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ZERO EMISSION FUEL SYSTEM FOR USE WITH A FUEL CELL

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

CROSS REFERENCE TO OTHER RELATED APPLICATIONS

[0002] Not applicable.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates to fuel systems, and more specifically to a zero emission fuel system designed for use with power conversion devices such as fuel cells.

(2) Description of the Prior Art

[0004] The most logical choice of an energy source for an unmanned underwater vehicle would appear to be a battery, since it can be operated in the absence of air. However, most batteries lack sufficient energy density to carry out the long missions associated with unmanned undersea vehicles, and the few batteries that might find application, for example lithium

thionyl chloride, are prohibitively expensive. There continues to be a need for energy sources with a high energy density that can power unmanned undersea vehicles. These energy sources need to have long endurance, quiet operation, be relatively inexpensive, environmentally friendly, safe to operate, reusable, capable of a long shelf life and not prone to spontaneous chemical or electrochemical discharge.

[0005] In an effort to develop power sources for unmanned undersea vehicles with increased energy density, research has been directed towards semi fuel cells and fuel cells as one of several high energy density power sources being considered. For larger scale unmanned underwater vehicles, and longer duration missions, proton exchange membrane fuel cells and solid oxide fuel cells are being used because they can be completely refueled from both a fuel and oxidizer standpoint.

[0006] A key requirement for an unmanned underwater vehicle powered by a solid oxide fuel cell is the ability to readily utilize synthesis gas (a mixture of hydrogen, carbon monoxide and methane) at high electrochemical conversion efficiency making the fuel cell a good candidate for use with a carbide-hydride fuel system. For this reason, what is needed is a solid oxide fuel cell fuel system that offers an innovative solution to address carbon dioxide evolution while using synthesis gas as a fuel component.

SUMMARY OF THE INVENTION

[0007] It is a general purpose and object of the present invention to provide a zero emission fuel system for use with power conversion devices to address carbon dioxide evolution.

[0008] It is a further object to have a solid oxide fuel cell as the power source in a self-contained fuel system.

[0009] These objects are accomplished by employing a chemical combination that when combined with water creates a fuel for the solid oxide fuel cell and a water soluble byproduct that can then be combined with the carbon dioxide gas generated by the fuel cell to create a storable solid precipitate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

[0011] FIG. 1 is an illustration of the components of the self-contained fuel system of the present invention;

DETAILED DESCRIPTION OF THE INVENTION

[0012] Referring now to FIG. 1 there is illustrated a unique fuel system 10 that is intended for use with a high-temperature fuel cell that operates above 600°C, such as a solid oxide fuel cell 12. A low-temperature fuel cell like a proton exchange membrane (PEM) fuel cell would not be applicable since it cannot tolerate carbon monoxide in the fuel feed. A glycerin slurry 14 containing calcium carbide (CaC_2) and calcium hydride (CaH_2) is contained in a slurry chamber 16 and pumped into a reaction chamber 18 to react with water (H_2O). In a preferred embodiment, the slurry is comprised of calcium carbide and calcium hydride powders in mass ratios of approximately 3.8 to 2.5 of calcium carbide to calcium hydride. The powders are mixed together and then added to a volume of glycerin (liquid) to form slurry. The mixture is stored under argon and pumped into water H_2O in the reaction chamber 18 (using a peristaltic pump) to co-generate acetylene C_2H_2 and hydrogen H_2 . The use of calcium hydride is a key improvement over the prior art. It is an active ingredient, in that it produces hydrogen gas, which is later used in the fuel processing of acetylene. It also produces calcium hydroxide $\text{Ca}(\text{OH})_2$, which traps CO_2 by converting it to calcium carbonate CaCO_3 .

