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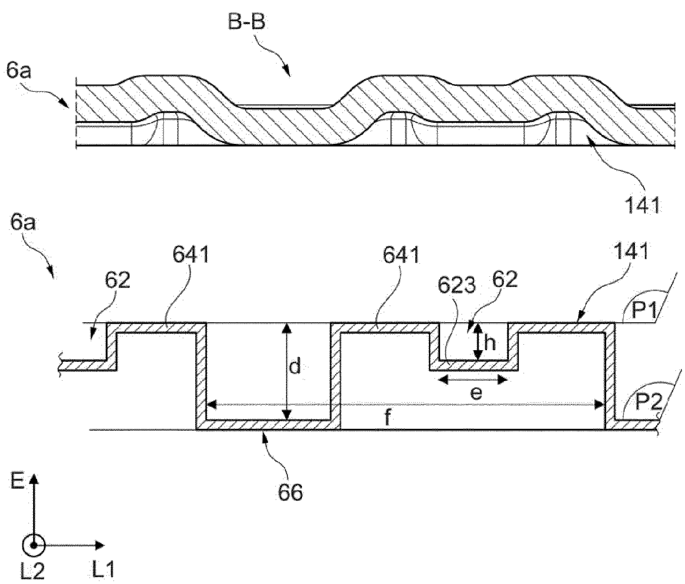
(54) REDUCTION FLOW MEMBER FOR A WATER ELECTROLYSIS CELL, WATER ELECTROLYSIS CELL AND WATER ELECTROLYSIS MODULE

(57) The invention relates to a reduction flow member for a water electrolysis cell, the reduction flow member comprising a first face lying in a first plane (P1), a second face lying in a second plane (P2) parallel to the first plane (P1), at least one first barrier (64) and a second barrier (64) extending between the first plane (P1) and the second plane (P2), at least one channel being arranged between the first barrier (64) and the second barrier (64), wherein a height (h) of at least a portion (621) of the channel (62), measured orthogonally to the first plane (P1) between a bottom wall (623) of the channel (62) and the first plane (P1), is strictly less than a height (d) of the first or the second barrier (64), measured orthogonally to the first plane (P1).



[fig 10]

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Description

[0001] The present invention relates to the field of electrochemistry and more particularly to cells for the electrolysis of water to form dihydrogen and dioxygen.

[0002] These cells are connected electrically in series and hydraulically in parallel to form modules, also called electrochemical reactors or stacks, allowing the delivery of significant volumes of CO2 free dihydrogen and dioxygen, in case the electrical energy for the reaction is of renewable origin. Subsequently, these products of water electrolysis can serve as a CO2 free energy vector to feed various sectors like e.g. the industry or mobility sector with CO2 free feedstock. Dihydrogen can be used for example in the mobility sector to power fuel cells of cars or for example in the steel making industry for carbon free reduction of iron ore.

[0003] In such an electrochemical reactor, the cells each comprise a stack of material layers and are stacked on top of each other. The cathode and anode of each cell each comprise a metal plate known as a "bipolar plate", because the cells being connected electrically in series, the bipolar plate of the anode of a first cell is also the bipolar plate of the cathode of a second cell immediately superimposed on this first cell.

[0004] Water is fed into each cell by means of a dedicated water circuit arranged in the reactor, allowing the water to circulate tangentially to the plane of each metal plate, between the latter and a separator, acting as an electrolyte, for example a polymeric membrane with cationic conduction (conduction by protons) or anionic conduction (conduction by hydroxyl ions), separating within each cell, an anode compartment from a cathode compartment. Other types of separators can be used depending on the electrolysis technology adopted, for example thermoplastic separators or ceramic separators.

[0005] In particular, in PEM (proton-exchange membrane or polymer electrolyte membrane) technology, a proton-exchange membrane separates the anode from the cathode of each cell, as well as the dihydrogen released by the cathode and the dioxygen released by the anode, by allowing protons to flow from the anode to the cathode.

[0006] Indeed, during the operation of a PEM water electrolysis cell, electrons are released at the anode of the cell within the oxygen evolution reaction (OER). H+ protons cross the proton-exchange membrane and form together with H+ protons H2 within the hydrogen evolution reaction (HER).

