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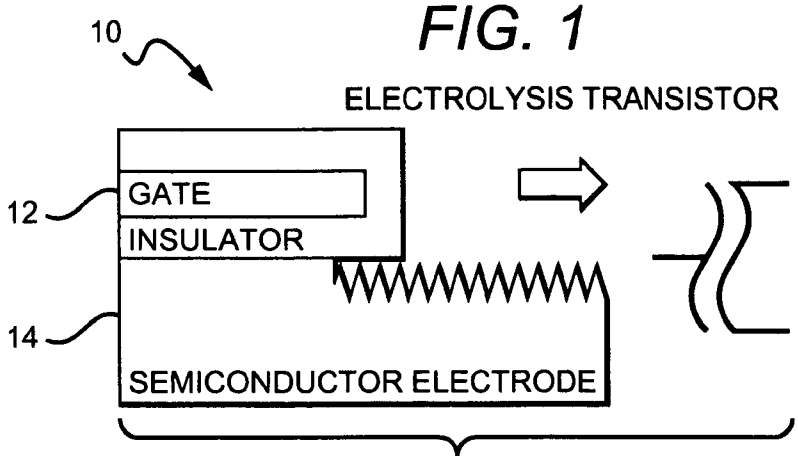
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(54) **Title:** COMPACT ELECTRIC APPLIANCE PROVIDING HYDROGEN INJECTION FOR IMPROVED PERFORMANCE OF INTERNAL COMBUSTION ENGINES

FIG. 1



(57) **Abstract:** Devices, systems and methods for improved electrical appliances which allow for efficient and safe production of hydrogen and oxygen gas for internal combustion engines and the like are disclosed. An appliance for providing gas for combustion may comprise a water inlet, a power source, and an electrolyzer with at least one electrolysis transistor generating hydrogen and oxygen. The appliance may also comprise a gas handling unit for collecting the output of the electrolyzer and transporting it to an engine.

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COMPACT ELECTRIC APPLIANCE PROVIDING HYDROGEN INJECTION FOR IMPROVED PERFORMANCE OF INTERNAL COMBUSTION ENGINES

[0001] This application claims the benefit of provisional application Serial Number 60/999,052 to Umesh Mishra et al., which was filed on October 15, 2007.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Hydrogen enrichment of hydrocarbon fuels improves the efficiency of and reduces emissions from internal combustion engines. Due to hydrogen's higher flame velocity, short quenching distance, and larger flammability limits, hydrogen enrichment of fuels enables more complete and cooler combustion with lesser knocking, even with leaner fuel mixes. As a result, emission of carbon monoxide, carbon particulates, hydrocarbons, and oxides of nitrogen are reduced. Hydrogen enrichment has been practiced by blending hydrogen with compressed natural gas ("CNG") at bottling plants for CNG engines, reforming gasoline or diesel to produce hydrogen, and generating hydrogen via electrolysis.

[0003] Various systems have used traditional methods to generate hydrogen for use in automobiles and other internal combustion engine ("ICE") applications. Such devices have focused on conventional known processes for the electrolysis of water, typically using parallel plates submerged in an electrolyte and either separated or not separated by a membrane. Examples of some well-known systems for producing hydrogen and oxygen from water include: liquid alkaline electrolyzers; proton exchange membrane ("PEM") electrolyzers; or, high temperature steam electrolyzers. However, all of these methods either require a large device footprint to produce the necessary quantities of hydrogen, or (for a smaller footprint) have other drawbacks.

[0004] For example, alkaline electrolyzers use extremely caustic KOH solutions to reduce operating voltages and increase cell efficiency. They also operate at lower (although still elevated) temperatures relative to steam electrolysis. However, current densities are still low, and large platinized or nickel coated stainless steel electrodes are required. Additionally, the highly caustic electrolytes severely limit material choices and pose considerable safety and disposal concerns.

[0005] PEM-based electrolyzers use advanced polymer membranes in place of alkaline electrolytes. This enhances the usability of the system, and provides modest current densities at acceptable efficiencies. However, these current densities lead to systems requiring large quantities of expensive membrane and platinized electrode

materials, as well as expensive assembly techniques. Furthermore, vibration isolation is required for automotive applications to prevent membrane damage.

[0006] High temperature steam electrolysis requires less electrical power than other systems, but requires large amounts of thermal energy to maintain operating temperatures of 1000 °C. For high-efficiency operation, these electrolyzers need large, constant heat sources such as nuclear power plants or solar concentrator heating systems. Steam electrolysis also suffers from low current density and requires steady-state operation. Finding electrode materials that can withstand the aggressive high-temperature oxidizing and reducing environments that are present in steam electrolyzers is a significant challenge. Such systems have niche applications in back-up power plants.

[0007] A large number of U.S. patents discuss onboard generation of hydrogen using electrolysis, including: U.S. Pat. No. 1,379,077 to Blumenberg, U.S. Pat. No. 4,031,865 to Dufour, U.S. Pat. No. 4,111,160 to Talenti, U.S. Pat. No. 4,774,810 to Bidwell, U.S. Pat. No. 5,105,773 to Cunningham, et al., U.S. Pat. No. 5,231,954 to Stowe, U.S. Pat. No. 5,513,600 to Teves, U.S. Pat. No. 5,450,822 to Cunningham, U.S. Pat. No. 5,450,822 to Cunningham, U.S. Pat. No. 6,209,493 B1 to Ross, U.S. Pat. No. 6,817,320 to Balan et al., U.S. Pat. No. 6,896,789 to Ross, U.S. application 2007/0012264 A1 to Holt et al., U.S. application 2007/0080071 A1 to Perry, U.S. Pat. No. 7,021,249 to Christison, U.S. Pat. No. 7,240,641 to Balan

et al., and U.S. Pat. No. 7,430,991 to VanHoose et al. All these patents essentially use traditional two-electrode electrolysis to split water and enrich the fuel with hydrogen. However, each of these approaches result in certain disadvantages, some examples of which include: relatively large footprints to produce necessary quantities of hydrogen; poor mixing of hydrogen and oxygen; large dead volumes from which hydrogen needs to be flushed; and large response and equilibration times that prevent real time control of hydrogen injection.

