Claims

Claim 1. A portable hydrogen proton exchange membrane fuel cell (PEMFC) ~~apparatus and~~ system comprising a housing enclosing the following:

a proton exchange membrane fuel cell (PEMFC) stack ~~and its balance of plant components~~;

a water storage vessel ~~and its balance of plant components~~;

a magnesium hydride powder disposed in a hydrogen reactor vessel ~~and balance of plant components~~ for the hydrogen reactor vessel;

a water pump disposed between the water storage vessel and the reactor vessel;

wherein the PEMFC ~~apparatus~~ stack, the water storage vessel and the reactor vessel are in fluid communication; and

a check valve disposed in a discharge line connecting the water pump to the reactor vessel, wherein the discharge line comprises a tubing with a predetermined rupture pressure range.

~~Claim 2. The portable PEMFC apparatus and system according to Claim 1~~, further comprising a cooling coil disposed in the water storage vessel to cool down hydrogen gas generated from an exothermic MgH2 hydrolysis reaction of the magnesium hydride powder in the hydrogen reactor vessel~~.~~;

~~Claim 3. The portable PEMFC apparatus and system according to Claim 2~~, further comprising a buffer tank and a recollection valve, wherein the buffer tank is in fluid communication with the cooling coil and the recollection valve is operable to recycle water condensed in the buffer tank ~~(caused by cooling of the hydrogen gas)~~ via cooling of the hydrogen gas into the water storage vessel.

Claim ~~4~~ 2. The ~~portable PEMFC apparatus and~~ system according to Claim ~~3~~1, further comprising a purifying filter disposed in fluid communication with the buffer tank.

Claim ~~5~~3. The ~~portable PEMFC apparatus and~~ system according to Claim ~~4~~ 2, further comprising a supply valve disposed in fluid communication between the buffer tank and the purifying filter, wherein the supply valve is operable by a solenoid.

Claim ~~6~~4. The ~~portable PEMFC apparatus and~~ system according to any one of Claims ~~2~~1-~~5~~3, wherein fluid communication for the hydrogen gas is formed in a manifold.

Claim ~~7~~5. The ~~portable PEMFC apparatus and~~ system according to Claim ~~6~~4, wherein the manifold further supports the check valve defined in Claim 1.

Claim ~~8~~6. The ~~portable PEMFC apparatus and~~ system according to any one of preceding ~~items~~ claims, wherein the reactor vessel has a double-wall construction, which interior of the double-wall is evacuated to a vacuum.

Claim ~~9~~7. The ~~portable PEMFC apparatus~~ system according to Claim ~~8~~6, further comprising a vessel cap disposed for closing a mouth of the hydrogen reactor vessel.

Claim ~~10~~8. The ~~portable PEMFC apparatus and~~ system according to Claim ~~8~~6, further comprising heat insulation disposed on an exterior of the hydrogen reactor vessel and the vessel cap.

Claim ~~11~~9. The ~~portable PEMFC apparatus and~~ system according to any one of the preceding ~~items~~ claims, further comprising a controller, wherein the controller receives signals from a temperature sensor and a pressure sensor, and in response turns on a battery to supply electric power to a heater disposed in the hydrogen reactor vessel before voltage generated from the ~~portable PEMFC apparatus and~~ system exceeds voltage across the battery.

Claim ~~12~~10. The ~~portable PEMFC apparatus and~~ system according to Claim ~~11~~9, further comprising an electric outlet port, wherein the electric outlet port is controlled by the controller so that the hydrogen reactor vessel is hot-swappable when the ~~portable PEMFC apparatus and~~ system is operating and power supply at the electric outlet port is not interrupted.

