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(54) **SOLID OXIDE FUEL CELL WITH SELECTIVE ANODE TAIL GAS CIRCULATION**

FESTOXIDBRENNSTOFFZELLE MIT SELEKTIVER ANODENENDGASZIRKULATION

PILE A COMBUSTIBLE A OXYDE SOLIDE A CIRCULATION SELECTIVE DU GAZ RESIDUAIRE
D'ANODE

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Description

[0001] The present invention is generally directed to Solid Oxide Fuel Cells (SOFC's), and more specifically to SOFC's having a circulation of a portion of the anode tail gas (i.e., exhaust).

[0002] The circulation of a portion of the anode exhaust is known in the solid oxide fuel cell field. This technique is used to provide water to the hydrocarbon fuel inlet of the SOFC to support the steam reforming of the hydrocarbon fuel. Two methods are known for conducting this anode circulation.

[0003] In the first method, a portion of the anode exhaust is simply injected back to the SOFC fuel inlet by aspiration or with a mechanical blower. In this case the composition of the anode inlet injected gas stream is similar to the anode exhaust stream. The composition of the exhaust stream is a function of the type of fuel used, the effectiveness of the reforming process, the fuel stoichiometry, and the circulation rate. The composition of the anode exhaust will typically contain water, carbon dioxide and non reacted fuel (i.e., hydrogen, carbon monoxide, and primary fuel feedstock).

[0004] In the second method, the anode exhaust is mixed with a portion of the cathode exhaust and a portion of this gas stream is injected into the SOFC fuel inlet by aspiration or with a mechanical blower. In this case, the composition of the anode inlet injected gas stream is modified from the anode exhaust. In general, the composition of the anode inlet injected gas, resulting from partial combining the anode and cathode exhausts, will have a lower fuel content (i.e., hydrogen, carbon monoxide, and primary fuel feedstock) and higher water and carbon dioxide content. Additionally, if as typical, the cathode oxygen source is from ambient air, there will be a quantity of nitrogen in the anode inlet injected gas not normally existent within the anode inlet injected gas from simple partial anode exhaust circulation.

[0005] US 5,079,103 describes a solid oxide fuel cell (SOFC) comprising a hydrocarbon gas feed stream into the anode of the system. The anode waste gas is withdrawn, and the water is separated from the waste gas and discharged. Further, a separation of the hydrogen-containing waste gas into a hydrogen stream and a residual gas is described, wherein parts of that resultant hydrogen stream are then added to the gas feed stream.

[0006] EP 0 473 153 A2 describes an internal reforming fuel cell system in which the anode exhaust stream of the fuel cell is processed in a hydrogen separation and recovery device to separate and recover the unspent hydrogen from the remaining fuel components in the stream. The document discloses the recycling of the recovered hydrogen into the gasifier input, but does not disclose a separation of water or carbon dioxide from the anode waste stream.

[0007] US 4,532,192 describes an internally reforming fuel cell system wherein gas exhausted from the anode section is passed through a gas separation device which

is adapted to separate unused hydrogen gas from the exhaust stream and fed into the input fuel line to the anode section. Further, the document describes the removal of water from the exhaust stream which is then added to the hydrogen gas of the input fuel line, but there is no disclosure of a removal of carbon dioxide from the exhaust stream.

SUMMARY OF THE INVENTION

[0008] A solid oxide fuel cell system is described, comprising a solid oxide fuel cell stack, a fuel supply inlet conduit adapted to provide a hydrocarbon fuel inlet stream into the solid oxide fuel cell stack and a fuel exhaust outlet conduit adapted to remove a fuel exhaust stream from the solid oxide fuel cell stack. The system also includes a water vapor and enthalpy recovery unit operatively connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit. The water vapor and enthalpy recovery unit is adapted to selectively transfer at least a portion of water vapor and heat from the fuel exhaust stream to the hydrocarbon fuel inlet stream. The system also includes a hydrogen recovery unit connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit. The hydrogen recovery unit is adapted to selectively transfer at least a portion of hydrogen from the fuel exhaust stream to the hydrocarbon fuel inlet stream.

[0009] The present invention provides a solid oxide fuel cell system, comprising a solid oxide fuel cell stack, a fuel supply inlet conduit adapted to provide a hydrocarbon fuel inlet stream into the solid oxide fuel cell stack, a fuel exhaust outlet conduit adapted to remove a fuel exhaust stream from the solid oxide fuel cell stack, and a fuel exhaust processing subsystem operatively connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit, as defined in the claims. The fuel exhaust processing subsystem comprises: a carbon dioxide scrubbing unit which is adapted to remove at least a portion of carbon dioxide present in the fuel exhaust stream to form a scrubbed fuel exhaust stream; a water vapor recovery unit which is adapted to transfer at least a portion of water vapor from the scrubbed fuel exhaust stream to the hydrocarbon fuel inlet stream; and a hydrogen recovery unit which is adapted to transfer at least a portion of hydrogen from the scrubbed fuel exhaust stream to the hydrocarbon fuel inlet stream.

[0010] Also, the present invention provides a method of operating a solid oxide fuel cell system, comprising providing a hydrocarbon fuel inlet stream into a solid oxide fuel cell stack and removing fuel exhaust stream from the solid oxide fuel cell stack. The method also comprises recovering at least a portion of water vapor and heat from the fuel exhaust stream and providing the at least a portion of the recovered water vapor and heat into the hydrocarbon fuel inlet stream being provided into the solid oxide fuel cell stack. The method also comprises recovering at least a portion of hydrogen from the fuel exhaust

stream, and separately providing the at least a portion of the recovered hydrogen into the hydrocarbon fuel inlet stream being provided into the solid oxide fuel cell stack.

[0011] Another preferred embodiment of the present invention provides a method of operating a solid oxide fuel cell system, comprising providing a hydrocarbon fuel inlet stream into a solid oxide fuel cell stack, removing a fuel exhaust stream from the solid oxide fuel cell stack, removing at least a portion of carbon dioxide present in the fuel exhaust stream to form a scrubbed fuel exhaust stream, and providing at least a portion of the scrubbed fuel exhaust stream into the hydrocarbon fuel inlet stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. 1 is a system schematic of the major SOFC components.

[0013] FIG. 2 is a system schematic of the major SOFC components of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The present inventor has realized that even with the injection of exhaust gases into the anode inlet, several problems in conducting internal reforming within the active area of the SOFC cells still exists in the prior art methods.

[0015] First, because the SOFC operates at an elevated temperature, steam reforming of the fuel (i.e., methane as an example) occurs within the SOFC stack fuel inlet manifold. As much as 80% of the reforming can be completed before the fuel gas mixture reaches the active cell area. This negates much of the significant advantage of endothermic internal reforming relative to the lowering of cooling airflow requirements and the leveling of the thermal gradients.

[0016] Second, even if the fuel steam reformation within the SOFC fuel inlet manifold was avoided, the fuel steam reaction can overwhelm the fuel cell oxidation reaction with most of the reforming occurring near the fuel inlet active area leading to negative results. These negative results include misdistribution of current density, higher thermal gradients and poorer performance.

[0017] Third, the gas injected into the anode inlet contains a significant portion of carbon dioxide or carbon dioxide and nitrogen. This negatively impacts the system performance in two characteristics. A pressure drop across the anode flow field is increased, which in turn increases the blower parasitic power, and the fuel is diluted to a lower partial pressure reducing the cell performance.

