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(54) **FUEL CELL FOR AIRSHIP POWER GENERATION AND HEATING**

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(52) **U.S. Cl.** ..... **429/26**; 429/13; 429/17; 429/21; 429/22; 429/24; 429/30

(58) **Field of Search** ..... 429/26, 13, 17, 429/21, 22, 24, 30

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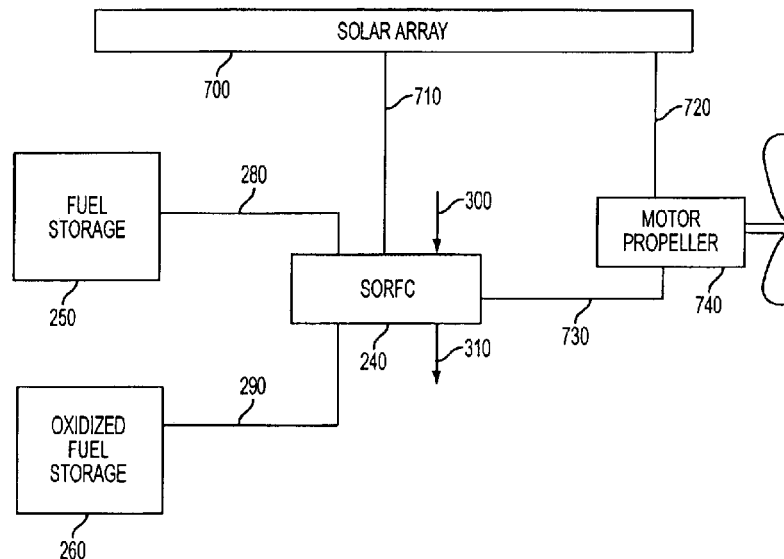
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(57) **ABSTRACT**

A neutrally buoyant airship, such as a blimp, contains a lifting body which allows the airship to remain neutrally buoyant in air and a fuel cell located in the airship. A method of generating power in the neutrally buoyant airship, comprising providing a fuel and an oxidizer to a solid oxide fuel cell to generate power, and providing heat from the fuel cell to a remotely located lifting body, wherein the lifting body allows the airship to remain neutrally buoyant in air.