SUMMARY OF THE INVENTION

[0008] The present invention provides systems and methods for improved hydrogen enrichment of fuels which allow for, amongst other improvements, better combustion with lower emissions from internal combustion engines. One embodiment comprises an appliance for providing commingled hydrogen and oxygen gas for improving combustion in engines. The appliance comprises a water inlet, a power source, and an electrolyzer with at least one electrolysis transistor generating commingled hydrogen and oxygen. It further comprises a gas handling unit for collecting the output of the electrolyzer and transporting the output to an engine.

[0009] Pursuant to another specific, exemplary embodiment, a system for providing gas for improved combustion is provided. The system comprises a water supply, a power source, and an electrolyzer comprising an

array of electrolysis transistors for generating commingled hydrogen and oxygen. An air intake system for transporting the gas output of the electrolyzer to an engine is also provided.

[0010] In accordance with yet another specific, exemplary embodiment, a method for providing gas for improved combustion is provided. The method includes providing: a water source, a power source to activate an appliance, an electrolyzer comprising at least one electrolysis transistor generating hydrogen and oxygen, and a unit for collecting the gas output of the electrolyzer and transporting it to an engine.

[0011] These and other further features and advantages of the invention would be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** is a cross-sectional view of one embodiment of an electrolysis transistor used with an embodiment of a gas generator device according to the present invention;

[0013] **FIG. 2** is a schematic of a conventional 2-electrode cell compared with one embodiment of an electrolysis transistor used with an embodiment of a gas generator device according to the present invention;

[0014] **FIG. 3** is a cross-sectional view of one embodiment of an electrolysis transistor used with an embodiment of a gas generator device according to the present invention;

[0015] **FIG. 4** is an architectural schematic of one class of embodiment of an electrolysis gas generation unit according to the present invention;

[0016] **FIG. 5** is a block diagram of one embodiment of a hydrogen injector for an ICE according to the present invention;

[0017] **FIG. 6** is a schematic for one embodiment of an H_2 injector arrangement according to the present invention for a multi-point fuel injection system; and

[0018] **FIG. 7** is a schematic for another embodiment of an H_2 injector arrangement according to the present invention for direct injection into cylinders.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The following description presents preferred embodiments of the invention representing exemplary modes contemplated for practicing the invention. This description is not to be taken in a limiting sense but is made merely for the purpose of describing the general principles of the invention, the scope of which is better understood by the appended claims.

[0020] The present invention is applicable to any electrical device (including those powered by battery, the alternator in the vehicle, or the mains or a renewable energy source, such as solar, wind, and the like for stationary ICEs) for generating a combustible gas for various uses. The resulting combustion mixture may be used in a variety of different applications, for example by adding it to a fuel mixture in Internal Combustion Engines (ICE) to enhance fuel efficiency, reduce emissions, and provide other benefits related to the more complete and efficient burning of fuel.

[0021] The present invention provides new devices and methods of generating combustion and/or combustion gas for use in vehicles, generators, any other applications utilizing ICEs, turbine engines, heaters, burners, and other suitable devices reliant on combustion and/or combustion gas. The combustion gas generated from devices and methods according to the present invention comprises hydrogen/oxygen (H_2/O_2) mixtures in a compact device. Thus, various embodiments of the present invention are also applicable to any apparatus used to electrically generate hydrogen and/or oxygen for the purpose of improving the cost, performance, and/or emissions characteristics of ICEs.

[0022] Additionally, features of the present invention may also be used to provide specific benefits during various phases of operation, including but not limited to: start-up, shut-down, and/or high or low load conditions for which the engine may not be optimally tuned or designed.

By having hydrogen or hydrogen/oxygen mixtures injected into either the fuel or air intake systems of internal combustion engines, the efficiency of the engine can be increased and/or unwanted emissions such as NOx, CO, and hydrocarbon compounds can be reduced. This can be achieved through increased uniformity because of fast flame propagation of the combustion process within the cylinder. Various concentrations of the H_2 or H_2/O_2 to the fuel and air in the cylinder can be used to achieve the desired effects. Fast flame propagation allows ignition to be retarded with complete combustion at a lower gas temperature.

[0023] Different embodiments of the present invention generally relate to the process used to generate the gas, which is based on a novel method of the electrolysis of water, namely the electrolysis transistor. The present invention utilizes the electrolysis transistor disclosed in U.S. Patent Application 12/156,178 to Umesh Mishra, et al. ("the '178 Application") and the gated electrode structures in U.S. Patent Application US2008/0116080 to Rakesh Lal et al., which are assigned or licensed to the same assignee of the present invention and are incorporated in their entirety herein by reference. The electrolysis transistor allows for the electrolysis of water to produce hydrogen and oxygen, and provides many improvements and overall superior performance compared with other existing electrolyzer technologies. For example, some of the improvements resulting from the electrolysis transistor include: high-density electro-chemistry and products utilizing the same; very high current densities (or

equivalently compact footprint); high-efficiency electrolysis and electrochemical processes; and, cost effectiveness.

[0024] There are also numerous additional advantageous features of the present invention. For example, the high current densities and high efficiency achievable with the electrolysis transistor permit the placement of the H_2 generation apparatus directly within the engine compartment, and potentially within the air intake manifold itself or other parts of the air intake system. Such placement can also reduce the quantities of stored gas in supply lines, as well as increase the ability of the system to dynamically adjust its output as needed by the engine.

[0025] In one embodiment the electrolysis transistor can be used as a direct injector to inject hydrogen/oxygen mixtures directly into the cylinder to reduce the amount of gas storage in supply lines. This can in turn increase the safety of the system. Further, the electrolysis transistor enables injection timing for direct injection of hydrogen. Some of the other features according to the present invention include, but are not limited to: zero to minimal storage of flammable gas (when compared to storage requirements for other gas-based devices); integrated gas detection and leak protection auto-shutoff; gas flow monitoring and indication for appliances requiring low-flow service; and, closed and open water flow systems.

[0026] **FIG. 1** shows one embodiment of an electrolysis transistor 10 utilizing established micro-fabrication techniques in which the core technical innovations of a

proximal gate 12 on a micro-fabricated, nano-structured electrode 14 are provided. The gating electrode lowers the barrier at the electrode-electrolyte interface, reducing the voltage necessary for electrolysis. The result of this effect is at least a 10x increase in generation density compared to other electrolyzers. The advantages of this type of gated electrode arrangement and innovations designed to improve performance of this arrangement are discussed in detail in the '178 Application.