[0007] The membrane is of polymer type and has a typical thickness between 50 and 250 microns (or micrometers). Electro-catalysts are deposited on both sides of the membrane, each forming a layer of a few micrometers to a few tens of micrometers thick.

[0008] In a water electrolysis reactor using such a technology, each anode or cathode compartment of each cell comprises a water inlet fed by an injection well of the reactor, and a reaction mixture outlet (monophasic or biphasic depending on the technology) connected to a collection well of the reactor.

[0009] In the simplest case, the electrochemical reactor is connected to two separate and closed water circulation circuits: an anode circuit and a cathode circuit. Each circuit has different functional blocks, for example, a liquid-gas separator which allows the separation and collection of the gases resulting from the reaction, a heat exchanger, typically only on an anode side, which allows the extraction of the heat produced in the cells during electrolysis, a resin bed which allows the control of the conductivity of the circulating water, a pump which ensures the circulation of the water in the circuit, and different pressure, temperature and flow sensors which allow the operation to be controlled by an automatic control system.

[0010] In more complex systems, several reactors are electrically and fluidly interconnected, in series or in parallel, each of them having an individual or common anode and cathode circuit.

[0011] In operation, liquid water is injected by a pump into each compartment of each cell and a biphasic mixture (liquid water and gas generated in the cell during electrolysis) is collected at the outlet of each compartment. A mixture of liquid water and oxygen gas is collected at the outlet of the anode compartment and a mixture of liquid water and hydrogen gas is collected at the outlet of the cathode compartment. The flow of liquid water through the anode compartment of each cell is used both to feed the electrolysis reaction and to cool the anode compartment because the oxygen release reaction is exothermic. The liquid water flowing through the cathode compartment of each cell is used both to collect the electroosmotic water flowing through the membrane and to cool the cathode because the hydrogen release reaction is exothermic.

[0012] To operate electrochemical cells in an optimal way, it is of major importance to ensure a uniform electrical distribution on all the active surfaces of the cell, a uniform fluidic distribution on all these active surfaces and a good mechanical support between the anode and cathode compartments, to endure differential pressure application.

[0013] Such an operating electrolysis cell 50, represented in figure 1, comprises different conductive layers which are stacked in the following order:

- a metallic bipolar plate 51, generally in titanium, working as an anode for this cell (and as a cathode for another cell adjacent to this metallic bipolar plate),

- an anodic flow control device 52, consisting of a metallic mesh structure,

- an anodic porous material 53, generally consisting of titanium particles or fibers sintered together,

- a proton exchange membrane 54,

- a cathodic porous material 55, generally consisting of titanium particles or fibers sintered together, or of carbon fibers,

- a cathodic flow control device 56, consisting of a metallic mesh structure, and

- a metallic bipolar plate 57 working as cathode for this cell (and as an anode for another cell adjacent to this metallic bipolar plate).

[0014] The interfaces between these different layers are active surfaces of the electrolysis cell 50.

[0015] The main purpose of the flow control devices 52, 56 is to mechanically support the anodic and cathodic porous material 53, 55 and proton exchange membrane 54 especially under differential pressure operation, and to serve as an electrical conductor.

[0016] The bipolar plates 51, 57 are flat metal sheets with the required cut outs for input and output manifold lines. Notably, bipolar plate 51 has an anode water inlet 59, an anode water and gas (O2) outlet 60, a cathode water inlet 61a and a cathode water and gas (H2) outlet 61b.

[0017] The anodic flow control device 52, the anodic porous material 53, the proton exchange membrane 54, the cathodic porous material 55, and the cathodic flow control device 56 are maintained in a frame 58, generally in moulded plastic.

[0018] The water circulation in the electrolysis cell is indicated in bolded arrows. Dotted arrows show circulation water in another plan than the cutting plane. Circled crosses indicate a water circulation which is orthogonal to the cutting plane.

