Title: FUEL CELL STACK WITH A BIPOLAR FLOW FIELD PLATE

Abstract: A fuel cell stack (100) including a bipolar flow field plate (305) between a pair of fuel cell assemblies (103a, 103b) is provided. The fuel cell stack includes a pair of end plates (101, 102) and multiple fuel cell assemblies. A pair of fuel cell assemblies includes a pair of membrane electrode assemblies and the bipolar flow field plate. A first membrane electrode assembly (304) and a second membrane electrode assembly (308) have an anode face (304b, 308b) and a cathode face. The bipolar flow field plate includes a front surface (306b) with serpentine first flow channels (401) for reactant air and a second surface (306a) with serpentine second flow channels (501) for hydrogen, and multiple coolant fins (404, 405, 406, and 407) for coolant air on the front surface. The bipolar flow field plate prevents crossover of reactant air and hydrogen and avoids seam welding of two monopolar plates.
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FUEL CELL STACK WITH A BIPOLAR FLOW FIELD PLATE
TECHNICAL FIELD OF INVENTION

[0001] The invention generally relates to a fuel cell stack and more particularly to a bipolar flow field plate in the fuel cell stack.

BACKGROUND

[0002] A fuel cell is an electrochemical device that generates electricity on reaction between a fuel, that is, hydrogen and oxygen. Pure oxygen or air containing a large amount of oxygen reacts with pure hydrogen or a fuel containing a large amount of hydrogen in the fuel cell. Hydrogen may be generated by reforming a hydrocarbon fuel, such as methanol. The fuel is channeled through a flow field plate to an anode on one side of a proton exchange membrane in the fuel cell and oxygen is channeled through another flow field plate to the cathode on another side of the proton exchange membrane. Electrochemical reactions occur at the anode and the cathode to produce electricity, water, and heat. However, flow field plates account for 60% of the cost of a fuel cell and an optimal design of the flow field plate is critical to the performance of the fuel cell.

BRIEF DESCRIPTION OF DRAWINGS

[0003] The foregoing summary, as well as the following detailed description of the invention, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, exemplary constructions of the invention are shown in the drawings. However, the invention is not limited to the specific structures and methods disclosed herein. The description of a structure referenced by a numeral in a drawing is applicable to the description of that structure shown by that same numeral in any subsequent drawing herein.

[0004] Figs. 1A-1B exemplarily illustrate perspective views of a fuel cell stack;
[0005] Fig. 2 exemplarily illustrates an exploded perspective view of the fuel cell stack exemplarily illustrated in Fig. 1A;
[0006] Fig. 3 exemplarily illustrates an exploded view of an embodiment of a pair of fuel cell assemblies in the fuel cell stack;

[0007] Fig. 4 exemplarily illustrates a front perspective view of a bipolar flow field plate in the pair of fuel cell assemblies exemplarily illustrated in Fig. 3;

[0008] Fig. 5 exemplarily illustrates an elevation view of a rear surface of the bipolar flow field plate exemplarily illustrated in Fig. 4;

[0009] Fig. 6 exemplarily illustrates an enlarged partial front perspective view of the bipolar plate showing multiple bypass grooves;

[0010] Fig. 7 exemplarily illustrates an enlarged partial front perspective view of the bipolar plate showing a stopper rib;

[0011] Fig. 8 exemplarily illustrates an elevation view of an elastic member accommodated in a groove of the bipolar plate or a current collector plate;

[0012] Fig. 9 exemplarily illustrates an elevation view of a membrane electrode assembly

[0013] Fig. 10 exemplarily illustrates an elevation view of a current collector plate of the fuel cell stack;

[0014] Figs. 11A-11B exemplarily illustrate elevation views of a front surface and a rear surface of an end plate of the fuel cell stack; and

[0015] Figs. 12A-12B exemplarily illustrate elevation views of a front surface and a rear surface of another end plate of the fuel cell stack.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Various designs of flow field plates to channelize the fuel and air towards the proton exchange membrane are available. One such design of the flow field plate, for low temperature proton exchange membrane fuel cells (PEMFC), is to have two single serpentine channels running parallel to each other such that one serpentine channel covers half of the flow area of the flow field plate and other serpentine channel covers the other half of the flow field plate. These two single serpentine channels are connected to an inlet manifold of the PEM fuel cell through a header. The same design of the flow field plate is used for both hydrogen and air on either side of the flow field plate. The bipolar plate is made in
such a way that the flow field of hydrogen on one side (anode side) is at right angle to the flow field of air/oxygen on other side (cathode side).

[0017] However, when a stack is assembled with such bipolar plates, flow field on one side is vertical in direction and another flow field is horizontal in direction. When humidified gases (hydrogen and oxygen) pass through the single serpentine channels, water clogging is observed in a lower portion of the horizontal flow field due to gravity, while upper portion of the horizontal flow field is dried, thereby affecting the performance of the fuel cell. There is a need to avoid water clogging from occurring in the bipolar plate for preventing deterioration in the performance of the fuel cell.

[0018] Further, heat is being generated in the fuel cell due to the electrochemical reaction and the generated heat has to be removed continuously with the help of a coolant, for example, air or liquid, to maintain operating temperature of the fuel cell. The operating temperature for low temperature PEMFC is about -50°C to -80°C and the operating temperature for high temperature PEMFC is about 80°C to 160°C. If this operating temperature is not maintained, permanent damage may occur to the membrane electrode assembly and the membrane electrode assembly needs replacement.

[0019] To maintain the operating temperature of the fuel cell stack, a coolant needs to be re-circulated in the stack continuously to maintain the temperature. If air is used as a coolant, then coolant air is sent along with reactant air which flows through the flow field and cools the stack. However, such passage of coolant along the flow field plate along with the reactant air results in leaching of acids from membrane electrode assembly, carbon corrosion of carbon-based materials, such as, gas diffusion layer, catalyst poisoning due to the presence of CO, etc., resulting in degradation of performance of the fuel cell. To address such scenarios of degradation in the performance of the fuel cells, separate manifolds/channels to use air or any liquid coolant apart from the inlet manifolds/channels for the
reactive air may be provided. Such an arrangement may require installation of additional components, adding to the cost of manufacturing and maintenance in the PEMFC. Therefore, there exists a need for circulating a coolant in the PEMFC without degrading the performance of the PEMFC.

[0020] Furthermore, another existing design of the flow field plate includes forming flow fields for hydrogen and air on two different plates (monopolar) and seam welding the monopolar plates to obtain a bipolar plate. However, the inlets and outlets for hydrogen and air on both sides of the flow field plate are almost near to each other, resulting in difficulties in scaling especially at the inlets and outlets. Inadequate sealing of the inlets and the outlets may lead to internal combustion of gases.