**29 Claims, 13 Drawing Sheets**



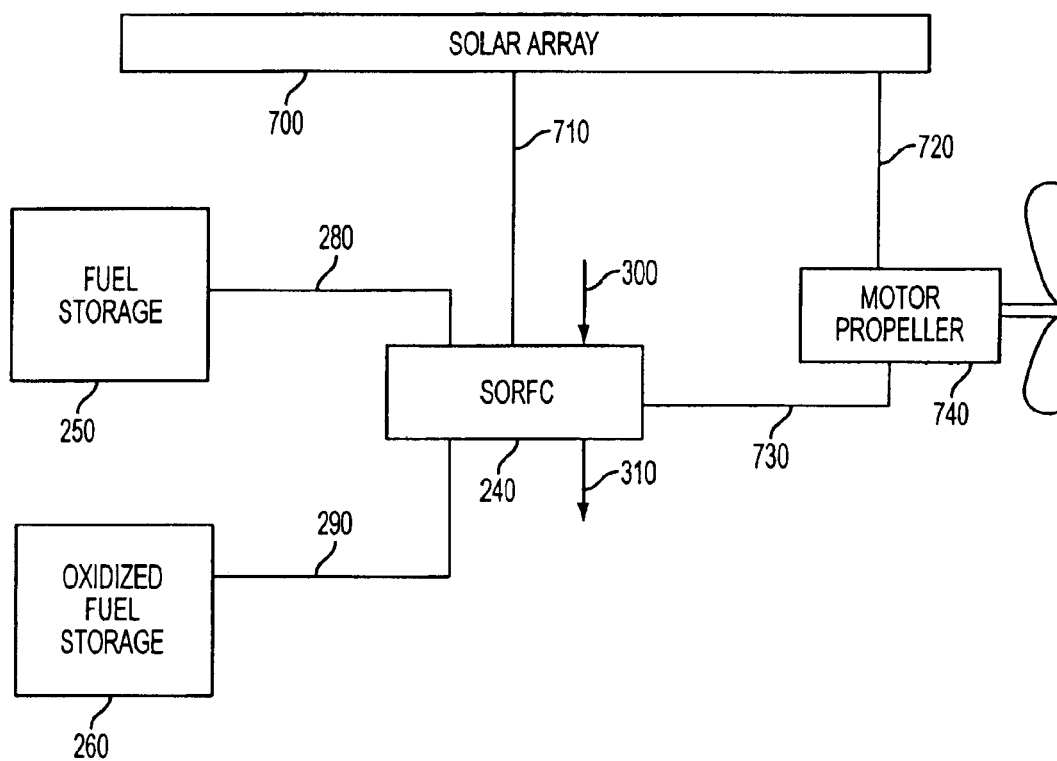


FIG. 1

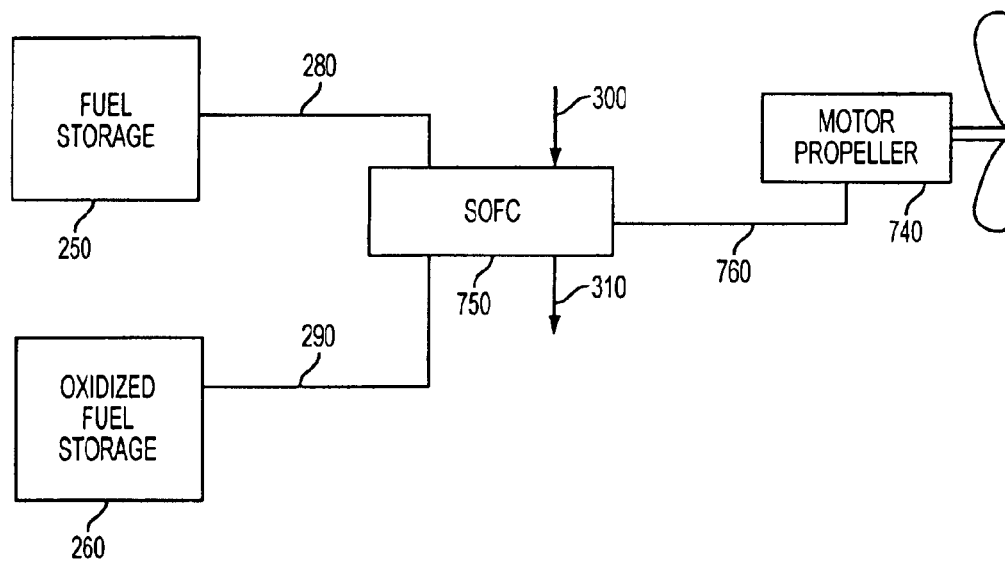


FIG. 2

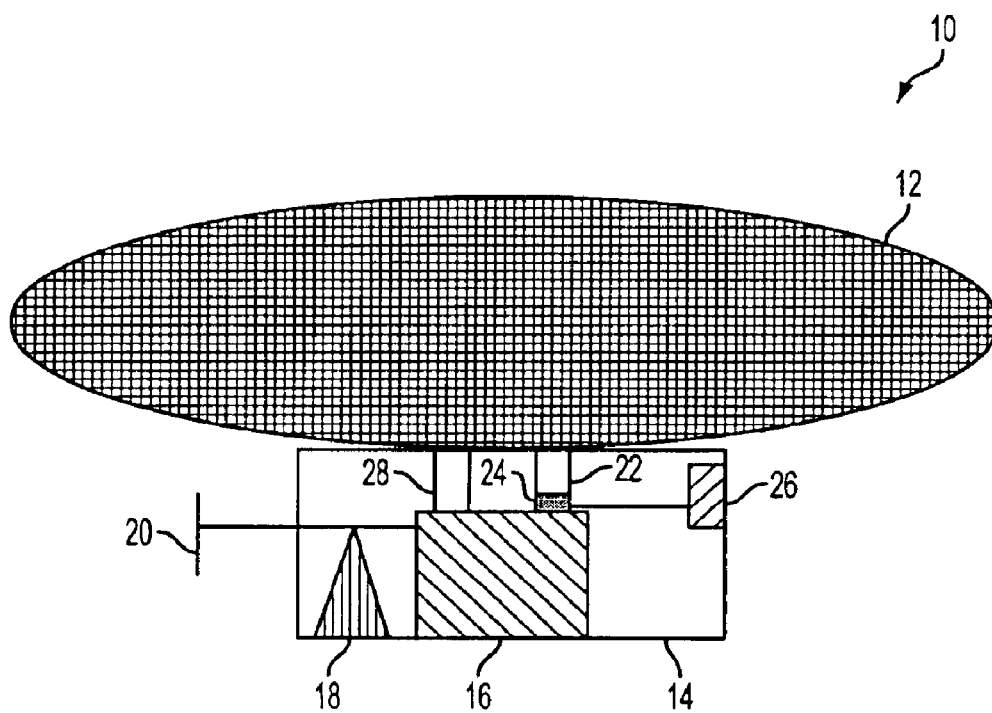


FIG. 3

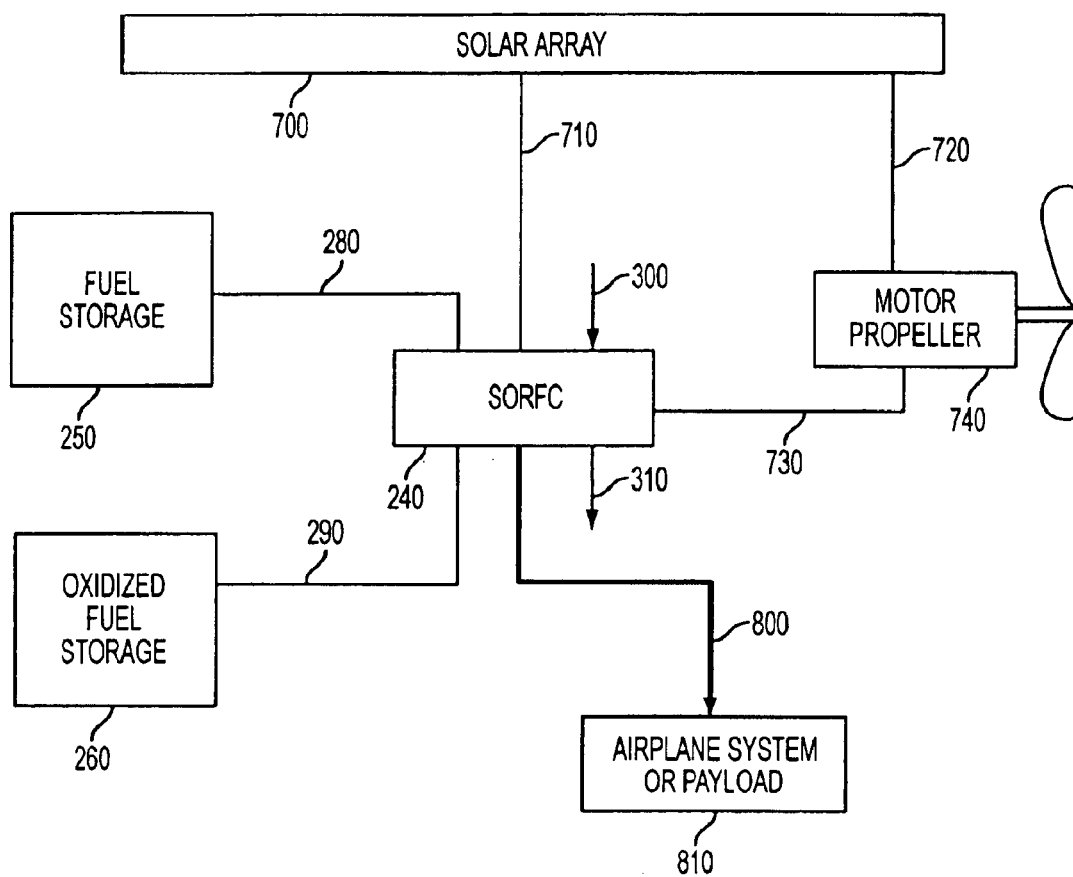


FIG. 4

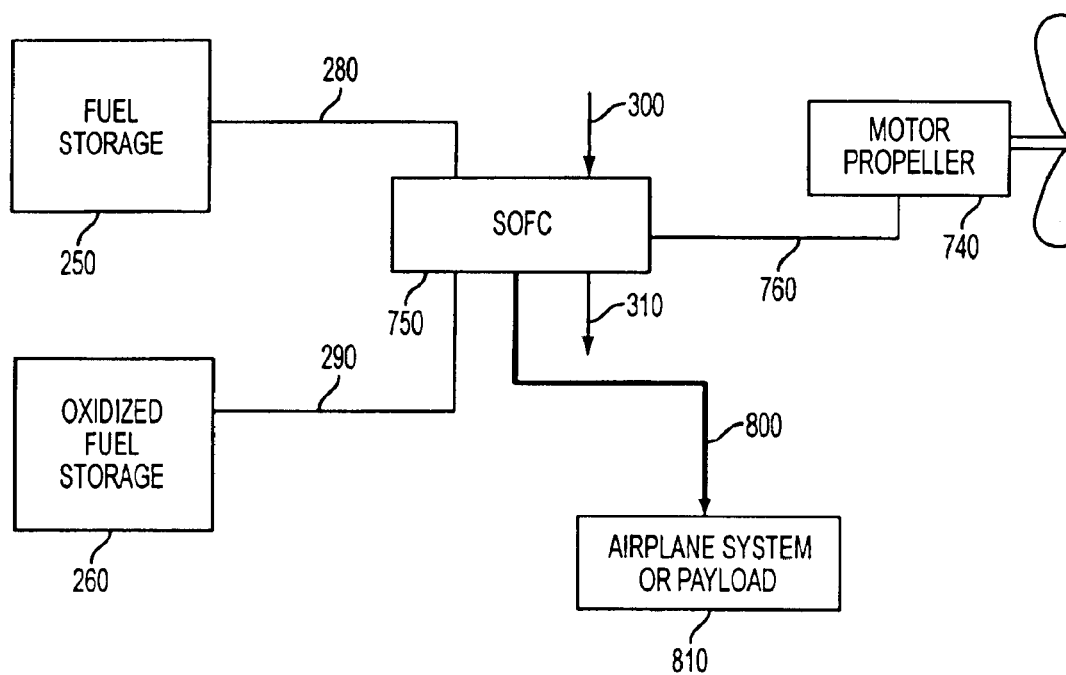


FIG. 5

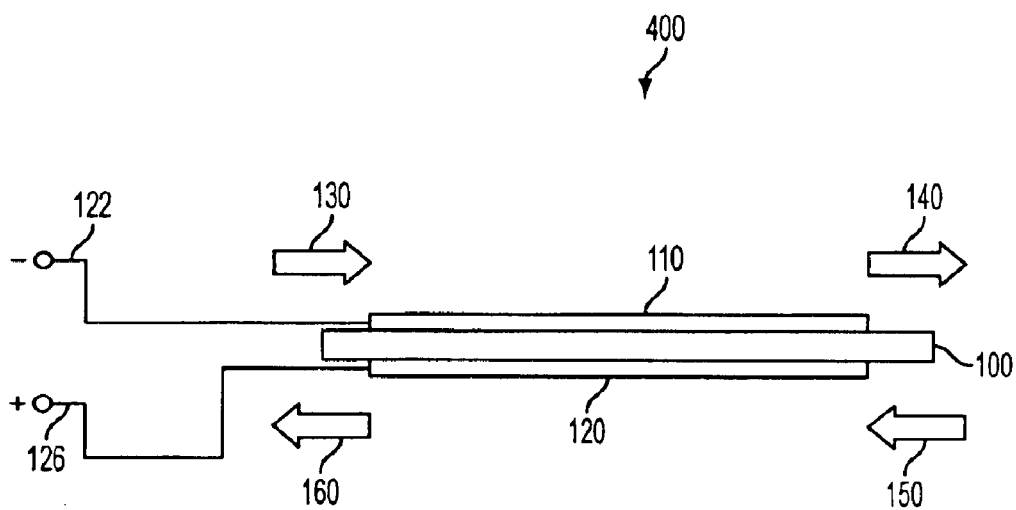


FIG. 6A