[0027] In an electrolyzer, there is a barrier to electrolysis at each electrode. **FIG. 2(a)** provides an illustration for a conventional 2-electrode cell 20, a simplified equivalent circuit 22 with the potential barriers represented by diodes, and a schematic 24 of this potential barrier. These barriers depend on the interface properties of the electrode-electrolyte system, and it is desirable for these barriers to be as low as possible. Conventionally, this has been achieved by optimizing the electrode-electrolyte system.

[0028] An analogy for the operation of the electrolysis transistor can be found in the field of semiconductor MOS transistors as illustrated in **FIG. 2(b)**. In a semiconductor MOS transistor device 26, a barrier exists between the source and drain electrodes, 28 and 30 respectively. This barrier is modulated by applying a voltage to the gate electrode 32. As the barrier is lowered and as shown in schematic 34, the channel current increases exponentially for a given source-drain voltage.

[0029] An exemplary embodiment of an electrolysis transistor 36 is described in the '178 Application, and extends this concept to the barrier at the electrode-electrolyte interface, as shown in **FIG. 2(c)**. This allows independent control of the electrolysis barrier, with the gate electrode 38 acting in much the same way as the gate terminal 32 in the MOS transistor 26 described above. This solution can provide an approximate 10x potential increase of generation current density to 10 A/cm^2 or more, while maintaining high-efficiency and eliminating caustic electrolytes.

[0030] As illustrated in schematic 40, at the cathode, electrons must tunnel through the potential barrier to the hydrogen ion or a hydrogen containing radical for electrolysis to take place, and a similar process is required at the anode where electrons tunnel from a radical/molecule to empty states in the anode. In a two terminal electrolysis cell, the only way the barrier can be reduced and the current increased for these processes is by increasing the cell voltage, which reduces the efficiency of the device.

[0031] **FIG. 3** shows one possible embodiment for an electrolysis transistor 42 according to the '178 Application that can be incorporated into one embodiment of a device according to the present invention. A proximal gate 44 near the cathode 46 can lower the barrier to electron transport without requiring a large cell voltage. By applying a positive voltage to the gate, image charges in the cathode create an enhanced field in the electrolyte,

thus reducing the barrier and leading to electrolysis and the formation of hydrogen and oxygen.

[0032] To prevent screening of the electrodes, the gate and the dielectric can be brought sufficiently close to the cathode. Semiconductor nano-fabrication technology, capable of manufacturing integrated transistors with feature sizes in the 10s of nm range, can be utilized to fabricate such structures where the gate and dielectric can be brought sufficiently close to the cathode. Alternatively, other processes known in the art for producing nano-structured materials can be used to fabricate the electrodes.

[0033] The electrolysis transistor can overcome many key roadblocks plaguing the current state of the art electrolysis, including but not limited to: low current density-efficiency product; exotic electrode materials, caustic electrolytes and/or expensive polymer electrolytes; and, complex, high-cost systems. The electrolysis transistor can also provide the following advantages, which include but are not limited to: a reduction in the module footprint and weight; an increase in generation efficiency; and, a reduction in overall system complexity.

[0034] A reduction in the footprint and weight of the device can be achieved through an increase in the generation density of the electrolytic cell, or in other words, an increase in the volume of hydrogen and oxygen (liters per minute) generated by the cell. Since there is a 1:1 relationship between the rate of hydrogen generation and the current applied to the electrodes, the current

density at an electrode in a cell is an appropriate measure for generation density as long as the coulombic efficiency is close to one.

[0035] In one embodiment of an electrolysis transistor that may be incorporated into a device according to the present invention, commingled hydrogen and oxygen are generated using nano-structured GaN semiconductor surfaces as a cathode, and proximal Ti/Pt electrodes as anodes. However, it is understood that other suitable materials may also be used. For example, a base metal coated with platinum and its oxides may be used as the cathode and a base metal covered with iridium oxide may be used as the anode.

[0036] **FIG. 4** shows an architectural schematic of the electrolysis gas generation unit 60 according to the present invention, which incorporates a desired embodiment of an electrolysis transistor as discussed above. Water can be provided to the unit in many different ways, and depending on the application, can include a mechanism for storing a supply of water for use in gas generation. In the embodiment shown, a water inlet 62 is provided that serves as the path for water to enter the unit 60, and a valve or a cap 64 can be provided on the inlet 62 to block the inlet or to allow water to pass.

[0037] The architectural embodiment shown includes a water reservoir 66 for additional water storage or capacity, and the water inlet 62 is coupled to the water reservoir 66 such that water entering the unit through the inlet 62 is passed into the reservoir 66. The water

reservoir 66 may include an additional water purification unit/filter mechanism (not shown) if desired, to clean and purify the water in the reservoir 66 (such as for stationary ICEs). In other embodiments of the unit according to the present invention, a connection to a continuous water supply or an external water supply (such as a supply within a vehicle) may be integrated, meaning the reservoir may not be needed. However, in these embodiments, the water purification unit/filter can still be included.

[0038] Units according to the present invention may be powered in many different ways, from many different supplies/sources 68. In one embodiment according to the present invention, the gate electrode on the electrolysis transistor may be driven and/or triggered by an AC gate drive circuit. However, the unit preferably relies on vehicle power, such as from the vehicle batteries or generated by the alternator. The power can be in the form of: AC converted to DC via an integrated AC-DC power supply; AC converted to lower voltage AC through a step-down transformer or switch-mode convertor; or, in other embodiments an AC-DC power supply can be replaced by DC from vehicle batteries from which the appropriate voltages for driving the electrolysis cells and the control electronics can be derived using convertors. Both AC and DC control voltages may also be supplied to the unit, if needed, for interfacing with the ECU and controlling the cells, fluid handling sub-systems, safety devices, and user interface.

[0039] Still, in other embodiments, both the AC-DC power supply and the battery can be combined for a dual-use option. In some embodiments, a DC battery, fuel cell, or other type of power source (e.g. solar or other renewable) may be converted to an AC signal voltage via a DC-AC inverter. In other embodiments, power can be supplied from regenerative braking systems or solar collectors. Excess hydrogen may be generated in situations where excess DC power exists (such as the case of regenerative braking), and the excess hydrogen is stored in metal hydride containers, or other acceptable hydrogen storage methods, for future use as is more fully described below.