Claim ~~13~~11. A method of using a portable hydrogen proton exchange membrane fuel cell (PEMFC) system comprising:

connecting a water pump to supply water from a water storage vessel to a reactor vessel, wherein a pump discharge line comprises a tubing with a predetermined rupture pressure range and a check valve;

thermally insulating the reactor vessel with a vacuum double wall and, on an exterior of the hydrogen reactor vessel, surrounding the hydrogen reactor vessel with a thermal insulator;

hydrolysing a hydride powder disposed in the reactor vessel with a controlled amount of water supplied through the water pump to generate hydrogen gas on demand via exothermic MgH2 hydrolysis reaction pathway; and

directing the hydrogen gas to flow from an outlet of the reactor vessel to a PEMFC stack to generate electric power~~.~~;

~~Claim 14. The portable PEMFC system according to Claim 13,~~ further comprising:

passing the hydrogen gas through a cooling coil disposed in the water storage vessel to cool the hydrogen gas to a predetermined temperature;

condensing water vapour in the hydrogen gas in a buffer tank, which buffer tank is disposed downstream of the cooling coil, so that the condensed water collected in the buffer tank is recycled back into the water storage vessel via a recollection solenoid valve.

Claim ~~15~~12. The ~~portable PEMFC system~~ method according to Claim ~~14~~11, further comprising:

purifying the hydrogen gas by passing the hydrogen gas through a purifying filter disposed downstream of the buffer tank.

Claim ~~16~~13. The ~~portable PEMFC system~~ method according to any one of Claims ~~13~~11-~~15~~12, further regulating operation of the PEMFC with a controller, wherein the controller comprises an algorithm that responds adaptively to a utilization level remaining in the hydride powder.

Claim ~~17~~14. The ~~portable PEMFC system~~ method according to Claim ~~16~~13, wherein the battery allows hot-swapping of the hydrogen reactor vessel when the hydride powder is depleted and the ~~portable PEMFC apparatus and~~ system is still operating.

~~Claim 18. A process for operating a PEMFC system and for producing electric power to drive an electric load carried on a soldier, the process comprising:~~

~~generating hydrogen on demand by supplying an amount of water to hydrolyse a magnesium hydride powder disposed in a hydrogen reactor vessel;~~

~~cooling down a temperature of the hydrogen gas produced by passing the hydrogen gas through a cooling coil disposed in a water storage vessel, condensing water vapour from the hydrogen gas, and purifying the hydrogen gas by passing the hydrogen gas through a purifying filter, before supplying the hydrogen gas to a PEMFC stack;~~

~~rupturing the water discharge line at a predetermined pressure range, with the water discharge line connected to the hydrogen reactor vessel; and~~

~~closing the water discharge line with a check valve, so as to maintain leak-proof inside the hydrogen reaction vessel, and shutting down the hydrogen reactor vessel in a non-recoverable fail-safe mode when the portable PEMFC apparatus and system encounters a safety issue.~~

Claim ~~19~~15. A portable hydrogen PEMFC apparatus ~~and system that is given in Claim 1 is comprised of~~ comprising

~~a fuel cell system~~ the portable hydrogen PEMFC system of Claim 1;

a hydrogen generation system;

a battery;

a casing;

a pouch;

where the PEMFC ~~apparatus and~~ system ~~is comprised of a PEMFC stack,~~ further comprises a PEMFC controller, an LCD display and its controller, fluidic/electrical/communication and diagnosis interfaces, and ~~PEMFC~~ a balance of plant components of the portable hydrogen PEMFC system;

where the PEMFC stack is based on ~~the~~ an open cathode / closed anode fuel cell design and it produces power in the range of 0 to 20 Watts and has a nominal operational envelope of 10-20 Watts ~~(in order to achieve a minimum of 50% electrical efficiency and a desired lifetime of 500 hours) for a soldier power pack application~~,

where the open cathode / closed anode PEMFC stack ~~technology~~ does not carry an external humidifier device and utilizes an electromechanical connection between the ends of the PEMFC stack in order to humidify the PEMFC stack ~~(this process is also known as~~