[0021] Humidification plays an important role in low temperature PEM fuel cells as the proton exchange membrane needs water content to transfer the H+ ions from anode to cathode. Humidifying inlet gases will provide the necessary water content for this transfer. However, during this process, sometimes water clogging might happen in flow channel due to condensation of water. The water clogging blocks the incoming reactants to pass through the rest of the flow field, thereby making that particular cell in fuel cell stack non-functional. Also, breakage of a gas diffusion layer (GDL) in a low temperature and a high temperature PEM fuel cell might happen when the fuel cell is over compressed in a fuel cell stack. The GDL which is broken blocks the flow channel, thereby not allowing the reactants to pass through the rest of flow field.

[0022] Therefore, there exists a long felt need for a fuel cell stack with one or more bipolar flow field plates that caters for the flow of coolant and reactant, without adding additional cost to the manufacturing and maintenance of the fuel cell stack. The present subject matter addresses the above need for the bipolar flow field plates that allows flow of a coolant and reactants without additional costs.
[0023] A bipolar flow field plate in a pair of fuel cell assemblies is disclosed. The bipolar flow field plate includes a front surface comprising at least one serpentine first flow channel extending between an air inlet header and an air outlet header for reactant air. The bipolar flow field plate further includes a rear surface comprising at least one serpentine second flow channel extending between a hydrogen inlet header and a hydrogen outlet header for hydrogen. Each of the first flow channels includes multiple first bypass grooves for bypassing one or more sections of the first flow channels. Each of the second flow channels include a plurality of second bypass grooves for bypassing one or more sections of the second flow channels.

[0024] The bipolar flow field plate further includes multiple coolant fins for coolant air formed on the front surface and the rear surface between the air inlet header, the air outlet header, the hydrogen inlet header, and the hydrogen outlet header. The bipolar flow field plate further includes a stopper rib formed on edges of each of the front surface and the rear surface, for preventing excessive compression of an elastic member. The elastic member is accommodated in a groove formed parallel to the stopper rib on the each of the front surface and the rear surface.

[0025] The air inlet header and the air outlet header are in-line or perpendicular to the hydrogen inlet header and the hydrogen outlet header. The air inlet header, the air outlet header, and the multiple coolant fins engage with a discharge of an aeration device. The hydrogen inlet header and the hydrogen outlet header engage with an inlet manifold and an outlet manifold for hydrogen on a pair of end plates. The reactant air and hydrogen reactively engage with a membrane electrode assembly in each of the pair of fuel cell assemblies for supplying electric current to an electric circuit. The reactant air from the serpentine first flow channels diffuses towards a cathode surface of the membrane electrode assembly, and hydrogen from the serpentine second flow channels diffuses towards an anode
surface of the membrane electrode assembly. The aeration device is a blower or a centrifugal pump.

[0026] In an embodiment, a fuel cell stack is disclosed herein including the pair of end plates and the multiple fuel cell assemblies positioned between the pair of end plates. The pair of end plates accommodate the aeration device, the inlet manifold and the outlet manifold for hydrogen on an outer surface. A pair of fuel cell assemblies in the plurality of fuel cell assemblies includes a pair of membrane electrode assemblies and the bipolar flow field plate. Each of the first membrane electrode assembly and the second membrane electrode assembly comprises an anode face and a cathode face. The bipolar flow field plate is positioned between the first membrane electrode assembly and the second membrane electrode assembly.

[0027] The fuel cell stack further includes a pair of current collector plates for collecting electric current generated in the plurality of fuel cell assemblies, wherein each current collector plate is positioned between an end plate and the first membrane electrode assembly or the second membrane electrode assembly. Multiple fasteners compress the pair of end plate, the multiple fuel cell assemblies, and the pair of current collector plates together. The detailed description is described below with reference to the accompanying figures.

[0028] Figs. 1A-1B exemplarily illustrate perspective views of a fuel cell stack 100. The fuel cell stack 100 is a stacked arrangement of multiple fuel cell assemblies 103 that generate higher voltage and power than an individual fuel cell assembly. The fuel cell assemblies 103 are connected in series to form the fuel cell stack 100. In an embodiment, the number of fuel cell assemblies 103 may be increased to increase output voltage of the fuel cell stack 100. A fuel cell assembly is an electrochemical cell that converts chemical energy of hydrogen and oxygen into electric current and heat through a pair of oxidation and reduction. In the fuel cell assembly, chemical reactions occur between an anode
and an electrolyte, and a cathode and the electrolyte. At the anode, hydrogen is oxidized generating positive hydrogen ions and negatively charged electrons. The positive hydrogen ions travel through the electrolyte and the electrons travel through an external circuit. At the cathode, the positive hydrogen ions combine with the electron and oxygen to generate water. Based on the types of the cathode, the anode, and the electrolyte, the fuel cell assembly may be a proton exchange membrane (PEM) fuel cell assembly, a phosphoric acid fuel cell assembly, a solid acid fuel cell assembly, an alkaline fuel cell, etc.

[0029] As exemplarily illustrated in Fig. 1A, such multiple fuel cell assemblies 103 are stacked between a pair of end plates 101 and 102. The end plates 101 and 102 have guide holes for fasteners 107, for example, tie rods, nut and bolt assemblies, belt assembly, spring assembly etc., to apply pressure on the fuel cell assemblies 103 to compress the fuel cell stack 100 intact and prevent escape of gases from the fuel cell assemblies 103. The torque of tightening the fasteners 107 is maintained uniform to avoid the leakage of gases. The end plates 101 and 102 further include one or more inlet manifolds, such as, 104 for hydrogen, one or more outlet manifolds, such as, 105 for the reactant air, 114 for hydrogen, exemplarily illustrated in Fig. 1B, and an inlet duct 106 for the reactant air and the coolant air and an outlet duct 110 for coolant air exemplarily illustrated in Fig. 1B. As exemplarily illustrated in Fig. 1A, the endplate 101 accommodates an aeration device 108, such as, a blower. The inlet duct 106 is centrally located on the end plate 101 and receives the discharge of the aeration device 108. The inlet duct 106 for the reactant air and the coolant air of the fuel cell stack 100 removably engages with the discharge of the aeration device 108. The reactant air from the inlet duct 106 is fed to the fuel cell assemblies 103 via the inlet piping 109.

[0030] As exemplarily illustrated in Fig. 1B, the end plate 102 includes the outlet duct 110 for coolant air, the inlet manifold 104 for hydrogen, and the outlet manifold 105 for the reactant air. The outlet duct 110 is connected to the inlet duct
via a recirculation piping 111 through a heat exchanging mechanism, for recirculation of coolant air into the fuel cell stack 100. In the recirculation piping 111, an inlet manifold 112, and an outlet manifold 113 are connected for a coolant fluid to exchange heat with the coolant air from the outlet duct 110. The aeration device 108 is housed in a housing 115. The aeration device 108 is supported by brackets 116 on both sides, to position it in an erect position and locate centrally on the end plate 101. In an embodiment, the inlet manifold 104 and the outlet manifold 114 for hydrogen are positioned on the same end plate, such as, 102. In an embodiment, the inlet manifold 104 and the outlet manifold 114 for hydrogen may be positioned on different end plates such as, 101 and 102. The fasteners 107, such as, tie rods pass through the guide holes present on the end plates 101 and 102 and the fuel cell assemblies 103 and the nuts are tightened on threads of the tie rods to compress the fuel cell assemblies 103 together. By virtue of the fasteners 107, the fuel cell stack 100 has a dense packaging of the fuel cell assemblies 103.