[0040] The output of the unit can be controllable based on a control voltage, and can be increased to >1A/cm^2 (with >70% efficiency), >2A/cm2 (with >60% efficiency), >4A/cm2 (with >50% efficiency), and >6A/cm2 (with >40% efficiency). Furthermore, in some embodiments the percentage of hydrogen introduced into the fuel-air mixture can be controlled for various load/demand conditions to increase efficiency.

[0041] The unit may also comprise one or more electrolysis cells (as discussed above) in different arrangements, with the cells utilizing water from the water inlet 62 or water reservoir 66 for use in the electrolysis process. In the embodiment shown, a series of electrolysis cells represented by 70 and 72 are arranged in an array, with each cell of the array having arrays of electrodes that are designed according to the intended use and scalability requirements. While there are two cells shown in FIG. 4, it is understood that any number of cells may be

incorporated depending on the intended use and applications. In the unit shown, each of the arrays accepts water from a water reservoir 66 through water conduits 74, with the water being supplied to each of the electrolysis cells 70, 72 in the arrays. The detailed description of the electrolysis cell structure and architecture is provided in U.S. Provisional Application No. 60/866,560 and the '178 Application, both of which are incorporated herein by reference.

[0042] The electrolyzer produces hydrogen and oxygen in a commingled fashion, with the gas being fed to a gas handling unit 76 that collects the output (hydrogen and oxygen) from multiple cells 70, 72 and feeds it to the output interface unit 78 where gas may then exit the system via the gas outlet 82. In other embodiments, the hydrogen and oxygen are fed to the air intake of an ICE. The output interface unit 78 design is flexible, and is based upon the desired end use or application. In different embodiments, it can include one or more sub-units, consisting of the following optional features: gas detection and an indicator with an auto-shutoff feature to turn off the electrolyzer, an output gas flow monitor, gas storage, an easy/auto shutoff safety control, a display, and a user interface. The control unit 80 may interface with the various portions of the unit to monitor and maintain the electrolysis process as well as the gas output process.

[0043] Aspects of the present invention may be practiced in many ways, with one embodiment providing a safe application relying on the fast response of the

electrolysis transistor to have an extremely small dead volume of the mixed gases. Dead volume refers to the volume of gasses not immediately being consumed, with dead volume of gas typically forming during the electrolysis process or remaining in the unit when it is not in operation, such as when the unit is turned off or when it is not in use. The reduction or elimination of the dead volume results in a negligible possibility of an explosion by ignition of the dead volume gasses.

[0044] Moreover, different embodiments of the invention can be arranged in many different ways. In one embodiment according to the present invention, intake air can be used to dilute the generated gasses to levels below the flammability threshold (4%). Some embodiments can use on demand generation of hydrogen or stoichiometric hydrogen-oxygen mixtures to reduce the dangers associated with storing high volumes of hydrogen. Since the gas is injected directly into the intake air stream, the enriched intake air is below the threshold for flammability.

[0045] The control unit uses known processes and devices to interface with the various portions of the unit to monitor and maintain the electrolysis process as well as gas output process. The footprint of the electrolysis cell can be a variety of different sizes to achieve different gas production capabilities. For example, for a production capability of 1 liter/minute, the footprint may be < 100 $inch^3$, < 200 $inch^3$, < 500 $inch^3$, or < 1000 $inch^3$.

[0046] **FIG. 5** shows a simplified block diagram of one embodiment of a hydrogen enrichment system for an ICE according to the present invention. Ambient air is drawn through the air filter into the input manifold 91, to which the H_2 injector 90 is connected via a solenoid valve 92 and non-return valve 93. The core of the hydrogen generator comprises one or more electrolysis transistors 94 generating commingled hydrogen and oxygen. In some embodiments, one or more of the gas generation units may be used. Air with the desired level of H_2 can then be provided to the engine, where it can be injected directly into the cylinders or appropriately mixed with fuel in a carbureted system for injection into the combustion cylinders. Deionized water may be stored in a polycarbonate or other inert plastic bottle 95, and is introduced into the electrolysis cell as needed via a solenoid 96 and pump 97 with the appropriate power and control being provided via a power cum control module 98 that has the appropriate analog and/or digital control implemented in hardware or firmware.

[0047] **FIG. 6** shows an embodiment of an H_2 injector arrangement 100 according to the present invention, wherein the base unit is similar to the one in FIG. 5. However, the gases produced are released close to the input ports in a multi-point fuel injection system. The electrolysis transistor generates H_2 and O_2 that is piped through a manifold to the ports near fuel injection ports 102 in the engine. The mixture of air and H_2 + O_2 is released via solenoid valves 103 in synchronism with the fuel release at the port. This permits better optimization and use of the hydrogen for fuel enrichment. The solenoids may be

controlled by the control unit, which also needs to be coupled to an engine control module ("ECM") for synchronization with fuel injection at a port.

[0048] **FIG. 7** shows another embodiment of an H_2 injector arrangement 110 according to the present invention, comprising one or more electrolysis transistors 112 in a high pressure cell that generates commingled H_2 and O_2. The gases are fed into a manifold 113 for direct injection into the cylinders 114 via solenoids 115 prior to fuel injection in a direct injection engine. Such an arrangement is necessary when higher amounts of hydrogen enrichment are required and a communication link between the ECM and the hydrogen injector will be necessary.

[0049] A brief description of various possible features of different embodiments of the invention is given in the following:

(a) An air compressor or an elastomer/flexible membrane-based passive compressor pressurizes the water so the electrolyzer operates at adequate pressure, which allows the stoichiometric mixture to be driven to the nozzle at velocities greater than the flame velocity. A pressure valve ensures the gasses exit only when the pressure is high enough.

(b) A very small dead volume above the electrolyzer may exist so even in the case of flash back, only the safety valve on the

electrolyzer will be actuated and the event will not result in a catastrophic explosion.

(c) A flashback arrestor lies immediately above the electrolyzer to prevent flame from entering the electrolyzer. This might be a classic design or a special design integrated into the delivery tubing.

(d) A mix control module dilutes the gases so the temperature is lowered if required to reduce NO_x (oxides of nitrogen) formation. The ECM could also control spark advance or fuel injection to control/optimize NO_x & soot formation.

(f) A hydrogen or reducing gas sensor monitors any gas leakage with an auto-shutoff feature to turn off the electrolyzer in the event of a leak.