~~electrical shorting)~~ and the electromechanical connection is located on the PEMFC controller,

where the PEMFC controller ~~is a set of electrical/electronics, printed circuit boards, etc. that~~ manages the safe operation of the PEMFC system,

where the PEMFC stack manifold is used to integrate all of the PEMFC system components onto a common platform and as a single module form,

where the PEMFC balance of plant components are comprised of a fan, temperature sensor(s), pressure sensor(s), pressure regulator(s), purifying filter(s), supply and purge valve(s), and a PEMFC stack manifold ~~(but not limited to these components)~~,

where the operation of the hydrogen generator system is controlled based on the internal pressure of the fuel cell stack, hydrogen gas consumption of the fuel cell stack, and/or power output of the fuel cell stack,

where the hydrogen generator system is comprised of a hydride fuel cartridge, a water tank module, a hydrogen generation system controller, fluidic/electrical/communication interface components between the ~~magnesium~~ hydride fuel cartridge and the water tank module ~~(but not limited to these)~~;

where hydride fuel of the hydride fuel cartridge is comprised of magnesium hydride,

where the hydrolysis reaction is based on ~~the~~ an exothermic MgH2 hydrolysis reaction pathway,

where fuel cartridge has the hydrogen storage capacity of 2.4 to 480 Wh, preferably 250 Wh to 350 Wh, more preferably 280 to 325 Wh, even more preferably around 300 Wh ~~(with the final Wh capacity for the magnesium hydride cartridge being dictated by the nominal power envelope of the stated micro fuel cell)~~,

where the ~~magnesium~~ hydride fuel cartridge is comprised of a housing comprising a ~~(~~vacuum insulated double wall flask~~)~~, a cover, a reactor manifold that contains ~~all the essential~~ fluidic/electrical/communication interfaces, temperature and pressure sensors, an electrically energized heating tube that is directly connected to a porous tube or porous structure for transferring and heating the water and then converting it into steam before introducing it into the magnesium hydride powder, porous tubes or porous structures to collect the generated hydrogen, and take ~~it~~ the water out ~~off~~ of the hydride fuel cartridge,

where the water tank module is comprised of the water storage tank medium, the water pump, a weighted clunk placed inside the water tank to transfer water to the ~~magnesium~~ hydride fuel cartridge in any orientation ~~in order to enable orientation independency for the operation of the entire portable PEMFC apparatus, check valve, pressure sensor, buffer tank or condenser, recollection valve, a battery, etc.~~,

where fuel cartridge is hot-swappable and have quick-disconnect couplings at the fluidic interfaces for easy replacing,

where the hydrogen generation system controller ~~is a set of electrical/electronics, printed circuit boards, etc. that~~ manages the safe operation of the hydrogen generation system,

where the entire hydrogen generation system is assembled as a single module form,

where the battery is used to initiate the start-up sequence for the portable PEMFC apparatus, act as the primary power for the hydride reactor for the pre-heating period in order to start the hydrolysis reaction, and provide uninterruptable power during hot-swapping action of the ~~magnesium~~ hydride fuel cartridge,

where the casing's main function is to provide a form factor to integrate the fuel cell system and hydrogen generation inside a common housing,

where the pouch is used to carry the portable PEMFC apparatus ~~and system~~ over a soldier's body ~~in a safe manner and also provide protection to the portable PEMFC apparatus and system from different environmental damages,~~.

Claim ~~20~~16. ~~A portable PEMFC apparatus and system that is given in Claim 19 is comprised of;~~ The apparatus according to Claim 15, further comprising

~~a fuel cell system~~

~~a hydrogen generation system~~

a main controller

~~a battery~~

~~a casing~~

~~a pouch~~

~~where the fuel cell system is comprised of a PEMFC stack, LCD display and its controller, fluidic/electrical/communication and diagnosis interfaces, and PEMFC balance of plant components;~~