[0019] Part of the electrical energy produced inside the cell is transformed into heat, by Joule effect, and another part of this electrical energy is transformed into chemical energy (production of hydrogen within the HER and oxygen within the OER). The uniformity of the fluidic distribution is a crucial condition linked to the evacuation of the calories released by Joule effect. Subsequently, the uniformity of water flow and more specifically the uniformity of the local velocity fields of the water in the active surface of a PEM electrolysis cell is directly associated with the proper functioning of the cell. This uniformity allows to locally evacuate the heat generated during electrolysis operation due to the occurring overpotentials in the cell and is crucial to avoid the formation and stagnation of hot spots which could damage the components (especially the proton exchange membrane) irreversibly.

[0020] Homogenizing the water flow within the active surfaces of the cell 50 is mainly affected and driven by the frame 58 which includes at least different zones z1, z2 and z3 as presented in figure 2, which shows an active surface area z4 between the bipolar plate 51 and the flow control device 52. The frame 58 also includes:

- an anode water inlet 58a communicating with the bipolar plate 51 anode water inlet 59,

- an anode water and gas (O2) outlet 58b communicating with the bipolar plate 51 anode water and gas (O2) outlet 60,

- a cathode water inlet 58d communicating with the bipolar plate 51 cathode water inlet 61a and

- a cathode water and gas (H2) outlet 58c communicating with the bipolar plate 51 cathode water and gas (H2) outlet 61b.

[0021] The first zone z1 is a transition zone between the anode water inlet 58a and the second zone z2. This first zone z1 is subject to a fast flow. The thickness of the flow path in this first zone z1 is characterized by the distance between the frame 58 and the bipolar plate 51. Support studs moulded on the frame surface in this first zone z1 allow to maintain this distance.

[0022] The second zone z2 is an inlet jet breaker zone. The turbulent water flow arriving at high speed from first zone z1, must turn 90° to spread out all along the third zone z3, which extends along the active surface area z4. A plurality of studs in this second zone z2 contains overpressure and facilitates the change of direction of at least part of the incoming water flow. These studs are moulded on the frame surface.

[0023] The third zone z3 is a fluid distribution zone characterized by the distance between the frame 58 and the bipolar plate 51, as well as by the distances between a plurality of studs of generally rectangular shape arranged in a hydrodynamic way inside this third zone z3. These studs are moulded on the frame surface. This third zone z3 is subjected to the mechanical pressure exerted by the cathode fluid at the cell inlet (monophasic) on the other face of the frame 58 and on the other face of the bipolar plate 51, because this cathode fluid has a higher pressure than the anode fluid circulating in the third zone z3. The studs in this third zone z3 therefore have the dual function of maintaining the distance between the frame 58 and the bipolar plate 51 despite the opposing forces and of creating fluid paths that can distribute the fluid along the active surface area z4. The number of rows of studs is determined to maintain a compromise between the roughness created by their presence resulting in a pressure drop and the distance between the studs allowed by the rigidity and strength of the frame 58 and the bipolar plate 51.

[0024] The first, second and third zones z1, z2, z3 are reproduced at the outlet side of the frame 58, to facilitate the water flow convergence towards the anode water and gas (O2) outlet 58b. These zones at the outlet side provide similar functions as those at the inlet side of the frame 58.

[0025] The combination of zones z1 to z3 aims at ensuring good fluid distribution while maintaining the mechanical stability of the cell stack. This is achieved by the surface of frame 58, which contains moulded studs and can change its thickness on the different zones in order to regulate the water flow.

[0026] However, there is a need to reduce the size of electrolysis cells, in order to build compact and powerful electrolysis reactors. This reduction of cells implies a reduction of the studs' sizes in the different zones, which is not feasible by injection moulding of frame 58.

[0027] The present invention aims at solving at least part of the state-of-the-art drawbacks, by providing a reduction flow member for a water electrolysis cell, a bipolar plate for a water electrolysis cell integrating such a reduction flow member, such a water electrolysis cell and an associated water electrolysis module, the reduction flow member ensuring a pressure drop at entrance of water flow in a flow control device of the cell, and a uniform flow in the flow control device, in a manner consistent with a size reduction of the cell.

[0028] To this end, the invention proposes a reduction flow member for a water electrolysis cell, the reduction flow member comprising a first face lying in a first plane, a second face lying in a second plane parallel to the first plane, at least one first barrier and a second barrier extending between the first plane and the second plane, at least one channel being arranged between the first barrier and the second barrier, wherein a height of at least a portion of the channel, measured orthogonally to the first plane between a bottom wall of the channel and the first plane, is strictly less than a height of the first or the second barrier, measured orthogonally to the first plane.