[0018] The present inventor has realized that a use of selective rather than total circulation of the anode exhaust gas species in a SOFC reduce or eliminate the problems of the prior art methods. The present inventor has devised methods for shifting the methane/steam re-

forming equilibrium such that reforming within the fuel manifold is minimized and the fuel cell oxidation is encouraged or even preferred over the methane/steam reformation reaction.

[0019] The terms anode exhaust, fuel exhaust, anode outlet and fuel outlet are used interchangeably herein. Likewise, the terms anode inlet and fuel inlet are also used interchangeably.

[0020] In the selective circulation of the SOFC anode exhaust, only hydrogen and water are sequestered from the fuel or anode exhaust or outlet stream and injected into the SOFC fuel inlet stream, while all but trace quantities of carbon dioxide and any existing nitrogen are exhausted. Additionally, the proportions of the hydrogen and water injected can be varied independently of each other. For example the amount of hydrogen injected into the SOFC fuel inlet can be increased while the water injected into the SOFC fuel inlet is reduced or vice versa. Also the hydrogen and water injected into the SOFC fuel inlet can both be increased or decreased together, but to different degrees. In summary, a complete and independent flow rate control of injected hydrogen and water into the SOFC fuel inlet stream is possible while blocking the injection of carbon dioxide and nitrogen into the fuel inlet stream.

[0021] By selecting a high hydrogen flow rate and a lower water flow rate from the anode exhaust gas for circulation into the SOFC fuel inlet, the suppression of manifold methane/steam reforming within the fuel inlet manifold results. At the same time, the high hydrogen content of the SOFC fuel inlet enhances the fuel cell oxidation reaction and encourages a leveling of the in-cell methane/steam reforming. The combination of the endothermic methane/steam reforming reaction with the exothermic SOFC fuel cell reaction, within the cell active area, produces about half the net heat normally produced by just the SOFC fuel cell.

[0022] Since the heat generated by the fuel cell is primarily rejected from the SOFC with the cathode air flow, this flow rate can be reduced by about half. This has a positive impact on the parasitic power for the air blower and the size of the air heat exchanger.

[0023] In a first preferred embodiment of the SOFC system with a selective anode tail gas circulation, the water (such as water vapor) and hydrogen are recovered from the fuel exhaust or outlet stream in separate stages using separate devices. The water is transferred from the anode exhaust to the SOFC inlet fuel using a rotating desiccant enthalpy wheel. The rate of the water transferred within the enthalpy wheel is controlled by the rotational speed. The water circulation is preferably controlled without using aspirators or blowers.

[0024] Also in the first embodiment of the SOFC with selective anode tail gas circulation, the hydrogen is transferred from the anode exhaust to the SOFC fuel inlet stream using an electrochemical hydrogen pump. The rate of hydrogen transferred within the electrochemical hydrogen pump is directly proportional to the cell current.

The hydrogen circulation is preferably controlled without using aspirators or blowers.

[0025] In the second embodiment of the SOFC system with selective anode tail gas circulation, the hydrogen and water are independently separated from the SOFC anode exhaust using thermally driven absorption/ad-sorption processes. The circulation flow rate of the hydrogen and water are controlled by mechanical devices such as blowers and/or pumps. The high quality waste heat of the SOFC allows the separation of exhaust gas species without significant parasitic electric power usage.

[0026] The SOFC system 10 is shown in Fig. 1 as a simplified system schematic. The SOFC of system 10 includes a cathode chamber 14, a cathode electrode 15, a ceramic electrolyte 16, an anode electrode containing an anode catalyst 17 and an anode chamber 27. While only one SOFC is shown in Figure 1 for clarity, it should be understood that the system 10 preferably contains a stack of SOFCs. The SOFC system 10 also contains a fuel supply inlet conduit (i.e., an anode inlet conduit) containing conduit portions 20, 22, 24 and 26, and a fuel exhaust outlet conduit (i.e., an anode outlet conduit) containing conduit portions 28, 29, 30 and 31.

[0027] The SOFC system 10 also contains a hydrogen recovery unit 21 which transfers hydrogen gas from within a gas mixture into a secondary gas stream. The hydrogen recovery unit 21 may be any suitable selective hydrogen recovery device. Preferably, unit 21 is a device based on an electrochemical proton exchange process (i.e., an electrochemical proton exchange pump), such as a polymeric or ceramic proton exchange membrane, or a device which uses pressure swing absorption for selective hydrogen recovery. The SOFC system 10 also contains a water vapor and enthalpy recovery unit 23. The water vapor and enthalpy recovery unit 23 may be any device which selectively transfers water vapor from one gas stream to a secondary gas stream. The water vapor and enthalpy recovery unit 23 is preferably a device which contains a rotating desiccant wheel (also known as an enthalpy wheel) or cyclic desiccant beds. The rate of rotation of the desiccant wheel controls the amount of water vapor transferred by the device. Heat exchanger 25 is a counter flow gas-gas heat exchanger.

[0028] The units 21 and 23 are operatively connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit. Thus, the units 21 and 23 are either directly connected to the inlet and outlet conduits or indirectly connected to the inlet and outlet conduits by respective water and hydrogen delivery conduits. A method of operating the system 10 is described below.

[0029] As shown in Fig. 1, air containing reactant oxygen is delivered by a blower (not shown) to the cathode heat exchanger 12 through conduit 11. Within the cathode heat exchanger 12 fuel cell waste heat is exchanged into the cathode inlet air raising the air temperature close to the cell operating temperature. The heated air is then delivered to the cathode chamber 14 through conduit 13.

Within the cathode chamber 14 the oxygen gas within the air contacts the cathode electrode 15 and becomes oxygen ions with the addition of electrons. The oxygen ions pass through the solid oxide electrolyte 16 and are available on the anode catalyst 17 to oxidize available fuel. As the air flows through the cathode chamber 14 the air is partly depleted of oxygen and its temperature is increased from the waste heat generated within the fuel cell. The temperature rise across the cathode chamber can be as much as 200C depending on the fuel cell current, operating voltage, degree of internal fuel reforming and the flow rates of the exhaust gases. The cathode air exhaust from cathode chamber 14 is directed back to the cathode heat exchanger 12 through conduit 18. Within heat exchanger 12, heat is transferred from the exhaust air stream to the air inlet stream in a counter flow arrangement. The cooled exhaust air is then discharged from heat exchanger 12 through conduit 19.

[0030] A hydrocarbon fuel, such as methane gas and/or another suitable hydrocarbon or hydrogen gas, is introduced into the SOFC system 10 through conduit 20 into hydrogen recovery unit 21. The fuel may be located in a fuel storage vessel, such as a methane storage vessel, connected to conduit 20. Within hydrogen recovery unit 21 hydrogen gas is transferred from the outlet stream (i.e., the fuel exhaust stream) into the hydrocarbon fuel inlet stream. This hydrogen supports a uniform methane reformation process within the anode catalyst 17. The methane and hydrogen mixture (i.e., the fuel inlet stream) flows from the hydrogen recovery unit 21 into the enthalpy recovery unit 23 through conduit 22.