~~where the PEMFC stack is based on the open cathode / closed anode fuel cell design and it produces power in the range of 0 to 20 Watts and has a nominal operational envelope of 10-20 Watts (in order to achieve a minimum of 50% electrical efficiency and a desired lifetime of 500 hours),~~

where~~in~~ ~~the open cathode / closed anode PEMFC stack technology does not carry an external humidifier device and utilizes an electromechanical connection between the ends of the fuel cell stack in order to humidify the fuel cell stack (this process is also known as~~

~~electrical shorting) and~~ the electromechanical connection is located on the main controller,

~~where the management of the PEMFC system is carried out by the main controller,~~

wherein the main controller is configured to manage the portable hydrogen PEMFC system,

~~where the PEMFC stack manifold is used to integrate all of the PEMFC system components onto a common platform and as a single module form,~~

~~where the PEMFC system balance of plant components are comprised of fan, temperature sensor(s), pressure sensor(s), pressure regulator(s), purifying filter(s), supply and purge valve(s), and a fuel cell stack manifold (but not limited to these components),~~

~~where the operation of the hydrogen generation system is controlled based on the internal pressure of the fuel cell stack, hydrogen gas consumption of the fuel cell stack, and/or power output of the fuel cell stack,~~

~~where the hydrogen generation system is comprised of hydride fuel cartridge, water tank module, fluidic/electrical/communication interface components between the magnesium hydride fuel cartridge and water tank module (but not limited to these);~~

~~where hydride fuel is comprised of magnesium hydride,~~

~~where the hydrolysis reaction is based on the exothermic MgH2 hydrolysis reaction pathway,~~

~~where fuel cartridge has the hydrogen storage capacity of 2.4 to 480 Wh, preferably 250 Wh to 350 Wh, more preferably 280 to 325 Wh, even more preferably around 300 Wh (with the final Wh capacity for the magnesium hydride cartridge being dictated by the nominal power envelope of the stated micro fuel cell),~~

~~where magnesium hydride fuel cartridge is comprised of a housing (vacuum insulated double wall flask), a cover, a reactor manifold that contains all the essential fluidic/electrical/communication interfaces, temperature and pressure sensors, electrically energized heating tube that is directly connected to a porous tube or porous structure for transferring and heating the water and then converting it into steam before introducing it into the magnesium hydride powder, porous tubes or porous structures to collect the generated hydrogen, and take it out off the hydride fuel cartridge,~~

~~where the water tank module is comprised of the water storage tank medium, water pump, a weighted clunk placed inside the water tank to transfer water to the magnesium hydride fuel cartridge in any orientation in order to enable orientation independency for the operation of the entire portable PEMFC apparatus, check valve, pressure sensor, buffer tank or condenser, recollection valve, a battery, etc.,~~

~~where fuel cartridge is hot-swappable and have quick-disconnect couplings at the fluidic interfaces for easy replacing,~~

~~where the management of the magnesium hydride based hydrogen generation system is carried out by the main controller,~~

wherein the main controller is configured to manage the hydrogen generation system

~~where the entire hydrogen generation system is assembled as a single module form,~~

~~where the battery is used to initiate the start up sequence for the portable PEMFC apparatus, act as the primary power for the hydride reactor for the pre-heating period in order to start the hydrolysis reaction, and provide uninterruptable power during hot-swapping action of the magnesium hydride fuel cartridge,~~

~~where the main controller is comprised of electrical/electronics, printed circuit boards, etc. in order to safely operate and diagnose all aspects of the portable fuel cell apparatus,~~
~~where the casing's main function is to provide a form factor to integrate the PEMFC system and hydrogen generation inside a common housing,~~

~~where the pouch is used to carry the portable PEMFC apparatus and system over a soldier's body in a safe manner and also provide protection to the portable PEMFC apparatus and system from different environmental damages,~~.