[0029] Such a reduction flow member is intended to be arranged between on the one hand a water distribution zone interposed between a bipolar plate of a water electrolysis cell and a frame of the water electrolysis cell, and on the other hand a flow control device of the water electrolysis cell, interposed between the bipolar plate and a porous material of this water electrolysis cell.

[0030] Such a reduction flow member preferably comprises several channels arranged along the flow control device, in a way such that they are oriented longitudinally (lengthwise) orthogonal to the stacking direction and to a proximal inner edge of the frame. The limited height of the at least one channel portion of each channel, compared to the thickness of the reduction flow member extending between the bipolar plate and the porous material, allow to adjust the pressure drop at entrance of the water flow into the flow control device. The channels are regularly arranged along the flow control device, each having the same cross sections, so that the water flow is uniform in the flow control device. This reduction flow member, which is not present in the prior art, allows to consider other processes than injection molded studs to control the water flow in the active surface areas of the cell, and to ensure the mechanical strength of the whole cell.

[0031] As an example, the height of the at least one channel portion is 20% to 90% lower than the height of the first or second barrier. Preferably, a cross section area of the at least one channel portion is 2% to 10% of that of a repeating pattern of the reduction flow member, the pattern extending between the first plane and the second plane. As an example, the cross-section area of the channel portion is about 0,6mm^2, or between 0,15mm^2 and 2mm^2, or more preferably between 0,15mm^2 and 0,8mm^2.

[0032] In one embodiment of the invention, each of the first and second barriers have a U-shape when seen in the first plane. In this embodiment, the first plane is in contact with the porous material. Having these U-shapes, the barriers each includes a void zone between the branches of the U, this void zone having a bottom wall in the second plane, in contact with the bipolar plate and thus transmitting a clamping force between a frame of another cell located at the other side of the bipolar plate, and the porous material. This frame preferably includes a stud in contact with this bottom wall, in order to ensure this clamping force, which is transmitted to a gasket underneath the porous material, as described further in relation with the description.

[0033] Moreover, in this embodiment of the invention, the at least one portion of the channel is a first portion of the channel, the channel comprising a second portion of the channel in which the height of the channel is strictly greater than the height of the channel in the first portion of the channel, the second portion of the channel extending from the first portion of the channel to an end of one of the U-shapes, corresponding to a junction of branches of the U. This second portion of the channel preferably extend from a bottom wall of the reduction flow member, in the second plane, to the first plane. This bottom wall thus allows to transmit a clamping force between the frame at the other side of the bipolar plate, and the porous material, thus between the frame at the other side of the bipolar plate, and the gasket underneath the porous material. Besides, the second portion of the channel generates more hydraulic resistance to supply water uniformly to the flow control device along the entire length of the reduction flow member. Moreover, this second portion associated with the first portion creates a venturi effect.

[0034] In one embodiment of the invention, the reduction flow member is formed by stamping or hydroforming of a strip of metal material. When stamped, the barriers have rounded shapes, making the second channel portion wider than the first channel portion, when this stamping process is associated with this optional second portion feature of the invention.

[0035] The invention also concerns a bipolar plate for a water electrolysis cell, the water electrolysis cell comprising a stack of at least the bipolar plate, a flow control device and a porous material, the stack being bordered at least in part by a frame, the bipolar plate being characterized in that the bipolar plate comprises at least one reduction flow member according to the invention, allowing a circulation of water between, on the one hand, a distribution zone comprised between the frame and the bipolar plate and, on the other hand, the flow control device.

[0036] The reduction flow member is preferably stamped or hydroformed and integrally formed with the bipolar plate. Alternatively, the reduction flow member is produced by deforming the material of the bipolar plate, which can involve subtracting or adding material, or the reduction flow member is integrated into the bipolar plate by soldering or welding a strip of metal material on an initially plate bipolar plate.