[0031] Fig. 2 exemplarily illustrates an exploded perspective view of the fuel cell stack 100 exemplarily illustrated in Fig. 1A. As exemplarily illustrated, multiple fuel cell assemblies 103 are stacked together between the end plates 101 and 102 using the fasteners 107. The fasteners 107 are inserted through the guide holes 201 in the end plates 101 and 102. The brackets 116 are screwably attached to the end plate 101 to mount the inlet duct 106 centrally on an outer surface of the end plate 101. The outlet duct 110 is centrally positioned on an outer surface of the end plate 102 using the fasteners 107, for example, screw and nut assembly. Insertion of the fasteners 107, that is, tie rods and nuts through the guide holes 201 through the structure of the fuel cell stack 100 ensures proper assembly of the fuel cell stack 100. The fasteners 107 ensure adequate compression of the structure of the fuel cell stack 100.

[0032] The discharge of the aeration device 108 is connected to the inlet duct 106 of the fuel cell stack 100. The discharge of the aeration device 108 includes both
the reactant air for the electrochemical reaction in the fuel cell assemblies 103 and coolant air to remove the heat generated in the fuel cell stack 100. The reactant air from the inlet duct 106 is fed to the fuel cell assemblies 103 via the inlet piping 109. Remaining unreacted reactant air exits from the fuel cell stack 100 via the outlet manifold 105. The hot coolant air on extraction of heat from the fuel cell assemblies 103 along with the water vapors reaches the outlet duct 110 of the fuel cell stack 100 and is re-circulated to the inlet duct 106 via the recirculation piping 111 accommodating the heat exchanging mechanism. The aeration device 108, for example, includes a blower which increases the velocity and pressure of air through impellers to supply air for the electrochemical reaction and cooling of the fuel cell stack 100. The supplied air acts as a source of oxygen for the electrochemical reaction in each fuel cell assembly of the fuel cell stack 100. Hydrogen is supplied through the inlet manifold 104 in the end plate 102 and unreacted hydrogen remaining after the electrochemical reaction is sent out through the outlet manifold 114 in the end plate 101. Hydrogen may be derived from substances containing hydrogen, such as, methanol, gasoline, natural gas, and water. Pure hydrogen and oxygen, with no impurities are pressurized and injected into the fuel cell stack 100.

[0033] Fig. 3 exemplarily illustrates an exploded perspective view of a pair of fuel cell assemblies 103a and 103b in the fuel cell stack 100. The pair of fuel cell assemblies 103a and 103b is compressed between the pair of end plates 101 and 102. The pair of fuel cell assemblies 103a and 103b includes a pair of membrane electrode assemblies, that is, a first membrane electrode assembly 304 and a second membrane electrode assembly 308 and a bipolar flow field plate 306 positioned between the membrane electrode assemblies 304 and 308. Each of the membrane electrode assemblies 304 and 308 is a combination of an electrolyte, an anode, and a cathode. Each of the membrane electrode assemblies 304 and 308 includes a proton exchange membrane that is selectively permeable, an anode catalyst layer, and a cathode catalyst layer on either sides of the proton exchange membrane, and gas diffusion layers on both sides of the proton exchange
membrane. The proton exchange membrane conducts positively charged hydrogen ions and blocks the negatively charged electrons. The cathode catalyst layer forms a cathode surface 304a and 308a of the membrane electrode assemblies 304 and 308 respectively. The anode catalyst layer forms an anode surface 304b and 308b of the membrane electrode assemblies 304 and 308 respectively. On the anode surface 304b and 308b of the membrane electrode assemblies 304 and 308, hydrogen oxidation reaction takes place splitting hydrogen into positively charged ions and negatively charged electrons. The half-cell oxidation reaction is represented as:

\[ \text{H}_2 \rightarrow 2\text{H}^+ + 2e^- \]

[0034] The positively charged ions pass through the membrane electrode assemblies 304 and 308 to the cathode surface 304a and 308a, respectively. The electrons travel along an external load circuit to the cathode surface 304a and 308a of the membrane electrode assemblies 304 and 308, thus creating the current output of the fuel cell assemblies 103a and 103b. At the cathode surface 304a and 308a of the membrane electrode assemblies 304 and 308, oxygen molecules react with the protons permeating through the proton exchange membrane and the electrons arriving through the external circuit to form water molecules. The half cell reduction reaction is represented as: 1/2 \( \text{O}_2 \) + 2 \( \text{H}^+ \) + 2\( e^- \) \( \rightarrow \) \( \text{H}_2\text{O} \).

[0035] On the anode surface 304b and 308b and the cathode surface 304a and 308a of the membrane electrode assemblies 304 and 308, respectively, a platinum catalyst enables initiation of the half-cell oxidation reaction and the half-cell reduction reaction, respectively. The gas diffusion layer is positioned above the anode catalyst layer and the cathode catalyst layer of the membrane electrode assembly 304 and 308. The gas diffusion layer facilitates transport of hydrogen and oxygen into the catalyst layers and also, aids in removal of water generated in the fuel cell assemblies 103a and 103b. The gas diffusion layer has pores through which the reactant air and hydrogen diffuse towards the cathode surface 304a and
308a and the anode surface 304b and 308b of the membrane electrode assemblies 304 and 308.

[0036] As exemplarily illustrated, a bipolar flow field plate 306 is positioned between the first membrane electrode assembly 304 and the second membrane electrode assembly 308. The bipolar flow field plate 306 is positioned rear side up in the fuel cell stack 100. A rear surface 306a of the bipolar flow field plate 306 faces the anode face 304b of the first membrane electrode assembly 304 and a front surface 306b of the bipolar flow field plate 306 faces the cathode surface 308a of the second membrane electrode assembly 308. The bipolar flow field plate 306 uniformly distributes the reactant air on the front surface 306b and hydrogen on the rear surface 306a towards the membrane electrode assemblies 308 and 304 respectively. The bipolar flow field plate 306 has flow fields on both surfaces 306a and 306b to cater for diffusion of hydrogen and oxygen, respectively. The flow fields may be of different shapes, such as, rectangular, triangular, circular, etc. The flow channels on both surfaces 306a and 306b constitute the flow fields for hydrogen and oxygen respectively. On the front surface 306b of the bipolar flow field plate 306, at least one serpentine first flow channel of the reactant air is formed and on the rear surface 306a of the bipolar flow field plate 306, at least one serpentine second flow channel of hydrogen is formed. The first flow channels of the bipolar flow field plate 306 cater to the electrochemical reaction in the fuel cell assembly 103b and the second flow channels of the bipolar flow field plate 306 cater to the electrochemical reaction in the adjacent fuel cell assembly 103a. The bipolar flow field plate 306 with the front surface 306b and the rear surface 306a is exemplarily illustrated in Figs. 3, 4, and 5.