[0013] The use of glycerin offers two distinct advantages. First, it coats the carbide/hydride particles preventing water from immediately reacting with the particles. In doing so, the generation of acetylene and hydrogen is slowed making better control of the

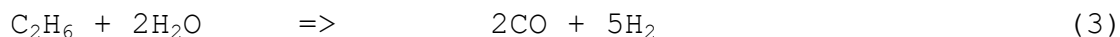
reaction possible. Secondly, it allows the carbide/hydride mixture to be pumped by containing it in a liquid medium rather than a powdered medium. The glycerin therefore moderates the rate of the highly exothermic reaction (above 100°C) between the calcium carbide, calcium hydride and water, and provides an efficient means of delivering solid reactants to the reaction chamber 18. An uncontrolled highly exothermic reaction is not desirable since heat management becomes an issue. By pumping the slurry into a water reservoir, the heat generated by the reaction is absorbed by the water offering better thermal management of the system. The hydrolysis reaction generates acetylene gas (C₂H₂), hydrogen (H₂) and the byproduct calcium hydroxide (Ca(OH)₂). Hydrogen is used to hydrogenate acetylene to ethane C₂H₆. Acetylene cannot be directly reformed to synthesis gas. Since calcium hydroxide is in solution, no separation is required. The gases will eventually flow into the fuel processor. The chemical reactions are illustrated in equation (1):



The byproduct calcium hydroxide, Ca(OH)₂ begins dissolving in the water immediately and is available as a reactant for subsequent reactions in a precipitation chamber 26.

[0014] In this embodiment, the acetylene and hydrogen resulting from equation (1) are converted in a fuel processor 20 to carbon monoxide (CO) and hydrogen in a two-step process. Acetylene is first

reacted with hydrogen over a hydrogenation catalyst to form ethane, C_2H_6 , as depicted in equation (2). The second step involves the steam reforming of ethane to synthesis gas, CO and H_2 shown in equation 3.



The CO and H_2 are fed to the solid oxide fuel cell where they undergo electrochemical oxidation according to equation (4):



The CO_2 effluent is then directed via a hose 24 or some other device in combination with the system flow to the precipitation chamber 26 where it is then reacted with $Ca(OH)_2$ in solution to precipitate calcium carbonate ($CaCO_3$), which can be stored in solid form. The chemical reactions are illustrated in equation (5):



[0015] The liquid oxidant, hydrogen peroxide, H_2O_2 , can be used as the oxygen, O_2 , source in equation (2) for the solid oxide fuel cell. The hydrogen peroxide, H_2O_2 , is decomposed over an appropriate catalyst in a decomposition chamber 28 connected to the reaction chamber 18 and the solid oxide fuel cell 12, to produce water and oxygen according to the reaction illustrated in equation (6):



[0016] The water, H_2O , formed by this reaction can be used in equation (1) to convert the glycerin slurry 14 consisting of calcium

carbide, CaC_2 , and calcium hydride, CaH_2 , to acetylene, C_2H_2 , hydrogen, H_2 , and calcium hydroxide, $\text{Ca}(\text{OH})_2$, hence eliminating the need for carrying an additional source of water, H_2O .

[0017] The advantage of the present invention over the prior art is that it is a self contained, zero-effluent fuel system with three distinct features: (1) active fuel generating components comprising calcium carbide and calcium hydride; (2) the use of glycerin slurry as a medium for dispersing and delivering the reactants, calcium carbide and calcium hydride; (3) increased energy storage.

[0018] In light of the above, it is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

ZERO EMISSION FUEL SYSTEM FOR USE WITH A FUEL CELL

ABSTRACT OF THE DISCLOSURE

A self-contained fuel system for use with a high temperature fuel cell is described to address containment of carbon dioxide evolution. The system utilizes a slurry containing calcium carbide and calcium hydride that is pumped into a water reservoir. The resulting hydrolysis reaction generates acetylene, hydrogen and water-soluble calcium hydroxide. The acetylene and hydrogen are catalytically converted to synthesis gas, which is used by a fuel cell to generate electricity. Carbon dioxide exhaust from the fuel cell is reacted with calcium hydroxide to form a storable solid, calcium carbonate.