[0031] Within the water vapor and enthalpy recovery unit 23, a portion of the water vapor is transferred from the exhaust or outlet stream into the methane hydrogen inlet stream. From the water vapor and enthalpy recovery unit 23, the methane, hydrogen and water vapor mixture (i.e., the inlet stream) is introduced into heat exchanger 25 through conduit 24. In the heat exchanger 25, the gas mixture temperature is increased near to the operational temperature of about 600 to 1000 C, such as 800 C, using the high temperature waste heat from the exhaust stream. From heat exchanger 25, the hot mixture of methane, hydrogen, and water vapor (i.e., the inlet stream) is delivered to the anode chamber 27 through conduit 26. Some steam reformation of the methane will occur in the heat exchanger 25 and conduit 26, but the amount is suppressed by the existence of the hydrogen. The completion of the steam reforming of the methane is accomplished in the anode catalyst 17.

[0032] Within the anode catalyst 17, the steam reforming of methane and the oxidation of carbon and hydrogen in the fuel cell reactions convert the discharged gas mixture to carbon dioxide, additional water vapor, and excess hydrogen. The discharged gas mixture (i.e., the exhaust or outlet stream) flows to heat exchanger 25 through conduit 28, releasing waste heat. The discharged gas mixture (i.e., the exhaust or outlet stream) then flows through conduit 29 to the enthalpy recovery

unit 23 to supply a portion of the water vapor to support the input methane reformation. The discharged gas mixture (i.e., the exhaust stream) is then directed to the hydrogen recovery unit 21 through conduit 30, where a selected amount of the hydrogen is transferred to the methane inlet stream. Using the electrochemical proton exchange process as the hydrogen recovery unit 21 is preferred because it provides a measure of the hydrogen content within the discharged gas mixture which can be used to adjust the input methane flow rate. However, other hydrogen recovery devices may also be used. Preferably, the hydrogen recovery unit 21 is located separately from the water vapor and enthalpy recovery unit 23 and the hydrogen recovery unit is located further downstream from the water vapor and enthalpy recovery unit relative to the solid oxide fuel cell stack, such that hydrogen is introduced into the fuel inlet stream before water vapor. The exhaust stream from hydrogen recovery unit 21, containing mostly carbon dioxide, water, and a small quantity of non-reacted fuel, is discharged from the SOFC system 10 through conduit 31.

[0033] The SOFC system 40 of the invention is shown in Fig. 2 as a simplified system schematic. System 40 contains the same components as system 10 of the first embodiment, except that the hydrogen recovery unit 21 and the water vapor and enthalpy recovery unit 23 are replaced with a fuel exhaust processing subsystem 41. The subsystem 41 is operatively (i.e., directly or indirectly) connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit. The SOFC system 40 also contains a fuel supply inlet conduit (i.e., an anode inlet conduit) containing conduit portions 20, 22, 24 and 26 (conduit portions 20, 22 and 24 may comprise a single continuous conduit, if desired) and a fuel exhaust outlet conduit (i.e., an anode outlet conduit) containing conduit portions 28, 29 and 31. Hydrogen delivery conduit 43 and water vapor delivery conduit 42 connect the subsystem 41 with the fuel supply inlet conduit.

[0034] The fuel exhaust processing subsystem 41 preferably contains a carbon dioxide scrubbing unit, a water vapor recovery unit and a hydrogen recovery unit. The carbon dioxide scrubbing unit removes at least a portion of carbon dioxide present in the fuel exhaust to form a scrubbed fuel exhaust or outlet stream. The water vapor recovery unit transfers at least a portion of water vapor from the scrubbed exhaust stream to the hydrocarbon fuel inlet stream. The hydrogen recovery unit is adapted to transfer at least a portion of hydrogen from the scrubbed fuel exhaust stream to the hydrocarbon fuel inlet stream. Thus, in the system of the invention, a single subsystem 41 can be used to separate hydrogen and water vapor from the fuel exhaust or outlet stream. Preferably, the subsystem 41 is an absorption/adsorption gas recovery and separation subsystem which separates hydrogen and water vapor based on absorption/adsorption techniques, such as a device containing an adsorption based gas separation column and/or a polymeric gas separation membrane. Alternatively, the subsystem 41

may comprise a molecular sieve.

[0035] Preferably, a carbon dioxide scrubbing unit is used to remove at least a portion of carbon dioxide from the exhaust stream prior to separating the water vapor and hydrogen from the exhaust stream. Thus, the method of the invention preferably includes removing at least a portion of carbon dioxide present in the fuel exhaust or outlet stream to form a scrubbed fuel exhaust and providing at least a portion of the scrubbed fuel exhaust into the hydrocarbon fuel inlet stream, such as providing a portion of hydrogen and water vapor from the scrubbed fuel exhaust into the fuel inlet stream. Preferably, about 45% to about 55%, such as about 50% of the hydrogen and water vapor recovered from the scrubbed fuel exhaust are provided separately into the hydrocarbon fuel inlet stream to obtain a fuel utilization of about 70 to about 80%.

[0036] A method of operating the system 40 is described with respect to Fig. 2. Air containing reactant oxygen is delivered by a blower (not shown) to the cathode heat exchanger 12 through conduit 11. Within the cathode heat exchanger 12, fuel cell waste heat is exchanged into the cathode inlet air raising the air temperature close to the cell operating temperature. The heated air is then delivered to the SOFC cathode chamber 14, through conduit 13. Within the cathode chamber 14, the oxygen gas within the air contacts the cathode electrode 15 and becomes oxygen ions with the addition of electrons. The oxygen ions pass through the solid oxide electrolyte 16 and are available on the anode catalyst 17 to oxidize available fuel. As the air flows through the cathode chamber 14 the air is partly depleted of oxygen and its temperature is increased from the waste heat generated within the fuel cell. The temperature rise across the cathode chamber can be as much as 200C depending on the fuel cell current, operating voltage, degree of internal fuel reforming and the flow rates of the exhaust gases. The cathode air exhaust from cathode chamber 14 is directed back to the cathode heat exchanger 12 through conduit 18. Within heat exchanger 12 heat is transferred from the exhaust air stream to the air inlet stream in a counter flow arrangement. The cooled exhaust air is then discharged from heat exchanger 12 through conduit 19.

[0037] A hydrocarbon fuel, such as methane gas, is introduced into the SOFC system 40 through conduit 20. Hydrogen is injected into the methane gas inlet stream through conduit 43. This hydrogen supports a uniform methane reformation process within the anode catalyst 17. The methane and hydrogen mixture (i.e., inlet stream) flows through conduit 22. Water is injected into inlet stream through conduit 42 and the methane, hydrogen and water mixture (i.e., the inlet stream) flows through conduit 24 to heat exchanger 25. In the heat exchanger 25, the mixture temperature is increased near to an operational temperature of about 600 C to about 1000 C, such as about 800 C, using the high temperature waste heat from the exhaust stream. From heat exchanger 25, the hot mixture of methane, hydrogen, and water vapor

(i.e., the inlet stream) is delivered to the SOFC anode chamber 27 through conduit 26. Some steam reformation of the methane will occur in the heat exchanger 25 and conduit 26 but the amount is suppressed by the existence of the hydrogen. The completion of the steam reforming of the methane is accomplished in the anode catalyst 17.