[0037] An elastic member 305, for example, a gasket is positioned between the bipolar flow field plate 306 and the membrane electrode assembly 304. An elastic member 307, for example, a gasket is positioned between the bipolar flow field plate 306 and the membrane electrode assembly 308. The elastic members 305
and 307, exemplarily illustrated in Fig. 8 provide a seal to prevent undue leakage of hydrogen or oxygen in the fuel cell stack 100. The fuel cell assemblies 103a and 103b include a pair of current collector plates 301 and 311 for collecting the current generated in the fuel cell assemblies 103a and 103b. The current collector plates 301 and 311 connect the fuel cell assemblies 103a and 103b to external loads. A pair of monopolar plates 302 and 310 is positioned against the monopolar plate 302 and the monopolar plate 310 respectively. Each monopolar plate 302 and 310 includes a flow field for oxygen or hydrogen on a front surface 302b and a rear surface 310a facing the membrane electrode assemblies 304 and 308. The front surface 302b of the monopolar plate 302 facing the cathode surface 304a of the first membrane electrode assembly 304 resembles the first flow channels of oxygen of the bipolar flow field plate 306 and the rear surface 310a of the monopolar plate 310 facing the anode surface 308b of the second membrane electrode assembly 308 resembles the second flow channels of hydrogen of the bipolar flow field plate 306.

[0038] Another pair of elastic members 303 and 309 is positioned between the monopolar plates 302 and 310 and the membrane electrode assembly 304 and 308 of the fuel cell assemblies 103a and 103b, respectively. The elastic member 303 provides a mechanical seal between the front surface 302b of the monopolar plate 302 and the cathode surface 304a of the membrane electrode assembly 304. The elastic member 309 provides a mechanical seal between the front surface 310a of the monopolar plate 310 and the anode surface 308b of the membrane electrode assembly 308 to prevent leakage of oxygen or hydrogen that flows through the flow field of the monopolar plates 302 and 310, respectively.

[0039] Each of the membrane electrode assemblies 304 and 308, the monopolar plates 302 and 310, the current collector plates 301 and 311, the bipolar flow field plate 306, and the elastic members 303, 305, 307, and 309 have a guide holes in proximity to the edges of each of them for accommodating the fasteners 107. The fasteners 107 through the guide holes 201 compress the membrane electrode
assemblies 304 and 308, the monopolar plates 302 and 310, the current collector plates 301 and 311, the bipolar flow field plate 306, and the elastic members 303, 305, 307, and 309 together.

[0040] Fig. 4 exemplarily illustrates a front perspective view of the bipolar flow field plate 306 between the pair of fuel cell assemblies 103a and 103b. The front surface 306b faces the cathode surface 308a of the second membrane electrode assembly 308 and the rear surface 306a, rear of the front surface 306b faces the anode surface 304b of the first membrane electrode assembly 304. The front surface 306b includes multiple flow channels, for example, four serpentine flow channels 401 for the reactant air to flow and the rear surface 306a includes multiple flow channels, for example, four serpentine flow channels 501 for hydrogen to flow as exemplarily illustrated in Fig. 5. The four serpentine first flow channels 401 extend from an air inlet header 402 up to an air outlet header 403 forming a flow field for the reactant air on the front surface 306b. The air inlet header 402 is located in proximity to a first edge 306c of the bipolar flow field plate 306 and the air outlet header 403 is located in proximity to a second edge 306d of the bipolar flow field plate 306 on the front surface 306b. The air inlet header 402 and the air outlet header 403 are through holes on the front surface 306b. The air inlet header 402 is connected to the inlet duct 106 of the fuel cell stack 100 and the air outlet header 403 is connected to the outlet duct 110 of the fuel cell stack 100. The difference in pressure of the reactant air between the air inlet header 402 and the air outlet header 403 of the flow field of the reactant air drives the flow of the reactant air on the front surface 306b.

[0041] The aeration device 108 blows the reactant air and the coolant air onto the fuel cell assemblies 103 at a predetermined pressure. The coolant air flows through coolant fins 404, 405, 406, and 407 formed on the front surface 306b and the rear surface 306a of the bipolar flow field plate 306. The coolant air flows from the inlet duct 106 over the coolant fins 404, 405, 406, and 407 towards the outlet duct 110 and removes heat from the fuel cell stack 100 by forced
convection. The reactant air flows through the first flow channels 401 to participate in the electrochemical reaction. The reactant air from the first flow channels 401 diffuses towards the cathode surface 308a of the membrane electrode assembly 308. The first flow channels 401 further include first bypass grooves 408 for bypassing one or more sections 409 of the first flow channels 401. The first flow channels 401 are depressions of a predetermined depth on the front surface 306b of the bipolar flow field plate 306, that results in raised edges along the length of the first flow channels 401. The first bypass grooves 408 are channels intermittently formed on the raised edges of the first flow channels 401. The reactant air flowing in one of the first flow channels 401 may bypass the section of the first flow channel below the bypass groove, such as, 408 and flow into a consecutive first flow channel on the front surface 306b as exemplarily illustrated in Fig. 6. Such flow of the reactant air through the first bypass grooves 408 ensures the reactant air reaches the cathode surface 308a of the membrane electrode assembly 308 for the electrochemical reaction faster than usual.

[0042] The bipolar flow field plate 306 further includes a groove 410 formed on the edges of the front surface 306b along the length of the first flow channels 401. The groove 410 accommodates the elastic member 307, that is, the gasket. The bipolar flow field plate 306 further includes the guide holes, such as, 411, 412 to accommodate the fasteners 106 through them. The groove 410 is formed around the guide holes 411, 412, the air inlet header 402, the air outlet header 403, the coolant fins 404, 405, 406, and 407, the hydrogen inlet header, and the hydrogen outlet header due to the raised edges of the guide holes 411, 412, the air inlet header 402, the air outlet header 403, the coolant fins 404, 405, 406, and 407, the hydrogen inlet header, and the hydrogen outlet header. A stopper rib 413 is formed on the edges of the front surface 306b parallel to the groove 410 at the edges of the front surface 306b for preventing excessive compression of the elastic member in the fuel cell stack 100, when the elastic member is positioned in the groove 410.
[0043] Fig. 5 exemplarily illustrates an elevation view of the rear surface 306a of the bipolar flow field plate 306 exemplarily illustrated in Fig. 4. The rear surface 306a of the bipolar flow field plate 306 includes, for example, four serpentine second flow channels 501 for hydrogen to flow. The four serpentine second flow channels 501 extend from the hydrogen inlet header 502 up to the hydrogen outlet header 503 forming a flow field for hydrogen on the rear surface 306a. The hydrogen inlet header 502 is located in proximity to the first edge 306c of the bipolar flow field plate 306 and the hydrogen outlet header 503 is located in proximity to the second edge 306d of the bipolar flow field plate 306 on the rear surface 306a. The hydrogen inlet header 502 and the hydrogen outlet header 503 are through-holes on the rear surface 306a. The hydrogen inlet header 502 is connected to the inlet manifold 104 of the fuel cell stack 100 and the hydrogen outlet header 503 is connected to the outlet manifold 114 of the fuel cell stack 100. The difference in pressure of hydrogen between the hydrogen inlet header 502 and the hydrogen outlet header 503 of the flow field of hydrogen drives the flow of hydrogen on the rear surface 306a of the bipolar flow field plate 306. Pressure drop occurs along the length of the second flow channels 501 and thus, hydrogen supplied at the hydrogen inlet header 502 from the inlet manifold 104 is at a higher pressure.