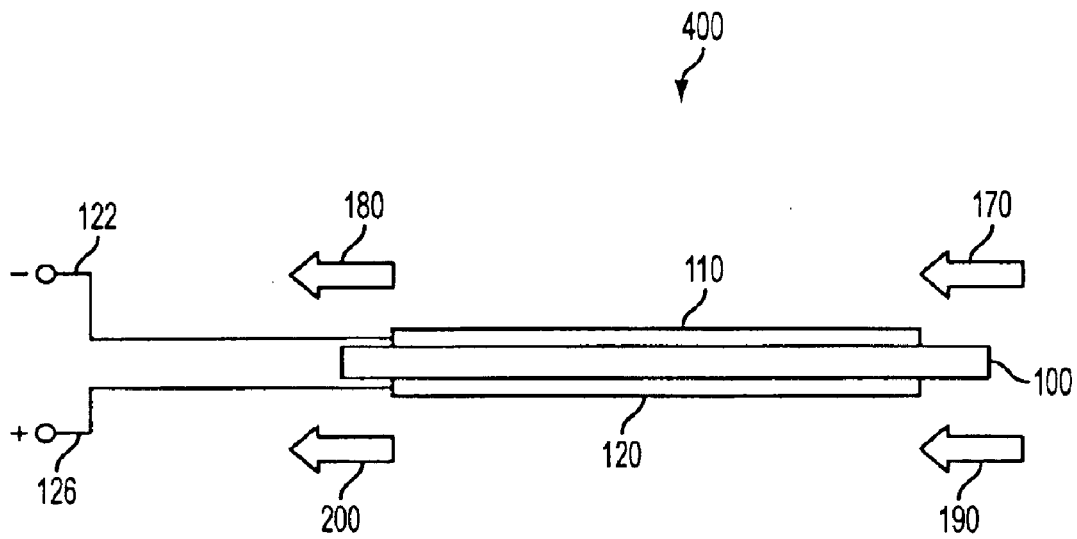


FIG. 6B



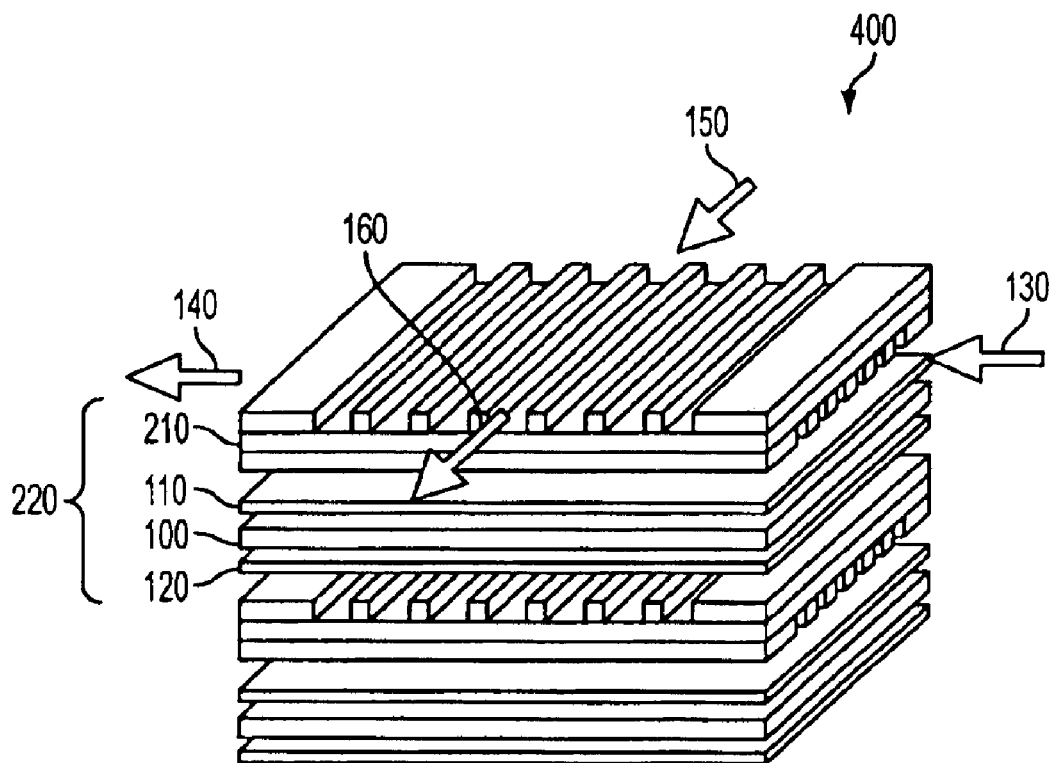


FIG. 7

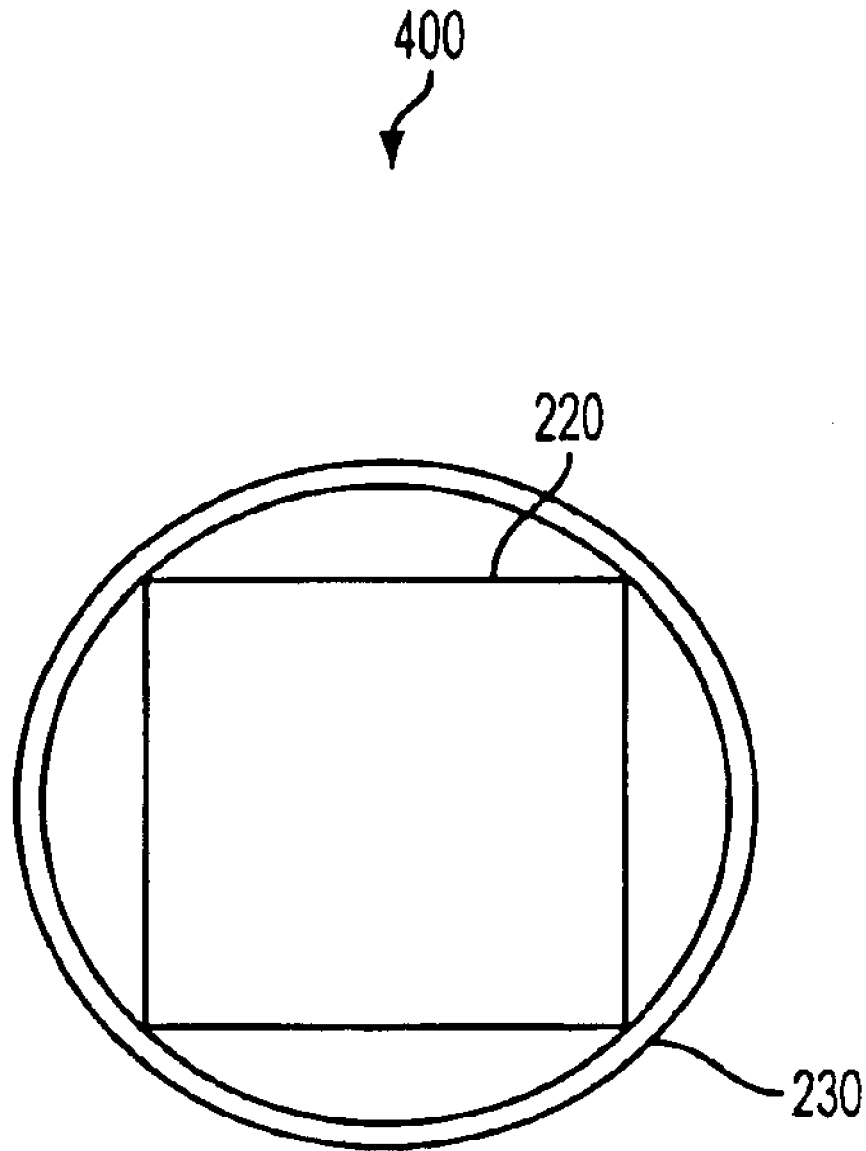


FIG. 8

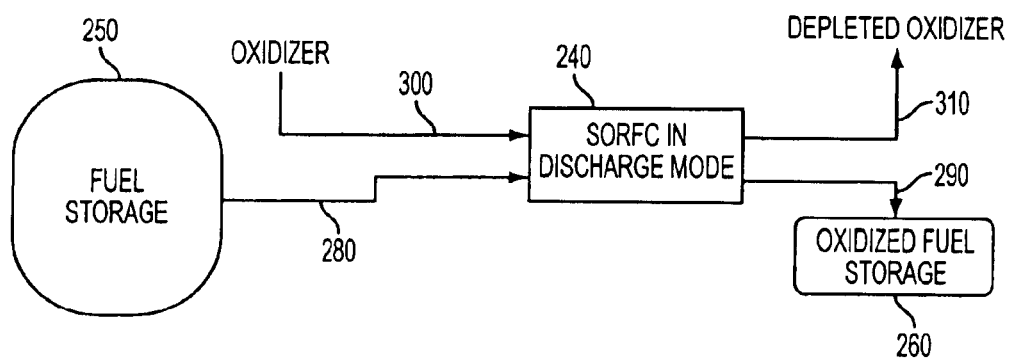


FIG. 9

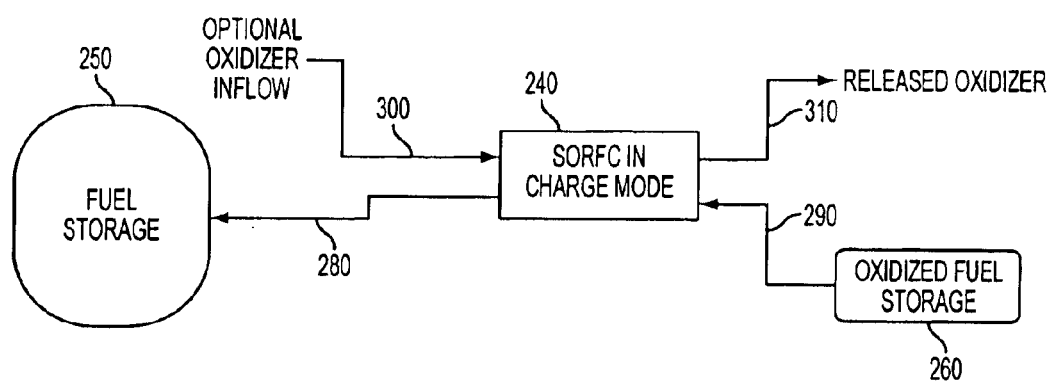


FIG. 10

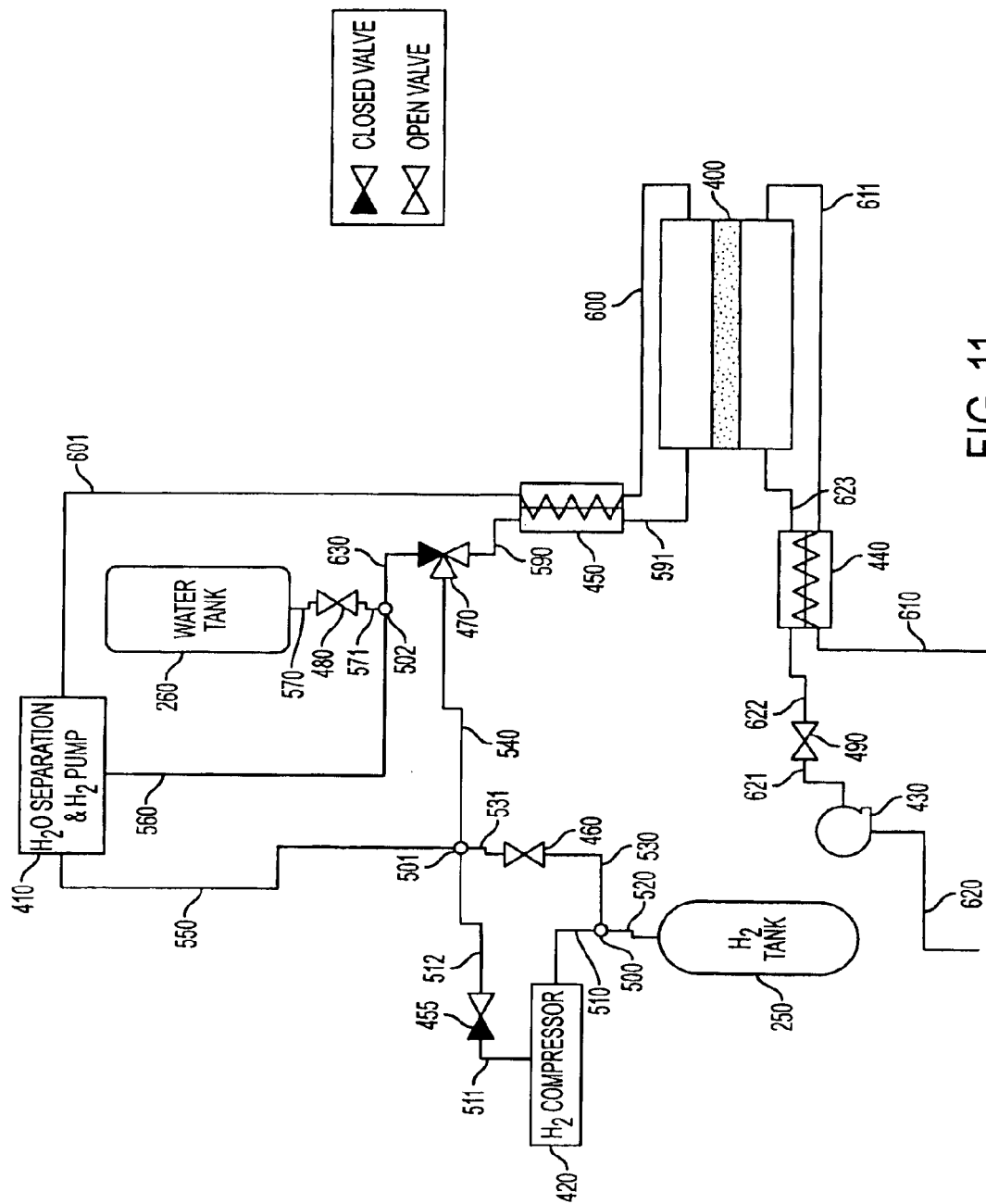
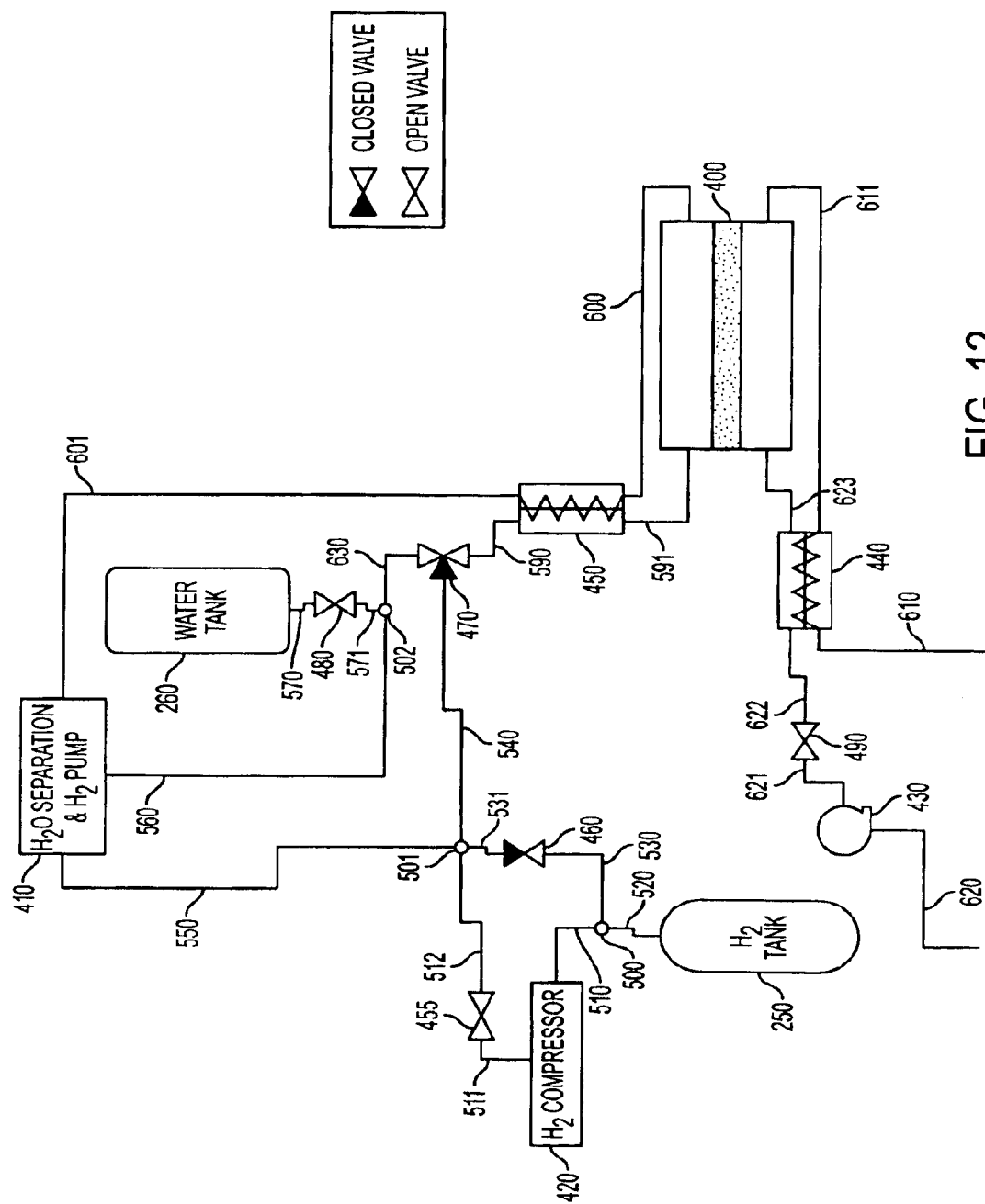