[0037] Preferably, the distribution zone of the water electrolysis cell comprises studs extending through a thickness of the bipolar plate. For example, these studs are stamped or hydroformed in the bipolar plate. Alternatively, they are produced by another type of deformation of the bipolar plate, or they are welded or soldered to the bipolar plate. This distribution zone made of studs on the bipolar plate, has the same functions as the third zone z3 in the prior art. The integration of the distribution zone in the bipolar plate allows avoiding making them by an injection moulding process, together with the frame.

[0038] Preferably, the distribution zone comprises a portion in which the studs are oblong in shape and extend mainly parallel to the water circulation, said portion being comprised between a water flow inlet zone and the reduction flow member. This portion corresponds to the inlet jet breaker zone z2 in the prior art and thus has the same functions, but is integrated in the bipolar plate, avoiding its realisation by injection moulding.

[0039] Moreover, the bipolar plate preferably comprises integrally formed protruding patterns constituting the flow control device. This integration of the flow control device into the bipolar plate allows to simplify the cell assembly process and to spare material. As an example, the protruding patterns are stamped on the bipolar plate. Alternatively, they are formed on a metal sheet which is then soldered or welded to the bipolar plate.

[0040] The invention also concerns a water electrolysis cell comprising a stack of at least one bipolar plate, a flow control device, an anodic porous material, a separator and a cathodic porous material, the water electrolysis cell having a frame bordering the stack, the frame having at least one inlet and one outlet configured to allow a circulation of water within an anode of the water electrolysis cell, and the water electrolysis cell including a distribution zone capable of supplying water from the inlet to the flow control device interposed between the bipolar plate and the anodic porous material of the water electrolysis cell,

[0041] the water electrolysis cell being characterized in that it comprises at least one reduction flow member according to the invention, the at least one reduction flow member being arranged between the water distribution zone and the flow control device.

[0042] In this water electrolysis cell, the bipolar plate is preferably a bipolar plate of the invention, thus integrating the reduction flow member.

[0043] The cell also preferably comprises a further distribution zone adapted to feed water from the flow control device to the outlet, and a further reduction flow member having channels adapted to circulate water between the flow control device and the further distribution zone. This further reduction flow member is preferably integrated into the bipolar plate and identical to the reduction flow member of the invention allowing to circulate water from the distribution zone to the flow control device, except that the further reduction flow member is arranged symmetrically to the reduction flow member with respect to a symmetry axis which is parallel to inner edges of the frame, along which extend the reduction flow members. Thus, corresponding channel portions of the reduction flow member and of the further reduction flow member are facing each other and are separated by the flow control device. The further distribution zone is preferably also integrated into the bipolar plate, for example by stamping. Different ways to integrate the further reduction flow member and the further distribution zone exist and were already mentioned in relation with the distribution zone and the reduction flow member (stamping, welding, soldering, etc).

[0044] The invention also concerns a water electrolysis module comprising a plurality of water electrolysis cells according to the invention, the water electrolysis cells being stacked on top of each other, a first cell and a second cell of the plurality of water electrolysis cells sharing the same at least one bipolar plate, the bipolar plate comprising integrally formed protruding patterns constituting a flow control device interposed between the bipolar plate and an anodic porous material of the first cell, and constituting a flow control device interposed between the bipolar plate and a cathodic porous material of the second cell. Thus, in this water electrolysis module, a same bipolar plate functions as a part of an anode electrode and as a flow control device for the first cell, and as a part of a cathode electrode and as a flow control device for the second cell. Due the fact that the water flow homogeneity is not as critical on the cathode side of each cell as on the anode side of each cell, a frame of the second cell integrates studs forming a distribution zone and a reduction flow device on top of the bipolar plate. For example, the studs are molded on the frame, itself made of molded plastic.

[0045] This arrangement is reproduced on the cathode side of the first cell. Thus, the frame of the first cell contains studs on its cathode side to perform the distribution zone and the reduction flow member function but is flat on the anode side of the cell, when the distribution zone in this anode side is integrated in the bipolar plate.

[0046] Indeed, it should be noted that the frame of a cell is preferably common to the anode side and the cathode side. For example, the frame is shaped like a thick rectangular frame which larger faces are each in contact with a bipolar plate. Each face has two parallel sides each formed by an inner and an outer edge between which the inlet or outlet is arranged. A reduction flow member extends along each inner edge of the frame.

