherein the apparatus includes a plurality of sensors and at least one flow meter to provide feedback which is used to alter, if required, a power pulse train used to control the provision of power to the electrode plates.
- 4 Apparatus according to claim 3 wherein the sensors include pressure sensors, current, voltage and temperature sensors.
5. Apparatus according to any of the preceding claims wherein the spacer plates are formed so as to be substantially transparent.
- 6 Apparatus according to any of the preceding claims wherein one or more light sources are provided to be illuminated at one or a series of predetermined wavelengths to emit light into the casing to increase the efficiency of the hydroxyl gas production.
7. Apparatus according to any of the preceding claims wherein the apparatus includes a dosing pump to add a material to modify the electrolyte.
- 8 Apparatus according to any of the preceding claims wherein the sealing shield is formed by a sealing compound.
- 9 Apparatus according to claim 8 wherein the said compound has chemical and/or electrical characteristics which create a unique detectable signature so as to allow identification of the same and prevent unauthorised modification or counterfeiting.
10. Apparatus according to any of the preceding claims wherein the apparatus includes connection means to supply hydroxyl gas provided from said cell assembly to be mixed with at least one hydrocarbon fuel.

11. Apparatus according to claim 10 wherein the apparatus includes a control system to provide a stoichiometric mix of said gas and said at least one hydrocarbon fuel that adapts the mix in response to detected requirements of a device to which the mix is supplied.
12. Apparatus according to claim 11 wherein the said device is a combustion engine into which the said mix is introduced to power the engine.
- 13 Apparatus according to any of claims 10-12 wherein the apparatus includes switching means to allow the operation of the combustion engine to be switched between using a hydrocarbon fuel and then change to using hydroxyl gas or hydroxyl gas mixed with a hydrocarbon fuel.
14. Apparatus according to claim 13 wherein the switching means allows the transition from the use of the hydrocarbon fuel at least at the starting of the combustion process and then the hydroxyl gas or hydroxyl gas mixed with said hydrocarbon fuel as the ongoing secondary running fuel for the combustion process.
- 15 Apparatus according to any of the preceding claims wherein the apparatus includes means to allow the injection of the hydroxyl gas or HHO into a combustion chamber of the combustion engine.
16. Apparatus according to claim 15 wherein the said injection means are piezo controlled solenoid valves.
- 17 Apparatus according to claim 16 wherein the said piezo controlled solenoid valves are provided as one or more modules for location and operation with the said combustion engine.
18. Apparatus according to any of the preceding claims wherein the apparatus includes connection means to supply hydroxyl gas provided from said cell assembly to be mixed with at least one hydrocarbon fuel.
19. Apparatus including a combustion engine with a combustion chamber, said apparatus including a control system to provide a stoichiometric mix of said HHO gas and at least one hydrocarbon fuel and wherein said control system adapts the mix in response to detected requirements of said combustion engine at that instant of time.
- 20 Apparatus according to any of claim 19 wherein the apparatus includes switching means to allow the operation of the combustion engine to be switched between using a hydrocarbon fuel and then change to using hydroxyl gas or hydroxyl gas mixed with a hydrocarbon fuel.
21. Apparatus according to any of claims 18-19 wherein the apparatus includes means to allow the injection of the hydroxyl gas or HHO into the combustion

chamber of the combustion engine in which the HHO is mixed with the said hydrocarbon base.

22 A method for creating a multi-component fuel for a combustion engine, said method including the steps of mixing hydroxyl gas (HHO) with a hydrocarbon fuel using a mixing device wherein the hydroxyl gas (HHO) is supplied as a preformed compound and said hydrocarbon is used as a base with which said hydroxyl gas (HHO) is mixed.

23 A method according to claim 22 wherein the molecular bonds of the HHO and/or multi-component fuel are changed from a dipole-permanent bond to an SP3 hybridised bond.

24. A method according to any of claims 22-23 wherein said mixing of the hydrocarbon base and said HHO is performed within a chamber of said combustion engine.

25. A method according to any of claims 22-24 wherein the combustion engine is designed to use diesel fuel and the multi-component fuel created in accordance with the invention is a mixture of the diesel and preformed compound.

26. A method according to any of the claims 22-25 wherein the said method includes the step of blending the HHO with NOy and/or ozone.

27. A method according to claim 26 wherein the NOy is created by passing NOx through ozone to create NOy:

28. A method according to claim 27 wherein the ozone used is unreacted Ozone.

29. A method according to any of the claims 22-28 wherein the method includes the steps of monitoring the condition of the combustion engine with respect to any or any combination of the load, speed, water condition and/or exhaust gasses in order to determine the optimal ratio and injection time using the said fuel.

30 A method according to any of the claims 22-29 wherein the method includes the step of varying the ignition timing in response to detected NOx, NOy and/or N₂O content in the air induction of the combustion engine.

31 A method according to any of the claims 22-30 wherein a corona discharge breakdown of NOx is performed when injecting the HHO, or HHO and secondary gas mixture with said hydrocarbon fuel into the engine to create said multi-component fuel.

32 A method according to any of the claims 22-31 wherein one or more further gases and/or liquids are mixed with the HHO and hydrocarbon base.