FIG. 11



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## FUEL CELL FOR AIRSHIP POWER GENERATION AND HEATING

This application claims benefit of priority of U.S. provisional application No. 60/377,199 filed on May 3, 2002, which is incorporated by reference in its entirety.

### BACKGROUND OF THE INVENTION

The invention generally relates to the fuel cells, and specifically to use of a solid oxide fuel cell system as an energy converter in an airborne vehicle, such as in a blimp.

A solid oxide fuel cell (SOFC) is an electrochemical device that converts chemical energy directly into electrical energy. A Solid Oxide Regenerative Fuel Cell (SORFC) is an electrochemical device that converts chemical energy directly into electrical energy and subsequently reconverts electrical energy back to the original chemical energy. This device differs significantly from rechargeable batteries in that the chemicals are stored outside of the SORFC converter. The SORFC system has many building electrical energy storage applications that cannot be satisfied by batteries. For example, a SORFC system for building power generation is discussed in the Proceedings of the 2001 DOE Hydrogen Program Review NREL/CP-570-30535.

### BRIEF SUMMARY OF THE INVENTION

In one preferred aspect of the present invention, there is provided an airborne vehicle, comprising a vehicle body which is adapted for flying, a fuel cell adapted to power the airborne vehicle, and a heat transport loop adapted to transfer heat from the fuel cell to equipment located remotely on the airborne vehicle.

In another preferred aspect of the present invention, there is provided a method of generating power in an airborne vehicle, comprising providing a fuel and an oxidizer to a fuel cell to generate power, and providing heat from the fuel cell to remotely located equipment on the airborne vehicle.

In another preferred aspect of the present invention, there is provided a neutrally buoyant airship, comprising a lifting body which allows the airship to remain neutrally buoyant in air, and a fuel cell located in the airship.

In another preferred aspect of the present invention, there is provided a method of generating power in a neutrally buoyant airship, comprising providing a fuel and an oxidizer to a solid oxide fuel cell to generate power, and providing heat from the fuel cell to a remotely located lifting body, wherein the lifting body allows the airship to remain neutrally buoyant in air.

In another preferred aspect of the present invention, there is provided a neutrally buoyant airship, comprising a hydrogen gas envelope which allows the airship to remain neutrally buoyant in air, a fuel cell located in the airship, and a conduit connecting the hydrogen gas envelope to a fuel inlet of the fuel cell, such that the fuel cell is adapted to use hydrogen from the hydrogen gas envelope during discharge mode.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of SORFC system in solar powered airborne vehicle.

FIG. 2 is a schematic illustration of SOFC system in an airborne vehicle.

FIG. 3 is a schematic illustration of a fuel cell system providing electrical power and heat in an airship.

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FIG. 4 is a schematic illustration of SORFC system providing electrical power and heat in solar powered high altitude airplane.

FIG. 5 is a schematic illustration of SOFC system providing electrical power and heat in electrically powered high altitude airplane.

FIG. 6A is a schematic illustration of basic elements of SORFC in discharge mode.

FIG. 6B is a schematic illustration of basic elements of SORFC in charge mode.

FIG. 7 is a three dimensional view of planar SORFC stack.

FIG. 8 is a schematic illustration of manifolded SORFC stack.

FIG. 9 is a schematic illustration of SORFC system in discharge mode.

FIG. 10 is a schematic illustration of SORFC system in charge mode.

FIG. 11 is a schematic illustration of SORFC system components in discharge mode.

FIG. 12 is a schematic illustration of SORFC system components in charge mode.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present inventors have realized that a solid oxide fuel cell, such as the SOFC and the SORFC, has unique properties that make it advantageous as an energy generation and storage device in an airborne vehicle, such as an airplane or a neutrally buoyant airship, such as a blimp. The present inventors have realized that the SORFC does not require an independent source of oxygen or pure water when the SORFC is used for energy generation or storage for an airborne vehicle that operates in Earth's atmosphere. The SORFC system is distinct from other hydrogen-oxygen (or hydrocarbon-oxygen) regenerative fuel cell systems in that no water (or other oxidized fuel) is lost from the cell with the air or oxygen oxidant discharge. Therefore the SORFC can be operated open loop on the oxygen oxidant side without requiring any makeup of any reactants or process chemicals. In contrast, other regenerative fuel cells that operate with an open oxygen oxidant loop must have an independent source of pure water, as process water is lost with the air oxygen oxidant discharge. Thus, the SORFC system operating in an airborne vehicle in the earth's atmosphere can obtain oxygen oxidant reactant from the air and avoid the complexity, weight, volume, and cost associated with oxygen oxidant storage.

An airborne vehicle is a vehicle capable of flying. One preferred type of airborne vehicle that uses the fuel cell is a neutrally buoyant airship. Such an airship is capable of floating in air at a desired altitude. The airship contains a lifting body which allows the airship to remain neutrally buoyant in air.

For example, the airship may be a blimp and the lifting body may be a gas envelope which is filled with a gas which is lighter than air. Examples of such gas are helium, hydrogen, helium-hydrogen mixtures and other light gases and mixtures.

Blimps may be used for surveillance, such as for filming of sporting or entertainment events and for security surveillance in security sensitive locations. For example, the blimps may be stationary blimps loaded with surveillance equipment which are located over land or water borders, over restricted access areas or over areas which are desirable to maintain under surveillance.

The fuel cell is adapted to provide power to components of the blimp, such as the surveillance electronics, the motor propeller which can be used to propel the blimp and/or for other electronics located on the blimp. Preferably the fuel cell is located in the chamber attached below the gas envelope.

Furthermore, the fuel cell is adapted to selectively provide heat to the lifting body to allow the blimp to maintain a desired altitude during cooler temperature, such as at night time, or in a high wind. The fuel cell may selectively provide heat to the lifting member in response to a sensed condition, such as temperature, altitude and/or wind speed.

#### The First Preferred Embodiment

In a first preferred embodiment, an SORFC is used to power the airborne vehicle, such as a blimp. The airborne vehicle may also contain a solar array and use solar generated electricity to drive an electric motor propeller and/or to power on board electronics and to electrolyze water in the SORFC during the daylight and use the stored fuel to generate electric power in the SORFC during the nighttime to drive an electric motor propeller system and/or to power the on board electronics. Using the SORFC eliminates the need to store oxygen, as none of the process water is lost. This greatly increases the capability of the vehicle due to the significant weight reduction. However, the SORFC may be used in any other type of airborne vehicle, such as a high altitude solar powered unmanned airplanes, manned airplanes, fuel powered airplanes or even helicopters.

A hydrogen/oxygen (i.e., hydrogen fuel, oxygen or air oxidizer) SORFC is preferred for use in the airborne vehicle. However, other SORFC types, such as hydrocarbon/oxygen types may be used instead. The use of a hydrogen/oxygen SORFC within blimp provides the blimp with the capability to stay aloft at high altitude for many months only returning to the ground for maintenance. The ability to use atmospheric oxygen (i.e., air) instead of stored oxygen saves sufficient mass to allow the blimp to fly at higher altitude and/or to carry an increased payload.

In one aspect of the first embodiment, the blimp is powered by one SORFC system. However, in a preferred aspect of the first embodiment, the blimp is powered by multiple smaller SORFC systems distributed along its length. This results in an advantage in mass distribution and redundancy.

Other potential regenerative fuel cell systems, such as the PEM regenerative fuel cell, may also be used in the blimp. However, the SORFC is advantageous because, an oxygen ion is transported across the electrolyte. Thus, the byproduct water is formed on the fuel side of the electrolyte in the SORFC. The only chemical produced or consumed within the SORFC oxidant chamber is oxygen and no water is lost from the open loop oxidant. This eliminates water make up, detectable condensation trails, and interference with sensors. Since no organic materials are preferably used within the SORFC stack, the hardware is immune to ozone degradation.

FIG. 1 illustrates a SORFC system within an airborne vehicle, such as a blimp or a high altitude solar powered unmanned airplane according to a preferred aspect of the first embodiment. If desired, all of the power comes from solar radiation. However, an alternative or an additional power source may also be used. The airborne vehicle contains a body and photovoltaic cells to form a solar array **700**. This array converts the solar radiation into DC electricity. During the daytime, when solar radiation is available, a portion of the DC electricity is delivered to the motor

propeller system **740** (i.e., an electrical motor which rotates the propeller) and/or to on board electronics from the solar array **700** via electrical cable **720**.

Another portion of the DC electricity is delivered to the SORFC **240** from the solar array **700** via electrical cable **710**. At the same time oxidized fuel (i.e., water) is delivered to the SORFC **240** from oxidized fuel storage vessel **260** via fluid conduit **290**. Within SORFC **240**, the water is electrolyzed using the DC electricity provided from array **700**. The oxygen oxidant is discarded from the SORFC **240** via fluid conduit **310**. For example, conduit **310** may be an outlet pipe which vents oxygen into the atmosphere. The hydrogen (or hydrocarbon) fuel is delivered to fuel storage vessel **250** from SORFC **240** via fluid conduit **280**. Ambient air, if needed for thermal control, is delivered to SORFC **240** via fluid conduit **300**. Any thermal control air is discharged from SORFC **240** via fluid conduit **310** along with the generated oxygen oxidant.