(g) The power convertor uses the most appropriate architecture to convert the input power to the voltage and current needed for the anode and gate drives.

(h) The control module, made using microcontrollers or FPGAs or ASICs, executes a failsafe algorithm to turn off the system in case the hydrogen is not ignited or there is a flash back into the system to ensure safe shutdown.

[0050] In addition, at the end of an operation session, an appropriate cell flush using air can ensure that no explosive gas mixture remains in the system. The safety and control of the system could be effected with or without the use of microprocessor control.

[0051] Many different modifications and variations can be implemented in the embodiments described above. Several safety and control mechanisms have been described above, but not all of them may be necessary and employed in practice. For embodiments where the electrolysis transistor is incorporated into the air intake system, the generated gasses will be immediately diluted to the point where the mixture is not flammable. In this way, although the air/hydrogen mix is not itself flammable, the flammability of the mixture when added to the fuel mixture will be increased, leading to enhancements in flame velocity, combustion uniformity, fuel efficiency, and so forth.

[0052] In another embodiment according to the present invention, the peak capacity of the electrolysis system can be much higher than that required for normal operation. This is particularly applicable where there is additional electrical power available (such as regenerative braking, solar power, and other means as described above). The excess hydrogen can be stored either in compressed or molecular form (i.e. metal hydride) and either used for the generation of electrical energy through a fuel-cell type unit, or injected into the engine in sufficient quantities to reduce the amount of normal fuel required.

[0053] In another embodiment according to the present invention, other gases such as methane and propane may be used for the same purpose as the hydrogen, or onboard hydrogen generation may be used to enrich CNG for the ICEs. These gasses may either be chemically synthesized, or stored conventionally for injection into the engine to increase efficiency and reduce emissions of gasoline, diesel or other engines in the same way hydrogen is used in preferred embodiments. In another embodiment, the electrolysis transistor may be used to decompose the fuel stream (such as gasoline, diesel, methane, and propane), extracting hydrogen to be used as an additive in the main fuel stream and thus increasing efficiency.

[0054] In still another embodiment, a cooling coil, orifice, or other means is used to extract the necessary water from the air intake stream or exhaust stream to supply the electrolysis transistor (the water may need to be purified). In such an embodiment, the manual filling of the reservoir tank is not necessary. Water may also be taken from air conditioner condensate if it is available. For ocean-going ICE embodiments according to the present invention, sea water can be used as the electrolyte for the generation of hydrogen. The sea water would have to be treated to remove chloride ions or the anode material in the electrolysis transistor would need to be suitably modified to have a hig over-potential for chloride ions so that they are not oxidized at the anode. Alternately, the formed chlorine could be used for other applications.

[0055] In such an embodiment, or any embodiment where salt water is used as the electrolyte, chlorine (a byproduct of the electrolysis of sea water) may be used in other applications, such as the purification of drinking water or other desirable chemical processes. In one embodiment where salt water is used as the electrolyte and the unit is integrated in diesel engines for use in applications such as shipping, the resultant chlorine gas can be scrubbed from the air intake system of the engine before the enriched intake air enters the engine, with the scrubbed liquid being used for the disinfection of the ship's brown water.

[0056] Known electrolysis systems to be used in this manner require much larger systems for gas generation, which limits the locations for such generating units. Also, these units must be located remotely with respect to the engine, which necessitates the use of supply lines, which present safety and reliability issues. At least one advantage of the systems and methods according to the present invention is the ability for direct integration with the air intake system, which eliminates the need for hydrogen supply lines, the safety hardware and controls associated with the supply lines, and any latent storage associated with the generator.

[0057] Customization features of electrolyisis transistor units according to the present invention can allow them to directly integrate in vehicles or other environmentally sensitive, static ICE applications, such as electrical back-up systems in homes.

[0058] While several illustrative embodiments of the invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art. Such variations and alternate embodiments are contemplated, and can be made without departing from the spirit and scope of the invention as defined in the appended claims.

WE CLAIM:

1. An appliance for providing gas for combustion, comprising:

a water inlet;

a power source;

an electrolyzer comprising at least one electrolysis transistor generating commingled hydrogen and oxygen; and

a gas handling unit for collecting the output of said electrolyzer and transporting said output to an engine.

2. The appliance of claim 1, wherein said at least one electrolysis transistor further comprises:

a pH neutral electrolyte;

one or more working electrodes for transferring charge to or from water molecules or ions in said electrolyte, wherein said electrodes comprise a cathode and/or an anode; and

one or more gate structures for reducing the voltage necessary for electrolysis.

3. The appliance of claim 1, wherein said gas output is mixed with air to provide a hydrogen-enriched air mixture, said mixture provided to an air intake manifold from where it is directly introduced into the combustion chambers of compression ignited engines or direct injection spark-ignited engines; or further mixed with atomized fuel for injection into the combustion chambers of spark ignited engines.

4. The appliance of claim 1, wherein the architecture of said at least one electrolysis transistor is used to operate at very high current density (>1A/cm^2, >2A/cm^2, >4A/cm^2, >6A/cm^2) simultaneously with high efficiency (>6A/cm^2 and >40%, >4A/cm^2 and >50%, >2A/cm^2 and >60%, >1A/cm^2 and >70%).

5. The appliance of claim 1, further comprising a water purification mechanism for filtering and de-ionizing the water entering the appliance.

6. The appliance of claim 1, wherein said water inlet comprises a control valve for controlling the rate of water flow through said inlet.

7. The appliance of claim 1, wherein said hydrogen is introduced into a fuel-air mixture, with the percentage of said introduced hydrogen being controllable via modulation of the gate and/or anode voltage for various load/demand conditions to increase efficiency and reduce emissions.

8. The appliance of claim 1, further comprising a water reservoir for storage and increasing the water capacity of the appliance.

9. The appliance of claim 1, wherein said power source may comprise one or more of the following sources: AC or DC mains, an integrated AC-DC supply, an alternator, a battery, a fuel cell, a solar cell module, and/or the motor generators of regenerative braking systems.

10. The appliance of claim 1, wherein the efficiency of said unit is controllable based on a control voltage and can be increased to greater than 80%.

11. The appliance of claim 1, further comprising a sub-unit such as a metal hydride container for the storage of excess hydrogen.

12. The appliance of claim 1, said appliance capable of direct integration into a vehicle or into a stationary engine with an existing water supply.