[0038] Within the anode catalyst 17, the steam reforming of methane and the oxidation of carbon and hydrogen in the fuel cell reactions convert the discharged gas mixture (i.e., the exhaust stream) to carbon dioxide, additional water vapor, and excess hydrogen. The discharged gas mixture (i.e., the exhaust stream) flows to heat exchanger 25 through conduit 28, releasing waste heat. The exhaust stream then flows through conduit 29 to fuel exhaust processing subsystem 41. The fuel exhaust processing subsystem 41 separates hydrogen and water from carbon dioxide and other non-reacted fuel using absorption/adsorption or other suitable techniques. A portion of the separated water is injected into a water vapor delivery conduit 42 to supply water into the fuel inlet stream flowing through conduit 22 to support the input methane reformation. The separated hydrogen is injected into a hydrogen delivery conduit 43 to supply hydrogen into the fuel inlet stream flowing through conduit 22 to modify the methane steam reforming equilibrium. Preferably, the water vapor delivery conduit 42 is located further upstream from the hydrogen delivery conduit 43 relative to the solid oxide fuel cell stack, such that the hydrogen is delivered into the fuel inlet stream before water vapor. The exhaust mixture from fuel exhaust processing subsystem 41, containing mostly carbon dioxide, water, and a small quantity of non-reacted fuel, is discharged from the SOFC system 40 through conduit 31.

[0039] In the methods of the invention, hydrogen may be provided into the fuel inlet stream without providing carbon dioxide which is present in the fuel exhaust stream into the fuel inlet stream. Furthermore, if desired, only a portion of the hydrogen and/or water vapor present in the fuel exhaust stream may be provided into the fuel inlet stream. The methods and systems of the invention allow control of an amount of water vapor provided into the hydrocarbon fuel to decrease or prevent reforming of the hydrocarbon fuel and water vapor in a fuel inlet conduit upstream from the solid oxide fuel cell stack. The control of the water vapor transfer may be achieved by the rotation rate of a desiccant wheel of the first embodiment or control of the absorption/adsorption cycle of the second embodiment. For example, the methods of the invention may be controlled to provide a sufficient amount of water vapor into the hydrocarbon fuel inlet stream such that the water vapor and hydrocarbon fuel mixture inlet stream contains less than two water molecules for each carbon atom, preferably 1.5 or less water molecules for each carbon atom. The hydrocarbon fuel and the water vapor can be reformed in the solid oxide fuel cell stack in parallel with an oxidation reaction proceeding in the solid oxide fuel cell stack. Preferably, about 45% to about 55%, such as about 50% of the hydrogen and water vapor recovered

from the scrubbed fuel exhaust are provided separately into the hydrocarbon fuel inlet stream to obtain a fuel utilization of about 70 to about 80%. The term "about" provides a variation based on given processes variables, such as a variation of 10% or less, preferably 5% or less.

[0040] The foregoing description of the invention has been presented for purposes of illustration and description.

Claims

Claims for the following Contracting State(s): AT, BE, BG, CH, CY, CZ, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LI, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR

1. A solid oxide fuel cell system, comprising:

a solid oxide fuel cell stack;
a fuel supply inlet conduit adapted to provide a hydrocarbon fuel inlet stream into the solid oxide fuel cell stack;
a fuel exhaust outlet conduit adapted to remove a fuel exhaust stream from the solid oxide fuel cell stack;
a heat exchanger connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit, wherein the heat exchanger is adapted to transfer heat from the fuel exhaust stream to the hydrocarbon fuel inlet stream;
a fuel exhaust processing subsystem operatively connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit, wherein the fuel exhaust processing subsystem comprises:

a water vapor recovery unit, wherein the water vapor recovery unit is adapted to transfer at least a portion of water vapor from the fuel exhaust stream to the hydrocarbon fuel inlet stream;
a hydrogen recovery unit, wherein the hydrogen recovery unit is adapted to transfer at least a portion of hydrogen from the fuel exhaust stream to the hydrocarbon fuel inlet stream, and
a carbon dioxide scrubbing unit, wherein the carbon dioxide scrubbing unit is adapted to remove at least a portion of carbon dioxide present in the fuel exhaust stream to form a scrubbed fuel exhaust stream.

2. The system of claim 1, wherein the water vapor unit comprises a water vapor and enthalpy recovery unit which is adapted to provide enthalpy from the fuel exhaust stream to the hydrocarbon fuel inlet stream.

3. The system of claim 1, wherein the hydrogen recov-

ery unit is adapted to selectively transfer at least a portion of hydrogen from the fuel exhaust stream to the hydrocarbon fuel inlet stream.

4. The system of claim 1, wherein:

the hydrogen recovery unit comprises an electrochemical pump or an adsorption hydrogen recovery device;
the hydrogen recovery unit is located separately from the water vapor unit; and
the hydrogen recovery unit is located further downstream from the water vapor unit relative to the solid oxide fuel cell stack.

5. A method of operating a solid oxide fuel cell system, comprising:

providing a hydrocarbon fuel inlet stream into a solid oxide fuel cell stack;
removing fuel exhaust stream from the solid oxide fuel cell stack;
recovering at least a portion of water vapor and heat from the fuel exhaust stream;
providing the recovered water vapor and heat into the hydrocarbon fuel inlet stream being provided into the solid oxide fuel cell stack;
recovering at least a portion of hydrogen from the fuel exhaust stream; and
separately providing the at least a portion of the recovered hydrogen into the hydrocarbon fuel inlet stream being provided toward the solid oxide fuel cell stack.

6. The method of claim 5, further comprising:

removing at least a portion of carbon dioxide present in the fuel exhaust stream to form a scrubbed fuel exhaust stream; and
providing at least a portion of the scrubbed fuel exhaust stream into the hydrocarbon fuel inlet stream.

7. The method of claim 5, wherein:

the hydrogen is recovered using an absorption hydrogen recovery device or an electrochemical pump;
the step of providing the at least a portion of hydrogen comprises providing hydrogen without providing carbon dioxide present in the fuel exhaust stream; and
hydrogen is provided into the hydrocarbon fuel inlet stream further upstream from where the water vapor is provided into the hydrocarbon fuel inlet stream, relative to the solid oxide fuel cell stack.

Claims for the following Contracting State(s): DE

1. A solid oxide fuel cell system, comprising:

a solid oxide fuel cell stack;
a fuel supply inlet conduit adapted to provide a hydrocarbon fuel inlet stream into the solid oxide fuel cell stack;
a fuel exhaust outlet conduit adapted to remove a fuel exhaust stream from the solid oxide fuel cell stack;
a heat exchanger connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit, wherein the heat exchanger is adapted to transfer heat from the fuel exhaust stream to the hydrocarbon fuel inlet stream;
a fuel exhaust processing subsystem operatively connected to the fuel supply inlet conduit and to the fuel exhaust outlet conduit, wherein the fuel exhaust processing subsystem comprises:

a water vapor recovery unit, wherein the water vapor recovery unit is adapted to transfer at least a portion of water vapor from the fuel exhaust stream to the hydrocarbon fuel inlet stream;
a hydrogen recovery unit, wherein the hydrogen recovery unit is adapted to transfer at least a portion of hydrogen from the fuel exhaust stream to the hydrocarbon fuel inlet stream, and
a carbon dioxide scrubbing unit, wherein the carbon dioxide scrubbing unit is adapted to remove at least a portion of carbon dioxide present in the fuel exhaust stream to form a scrubbed fuel exhaust stream, wherein the recovered hydrogen and water vapor are separately provided into the hydrocarbon fuel inlet stream.