During the nighttime, when solar radiation is not available, the previously generated hydrogen (or hydrocarbon) fuel is delivered to SORFC **240** from fuel storage vessel **250** via fluid conduit **280**. Simultaneously, ambient air as the oxidant source is delivered to the SORFC **240** via fluid conduit **300**. Within SORFC **240**, DC electricity is generated and delivered to the motor propeller system **740** and/or to on board electronics via electrical cable **730**. Depleted air is discharged from the SORFC **240** via fluid conduit **310**. The air oxidant source flow also serves as a thermal control fluid. The oxidized fuel (water) is delivered from the SORFC **240** to the oxidized fuel storage vessel **260** via fluid conduit **290**.

#### Second Preferred Embodiment

In a second preferred embodiment of the present invention, a non-regenerative solid oxide fuel cell (SOFC) is used as a primary power source for an airborne vehicle, such as the neutrally buoyant airship.

In this embodiment, all the energy for the airship comes from fuel carried onboard. The use of hydrogen as the fuel is preferred because it allows the airship to maintain a stealth character as the oxidized fuel (water) is stored and the airship retains a zero emission status. However, if desired, a conventional hydrocarbon fuel (such as methane or propane) may be used instead if the stealth characteristics are not important in the airship.

As in the SORFC, the SOFC uses atmospheric air as the source of oxygen oxidant without compromising the stealth. The advantages of the SOFC compared to the open loop oxidant PEM fuel cell include the lack of a water vapor condensation trail with its further interference with onboard sensors and the tolerance to atmospheric ozone.

FIG. 2 illustrates a SOFC system within an airship according to a preferred aspect of the second embodiment. Fuel (preferably hydrogen) is delivered from fuel storage vessel **250** to the SOFC **750** via fluid conduit **280**. Simultaneously, ambient air oxidant oxygen is supplied to SOFC **750** via fluid conduit **300**. Within SOFC **750**, reactions produce DC electricity and oxidized fuel (water). The oxidized fuel is delivered from the SOFC **750** to the oxidized fuel storage vessel **260** via fluid conduit **290**. If stealth characteristics are not important in the airship, then the oxidized fuel may be vented into the atmosphere and the storage vessel **260** and conduit **290** may be omitted. The depleted oxidizer (i.e., oxygen depleted air) is vented into the atmosphere through conduit **310**. The DC electricity is delivered from the SOFC **750** to the motor propeller system **740** via electrical cable **760** providing thrust for the airplane until the fuel is exhausted.



## Third Preferred Embodiment

FIG. 3 illustrates the use of a fuel cell in a neutrally buoyant airship 10, such as a blimp. The airship contains a lifting body 12 which allows the airship 10 to remain neutrally buoyant in air. Preferably, the lifting body 12 is a gas envelope which is filled with a gas which is lighter than air. Examples of such gas are helium, hydrogen, helium-hydrogen mixtures and other light gases and mixtures. Preferably, the envelope is a flexible balloon which expands when filled with the gas or when the gas is heated, and which contracts when the gas is cooled or emptied from the balloon. Alternatively, the envelope 12 may comprise a rigid gas storage vessel made of a gas impermeable material.

The airship 10 also preferably contains a chamber 14 attached below the envelope 12. This chamber is sometimes referred to as a "basket", but may have any suitable shape and size, such as a chamber which can house propulsion, control and electronic equipment. Preferably, a fuel cell 16 is located in this chamber. The fuel cell may be a SORFC, a SOFC or another fuel cell, such as a PEM or a molten carbonate fuel cell.

Preferably, the airship 12 is used for surveillance, such as for filming of sporting or entertainment events or for security surveillance in security sensitive locations. The chamber 14 preferably contains surveillance electronics 18, such as camera(s), computer(s), recorder(s), data transmission equipment, such as antenna and RF emitting device(s).

The airship 10 contains optional propulsion equipment. For example, the airship 10 may have one or more motor propellers 20 for propulsion. Alternatively, the airship may lack separate propulsion equipment, and be towed to a desired location by another vehicle and then tethered at the desired location to the ground, to a seabed or to a buoy or ship floating on water.

The fuel cell 16 is adapted to provide power to components of the airship 10, such as the surveillance electronics 18, the motor propeller 20 and/or for other electronics located on the airship. The fuel cell 16 provides power (i.e., electricity) to the components of the airship by wires or cables.

Preferably, the airship 10 also contains a heat transport loop 22 adapted to selectively transfer heat from fuel cell 16 to the gas envelope 12. The heat transport loop 22 may comprise one or more pipes or ducts filled with a heat transfer medium, such as a gas, liquid or solid material which transports heat relatively efficiently. Portions of the loop 22 may be located adjacent to the fuel cell 16 and the envelope 12 to provide heat transfer from the fuel cell to the envelope. In one preferred aspect, the loop 22 uses air as the heat transfer medium to provide hot air from the fuel cell 16 to the gas envelope 12 to heat the gas inside the gas envelope.

Preferably, the envelope 12 is located remotely from the fuel cell 16. The term "remote" means that the envelope is located at a distance from the fuel cell at which it would not be significantly heated by the operating fuel cell absent the heating loop 22.

In another preferred aspect, the loop 22 uses fuel and/or oxidizer exhaust gas from the fuel cell 16 as the heat transfer medium. In this case, the loop 22 is a pipe or conduit that is connected to the fuel and/or oxidizer exhaust outlets of the fuel cell 16. Preferably, the loop 22 is a pipe or conduit that is connected to the oxidizer exhaust outlet (i.e., the loop 22 is the oxidizer outlet line) and provides hot oxygen depleted oxidizer (i.e., oxygen depleted air) adjacent to the envelope 12, to heat the gas in the envelope 12.

In another preferred aspect, the loop 22 uses the light gas from the envelope 12 as the heat transfer medium. In this case, the loop 22 comprises a pipe or conduit which is open to the inside of the envelope to allow the light gas in the envelope, such as H or He, to enter the loop 22. The light gas passes adjacent to the hot operating fuel cell to heat the gas. The term "adjacent" includes passing the light gas next to the fuel cell, through a portion of the fuel cell and/or through a heat exchanger which carries hot fuel, oxidizer or exhaust gas from the fuel cell. The heated light gas then returns to the envelope 12 through another part of the loop 22.

Preferably, the airship 10 also contains a controller 24 which controls the flow of the heat transfer medium through the loop 24 to selectively provide heat from the fuel cell 16 to the gas envelope 12. The controller 24 may be a computer controlled valve, such as a gas valve if the heat transfer medium is a gas. The computer selectively opens and closes the valve to control the amount of gas (if any) being provided from the fuel cell 16 to the gas envelope 12 to provide a desired amount of heating to the gas in the envelope. If the heat transfer medium is a stationary gas (i.e., the light gas from the envelope or gas in a sealed loop), then the controller 24 may also comprise an optional blower control which forces the gas through the loop 22. The controller 24 may control heat provided to the envelope based on predetermined criteria, such as the time of day, and/or based on data received from an operator. For example, the controller 24 may provide heat to the envelope 12 during night time when the temperature is lower, to heat the light gas in the envelope to allow the airship to maintain its altitude. This prevents or reduces the shrinkage of the light gas and the shrinkage of a flexible envelope in cool weather. During the day, when the temperature is warmer, the controller 24 may provide less or no heat to the envelope 12.

Preferably, the controller 24 provides heat from the fuel cell 16 to the envelope 12, such as by opening the valve and/or operating the blower, in response to a sensed condition. In a preferred aspect of the third embodiment, the airship 10 also contains one or more condition sensors 26 which are operatively connected to (i.e., in electrical, optical or radio communication with) the controller 24.

In one preferred aspect of the third embodiment, the sensor 26 comprises an altitude detector adapted to detect an altitude of the airship. The controller 24 is adapted to selectively provide heat from the fuel cell 16 to the gas envelope 12 to elevate the airship to a different altitude if the detected altitude is below a desired altitude.

In another preferred aspect, the sensor 26 is a temperature detector adapted to detect an ambient temperature adjacent to the airship 10. The controller 24 is adapted to selectively provide heat from the fuel cell to the gas envelope if the detected temperature is below a desired temperature.

In another preferred aspect, the sensor 26 comprises a wind speed detector adapted to detect wind speed adjacent to the airship 10. The controller 24 is adapted to selectively provide heat from the fuel cell to the gas envelope to elevate the airship to a different altitude if the detected wind speed is above a desired speed.

The airship 10 may have more than one sensor 26 and may detect more than one condition. Thus, the airship may have at least two temperature, altitude and wind speed detectors. In this case, the controller 24 determines the effects of the plural sensed conditions and selectively provides a desired amount of heat to maintain the airship at a desired altitude.

In another preferred aspect of the third embodiment, the gas envelope **12** comprises a hydrogen gas envelope. The hydrogen gas envelope **12** is connected to the fuel inlet of the fuel cell **16** by a conduit **28**. In this case, the hydrogen gas envelope acts as a fuel storage vessel for the fuel cell **16**. The fuel cell **16** draws hydrogen from the envelope **12** as its operating fuel in the discharge or fuel cell mode.

Preferably, in this aspect, the fuel cell **16** comprises a regenerative fuel cell, such as a SORFC. The regenerative fuel cell **16** supplies hydrogen into the hydrogen gas envelope **12** in the charge or electrolysis mode. The operation of the fuel cell in the charge mode is explained in more detail below. Thus, since the hydrogen in the envelope is periodically recharged, it is not depleted by the operation of the fuel cell.

Preferably, in this preferred aspect, the airship **10** contains a solar array, such as array **700** shown in FIG. **1**. The array **700** converts sunlight into electrical energy during the day and provides the electrical energy to the regenerative fuel cell **16**. The fuel cell **16** is operated in the charge or electrolysis mode during the day to generate hydrogen and to provide the hydrogen into the gas envelope **12**. The solar array **700** may also provide power to the electronics **18**, **24** and/or **26** and/or to the propeller **20** during the day time. During night time or during cloudy days, the fuel cell **16** provides the power to the electronics **18**, **24** and/or **26** and/or to the propeller **20**.

#### Fourth Preferred Embodiment

In a fourth preferred embodiment a SORFC or a SOFC system is not only used to provide an airborne vehicle with electrical energy, but also provides heat for thermal conditioning of airborne vehicle systems or payload. SORFC and SOFC systems operate at elevated temperatures and generate heat during operation. Part of this heat can be harnessed and transported to airborne vehicle systems or payload that require heating.

For example, for an airplane operating at 66,000 ft altitude, the ambient air temperature is approximately -55° C. Some of the equipment within the airplane should be kept at temperatures above this ambient temperature. This equipment may be heated using electric heating. However, electric heating adds additional power requirements to the airplane power supply system which can result in additional mass. Some of this additional mass can be eliminated if a heat transport loop is provided which transports thermal energy from the SORFC or SOFC to the equipment or payload that needs to be heated. Alternatively, in a manned airplane, the occupant compartment may be heated using heat from the SOFC or SORFC.