13. The appliance of claim 12, said appliance further integrated into a marine diesel engine wherein salt water is used as an electrolyte and either the resultant chlorine gas is scrubbed from an air intake system of said engine or the anode material is modified to prevent formation of chlorine.

14. The appliance of claim 1, wherein said engine is an internal combustion engine.

15. A system for providing gas for combustion, comprising:

a water supply;

a power source;

an electrolyzer comprising an array of electrolysis transistors for generating commingled hydrogen and oxygen; and

an air intake system for transporting the gas output of said electrolyzer to an engine.

16. The system of claim 15, wherein on-demand generation of hydrogen and/or stoichiometric hydrogen-oxygen mixtures are incorporated to increase system safety by avoiding the need to store hydrogen.

17. The system of claim 15, wherein said gas output is mixed with air to provide a hydrogen-enriched air mixture, said mixture provided to said air intake manifold where it is further mixed with fuel for injection into combustion cylinders of an engine.

18. A method for providing gas for combustion, comprising:

providing a water source;

providing a power source to activate an appliance;

providing an electrolyzer comprising at least one electrolysis transistor generating hydrogen and oxygen; and

providing a unit for collecting the gas output of said electrolyzer and transporting it to an engine.

19. The method of claim 18, further comprising providing a powered, passive, or manual air compressor for pressurizing said water to allow said appliance to operate at adequate pressure.

20. The method of claim 18, further comprising providing a pressure valve to ensure gases exit said appliance when pressure is high enough.

21. The method of claim 18, further comprising a small dead volume above said electrolyzer so only a safety valve will be actuated in the event of a flashback.

22. The method of claim 19, further comprising providing a flashback arrestor to prevent flame from entering said electrolysis cells.

23. The method of claim 18, further comprising providing a mix control module to optimize gas mixture to get improved engine efficiency with reduced particulate, hydrocarbon, carbon monoxide, and NO_x formation.

24. The method of claim 18, further comprising an output nozzle array or a single nozzle for ensuring commingled gas velocities remain higher than flame velocity.

25. The method of claim 18, further comprising providing a control module for executing a failsafe algorithm to turn off the system in case said gas is not ignited or there is a flashback.

26. The method of claim 18, further comprising providing a cell flush using air to remove any excess explosive gas mixture from said appliance before appliance is turned off.