2. The system of claim 1, wherein the water vapor unit comprises a water vapor and enthalpy recovery unit which is adapted to provide enthalpy from the fuel exhaust stream to the hydrocarbon fuel inlet stream.

3. The system of claim 1, wherein the hydrogen recovery unit is adapted to selectively transfer at least a portion of hydrogen from the fuel exhaust stream to the hydrocarbon fuel inlet stream.

4. The system of claim 1, wherein:

the hydrogen recovery unit comprises an electrochemical pump or an adsorption hydrogen recovery device;
the hydrogen recovery unit is located separately from the water vapor unit; and
the hydrogen recovery unit is located further

downstream from the water vapor unit relative to the solid oxide fuel cell stack.

5. A method of operating a solid oxide fuel cell system, comprising:

providing a hydrocarbon fuel inlet stream into a solid oxide fuel cell stack;
removing fuel exhaust stream from the solid oxide fuel cell stack;
recovering at least a portion of water vapor and heat from the fuel exhaust stream;
providing the recovered water vapor and heat into the hydrocarbon fuel inlet stream being provided into the solid oxide fuel cell stack, wherein the recovered water vapor is separately provided into the hydrocarbon fuel inlet stream;
recovering at least a portion of hydrogen from the fuel exhaust stream; and
separately providing the at least a portion of the recovered hydrogen into the hydrocarbon fuel inlet stream being provided toward the solid oxide fuel cell stack.

6. The method of claim 5, further comprising:

removing at least a portion of carbon dioxide present in the fuel exhaust stream to form a scrubbed fuel exhaust stream; and
providing at least a portion of the scrubbed fuel exhaust stream into the hydrocarbon fuel inlet stream.

7. The method of claim 5, wherein:

the hydrogen is recovered using an absorption hydrogen recovery device or an electrochemical pump;
the step of providing the at least a portion of hydrogen comprises providing hydrogen without providing carbon dioxide present in the fuel exhaust stream; and
hydrogen is provided into the hydrocarbon fuel inlet stream further upstream from where the water vapor is provided into the hydrocarbon fuel inlet stream, relative to the solid oxide fuel cell stack.

Patentansprüche

Patentansprüche für folgende(n) Vertragsstaat(en):

AT, BE, BG, CH, CY, CZ, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LI, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR

1. Festoxidbrennstoffzellensystem, umfassend:

einen Festoxidbrennstoffzellenstack;
eine Brennstoffzufuhreinlassleitung, die ausgebildet ist, um einen Kohlenwasserstoff-Brennstoffeinlassstrom in den Festoxidbrennstoffzellenstack einzuleiten;
eine Brennstoffabgasauslassleitung, die ausgebildet ist, um einen Brennstoffabgasstrom aus dem Festoxidbrennstoffzellenstack zu entfernen;
einen Wärmetauscher, der mit der Brennstoffzufuhreinlassleitung und der Brennstoffabgasauslassleitung verbunden ist, wobei der Wärmetauscher ausgebildet ist, Wärme vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen;
ein Brennstoffabgasverarbeitungs-Subsystem, welches betriebsmäßig mit der Brennstoffzufuhreinlassleitung und der Brennstoffabgasauslassleitung verbunden ist, wobei das Brennstoffabgasverarbeitungs-Subsystem folgendes aufweist:

eine Wasserdampfrückgewinnungseinheit, wobei die Wasserdampfrückgewinnungseinheit ausgebildet ist, mindestens einen Teil an Wasserdampf vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen;
eine Wasserstoffrückgewinnungseinheit, wobei die Wasserstoffrückgewinnungseinheit ausgebildet ist, mindestens einen Teil an Wasserstoff vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen, und
eine Kohlendioxidreinigungseinheit, wobei die Kohlendioxidreinigungseinheit ausgebildet ist, mindestens einen Teil an Kohlendioxid, der im Brennstoffabgasstrom vorhanden ist, zu entfernen, und so einen gereinigten Brennstoffabgasstrom zu bilden.

2. System nach Anspruch 1, wobei die Wasserdampfeinheit eine Wasserdampf und Enthalpie-Rückgewinnungseinheit umfasst, die ausgebildet ist, Enthalpie vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu leiten.

3. System nach Anspruch 1, wobei die Wasserstoffrückgewinnungseinheit ausgebildet ist, selektiv mindestens einen Teil an Wasserstoff vom Brennstoffabgasstrom auf den Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen.

4. System nach Anspruch 1, wobei:

die Wasserstoffrückgewinnungseinheit eine elektrochemische Pumpe oder eine Adsorpti-

ons- Wasserstoffrückgewinnungsvorrichtung umfasst;
 die Wasserstoffrückgewinnungseinheit separat von der Wasserdampfeinheit angeordnet ist; und
 die Wasserstoffrückgewinnungseinheit, relativ zum Festoxidbrennstoffzellenstack, weiter stromabwärts von der Wasserdampfeinheit angeordnet ist.

5. Verfahren zum Betreiben eines Festoxidbrennstoffzellensystems, mit den folgenden Schritten:

Einleiten eines Kohlenwasserstoff-Brennstoffeinlassstroms in einen Festoxidbrennstoffzellenstack;
 Entfernen von Brennstoffabgasstrom aus dem Festoxidbrennstoffzellenstack;
 Rückgewinnen mindestens eines Teils an Wasserdampf und Wärme aus dem Brennstoffabgasstrom;
 Einleiten des rückgewonnenen Wasserdampfes und der rückgewonnenen Wärme in den Kohlenwasserstoff-Brennstoffeinlassstrom, der in den Festoxidbrennstoffzellenstack eingeleitet wird;
 Rückgewinnen mindestens eines Teils an Wasserstoff aus dem Brennstoffabgasstrom; und
 separates Einleiten des mindestens einen Teils an rückgewonnenem Wasserstoff in den Kohlenwasserstoff-Brennstoffeinlassstrom, der zum Festoxidbrennstoffzellenstack geleitet wird.

6. Verfahren nach Anspruch 5, weiterhin umfassend:

Entfernen mindestens eines Teils an Kohlendioxid, das in dem Brennstoffabgasstrom vorliegt, um einen gereinigten Brennstoffabgasstrom zu bilden; und
 Leiten mindestens eines Teils des gereinigten Brennstoffabgasstroms in den Kohlenwasserstoff-Brennstoffeinlassstrom.

7. Verfahren nach Anspruch 5, wobei:

der Wasserstoff unter Verwendung einer Absorptions- Wasserstoffrückgewinnungsvorrichtung oder einer elektrochemischen Pumpe rückgewonnen wird;
 der Schritt des Leitens des mindestens einen Teils an Wasserstoff das Leiten von Wasserstoff ohne das Leiten von Kohlendioxid umfasst, welches im Brennstoffabgasstrom vorhanden ist; und
 Wasserstoff in den Kohlenwasserstoff-Brennstoffeinlassstrom, relativ zum Festoxid-Brennstoffzellenstack, weiter stromaufwärts von dort

eingeleitet wird, wo der Wasserdampf in den Kohlenwasserstoff-Brennstoffeinlassstrom eingeleitet wird.