FIG. **4** illustrates an SORFC system within a high altitude solar powered unmanned airplane that also supplies heat to airplane systems or payloads, according to a preferred aspect of the fourth embodiment. The system of FIG. **4** is similar to that illustrated in FIG. **1**, except that the SORFC **240** is used to heat an airplane system or payload **810** that is located in the airplane body remote from the SORFC system. The term "remote" means that the system or payload is located at a distance from the fuel cell at which it would not be significantly heated by the operating fuel cell absent a heating loop. Preferably all of the airplane power comes from solar radiation. The top surface of the airplane's large wing structure is mostly covered with photovoltaic cells to form a solar array **700**. This array converts the solar radiation into DC electricity. During the daytime, when solar radiation is available, a portion of the DC electricity is delivered to the motor propeller system **740** from the solar

array **700** via electrical cable **720**. This provides thrust to the airplane during the daytime. Another portion of the DC electricity is delivered to the SORFC **240** from the solar array **700** via electrical cable **710**. At the same time oxidized fuel (water) is delivered to the SORFC **240** from oxidized fuel storage vessel **260** via fluid conduit **290**. Within SORFC **240** the water is electrolyzed using the DC electricity. The oxygen oxidant is discarded from the SORFC **240** via fluid conduit **310**. The hydrogen fuel is delivered to fuel storage **250** from SORFC **240** via fluid conduit **280**. Ambient air, if needed for thermal control, is delivered to SORFC **240** via fluid conduit **300**. Any thermal control air is discharged from SORFC **240** via fluid conduit **310** along with the generated oxygen oxidant.

During the nighttime, when solar radiation is not available, the previously generated hydrogen fuel is delivered to SORFC **240** from fuel storage **250** via fluid conduit **280**. Simultaneously, ambient air as the oxidant source is delivered to the SORFC **240** via fluid conduit **300**. Within SORFC **240** DC electricity is generated and delivered to the motor propeller system **740** via electrical cable **730** to provide thrust to the airplane during the nighttime. Depleted air is discharged from the SORFC **240** via fluid conduit **310**. The air oxidant source flow also serves as a thermal control fluid. The oxidized fuel (water) is delivered from the SORFC **240** to the oxidized fuel storage vessel **260** via fluid conduit **290**.

The SORFC generates heat during charge and discharge operation. A heat transport loop **800** transports heat from the SORFC to the equipment (i.e., electronics, etc.) or payload **810** in need of heat. The heat transport loop **800** may comprise pipe(s) or duct(s) filled with a heat transfer medium, such as a gas or liquid. Preferably, the loop **800** uses air as the heat transfer medium. Cooling air is blown past or adjacent to the hot fuel cell stack **240** through the loop **800**. The air absorbs heat as it is passed through loop **800** and the warmed air is guided toward or adjacent to the remotely located equipment or payload **810** that needs to be heated. Thus, the loop **800** provides heat to equipment or payload that would not ordinarily be heated by the SORFC (i.e., "remotely" located payload or equipment is payload or equipment that would not be substantially heated by the SORFC but for the loop **800**). The loop **800** may be an open or a closed loop. The heat transport loop can also operate with a liquid or a two-phase re-circulation loop. Other modes of heat transfer, such as conduction or radiation can also be used.

Waste heat can also be used to heat payload or equipment **810** when a SOFC is acting as a primary power source for a high altitude airplane. FIG. **5** illustrates a SOFC system within a high altitude unmanned airplane used to supply heat to airplane systems or payload. The SOFC system in FIG. **5** is similar to the SOFC system shown in FIG. **2**, except for the presence of the heat transfer loop **800**.

Fuel (hydrogen) is delivered from fuel storage vessel **250** to the SOFC **750** via fluid conduit **280**. Simultaneously, ambient air oxidant oxygen is supplied to SOFC **750** via fluid conduit **300**. Within SOFC **750**, reactions produce DC electricity and oxidized fuel (water). The oxidized fuel is delivered from the SOFC **750** to the optional oxidized fuel storage vessel **260** via fluid conduit **290**. The DC electricity is delivered from the SOFC **750** to the motor propeller system **740** via electrical cable **760** providing thrust for the airplane until the fuel is exhausted.

A heat transport loop **800** transports heat from the SOFC to the equipment or payload **810** in need of heat. The heat

transport loop **800** may comprise pipe(s) or duct(s) through which a heat transfer medium travels, similar to that described with respect to the system of FIG. 4. Heat transfer medium, such as cooling air, is blown past the hot SOFC stack **750**, where the air absorbs heat. The warmed air is guided through the loop **800** to the equipment or payload **810** that needs to be heated. The heat transport loop can be open or closed loop and also operate with a liquid or a two-phase recirculation loop. Other modes of heat transfer, such as conduction or radiation can also be used. It should be noted that while SORFC and SOFC systems are preferred for providing heat in the airplane, other fuel cell systems, such as PEM fuel cell systems, may be used instead.

#### Fifth Preferred Embodiment

Any type of SOFC or SORFC may be used to provide power and/or heating for an airborne vehicle of the first through fourth embodiments. A preferred SORFC system for use in the airborne vehicle is described below. However, it should be noted that the SORFC system described below may be used to power and/or heat objects other than an airborne vehicle, such as a ground based vehicle (i.e., automobile, etc.), water based vehicle (i.e., ship), a building or various devices requiring heat or power.

The SORFC is an electrochemical device based on a solid, oxygen ion conducting electrolyte, which is capable of generating electrical energy by oxidation of a fuel, and which is also capable of regenerating the oxidized fuel back into fuel. FIG. 6A shows a functional schematic of a SORFC in "discharge", "fuel cell" or "electricity generation" mode.

The SORFC **400** contains a solid electrolyte **100**, a fuel electrode **110** and an oxygen electrode **120**. The electrolyte **100** is an oxygen ion conducting material such as a ceramic material. Preferably, yttria stabilized zirconia (YSZ) is used, but other materials, such as gadolinia doped ceria or scandia doped zirconia can also be used. The oxygen electrode **120** is made from a material that can conduct electrons in an oxidizing environment. Two preferred materials are strontium doped lanthanum manganite (LSM) and platinum, which is often mixed with an oxygen ion conductor such as YSZ. Other materials capable of conducting electrons in an oxidizing environment can also be used.

In non-regenerative solid oxide fuel cells (SOFC), nickel YSZ mixtures are commonly used as fuel electrodes **110** for electrical energy generation. Nickel requires a reducing environment in order to work properly. In a SORFC, the fuel electrode **110** is exposed to a reducing environment during discharge, but is exposed to an oxidized fuel during charge operation. Therefore, materials capable of conducting electrons in an oxidizing environment should be used at the fuel electrode **110**. Similarly to the oxygen electrode **120**, platinum that is mixed with YSZ or LSM is preferably used as a fuel electrode **110** material. Other materials that are capable of conducting electrons in an oxidizing environment can also be used.

The fuel supply **130** reaches the fuel electrode side of the SORFC **400**. The fuel **130** is preferably hydrogen, but other fuels, for example hydrocarbons or oxygenated hydrocarbons can also be used. An oxidizer **150**, preferably air, reaches the SORFC on the oxygen electrode side. Other oxidizer, for example pure oxygen can be used. The fuel reacts with oxygen available at the fuel electrode **110** and thereby creates a low oxygen partial pressure on the fuel electrode **110** side of the cell.

Electrically conductive electrodes **110** and **120** on both sides of the electrolyte **100** can provide and absorb electrons and thereby oxygen ions can be generated and consumed.

The difference in partial pressure of oxygen between the fuel electrode **110** and the oxygen electrode **120** drives negatively charged oxygen ions from the oxygen electrode **120** through the electrolyte **100** to the fuel electrode **110**. Thereby, negative electrical charge is transported from the oxygen electrode **120** to the fuel electrode **110**. This charge transport generates an electrical potential difference between fuel electrode **110** and oxygen electrode **120**, which can be used to drive an electrical circuit (not shown in Figures for clarity) connected to the SORFC via the fuel electrode electrical connection **122** and the oxygen electrode electrical connection **126**.

Oxidized fuel leaves the SORFC in the oxidized fuel outflow **140**. The oxidized fuel preferable consists of a mixture of water vapor and unreacted hydrogen, but other materials are also possible. Oxygen depleted oxidizer leaves the SORFC in the depleted oxidizer outflow **160**. The oxygen depleted oxidizer is preferably air with a reduced oxygen content as compared to the oxidizer inflow **150**, but other materials can also be used.

FIG. 6B illustrates a functional schematic of the SORFC **400** in "electrolyzer" or "charge" mode. Oxidized fuel reaches the fuel electrode **110** at the oxidized fuel inflow **170**. The oxidized fuel is preferably water vapor, but other materials, for example a mixture of carbon oxides and water vapor can also be used. An electrical potential is applied through the fuel electrode electrical connection **122** and oxygen electrode electrical connection **126**. This creates a driving force to electrolyze the oxidized fuel **170** at the fuel electrode **110** and transport the oxygen through the electrolyte **100** to the oxygen electrode **120**. As in the discharge mode, the transfer of oxygen from the fuel electrode **110** through the electrolyte **100** to the oxygen electrode **120** occurs in the form of oxygen ion transport.

Regenerated fuel and residual oxidized fuel leave the SORFC at the regenerated fuel outflow **180**. This mixture preferably consists of hydrogen and water vapor, but other materials are also possible. An optional oxygen electrode inflow **190** can be provided to the oxygen electrode **120**. This optional oxygen electrode inflow **190** can, for example, provide temperature management of the SORFC, but can also serve other purposes and it may also be absent. Ambient air is a preferred material for the optional oxygen electrode inflow **190**, but other materials can also be used. The regenerated oxidizer outflow **200** removes regenerated oxidizer and optional oxygen electrode inflow **190** from the cell. This regenerated oxidizer outflow preferably consists of pure oxygen or an oxygen air mixture, but other materials can also be used.

For practical use the SORFC can be packaged in a multi-cell system by stacking a number of the repeating elements **220** as shown in FIG. 7. The amount of power available from an SORFC depends on the electroded area. Multi-cell systems provide for convenient packaging of large electroded areas.

FIG. 7 illustrates an example for packaging of multiple SORFC. Here a planar electrolyte **100**, with fuel electrode **110** and oxygen electrode **120** applied to either side of the planar electrolyte **100**, is sandwiched between interconnect plates **210** thereby forming a stack. The elements shown in FIG. 7 can be repeated many times to form a large SORFC stack. The interconnect plate **210** serves several functions. The interconnect plate **210** separates the gas volume adjacent to the fuel electrode **110** from the gas volume adjacent to the oxygen electrode **120**. This separation avoids uncontrolled reaction or mixing of the gases on the two sides of

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each electrolyte **100**. In SORFC, this separation is also important to avoid losses of the fuel or oxidized fuel, which would limit the useful life of the energy storage device. The interconnect **210** also provides a flow path for the gases on either side of the electrolyte. For example, the gas flow paths may comprise grooves in plate **210**.