[0044] Hydrogen flows through the second flow channels 501 to participate in the electrochemical reaction. Hydrogen from the second flow channels 501 diffuses towards the anode surface 304b of the membrane electrode assembly 304. The second flow channels 501 further include second bypass grooves 504 for bypassing one or more sections 505 of the second flow channels 501. The second flow channels 501 are depressions of a predetermined depth on the rear surface 306a of the bipolar flow field plate 306, that results in raised edges along the length of the second flow channels 501. The second bypass grooves 504 are channels intermittently formed on the raised edges of the second flow channels 501. Hydrogen flowing in one of the second flow channels 501 may bypass the section of the second flow channel below the bypass groove and flow into a
consecutive second flow channel on the rear surface 306a. Such flow of hydrogen through the second bypass grooves 504 ensures hydrogen reaches the anode surface 304b of the membrane electrode assembly 304 for the electrochemical reaction faster than usual.

[0045] The bipolar flow field plate 306 further includes a groove 410 formed on the edges of the rear surface 306a along the length of the second flow channels 501. The groove 410 accommodates the elastic member 305, that is, the gasket. The bipolar flow field plate 306 further includes the guide holes, such as, 411, 412 to accommodate the fasteners 106 through them. The groove 410 is formed around the guide holes 411, 412, the air inlet header 402, the air outlet header 403, the coolant fins 404, 405, 406, and 407, the hydrogen inlet header 502, and the hydrogen outlet header 503 due to the raised edges around each of them 411, 412, 402, 403, 404, 405, 406, 407, 502, and 503. A stopper rib 413 is formed on the edges of the rear surface 306a parallel to the groove 410 at the edges of the rear surface 306a for preventing excessive compression of the elastic member in the fuel cell stack 100, when the elastic member is positioned in the groove 410.

[0046] In an embodiment, the number of first flow channels may be same as the number of second flow channels, such as 401 and 501. In another embodiment, the number of first flow channels 401 may be less than the number of second flow channels 501. In another embodiment, the number of first flow channels 401 may be greater than the number of second flow channels 501. The bipolar flow field plate 306 is made of graphite, by virtue of which the bipolar flow field plate 306 possesses high corrosion resistance, low bulk resistivity, and low contact resistance with gas diffusion layer materials. The air inlet header 402, the air outlet header 403, the hydrogen inlet header 502, and the hydrogen outlet header 503 are exemplarily illustrated to be rectangular in shape. The shape of the air inlet header 402, the air outlet header 403, the hydrogen inlet header 502, and the hydrogen outlet header 503 may be same or different. In an embodiment, the shape of the air inlet header 402, the air outlet header 403, the hydrogen inlet
header 502, and the hydrogen outlet header 503 may be circular, triangular, club-shaped, etc.

[0047] The direction of flow of the reactant air and hydrogen in the first flow channels 401 and the second flow channels 501 is counter-flow to each other i.e. in opposing directions. In an embodiment, the air inlet header 402, the air outlet header 403, the hydrogen inlet header 502, and the hydrogen outlet header 503 may be formed in manner to ensure flow of the reactant air and hydrogen may be in the same direction on both sides of the bipolar flow field plate 306. The serpentine first flow channels 401 and the serpentine second flow channels 501 force the reactants, that is, air and hydrogen, to flow across entire active area of the front surface 306b and the rear surface 306a to eliminate stagnant areas due to improper reactant distribution. The flow of the reactant air and hydrogen through the first flow channels 401 and the second flow channels 501 may be laminar or turbulent. The serpentine second flow channels 501 on the rear surface 306a limit the pressure drop along the first flow channels 501 and manage water accumulation in the fuel cell stack 100. Since the first flow channels 401 and the second flow channels 501 are on either side of the bipolar flow field plate 306, crossover of air and hydrogen at the inlet of the bipolar flow field plate 306 is prevented.

[0048] Fig. 6 exemplarily illustrates an enlarged partial front perspective view of the bipolar flow field plate 306 showing the first bypass grooves 408 including 408a, 408b, 408c, 408d on the front surface 306b of the bipolar flow field plate 306. As exemplarily illustrated, the first flow channels 401a, 401c, and 401g are depressions of a certain depth on the front surface 306b. The serpentine first flow channels 401a, 401c, 401e, and 401g are contiguous with uniform width, run parallel to each other, and terminate at the air outlet header 403. On both sides of the depression are raised edges 401b, 401d, and 401f respectively, along the length of the first flow channels 401a, 401c, 401e, and 401g. On the raised edges 401b and 401f of the first flow channels 401a, 401c, 401e, and 401g, the first
bypass grooves 408a, 408b, 408c, and 408d are intermittently formed. The reactant air flowing in the first flow channel 401a may bypass the section 409a of the first flow channel 401a below the bypass groove 408a and flow into the successive first flow channel 401c on the front surface 306b. The width of the bypass groove 408a is less than the width of the first flow channel 401a to ensure only a limited amount of the reactant air bypasses the lower section 409a of the first flow channel 401a. The reactant air bypasses the section 409a of the first flow channel 401a, in case of water logging in the section 409a of the first flow channel 401a.

[0049] The first bypass grooves 408a, 408b, 408c, and 408d facilitate rapid movement of the reactant air towards the membrane electrode assembly 304 or 308 and ensuring maximum participation of the reactant air in the electrochemical reaction. This ensures substantially less amount of unreacted air exits from the bipolar flow field plate 306. Similarly, the second bypass grooves 504 present on the rear surface 306a of the bipolar flow field plate 306 are of substantially same dimensions as on the front surface 306b to ensure maximum participation of hydrogen in the electro chemical reaction, as disclosed in the detailed description of Fig. 5.

[0050] In an embodiment, the number of bypass grooves, such as, 408a, 408b, 408c, and 408d and the location of the bypass grooves, such as, 408a, 408b, 408c, and 408d along the length of the flow channels 401 and 501, is same across all the flow channels 401 and 501 on the front surface 306b and the rear surface 306a of the bipolar flow field plate 306. In an embodiment, the number of bypass grooves, such as, 408a, 408b, 408c, and 408d and the location of the bypass grooves, such as, 408a, 408b, 408c, and 408d along the length of the flow channels 401 and 501 is different on the front surface 306b and the rear surface 306a of the bipolar flow field plate 306. In an embodiment, the dimensions, for example, the length, the width, and the depth of the bypass grooves, such as, 408a, 408b, 408c, and 408d in each of the flow channels 401 and 501 are equal. In an embodiment, the
dimensions, for example, the length, the width, and the depth of the bypass grooves, such as, 408a, 408b, 408c, and 408d in each of the flow channels 401 and 501 are unequal.