**Patentansprüche für folgende(n) Vertragsstaat(en):
 DE**

1. Festoxidbrennstoffzellensystem, umfassend:

einen Festoxidbrennstoffzellenstack;
 eine Brennstoffzufuhreinlassleitung, die ausgebildet ist, um einen Kohlenwasserstoff-Brennstoffeinlassstrom in den Festoxidbrennstoffzellenstack einzuleiten;
 eine Brennstoffabgasauslassleitung, die ausgebildet ist, um einen Brennstoffabgasstrom aus dem Festoxidbrennstoffzellenstack zu entfernen;
 einen Wärmetauscher, der mit der Brennstoffzufuhreinlassleitung und der Brennstoffabgasauslassleitung verbunden ist, wobei der Wärmetauscher ausgebildet ist, Wärme vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen;
 ein Brennstoffabgasverarbeitungs-Subsystem, welches betriebsmäßig mit der Brennstoffzufuhreinlassleitung und der Brennstoffabgasauslassleitung verbunden ist, wobei das Brennstoffabgasverarbeitungs-Subsystem folgendes aufweist:

eine Wasserdampfrückgewinnungseinheit, wobei die Wasserdampfrückgewinnungseinheit ausgebildet ist, mindestens einen Teil an Wasserdampf vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen;
 eine Wasserstoffrückgewinnungseinheit, wobei die Wasserstoffrückgewinnungseinheit ausgebildet ist, mindestens einen Teil an Wasserstoff vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen, und
 eine Kohlendioxidreinigungseinheit, wobei die Kohlendioxidreinigungseinheit ausgebildet ist, mindestens einen Teil an Kohlendioxid, der im Brennstoffabgasstrom vorhanden ist, zu entfernen, und so einen gereinigten Brennstoffabgasstrom zu bilden,

wobei der rückgewonnene Wasserstoff und Wasserdampf separat in den Kohlenwasserstoff-Brennstoffeinlassstrom eingeleitet werden.

2. System nach Anspruch 1, wobei die Wasserdampfeinheit eine Wasserdampf- und Enthalpie-Rückge-

winnungseinheit umfasst, die ausgebildet ist, Enthalpie vom Brennstoffabgasstrom zum Kohlenwasserstoff-Brennstoffeinlassstrom zu leiten.

3. System nach Anspruch 1, wobei die Wasserstoffrückgewinnungseinheit ausgebildet ist, selektiv mindestens einen Teil an Wasserstoff vom Brennstoffabgasstrom auf den Kohlenwasserstoff-Brennstoffeinlassstrom zu übertragen.

4. System nach Anspruch 1, wobei:

die Wasserstoffrückgewinnungseinheit eine elektrochemische Pumpe oder eine Adsorptions- Wasserstoffrückgewinnungsvorrichtung umfasst;
die Wasserstoffrückgewinnungseinheit separat von der Wasserdampfeinheit angeordnet ist; und
die Wasserstoffrückgewinnungseinheit, relativ zum Festoxidbrennstoffzellenstack, weiter stromabwärts von der Wasserdampfeinheit angeordnet ist.

5. Verfahren zum Betreiben eines Festoxidbrennstoffzellensystems, mit den folgenden Schritten:

Einleiten eines Kohlenwasserstoff-Brennstoffeinlassstroms in einen Festoxidbrennstoffzellenstack;
Entfernen von Brennstoffabgasstrom aus dem Festoxidbrennstoffzellenstack;
Rückgewinnen mindestens eines Teils an Wasserdampf und Wärme aus dem Brennstoffabgasstrom;
Einleiten des rückgewonnenen Wasserdampfes und der rückgewonnenen Wärme in den Kohlenwasserstoff-Brennstoffeinlassstrom, der in den Festoxidbrennstoffzellenstack eingeleitet wird, wobei der rückgewonnene Wasserdampf separat in den Kohlenwasserstoff-Brennstoffeinlassstrom eingeleitet wird;
Rückgewinnen mindestens eines Teils an Wasserstoff aus dem Brennstoffabgasstrom; und
separates Einleiten des mindestens einen Teils an rückgewonnenem Wasserstoff in den Kohlenwasserstoff-Brennstoffeinlassstrom, der zum Festoxidbrennstoffzellenstack geleitet wird.

6. Verfahren nach Anspruch 5, weiterhin umfassend:

Entfernen mindestens eines Teils an Kohlendioxid, das in dem Brennstoffabgasstrom vorliegt, um einen gereinigten Brennstoffabgasstrom zu bilden; und
Leiten mindestens eines Teils des gereinigten Brennstoffabgasstroms in den Kohlenwasser-

stoff-Brennstoffeinlassstrom.

7. Verfahren nach Anspruch 5, wobei:

der Wasserstoff unter Verwendung einer Absorptions- Wasserstoffrückgewinnungsvorrichtung oder einer elektrochemischen Pumpe rückgewonnen wird;
der Schritt des Leitens des mindestens einen Teils an Wasserstoff das Leiten von Wasserstoff ohne das Leiten von Kohlendioxid umfasst, welches im Brennstoffabgasstrom vorhanden ist; und
Wasserstoff in den Kohlenwasserstoff-Brennstoffeinlassstrom, relativ zum Festoxid-Brennstoffzellenstack, weiter stromaufwärts von dort eingeleitet wird, wo der Wasserdampf in den Kohlenwasserstoff-Brennstoffeinlassstrom eingeleitet wird.

Revendications

Revendications pour l'(les) Etat(s) contractant(s) suivant(s): AT, BE, BG, CH, CY, CZ, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LI, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR

1. Un système de pile à combustible à oxyde solide (SOFC) comprenant:

- un empilement de piles à combustible à oxyde solide,
- un conduit d'entrée pour l'alimentation en combustible apte à distribuer un flux d'entrée de combustible hydrocarbure à l'empilement de piles à combustible à oxyde solide,
- un conduit de sortie pour l'évacuation du combustible apte à faire sortir un flux d'échappement de combustible de l'empilement de piles à combustible à oxyde solide,
- un échangeur de chaleur connecté au conduit d'entrée de combustible et au conduit de sortie pour l'évacuation de combustible, dans lequel l'échangeur de chaleur est adapté pour transférer la chaleur depuis le flux d'échappement de combustible jusqu'au flux d'entrée de combustible hydrocarbure ;
- un sous-système d'échappement du combustible fonctionnellement connecté au conduit d'entrée de combustible et au conduit d'échappement de combustible, dans lequel le sous-système d'échappement comprend :

- une unité de récupération de vapeur d'eau, dans laquelle l'unité de récupération de vapeur d'eau est apte à transférer au moins