FIG. 7 illustrates a system with the fuel inflow **130** on the right side of the SORFC stack and the oxidized fuel outflow **140** on the left side of the stack. The oxidizer flow proceeds from the oxidizer inflow **150** on the back side of the stack to the depleted oxidizer outflow **160** on the front of the stack. This cross-flow configuration is one preferred flow path. Other preferred flow paths are co-flow where both gases stream in the same direction and counter flow where the two gases flow in opposite directions. The system can also be provided with other flow paths, for example paths based on circular stack geometries. The interconnect plate **210** can also provide an electrical current path within the stack. One preferred example is an interconnect **210** fabricated from an electrically conductive material. One side of interconnect **210** contacts a fuel electrode **110**, and the other side contacts an oxygen electrode **120**. Current flows through the interconnect **210** to the fuel electrode **110**, through the electrolyte **100**, through the oxygen electrode **120**, and then through the next interconnect **210**. This group of conducting elements can be repeated. One preferred material for the interconnect **210** is a metal which expands at the same rate as the electrolyte **100** during temperature changes, such as a metal felt described in U.S. provisional application Ser. No. 60/357,636, filed Feb. 20, 2002, incorporated herein by reference. Other examples are high temperature alloys, ferritic steels, or electrically conductive ceramics. Other materials can be used for the interconnect **210**. For many of these materials surface coatings may be added in order to achieve a chemically stable system.

In a SORFC, both sides of the interconnect **210** need to be capable of operating in an oxidizing environment. In contrast, in a SOFC, the side of the interconnect **210** facing the fuel electrode **110** can be operated solely in a reducing environment which poses relaxed requirements for the interconnect **210**.

The planar stacked electrolytes in FIG. 7 are only one preferred example for packaging of SORFC. Other possibilities include, but are not limited to, cells in which the electrolyte is formed into tubes.

FIG. 7 does not show how the gases are manifolded in order to supply and remove gas from the repeating stack elements **220**. FIG. 8 presents one preferred example for external manifolding of the stack elements shown in FIG. 7. The repeating elements **220** are mounted inside a circular cylinder **230**. Gas distribution to the repeating elements **220** is provided in the space between the square stack repeating elements **220** and the inner wall of the circular cylinder **230**. Other manifolding schemes are also possible.

The electrolyte **100** is preferably between 50 and 400 micrometer thick, such as 100–200 micrometer thick. Systems with thinner and thicker electrolytes are also possible. The fuel electrode **110** is preferably 20 to 50 micrometer thick, such as 30–40 micrometer thick, while the preferred thickness for the oxygen electrode **120** is between 30 and 80 micrometer, such as 45–65 micrometer thick. Other electrode thicknesses are possible. The interconnect **210** is preferably 1 to 5 mm thick, such as 2–4 mm thick. Preferred operating voltages during discharge are 0.6V to 1.0V per cell. Preferred operating voltages during charging are 1.0 to 2.1V per cell. Different voltages may be used in operation.

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Preferred power densities during discharge range between 100 and 1000 mW per square centimeter, such as 100–300 mW per square centimeter of electroded area. Preferred current densities during charging range between 100 and 2000 mA per square centimeter, such as 500–1500 mA per square centimeter electroded area. Larger and smaller values for power density and current density are possible. The preferred active area for each cell within a stack ranges between 9 and 500 square centimeter. The preferred dimension for the cell stack elements shown in FIG. 7 is a side length between 3 and 25 cm, such as 7–15 cm. The preferred number of cells within a stack ranges from 5 cells to 200 cells, such as 50–100 cells. Larger and smaller cells as well as more and fewer cells per stack are possible.

FIGS. 9 to 12 illustrate a preferred SORFC system in which the fuel and the oxidized fuel are stored and regenerated. It is possible to also store and regenerate the oxidizer. However, one of the major advantages of SORFC is the ability to operate for an unlimited number of cycles without oxidizer storage.

The SORFC energy storage system in discharge or electricity generation mode is illustrated in FIG. 9. Fuel is stored in the fuel storage vessel or tank **250**. In one preferred embodiment the fuel is hydrogen which is stored as compressed gas. Other preferred storage options for hydrogen fuel include, but are not limited to cryogenic storage, metal hydrides, carbon adsorption (graphite, nanotube, or activated), sodium borohydride, and glass microspheres. Hydrocarbon fuel maybe used instead. The fuel tank SORFC connecting line **280** delivers fuel to the SORFC system **240**. Oxidizer is provided from ambient through oxidizer inlet line **300** to the SORFC system **240**. In the SORFC system **240**, fuel is oxidized with the oxidizer and electrical energy and heat are generated. The oxidized fuel is delivered to the oxidized fuel storage tank **260** through the oxidized fuel tank SORFC system connecting line **290**. In one preferred aspect, the oxidized fuel is water, and the water is stored in its liquid, solid, or partly frozen state. The depleted oxidizer is vented to ambient through the oxidizer outlet line **310**.

FIG. 10 illustrates the SORFC energy storage system in charge or electrolyzer mode. Stored oxidized fuel is provided from the oxidized fuel storage tank **260** to the SORFC system **240** via the oxidized fuel tank SORFC system connecting line **290**. In the SORFC system **240**, oxidized fuel is electrolyzed to fuel and oxidizer. The fuel generated is transported to the fuel storage tank **250** through the fuel tank SORFC system connecting line **280**. The oxidizer generated in the SORFC system **240** is vented back to ambient through the oxidizer outlet line **310**. Optionally, fresh oxidizer (i.e., air) can be provided to the SORFC system **240** during the charge mode through the oxidizer inlet line **300**. This optional inlet stream can for example serve as the thermal control of the SORFC system.

FIG. 11 illustrates one preferred layout of the SORFC energy storage system, which includes fuel and oxidizer flow control. FIG. 11 illustrates this system in discharge mode. Fuel from the fuel storage tank **250** is provided to the SORFC input selector valve **470** through the fuel tank delivery line **520**, the fluids junction **500**, the fuel compressor bypass line **530**, the fuel compressor bypass valve and regulator **460**, the fuel compressor bypass line **531** the fluids junctions **501**, and the fuel delivery line **540**. An additional stream of fuel from the water/hydrogen separator and pump **410** is also delivered to the SORFC input selector valve **470** through the separator fuel outlet line **550**, the fluids junction **501**, and the fuel delivery line **540**.

The fuel is transported from the SORFC input selector valve **470** to the SORFC **400** via the SORFC fuel side input

lines 590 and 591. The fuel can be preheated in the optional fuel heat exchanger 450. In the SORFC 400, the fuel is reacted with oxidizer and generates electrical energy and heat. In a preferred layout, the fuel is only partially oxidized, and the partially oxidized fuel (i.e., hydrogen and water) is transported to the separator and pump 410 via the SORFC fuel side outlet lines 600 and 601. Preferably, the optional fuel heat exchanger 450 extracts heat from the partially oxidized fuel. The heat extracted from the partially oxidized fuel is used to heat the fuel inflow to the SORFC 400.

In the separator and pump 410 oxidized fuel (i.e., water) and fuel (i.e., hydrogen) are separated. This separator and pump 410 can preferably be a centrifugal device that both separates and adds energy to (i.e. pressurizes) the liquid and the gaseous components. The fuel is pressurized and returned to the SORFC input selector valve 470 through the separator fuel outlet line 550, the fluids junction 501, and the fuel delivery line 540, as described previously. The oxidized fuel (i.e., water) is transported from the separator and pump 410 to the oxidized fuel tank 260, via the separator oxidized fuel outlet line 560, the fluids junction 502, the oxidized fuel tank line 571, the oxidized fuel storage valve and regulator 480, and the oxidized fuel tank line 570. The separator and pump 410 delivers the oxidized fuel at a pressure suitable for storage in tank 260. In one preferred embodiment the fuel storage tank 250 and the oxidized fuel storage tank 260 are combined in one vessel. For the preferred option of hydrogen fuel and water as the oxidized fuel, fuel and oxidized fuel can be easily separated due to their different phases (gas vs. liquid). The gaseous fuel can provide pressurization for the liquid oxidized fuel and thereby facilitate delivery of the oxidized fuel during charge mode.

Oxidizer, such as air, needed for the oxidation of the fuel is provided to the SORFC 400 through the SORFC oxidizer side inlet lines 620, 621, 622, and 623, and the oxidizer input valve 490. The oxidizer is driven into the SORFC 400 by the oxidizer blower 430. The oxidizer can be preheated in the optional oxidizer heat exchanger 440. The depleted oxidizer is vented through the SORFC oxidizer side outlet lines 610 and 611. Lines 610 and 611 preferably pass through the optional oxidizer heat exchanger 440 to extract heat from the depleted oxidizer outlet stream and thereby preheat the oxidizer inflow. Alternatively, the incoming fuel may be preheated by the depleted oxidizer stream and/or the incoming oxidizer may be preheated by the oxidized fuel stream, if the location of lines 600/601 and/or 610/611 is reversed with respect to heat exchangers 440, 450.

The valve and regulator 460 is open in the discharge mode, while the fuel compressor valve 455 is closed. Valve 470 is a three way valve, which is switched to allow fuel flow between lines 540 and 590, while preventing oxidized fuel flow from line 630 to line 590.

FIG. 12 illustrates how the system shown in FIG. 11 operates in the charge mode. Oxidized fuel (i.e., water) is delivered to the SORFC input selector valve 470 from the oxidized fuel storage tank 260 via the oxidized fuel tank line 570, the open oxidized fuel storage valve and regulator 480, the oxidized fuel tank line 571, the fluids junction 502, and the oxidized fuel delivery line 630. Additional oxidized fuel is provided from the separator and pump 410 to the SORFC input selector valve 470 via the separator oxidized fuel outlet line 560, the fluids junction 502, and the oxidized fuel delivery line 630. The oxidized fuel is transported from the SORFC input selector valve 470 to the SORFC 400 through the SORFC fuel side input lines 590 and 591. The oxidized fuel can be preheated in the optional fuel heat exchanger 450.

In the SORFC 400, the oxidized fuel is electrolyzed. Partly regenerated fuel (i.e., hydrogen and water) is transported from the SORFC 400 to the separator and pump 410 through the SORFC fuel side outlet lines 600 and 601. The optional fuel heat exchanger 450 can extract heat from the partially regenerated fuel and provide pre-heat to the oxidized fuel inflow. In the separator and pump 410, the regenerated fuel (i.e., hydrogen) and oxidized fuel (i.e., water) are separated. Fuel is transported from the separator and pump 410 to the fuel tank 250 through the separator fuel outlet line 550, the fluids junction 501, the fuel compressor line 512, the optional fuel compressor valve 455, the fuel compressor line 511, the optional fuel compressor 420, the fuel compressor line 510, the fluids junction 500, and the fuel tank delivery line 520. The optional compressor 420 pressurizes the fuel for storage in the fuel storage tank 250. The optional compressor 420 is preferably an electrochemical hydrogen pump. Oxidized fuel from the separator and pump 410 is re-circulated to the SORFC input selector valve 470 via the separator oxidized fuel outlet line 560, the fluids junction 502, and the oxidized fuel delivery line 630. The separator and pump 410 brings the output oxidized fuel to a pressure suitable for recirculation.