[0051] Fig. 7 exemplarily illustrates an enlarged partial front perspective view of the bipolar flow field plate 306 showing the stopper rib 413 on the front surface 306b of the bipolar flow field plate 306. The stopper rib 413 is formed on the edges of the front surface 306b on the outer perimeter of the bipolar flow field plate 306. The elastic member is positioned in the groove 410 around the raised edges of the guide holes 411, 412, the air inlet header 402, the air outlet header 403, the coolant fins 404, 405, 406, and 407, the hydrogen inlet header 502, and the hydrogen outlet header 503 for preventing excessive compression of the elastic member in the fuel cell stack 100. Similar stopper rib 413 is formed on the rear surface 306a of the bipolar flow field plate 306. The stopper rib 413 prevents excessive compression of the elastic members on both the sides of the bipolar flow field plate 306. The stopper rib 413 prevents direct contact of the bipolar flow field plate 306 with the membrane electrode assembly 304 and 308, avoiding breakage of the bipolar flow field plate 306 and the membrane electrode assembly 304 and 308 due to the compressive forces in the fuel cell stack 100, even though the graphite bipolar flow field plate 306 is brittle.

[0052] Fig. 8 exemplarily illustrates an elevation view of an elastic member, such as, 303, 305, 307, and 309 that engages with the bipolar flow field plate 306, the monopolar plates 302 and 310, or the current collector plates 301 and 311. The elastic members 303, 305, 307, and 309 are, for example, a gasket. The elastic members 305 and 307 are accommodated in the groove 410 on the front surface 306b and the rear surface 306a of the bipolar flow field plate 306. Similarly, the elastic members 303 and 309 are accommodated in the grooves (not shown) of the monopolar flow field plates 302 and 310 respectively. The elastic members 303, 305, 307, and 309 prevent leak of hydrogen and air and provide reactant tightness, when the fuel cell assemblies 103 are compressed. The elastic members 303, 305,
307, and 309 also provide vibration and shock resistance to the fuel cell stack 100, and prevent mechanical bonding of components when compressed in the fuel cell stack 100. The elastic members 303, 305, 307, and 309 are made of materials, such as, silicon, Polytetrafluoroethylene (PTFE), Ethylene Propylene Diene Monomer (EPDM) rubber, etc., that have greater compressibility and good sealing properties.

[0053] The elastic members 305 and 307 seal non-active regions of the bipolar flow field plate 306 and expose the active regions of the bipolar flow field plate 306 to the membrane electrode assemblies 304 and 308. The active regions are the flow fields formed by the first flow channels 401 and the second flow channels 501 along with the air inlet header 402, the air outlet header 403, the hydrogen inlet header 502, and the hydrogen outlet header 503. On the monopolar plates 302 and 310, the elastic members 303 and 309 seal the non-active regions and expose the active regions to the membrane electrode assemblies 304 and 308. The elastic members 303, 305, 307, and 309 may be in pre-cut form or may be formed-in-place. The formed-in-place type elastic member may be cured by activation and exposure to radiation, while assembling the fuel cell stack 100. The elastic members 303, 305, 307, and 309, further include multiple guide holes, such as, 401 similar to and in-line with the guide holes 411, 412 of the bipolar flow field plate 306 to accommodate the fasteners 107 to hold the structure of the fuel cell stack 100 intact. The elastic members 303, 305, 307, and 309 are non-conductive and provide electrical insulation between the bipolar flow field plate 306 and the membrane electrode assemblies 304 and 308, and the monopolar plates 302 and 310 and the membrane electrode assemblies 304 and 308. The elastic members 303, 305, 307, and 309 further expose the coolant fins 407 of the bipolar flow field plate and coolant fins 902 of the membrane electrode assembly, such as, 304 as exemplarily illustrated in Fig. 9.

[0054] Fig. 9 exemplarily illustrates an elevation view of a membrane electrode assembly, such as, 304 and 308 of the fuel cell assembly, for example, 103a and
103b. The membrane electrode assembly, for example, 304 is a central element of a fuel cell assembly 103a in the fuel cell stack 100 around which the elastic members 303 and 305 and the flow fields are designed and positioned. In the membrane electrode assembly 304, the electrolyte, the electrodes, that is, the anode face 304b and the cathode face 304a, and the reactants, oxygen and hydrogen are all in contact. Since ambient air is used instead of pure oxygen, the amount of oxygen available for the electrochemical reaction is less, and thus, the membrane electrode assembly 304 is thin for lower resistance in the fuel cell assembly 103a. Further, the catalyst layer on the anode face 304b and the cathode face 304a in the membrane electrode assembly 304 reduces the cost of the membrane electrode assembly 304. The membrane electrode assembly 304 optimizes the efficiency of portable applications and stationary application of the fuel cell stack 100. The membrane electrode assembly 304 allows proton transport while obstructing the reactants, that is, hydrogen and oxygen at lower temperatures of about 20°C to about 80°C. As exemplarily illustrated, the membrane electrode assembly 304 also has guide holes, such as, 901 in line with the guide holes 411 and 412 of the bipolar flow field plate 306 to accommodate the fasteners 107, similar to the elastic members 303, 305, 307, and 309. The membrane electrode assembly 304 further has coolant fins 902 for coolant air to flow and extract the heat from the membrane electrode assembly 304.

[0055] In an embodiment, humidifiers are also included in the membrane electrode assembly, such as, 304 and 308 of the fuel cell assemblies 103. In the humidifier, humidified air is obtained on flowing dry inlet air on one side of the humidifier, since air from the inlet duct 106 may be dry. In an embodiment, the humidifier may be part of the aeration device 108 and may supply wet air at the inlet duct 106 of the fuel cell stack 100. The wet air interacts with the membrane electrode assemblies 304 and 308, thereby not affecting the performance of the fuel cell stack 100 due to a dry proton exchange membrane.
[0056] Fig. 10 exemplarily illustrates an elevation view of one of the current collector plates 301 or 311 of the fuel cell stack 100. The current collector plate 301 or 311 has a current collector tab 1001 extending from a side to facilitate connection of the fuel cell stack 100 to an external circuit to draw current from the fuel cell stack 100. The current collector plate 301 or 311 also includes guide holes, such as, 1002 and 1003 to engage with the fasteners 107 to hold the fuel cell stack 100 intact. The current collector plate 301 towards the cathode surface 304a of the membrane electrode assembly 304 caters as a current collector for air side of the fuel cell stack 100 and the current collector plate 311 towards the anode surface 308b of the membrane electrode assembly 308 caters as a current collector for hydrogen side of the fuel cell stack 100. The external circuit is connected between the current collector tab 1001 of the current collector plates 301 and 311 to draw current from the fuel cell stack 100. Current (amperes), voltage, frequency, and other characteristics of the electrical current in the external circuit connected to the current collector plates 301 and 311 are conditioned to suit the electrical needs of application of the fuel cell stack 100.