- une partie de la vapeur d'eau provenant du flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure ;
 - une unité de récupération d'hydrogène, dans laquelle l'unité de récupération d'hydrogène est apte à transférer au moins une partie de l'hydrogène provenant du flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure ;
 - une unité d'épuration du dioxyde de carbone, dans laquelle l'unité d'épuration du dioxyde de carbone est apte à éliminer au moins une partie du dioxyde de carbone présent dans le flux d'échappement de combustible pour former un flux d'échappement de combustible purifié.
2. Système selon la revendication 1, dans lequel l'unité de récupération de vapeur d'eau comprend une unité de récupération de vapeur d'eau et d'enthalpie apte à distribuer l'enthalpie depuis le flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure.
3. Système selon la revendication 1, dans lequel l'unité de récupération d'hydrogène est apte à transférer sélectivement au moins une partie de l'hydrogène du flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure.
4. Système selon la revendication 1, dans lequel :
- l'unité de récupération d'hydrogène comprend une pompe électrochimique ou un dispositif de récupération d'hydrogène par adsorption,
 - l'unité de récupération d'hydrogène est séparée de l'unité de récupération de vapeur d'eau ; et
 - l'unité de récupération d'hydrogène est située en aval de l'unité de récupération de vapeur d'eau par rapport à l'empilement de piles à combustible à oxyde solide.
5. Méthode de mise en oeuvre d'un système de pile à combustible à oxyde solide comprenant le fait :
- de distribuer un flux d'entrée de combustible hydrocarbure dans un empilement de piles à combustible à oxyde solide ;
 - d'évacuer le flux d'échappement de combustible de l'empilement de piles à combustible à oxyde solide ;
 - de récupérer au moins une partie de la vapeur d'eau et de la chaleur provenant du flux d'échappement de combustible ;
 - de distribuer la vapeur d'eau et la chaleur ainsi récupérées dans le flux d'entrée de combustible hydrocarbure alimentant l'empilement de piles
- à combustible à oxyde solide ;
 - de récupérer au moins une partie de l'hydrogène provenant du flux d'échappement de combustible ; et
 - de distribuer de manière séparée au moins une partie de l'hydrogène récupéré dans le flux d'entrée du combustible hydrocarbure alimentant l'empilement de piles à combustible à oxyde solide.
6. Méthode selon la revendication 5, comprenant également le fait :
- d'éliminer au moins une partie du dioxyde de carbone présent dans le flux d'échappement de combustible pour former un flux d'échappement de combustible purifié ; et
 - de distribuer au moins une part du flux d'échappement de combustible purifié dans le flux d'entrée du combustible hydrocarbure.
7. Méthode selon la revendication 5 dans laquelle :
- l'hydrogène est récupéré en utilisant un dispositif de récupération d'hydrogène par absorption ou une pompe électrochimique ;
 - l'étape d'alimentation par au moins une partie de l'hydrogène comprend l'alimentation en hydrogène sans alimenter en dioxyde de carbone présent dans le flux d'échappement de combustible ; et
 - l'hydrogène alimente le flux d'entrée du combustible hydrocarbure en amont de l'alimentation en vapeur d'eau du flux d'entrée du combustible hydrocarbure, par rapport à l'empilement de piles à combustible à oxyde solide.
- Revendications pour l'(les) Etat(s) contractant(s) suivant(s): DE**
1. Un système de pile à combustible à oxyde solide (SOFC) comprenant :
- un empilement de piles à combustible à oxyde solide,
 - un conduit d'entrée pour l'alimentation en combustible apte à distribuer un flux d'entrée de combustible hydrocarbure à l'empilement de piles à combustible à oxyde solide,
 - un conduit de sortie pour l'évacuation du combustible apte à faire sortir un flux d'échappement de combustible de l'empilement de piles à combustible à oxyde solide,
 - un échangeur de chaleur connecté au conduit d'entrée de combustible et au conduit de sortie pour l'évacuation de combustible, dans lequel l'échangeur de chaleur est adapté pour transfé-

rer la chaleur depuis le flux d'échappement de combustible jusqu'au flux d'entrée de combustible hydrocarbure ;

- un sous-système d'échappement du combustible fonctionnellement connecté au conduit d'entrée de combustible et au conduit d'échappement de combustible, dans lequel le sous-système d'échappement comprend :

- une unité de récupération de vapeur d'eau, dans laquelle l'unité de récupération de vapeur d'eau est apte à transférer au moins une partie de la vapeur d'eau provenant du flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure ;
- une unité de récupération d'hydrogène, dans laquelle l'unité de récupération d'hydrogène est apte à transférer au moins une partie de l'hydrogène provenant du flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure ;
- une unité d'épuration du dioxyde de carbone, dans laquelle l'unité d'épuration du dioxyde de carbone est apte à éliminer au moins une partie du dioxyde de carbone présent dans le flux d'échappement de combustible pour former un flux d'échappement de combustible purifié,

dans lequel l'hydrogène et la vapeur d'eau obtenus sont distribués de manière séparée dans le flux d'entrée de combustible hydrocarbure.

2. Système selon la revendication 1, dans lequel l'unité de récupération de vapeur d'eau comprend une unité de récupération de vapeur d'eau et d'enthalpie apte à distribuer l'enthalpie depuis le flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure.

3. Système selon la revendication 1, dans lequel l'unité de récupération d'hydrogène est apte à transférer sélectivement au moins une partie de l'hydrogène du flux d'échappement de combustible vers le flux d'entrée de combustible hydrocarbure.

4. Système selon la revendication 1, dans lequel :

- l'unité de récupération d'hydrogène comprend une pompe électrochimique ou un dispositif de récupération d'hydrogène par adsorption,
- l'unité de récupération d'hydrogène est séparée de l'unité de récupération de vapeur d'eau ; et
- l'unité de récupération d'hydrogène est située en aval de l'unité de récupération de vapeur d'eau par rapport à l'empilement de piles à combustible à oxyde solide.

5. Méthode de mise en oeuvre d'un système de pile à combustible à oxyde solide comprenant le fait :

- de distribuer un flux d'entrée de combustible hydrocarbure dans un empilement de piles à combustible à oxyde solide ;
- d'évacuer le flux d'échappement de combustible de l'empilement de piles à combustible à oxyde solide ;
- de récupérer au moins une partie de la vapeur d'eau et de la chaleur provenant du flux d'échappement de combustible ;
- de distribuer la vapeur d'eau et la chaleur ainsi récupérées dans le flux d'entrée de combustible hydrocarbure alimentant l'empilement de piles à combustible à oxyde solide, dans lequel la vapeur d'eau récupérée alimente de manière séparée le flux d'entrée de combustible hydrocarbure ;
- de récupérer au moins une partie de l'hydrogène provenant du flux d'échappement de combustible ; et
- de distribuer de manière séparée au moins une partie de l'hydrogène récupéré dans le flux d'entrée du combustible hydrocarbure alimentant l'empilement de piles à combustible à oxyde solide.

6. Méthode selon la revendication 5, comprenant également le fait :

- d'éliminer au moins une partie du dioxyde de carbone présent dans le flux d'échappement de combustible pour former un flux d'échappement de combustible purifié ; et
- de distribuer au moins une part du flux d'échappement de combustible purifié dans le flux d'entrée du combustible hydrocarbure.

7. Méthode selon la revendication 5 dans laquelle :

- l'hydrogène est récupéré en utilisant un dispositif de récupération d'hydrogène par absorption ou une pompe électrochimique ;
- l'étape d'alimentation par au moins une partie de l'hydrogène comprend l'alimentation en hydrogène sans alimenter en dioxyde de carbone présent dans le flux d'échappement de combustible ; et
- l'hydrogène alimente le flux d'entrée du combustible hydrocarbure en amont de l'alimentation en vapeur d'eau du flux d'entrée du combustible hydrocarbure, par rapport à l'empilement de piles à combustible à oxyde solide.