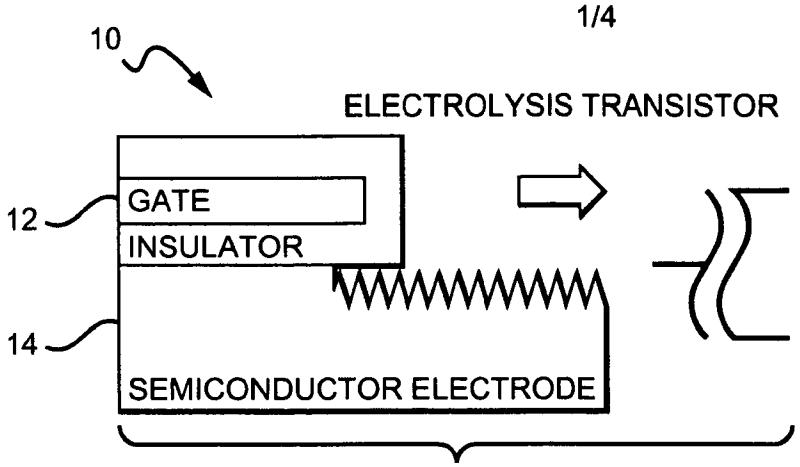


FIG. 1

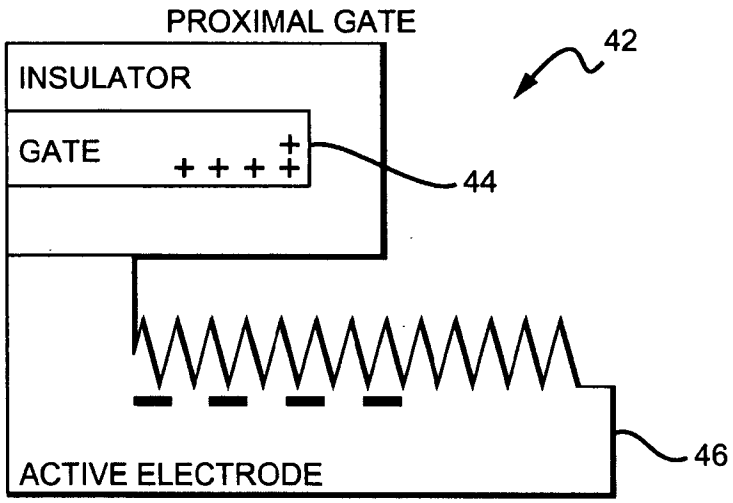


FIG. 3

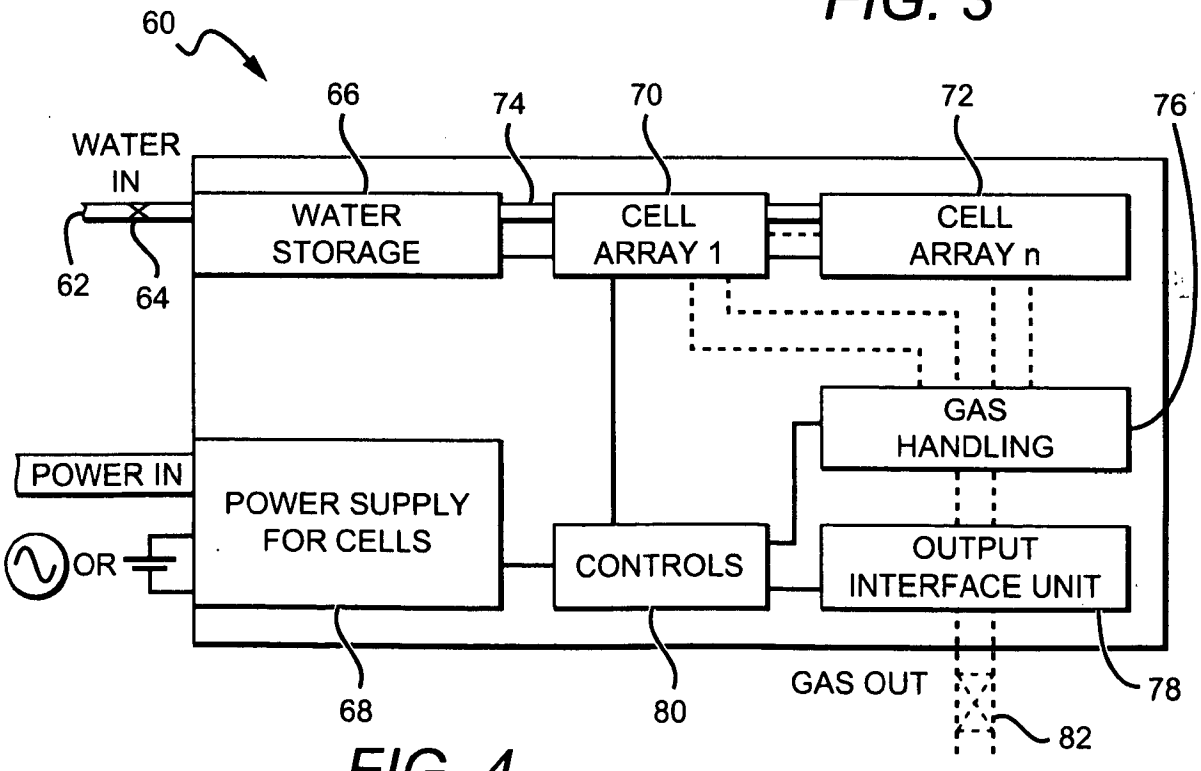


FIG. 4

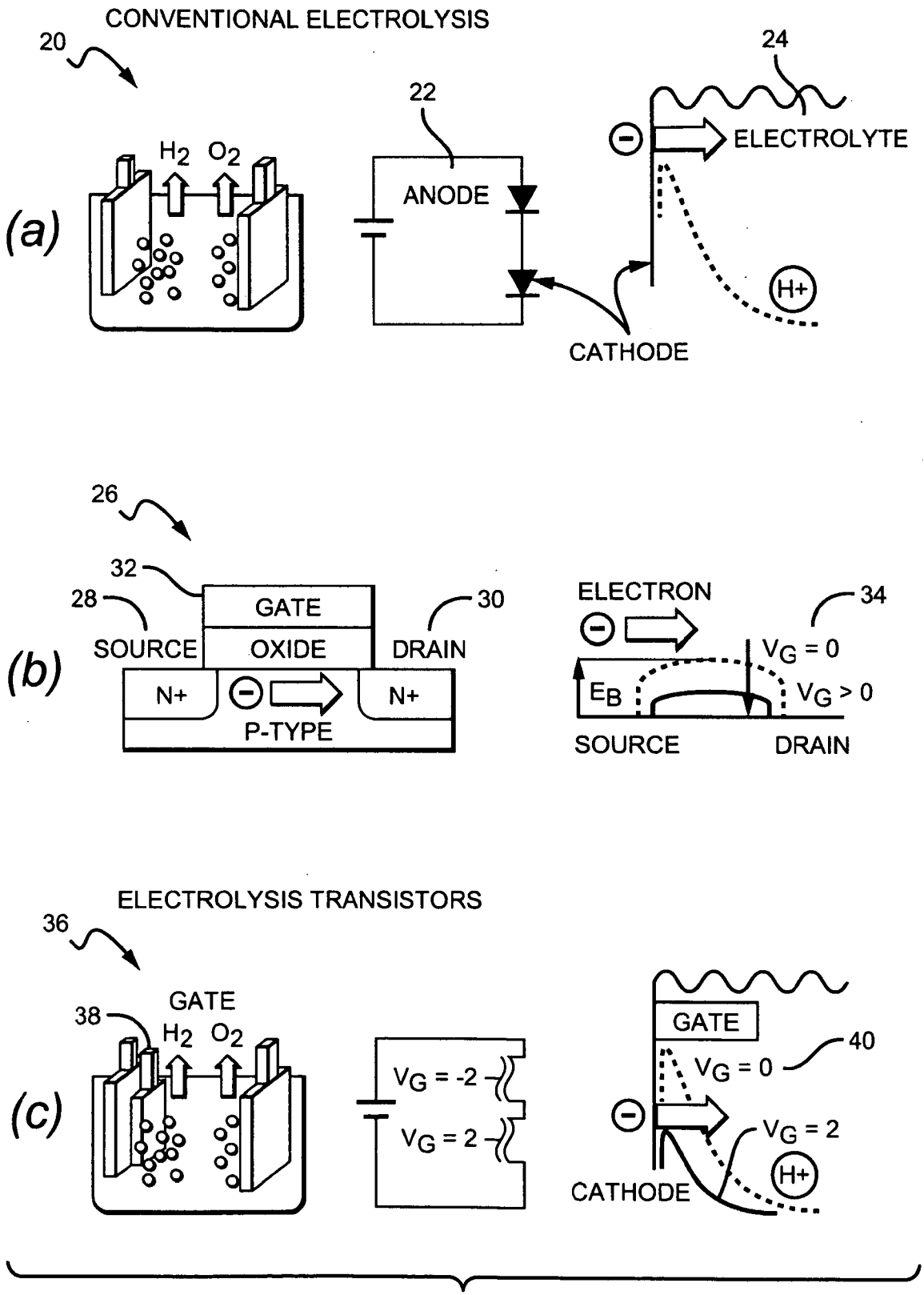

CONVENTIONAL ELECTROLYSIS
20
22
24
ELECTROLYTE
ANODE
H_2 O_2
(a)
H+
CATHODE
26
32
28
GATE
30
SOURCE
OXIDE
DRAIN
(b)
N+
N+
P-TYPE
ELECTRON
34
$V_G = 0$
E_B
$V_G > 0$
SOURCE
DRAIN
ELECTROLYSIS TRANSISTORS
36
GATE
38
H_2 O_2
(c)
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GATE
40
$V_G = 0$
$V_G = 2$
H+
CATHODE