[0057] Figs. 11A-11B exemplarily illustrate elevation view of a front surface and a rear surface of the end plate 101 of the fuel cell stack 100, respectively. The end plate 101 provides mechanical support to the fuel cell stack 100. The bipolar flow field plate 306, the membrane electrode assemblies 304 and 308, the monopolar flow field plates 302 and 310, the current collector plates 301 and 311, and the end plates 101 and 102 are parallel to each other in the fuel cell stack 100. The end plates 101 and 102 are sturdy to support the fuel cell stack 100 and uniformly distribute the compression forces to the fuel cell assemblies 103 in the fuel cell stack 100. The end plates 101 and 102 have substantially high compressive strength, vibration and shock resistance, and stable over the low temperatures of about 20°C to about 80°C. The materials used for the end plates 101 and 102 may be stainless steel, aluminum, titanium, nickel, polyethylene, poly vinyl chloride, etc.
[0058] Both the end plates 101 and 102 include an opening, such as, 1101 in the center to accommodate connection of the inlet duct 106 and the outlet duct 110 to the end plates 101 and 102 respectively. The end plate 101 accommodates connections to the hydrogen outlet manifold 114 for hydrogen in the fuel cell stack 100. The end plate 101 has guide holes 1102 similar and in-line to the guide holes 411 and 412 of the bipolar flow field plate 306 to insert tie rods and fasten the tie rods with a nut to hold the fuel cell stack 100 sturdy. The end plate 101 has a projection at an upper end that connects the inlet duct 106 to the inlet piping 109 to supply the reactant air to the fuel cell assemblies 103 in the fuel cell stack 100.

[0059] The end plate 102 at the other end of the fuel cell stack 100 accommodates connections to the inlet manifold 104 and the outlet manifold 105 of reactant air on the sides as exemplarily illustrated in Figs. 1A-1B. The inlet manifold 104 in the end plate 102 is connected to hydrogen inlet header of the monopolar flow field plate 302 and the hydrogen inlet header 502 of the bipolar flow field plate 306 and the outlet manifold 114 of hydrogen in the end plate 101 is connected to the hydrogen outlet header of the monopolar flow field plate 310 and the hydrogen outlet header 503 of the bipolar flow field plate 306. The inlet manifold 104 is connected to valves via external conduits to supply measured amount of hydrogen to the fuel cell stack 100. The unused heated hydrogen in the fuel cell stack 100 is ejected out through the outlet manifold 114. The outlet manifold 114 may be connected to valves, heat exchangers, and any other desired balance-of-plant components to utilize the ejected water vapor. On the rear surface of the end plate 101, multiple coolant channels 1104 are provided that connect holes in side walls of the opening 1101 to the coolant fins 407 in the bipolar flow field plate 306, the coolant fins 902 in the membrane electrode assembly 304, and the coolant fins of the monopolar flow field plate.

[0060] Fig. 12 exemplarily illustrates a front perspective view of the inlet duct 106 positioned on the end plate 101 and associated mounting means. The front opening 106a of the inlet duct 106 engages with the discharge of the aeration
device 108. The rear opening 106b of the inlet duct 106 corresponds to the opening 1101 in the end plate 101. The inlet duct 106 is removably attached to the end plate 101 by means of, for example, fasteners. The reactant air and the coolant air are passed through the inlet duct 106 to the fuel cell assemblies 103 in the fuel cell stack 100. Oxygen in the air participates in the electrochemical reactions in the fuel cell stack 100. A stoichiometric amount of the reactant air and the coolant air are blown into the inlet duct 109 by the aeration device 108 to react with the measured amount of hydrogen entering through the inlet manifold 104. The amount of reactant air involved in the reaction is controlled in the inlet duct 106. The reactant air is fed via the inlet piping 109. Since the electrochemical reaction is an exothermic reaction, heat generated in the fuel cell assemblies 103 is transmitted to the bipolar flow field plate 306, the monopolar flow field plates 302 and 310, and the membrane electrode assemblies 304 and 308. The water vapor generated in the electrochemical reaction absorbs some heat and an active coolant, such as, the coolant air flowing through the coolant channels and coolant fins in the fuel cell stack 100 absorbs the remaining heat in the fuel cell assemblies 103.

[0061] The hot air along with the water vapor from the fuel cell assemblies 103 is collected in the outlet duct 110. The heat in the hot air and the water vapor is extracted by means of an external heat exchanger installed in the recirculation piping 111. The hot air exchanges its heat with a fluid in the heat exchanger and the temperature of the hot air is reduced to room temperature. The air at room temperature mixes with the ambient air at the discharge of the aeration device 108 and is supplied to the fuel cell stack 100 via the air inlet duct 106. The water content in the water vapor may be utilized to humidify the air at the air inlet duct 106. Hydrogen at the inlet manifold 104 is pumped at a higher pressure compared to air at the inlet duct 106. This prevents crossover of reactants and improves stability of the fuel cell assemblies 103.

[0062] Further, the aeration device 108 is housed in the housing 115 and the housing 115 is supported by the mounting means, such as, clamps, brackets,
clamp washers, etc., via fasteners, such as, nut and bolts. The performance of the fuel cell stack 100 depends on the pressure of the reactant gases, hydrogen and air. The aeration device 108, such as, the blower ensures the pressure of air at the discharge of the aeration device 108 is about 2–4 times the ambient atmospheric pressure. Fan speed of the aeration device 108 is adjusted to vary the flow rate of the air supplied to the fuel cell assemblies 103. The amount of stoichiometric oxygen into the fuel cell stack 100 is manipulated by a controller which regulates the electrical power of the aeration device, thereby controlling the compression and air flow into the fuel cell stack 100.

[0063] The fuel cell stack 100 is portable and may function as a backup power generator. The fuel cell stack 100 offers extended runtime, high reliability, high efficiency, and reduced environmental impact. The fuel cell stack 100 can be used in laptops, military equipment, battery chargers, vehicles, etc., as a primary power source or a backup power source. The fuel cell stack 100 provides a technical advancement in battery technology as follows: The fuel cell stack 100 converts chemical potential energy directly into electrical energy. Such a fuel cell stack 100 on implementation in an electric vehicle acts as a primary source of electricity and is highly efficient since it avoids thermal bottle neck that usually occurs in an IC engine vehicle. The emissions from such an electric vehicle is only water vapor and a little heat. The heat is also extracted from the fuel cell assemblies 103 using the external heat exchanger. The fuel cell stack 100 is efficient since the exhaust is only water vapor and heat from the fuel cell stack 100, and not greenhouse gases that are harmful to the environment. The fuel cell stack 100 has no moving parts, and thus is much more reliable than traditional IC engines. The reactants supplied to the fuel cell stack 100 are hydrogen and air and hydrogen may be produced in an environmentally friendly manner, in contrast to oil extraction and refining for the IC engines.