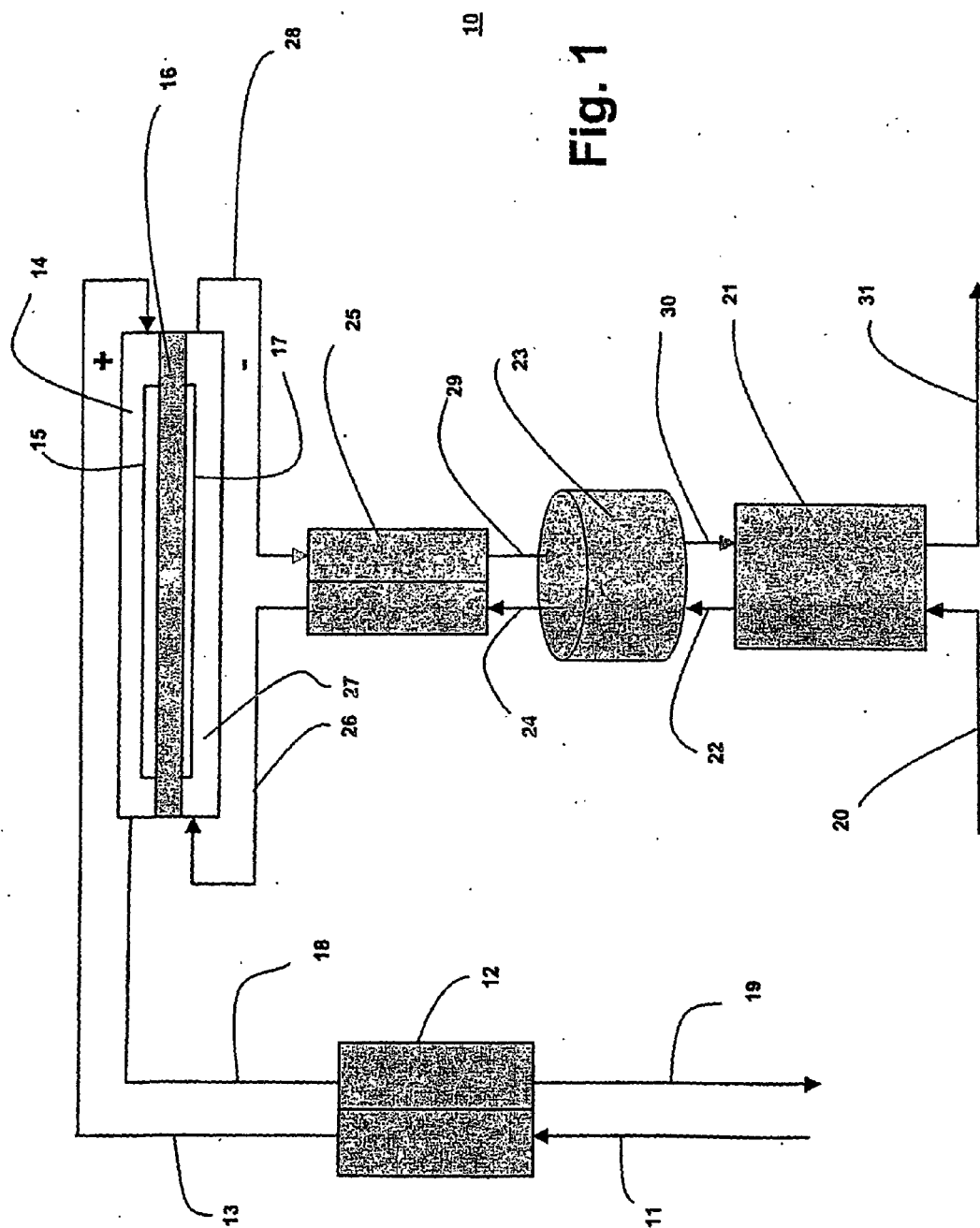


Fig. 1

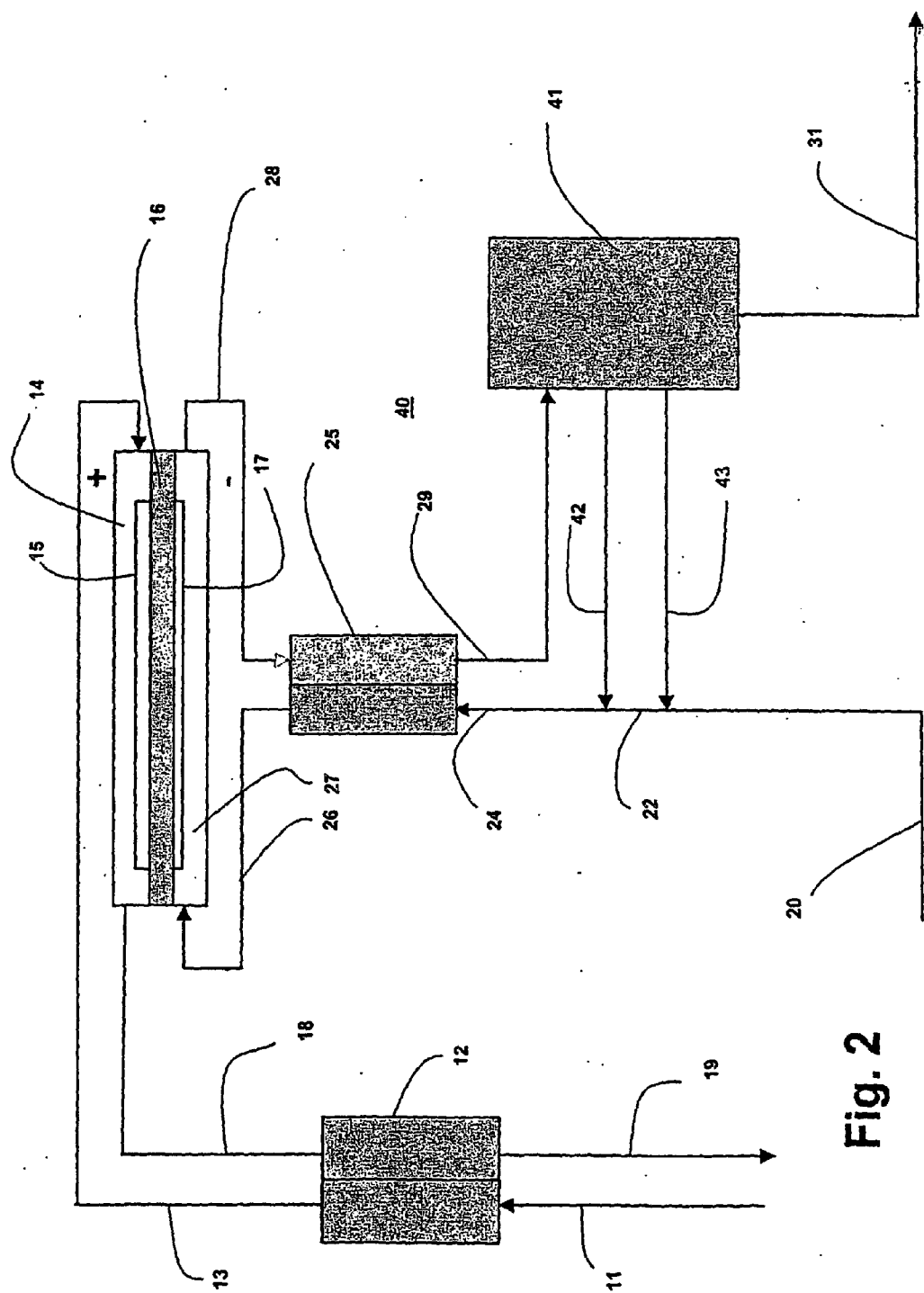


Fig. 2

REFERENCES CITED IN THE DESCRIPTION

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