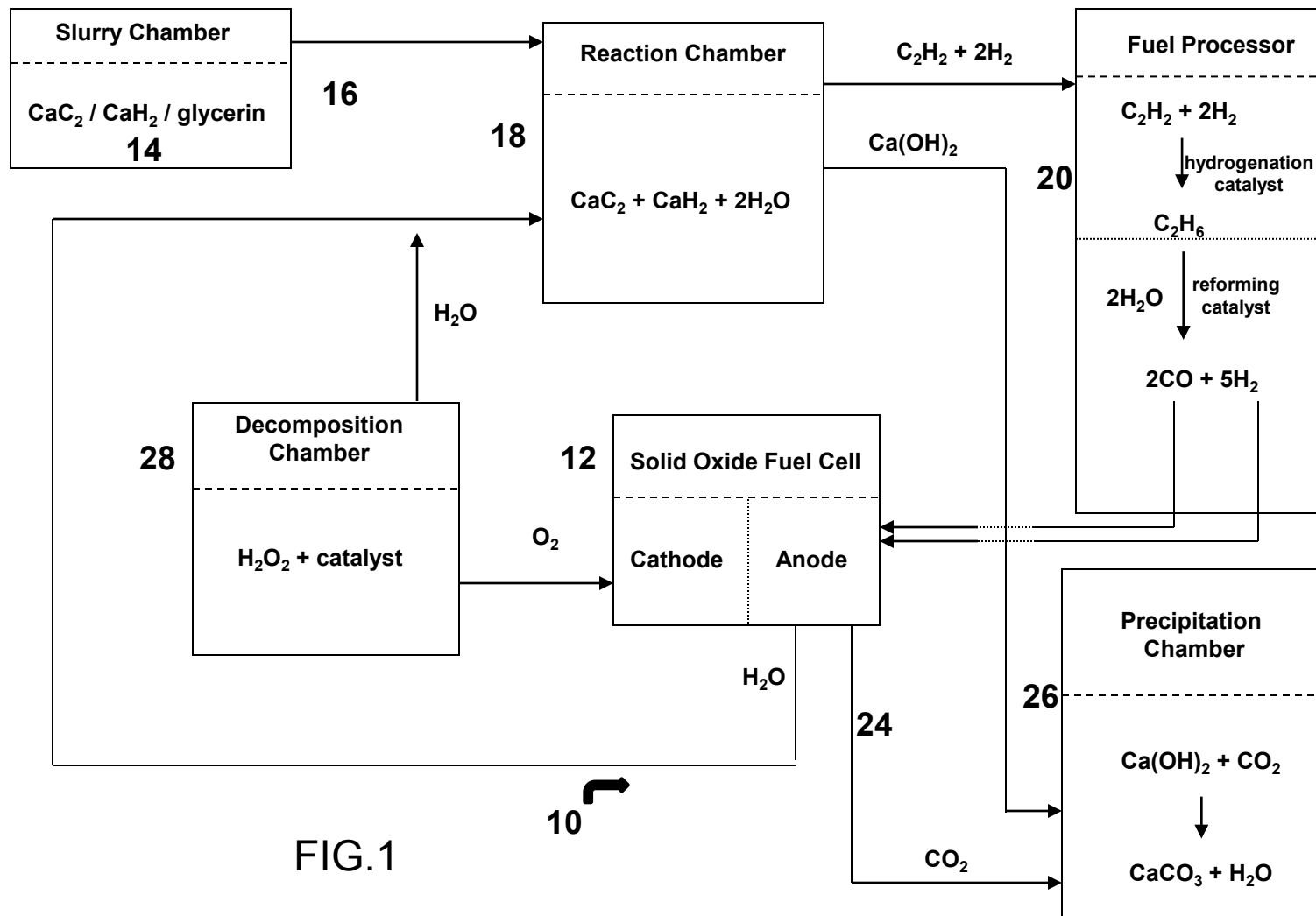


FIG.1