FIG. 2

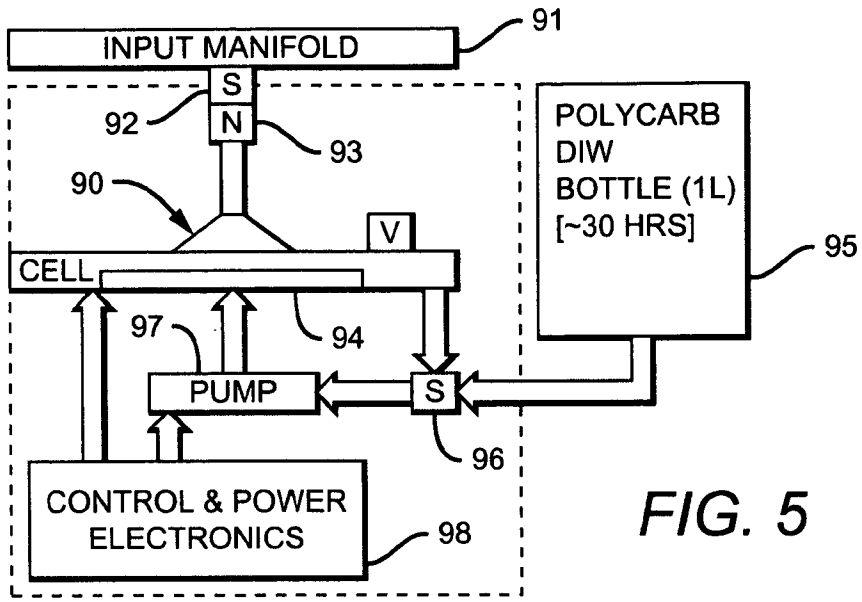

INPUT MANIFOLD
91
S
N
92
93
90
V
CELL
97
94
PUMP
S
96
CONTROL & POWER ELECTRONICS
98
POLYCARB DIW BOTTLE (1L) [~30 HRS]
95

FIG. 5

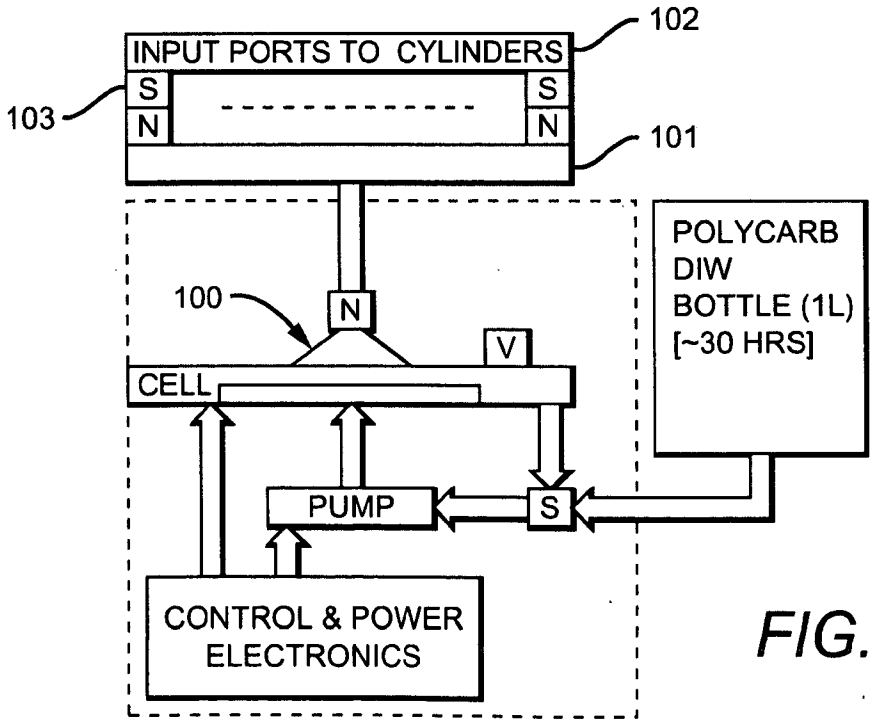

INPUT PORTS TO CYLINDERS
102
103
S
N
S
N
101
100
N
V
CELL
PUMP
S
CONTROL & POWER ELECTRONICS
POLYCARB DIW BOTTLE (1L) [~30 HRS]

FIG. 6

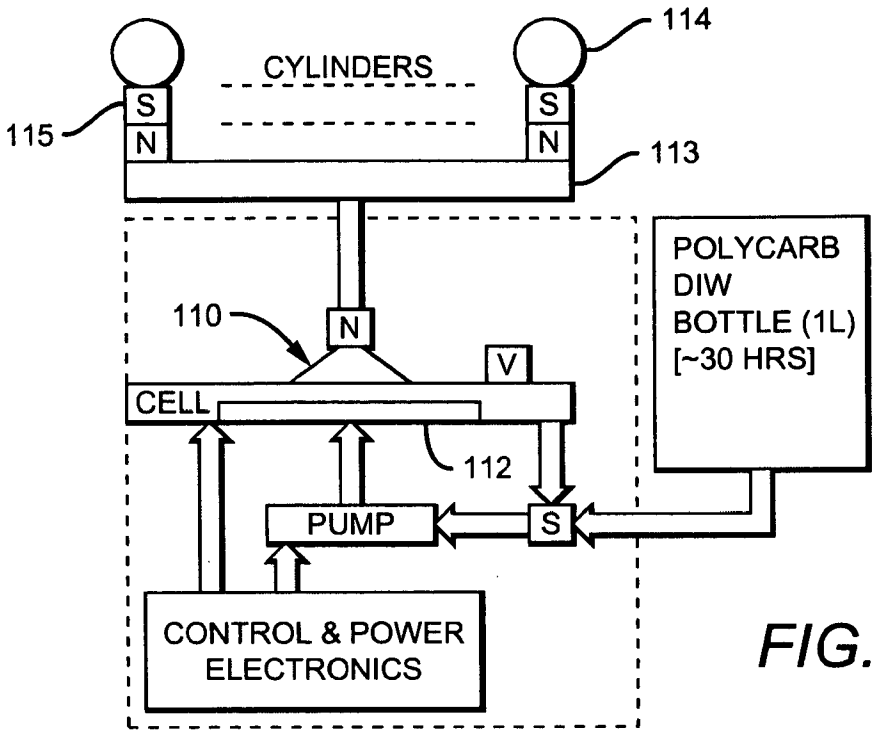

114
CYLINDERS
S
N
115
S
N
113
POLYCARB
DIW
BOTTLE (1L)
[~30 HRS]
110
N
V
CELL
112
PUMP
S
CONTROL & POWER
ELECTRONICS

FIG. 7