Regenerated oxidizer is vented from the SORFC 400 to ambient via the SORFC oxidizer side outlet lines 610 and 611. The optional oxidizer heat exchanger 440 can extract heat from the regenerated oxidizer outflow. Optionally, additional oxidizer can be provided from ambient to the SORFC 400 through the SORFC oxidizer inlet line 620, the oxidizer blower 430, the SORFC oxidizer inlet line 621, the oxidizer input valve 490, the SORFC oxidizer inlet line 622, and the SORFC oxidizer inlet line 623. The optional oxidizer heat exchanger 440 can add heat to the oxidizer inflow. In one preferred embodiment the optional oxidizer inflow provides thermal control for the SORFC 400.

The valve and regulator 460 is closed in the charge mode, while valve 455 is open. Valve 470 is a three way valve, which is switched to prevent fuel flow between lines 540 and 590, while allowing oxidized fuel flow from line 630 to line 590.

The SORFC system 240 described previously contains the SORFC 400 and controlling elements, associated electrical circuits, peripheral fluid lines, valves and heat exchangers. The fuel tank SORFC system connecting line 280 includes lines 510, 511, 512, 520 and 540. The oxidized fuel tank SORFC system connecting line includes lines 560, 570, 571, 590, 591, 600, 601, and 630. The oxidizer inlet line 300 includes lines 620, 621, 622, and 623. The oxidizer outlet line 310 includes lines 610 and 611.

The SORFC energy storage system can be sized for a wide range of power and energy storage requirement. Preferred power levels range from 1 kW to 10 MW, but smaller and larger systems are possible. There are virtually no limits for the amount of energy that can be stored. Appropriate tank sizing can store energy from a few Whr (Watt hours) to GWhr (Gigawatt hours). The SORFC energy storage system is especially advantageous at large energy levels, where large energy storage densities can be realized. Energy storage densities in excess of 450 Whr/kg can be realized. Energy storage efficiencies (energy available in discharge divided by energy needed to charge) on the order of 0.5 can be realized.

The foregoing description of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are

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possible in light of the above teachings or may be acquired from practice of the invention. The drawings are not necessarily to scale and illustrate the device in schematic block format. The drawings and description of the preferred embodiments were chosen in order to explain the principles of the invention and its practical application, and are not meant to be limiting on the scope of the claims. It is intended that the scope of the invention be defined by the claims appended hereto, and their equivalents.

Parts list:	
10	airship
12	gas envelope
14	chamber
16	fuel cell
18	surveillance electronics
20	propeller
22	heat transfer loop
24	controller
26	sensor
28	conduit
100	electrolyte
110	fuel electrode
120	oxygen electrode
122	fuel side electrical connection
126	oxygen side electrical connection
130	fuel inflow
140	oxidized fuel outflow
150	oxidizer inflow
160	depleted oxidizer outflow
170	oxidized fuel inflow
180	regenerated fuel outflow
190	optional oxygen side inflow
200	regenerated oxidizer outflow
210	interconnect
220	repeating elements
230	gas manifold
240	SORFC system
250	fuel storage tank
260	oxidized fuel storage tank
280	fuel tank SORFC system connecting line
290	oxidized fuel tank SORFC system connecting line
300	oxidizer inlet line
310	oxidizer outlet line
400	Solid Oxide Regenerative Fuel Cell (SORFC)
410	fuel/oxidized fuel separator and pump
420	fuel compressor
430	oxidizer blower
440	oxidizer heat exchanger
450	fuel heat exchanger
455	fuel compressor valve
460	fuel compressor bypass valve and regulator
470	SORFC input selector valve
480	oxidized fuel storage valve and regulator
490	oxidizer input valve
500	fluids junction
501	fluids junction
502	fluids junction
510	fuel compressor line
511	fuel compressor line
512	fuel compressor line
520	fuel tank delivery line
530	fuel compressor bypass line
531	fuel compressor bypass line
540	fuel delivery line
550	separator fuel outlet line
560	separator oxidized fuel outlet line
570	oxidized fuel tank line
571	oxidized fuel tank line
590	SORFC fuel side input line
591	SORFC fuel side input line
600	SORFC fuel side outlet line
601	SORFC fuel side outlet line
610	SORFC oxidizer side outlet line
611	SORFC oxidizer side outlet line
620	SORFC oxidizer inlet line

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Parts list:	
5	621 SORFC oxidizer inlet line
	622 SORFC oxidizer inlet line
	623 SORFC oxidizer inlet line
	700 solar array
	710 electrical cable
	720 electrical cable
10	730 electrical cable
	740 motor propeller
	750 SOFC
	760 electrical cable
	800 heat transfer loop
	810 payload or equipment

We claim:

1. A neutrally buoyant airship, comprising:  
a lifting body which allows the airship to remain neutrally buoyant in air; and  
a fuel cell located in the airship; wherein:  
the airship comprises a blimp;  
the lifting body comprises a gas envelope;  
the fuel cell comprises a solid oxide regenerative fuel cell; and  
the solid oxide fuel cell is adapted to provide power to components of the blimp.
2. The airship of claim 1, further comprising a heat transport loop adapted to selectively transfer heat from the solid oxide fuel cell to the gas envelope.
3. The airship of claim 2, wherein the heat transport loop comprises one or more pipes or ducts and contains a heat transfer material comprising a fuel cell exhaust gas or a gas circulated from the gas envelope.
4. The airship of claim 1, further comprising:  
at least one sensor adapted to sense at least one condition; and  
a controller adapted to selectively provide heat from the fuel cell to the gas envelope in response to the at least one sensed condition.
5. The airship of claim 4, wherein:  
the sensor comprises an altitude detector adapted to detect an altitude of the airship; and  
the controller is adapted to provide heat from the fuel cell to the gas envelope to elevate the airship to a different altitude if the detected altitude is below a desired altitude.
6. The airship of claim 4, wherein:  
the sensor comprises a temperature detector adapted to detect an ambient temperature adjacent to the airship; and  
the controller is adapted to provide heat from the fuel cell to the gas envelope if the detected temperature is below a desired temperature.
7. The airship of claim 4, wherein:  
the sensor comprises a wind speed detector adapted to detect wind speed adjacent to the airship; and  
the controller is adapted to provide heat from the fuel cell to the gas envelope to elevate the airship to a different altitude if the detected wind speed is above a desired speed.
8. The airship of claim 1, wherein:  
the blimp comprises a stationary surveillance blimp containing surveillance electronics; and  
the solid oxide fuel cell is adapted to provide power to the surveillance electronics and to a propulsion system of the blimp.

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9. The airship of claim 1, wherein:  
the gas envelope comprises a hydrogen gas envelope;  
the hydrogen gas envelope is connected to a fuel inlet of  
the solid oxide fuel cell; and  
the solid oxide fuel cell fuel storage vessel comprises the  
hydrogen gas envelope.
10. The airship of claim 9, wherein:  
the solid oxide regenerative fuel cell is adapted to supply  
hydrogen into the hydrogen gas envelope in a charge  
mode.
11. The airship of claim 10, wherein:  
the blimp contains a solar cell array;  
the solid oxide regenerative fuel cell is adapted to power  
the airborne vehicle in absence of sunlight; and  
the solid oxide regenerative fuel cell is adapted to regen-  
erate hydrogen using electricity generated from sun-  
light by the solar cell array.
12. A method of generating power in a neutrally buoyant  
airship, comprising:  
providing a fuel and an oxidizer to a solid oxide regen-  
erative fuel cell to generate power; and  
providing heat from the fuel cell to a remotely located  
lifting body, wherein the lifting body allows the airship  
to remain neutrally buoyant in air.
13. The method of claim 12, further comprising providing  
electrical power from the fuel cell to a propeller of the  
airborne vehicle.
14. The method of claim 12, further comprising:  
converting sunlight into electrical energy;  
providing the electrical energy to the fuel cell comprising  
a solid oxide fuel cell;  
providing oxidized fuel into the fuel cell;  
electrolyzing the oxidized fuel in the solid oxide fuel cell  
into partially regenerated fuel;  
separating fuel from oxidized fuel in the partially regen-  
erated fuel; and  
storing the fuel and the oxidized fuel.
15. The method of claim 12, wherein:  
the airship comprises a stationary surveillance blimp; and  
the fuel cell provides electrical power to surveillance  
electronics located on the blimp.
16. The method of claim 12, wherein:  
the airship comprises a blimp; and  
the lifting body comprises a gas envelope.
17. The method of claim 16, further comprising providing  
hydrogen gas from the gas envelope into the solid oxide fuel  
cell in a discharge mode.

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18. The method of claim 17, further comprising providing  
hydrogen gas from the solid oxide fuel cell into the gas  
envelope in a charge mode.
19. The method of claim 12, further comprising selec-  
tively controlling heat provided from the fuel cell to the  
lifting member in response to a sensed condition.
20. The method of claim 19, further comprising:  
detecting an altitude of the airship; and  
selectively providing heat from the fuel cell to the lifting  
body to elevate the airship to a different altitude if the  
detected altitude is below a desired altitude.
21. The method of claim 19, further comprising:  
detecting an ambient temperature adjacent to the airship;  
and  
selectively providing heat from the fuel cell to the lifting  
body if the detected temperature is below a desired  
temperature.
22. The method of claim 19, further comprising:  
detecting a wind speed adjacent to the airship; and  
selectively providing heat from the fuel cell to the lifting  
body to elevate the airship to a different altitude if the  
detected wind speed is above a desired speed.
23. The method of claim 12, wherein the step of providing  
heat from the fuel cell to a remotely located lifting body  
comprises providing an exhaust gas from the fuel cell  
adjacent to the lifting body.
24. The method of claim 12, wherein the step of providing  
heat from the fuel cell to a remotely located lifting body  
comprises circulating gas from inside the lifting body adja-  
cent to the fuel cell to heat the gas prior to returning the gas  
into the lifting body.
25. A neutrally buoyant airship, comprising:  
a hydrogen gas envelope which allows the airship to  
remain neutrally buoyant in air;  
a solid oxide regenerative fuel cell located in the airship;  
and  
a conduit connecting the hydrogen gas envelope to a fuel  
inlet of the fuel cell, such that the fuel cell is adapted  
to use hydrogen from the hydrogen gas envelope during  
discharge mode.
26. The airship of claim 25, wherein  
the regenerative fuel cell is adapted to supply hydrogen  
into the hydrogen gas envelope in a charge mode.
27. The airship of claim 25, wherein the airship does not  
lose water with oxidizer discharge from the fuel cell.
28. The airship of claim 1, wherein the airship does not  
lose water with oxidizer discharge from the fuel cell.
29. The method of claim 12, wherein the airship does not  
lose water with oxidizer discharge from the fuel cell.

\* \* \* \* \*