~~Claim 21. A portable PEMFC apparatus that is given in Claim 20 is comprised of;~~

~~a fuel cell system~~

~~a hydrogen generation system~~

~~a main controller~~

~~a battery~~

~~a casing~~

~~a pouchFst~~

~~where the fuel cell system is comprised of a PEMFC stack, LCD display and its controller, fluidic/electrical/communication and diagnosis interfaces, and fuel cell balance of plant components;~~

~~where the PEMFC stack is based on the open cathode / closed anode fuel cell design and it produces power in the range of 0 to 20 Watts and has a nominal~~

operational envelope of 10-20 Watts (in order to achieve a minimum of 50% electrical efficiency and a desired lifetime of 500 hours),

where the open cathode / closed anode fuel cell stack technology does not carry an external humidifier device and utilizes an electromechanical connection between the ends of the PEMFC stack in order to humidify the PEMFC stack (this process is also known as electrical shorting) and the electromechanical connection is located on the main controller,

where the management of the PEMFC system is carried out by the main controller,

where the fuel cell stack manifold is used to integrate all of the PEMFC system components onto a common platform and then this module is intimately integrated with the hydrogen generator system,

where the PEMFC balance of plant components are comprised of fan, temperature sensor(s), pressure sensor(s), pressure regulator(s), purifying filter(s), supply and purge valve(s), and a PEMFC stack manifold (but not limited to these components),

where the operation of the hydrogen generation system is controlled based on the internal pressure of the fuel cell stack, hydrogen gas consumption of the fuel cell stack, and/or power output of the fuel cell stack,

where the hydrogen generation system is comprised of hydride fuel cartridge, water tank module, fluidic/electrical/communication interface components between the magnesium hydride fuel cartridge and water tank module (but not limited to these);

where hydride fuel is comprised of magnesium hydride,

where the hydrolysis reaction is based on exothermic MgH_2 hydrolysis reaction pathway,

where fuel cartridge has the hydrogen storage capacity of 2.4 to 480 Wh, preferably 250 Wh to 350 Wh, more preferably 280 to 325 Wh, even more preferably around 300 Wh (with the final Wh capacity for the magnesium hydride cartridge being dictated by the nominal power envelope of the stated micro fuel cell),

where magnesium hydride fuel cartridge is comprised of a housing (vacuum insulated double wall flask), a cover, a reactor manifold that contains all the essential fluidic/electrical/communication interfaces, temperature and pressure sensors, electrically energized heating tube that is directly connected to a porous tube or porous structure for transferring and heating the water and then converting it into steam before introducing it into the magnesium hydride powder, porous tubes or porous structures to collect the generated hydrogen, and take it out off the hydride fuel cartridge,

where the water tank module is comprised of the water storage tank medium, water pump, a weighted clunk placed inside the water tank to transfer water to the magnesium hydride fuel cartridge in any orientation in order to enable orientation

~~independency for the operation of the entire portable PEMFC apparatus, check valve, pressure sensor, buffer tank or condenser, recollection valve, a battery, etc.,~~

~~where fuel cartridge is hot-swappable and have quick-disconnect couplings at the fluidic interfaces for easy replacing,~~

~~where the management of the magnesium hydride based hydrogen generation system is carried out by the main controller,~~

~~where the entire hydrogen generation system is intimately integrated with the PEMFC system,~~

~~where the battery is used to initiate the start-up sequence for the portable PEMFC apparatus and system, act as the primary power for the hydride reactor for the pre-heating period in order to start the hydrolysis reaction, and provide uninterruptable power during hot-swapping action of the magnesium hydride fuel cartridge,~~

~~where the main controller is comprised of electrical/electronics, printed circuit boards, etc. in order to safely operate and diagnose all aspects of the portable PEMFC apparatus,~~

~~where the casing's main function is to provide a form factor to integrate the PEMFC system and hydrogen generation inside a common housing,~~

~~where the pouch is used to carry the portable fuel cell apparatus over a soldier's body in a safe manner and also provide protection to the portable PEMFC apparatus from different environmental damages,~~