[0064] The bypass grooves 408 and 504 in the first flow channels 401 and the second flow channels 501 of the bipolar flow field plate 306 of the fuel cell stack
facilitate the reactants to bypass the path of gases, if there is any blockage due to water stagnation as in case of low temperature fuel cell and due to GDL blockage. The bypass grooves 408 and 504 also help the reactants to have a crisscross path in the flow field which makes the gas to cover the entire active region of the membrane electrode assembly 304 and 308. The design of the elastic members 303, 305, 307, and 309 is same and simple for both the surfaces 306a and 306b of the bipolar flow field plate 306. The elastic members 303, 305, 307, and 309 provide the required sealing for the reactants to avoid leakage and crossover by sitting into the groove in the bipolar flow field plate 306 without any mismatch. The cooling of the fuel cell stack 100 is by a simple installation of an aeration device 110, such as a blower. The issue of water logging in the fuel cell stack 100 is eliminated due to the serpentine flow channels 401 and 501 on both the surfaces 306a and 306b of the bipolar flow field plate 306. The serpentine flow channels 401 and 501 distribute the reactants uniformly over the membrane electrode assembly 303, thus increase efficiency of the fuel cell stack 100. The stopper rib 413 on both the surfaces 306a and 306b of the bipolar flow field plate 306 ensures safe compression of the fuel cell assemblies 103 in the fuel cell stack 100. The method of assembly of such a fuel cell stack 100 using the guides 202 and the guide holes 201 is also simple.
We Claim:

1. A bipolar flow field plate (306) in a pair of fuel cell assemblies (103), the bipolar flow field plate (306) comprising:
   a front surface (306b) comprising at least one serpentine first flow channel (401) extending between an air inlet header (402) and an air outlet header (403) for reactant air, wherein each of the at least one first flow channel (401) comprises a plurality of first bypass grooves (408) for bypassing one or more sections (409a) of the at least one first flow channel (401);
   a rear surface (306a) comprising at least one serpentine second flow channel (501) extending between a hydrogen inlet header (502) and a hydrogen outlet header (503) for hydrogen, wherein each of the at least one second flow channel (501) comprises a plurality of second bypass grooves (504) for bypassing one or more sections (505) of the at least one second flow channel (501); and
   a plurality of coolant fins (404, 405, 406, and 407) for coolant air formed on the front surface (306b) and the rear surface (306a) between the air inlet header (402), the air outlet header (403), the hydrogen inlet header (502), and the hydrogen outlet header (503).

2. The bipolar flow field plate (306) of claim 1, further comprises a stopper rib (413) formed on edges of each of the front surface (306b) and the rear surface (306a), for preventing excessive compression of an elastic member (305 and 307), wherein the elastic member (305 and 307) is accommodated in a groove (410) formed parallel to the stopper rib (413) on the each of the front surface (306b) and the rear surface (306a).

3. The bipolar flow field plate (306) of claim 2, wherein the elastic member (305 and 307) is in one of pre-cut form and formed-in-place by curing
using activation and exposure to radiation during assembling of the pair of fuel cell assemblies (103).

4. The bipolar flow field plate (306) of claim 1, wherein the air inlet header (402) and the air outlet header (403) are one of in-line and perpendicular to the hydrogen inlet header (502) and the hydrogen outlet header (503).

5. The bipolar flow field plate (306) of claim 1, wherein the air inlet header (402), the air outlet header (403), and the plurality of coolant fins (404, 405, 406, and 407) engage with a discharge of an aeration device (108); and wherein the hydrogen inlet header (502) and the hydrogen outlet header (503) engage with an inlet manifold (112) and an outlet manifold (113) for hydrogen on a pair of end plates (101 and 102).

6. The bipolar flow field plate (306) of claim 1, wherein the reactant air and hydrogen reactively engage with a membrane electrode assembly (304 and 308) in each of the pair of fuel cell assemblies (103) for supplying electric current to an electric circuit.

7. The bipolar flow field plate (306) of claim 5, wherein:
   the reactant air from the at least one serpentine first flow channel (401) diffuses towards a cathode surface (308a) of the membrane electrode assembly (308), and
   hydrogen from the at least one serpentine second flow channel (501) diffuses towards an anode surface (304b) of the membrane electrode assembly (304).

8. The bipolar flow field plate (306) of claim 1, wherein the aeration device (108) is one of a blower and a centrifugal pump.
9. A fuel cell stack (100) comprising:
   a pair of end plates (101 and 102) accommodating an aeration device (108), an inlet manifold (112) for hydrogen, and an outlet manifold (113) for hydrogen on an outer surface; and
   a plurality of fuel cell assemblies (103) positioned between the pair of end plates (101 and 102), wherein a pair of fuel cell assemblies (103a and 103b) in the plurality of fuel cell assemblies (103) comprises:
   a pair of membrane electrode assemblies (304 and 308), each of a first membrane electrode assembly (304) and a second membrane electrode assembly (308) comprising an anode face (304b and 308b) and a cathode face (304a and 308a); and
   a bipolar flow field plate (306) positioned between the first membrane electrode assembly (304) and the second membrane electrode assembly (308), the bipolar flow field plate (306) comprises:
   a front surface (306b) comprising at least one serpentine first flow channel (401) extending between an air inlet header (402) and an air outlet header (403) for the reactant air;
   a rear surface (306a) comprising at least one serpentine second flow channel (501) extending between a hydrogen inlet header (502) and a hydrogen outlet header (503) for hydrogen; and
   a plurality of coolant fins (404, 405, 406, and 407) for coolant air formed on the front surface (306b) between the air inlet header (402), the air outlet header (403), the hydrogen inlet header (502), and the hydrogen outlet header (503).

10. The fuel cell stack (100) of claim 9, wherein the bipolar flow field plate (306) further comprises a stopper rib (413) formed on edges of each of the front surface (306b) and the rear surface (306a), for preventing excessive compression of an elastic member (305 and 307), wherein the elastic member (305 and 307) is accommodated in a groove (410) formed parallel to the
stopper rib (413) on the each of the front surface (306b) and the rear surface (306a).

11. The fuel cell stack (100) of claim 10, wherein the elastic member (305 and 307) is in one of pre-cut form and formed-in-place by curing using activation and exposure to radiation during assembling of the fuel cell stack (100).

12. The fuel cell stack of claim 9, wherein the at least one serpentine first flow channel (401) comprises a plurality of first bypass grooves (408) for bypassing one or more sections of the at least one first flow channel (401) and the at least one serpentine second flow channel (501) comprises a plurality of second bypass grooves (504) for bypassing one or more sections (505) of the at least one second flow channel (501).

13. The fuel cell stack of claim 9, further comprises a pair of current collector plates (301 and 311) for collecting electric current generated in the plurality of fuel cell assemblies (103), wherein each current collector plate (301 and 303), is positioned between an end plate (101 and 102) and one of the first membrane electrode assembly (304) or the second membrane electrode assembly (308).

14. The fuel cell stack of claim 13, wherein a plurality of fasteners (107) compress the pair of end plates (101 and 102), the plurality of fuel cell assemblies (103), and the pair of current collector plates (301 and 311) together.
Fig. 9
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/0263 H01M8/04007
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Further documents are listed in the continuation of Box C.  X See patent family annex.

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"Z" document member of the same patent family

Date of the actual completion of the international search
16 June 2021

Date of mailing of the international search report
28/06/2021

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Wiedemann, Eric

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