[0047] Of course, as an alternative embodiment, the bipolar plate may also integrate a distribution zone and/or a reduction flow member on the cathode side of the cell.

[0048] Other characteristics and advantages of the invention will become apparent on the one hand from the following description, and on the other hand from several embodiments given by way of indication and not limitation with reference to the appended schematic drawings, on which:

[fig 1] already described in relation with prior art, schematically figures a water electrolysis cell,

[fig 2] already described in relation with prior art, figures a frame of such a water electrolysis cell,

[fig 3] figures a water electrolysis module according to the invention, in an embodiment of the invention,

[fig 4] shows a cross-section of a water electrolysis cell according to the invention, in an embodiment of the invention,

[fig 5] figures a face of a frame of the water electrolysis cell represented in figure 4,

[fig 6] figures a bipolar plate according to the invention, cooperating with the frame of figure 5 in the corresponding embodiment of the invention,

[fig 7] is an enlargement of a part of a reduction flow member integrated in the bipolar plate of figure 6,

[fig 8] further shows a part of figure 7 and how it looks when the reduction flow member is realized by stamping,

[fig 9] is a cross-section of the part shown in figure 8, represented both schematically and in a more realistic manner for the stamped case,

[fig 10] is another cross-section of the part shown in figure 8, represented both schematically and in a more realistic manner for the stamped case, and

[fig 11] is a cross-section of a part of the water electrolysis module of figure 3, showing an anode side of a first cell of the module and at least some components of a cathode side of a second cell of the module.

[0049] According to one embodiment of the invention, a water electrolysis module 70 shown in figure 3 is constituted by a plurality of water electrolysis cells 1 stacked on top of each other along a stacking direction E, perpendicular to a main plane of extension of each of the cells 1. In fact, each of the cells 1, although themselves made up of a stack of layers of materials, retain a generally flat shape.

[0050] The water electrolysis module 70 comprises a first incoming pipe 71 that connects to a water inlet passing through the stack of cells 1, more particularly through a frame of each cell 1 and through a bipolar plate of each cell 1. More precisely, this water inlet is intended to interact with anode compartments of all cells 1, to cool them and to feed the electrolysis reaction of the water.

[0051] The water electrolysis module 70 also comprises a second incoming pipe 72 that connects to another water inlet passing through the stack of cells 1, more particularly through the frames and bipolar plates of cells 1. More precisely, this other water inlet is intended to interact with cathode compartments of all cells 1, to cool them and to feed the electrolysis reaction of the water.

[0052] The electrolysis module 70 further comprises a first outgoing pipe 74 which connects to a water outlet passing through the stack of cells 1, more particularly through the frames and bipolar plates of cells 1. More precisely, this water outlet is intended to collect the two-phase water-oxygen mixture produced inside the anode compartments of the module 70 after circulation of the water in the vicinity of the anode catalytic layers of the module 70.

[0053] In a similar manner, the electrolysis module 70 also comprises a second outgoing pipe 73 which connects with another water outlet passing through the stack of cells, more particularly through the frames and bipolar plates of cells 1. More precisely, this other water outlet is intended to collect the two-phase water-hydrogen mixture produced inside the cathodic compartments of the module 70 after circulation of the water in the vicinity of the cathodic catalytic layers of the module 70.

[0054] Preferably, the first incoming pipe 71 and the first outgoing pipe 74 are connected to a water flow circuit comprising a heat exchanger, while the second incoming pipe 72 and the second outgoing pipe 73 are not connected to a water circuit benefiting from an active cooling. It is to say that the anode compartments of the stack of cells 1 benefit from an active cooling while the cathode compartments of the stack of cells 1 do not benefit from an active cooling, since less critical in terms of temperature.

[0055] The water inlets and outlets extend along the stacking direction E. Finally, in order to ensure the stacking and sealing of the cells 1 within the module 70, the latter also comprises a plurality of fastening means 75 allowing the cells 1 to be pressed together along the stacking direction E.

[0056] A first cell 1_1 of the module 70 is shown in a cross-section in figure 4. This cross-section doesn't cross the water inlets or outlets in cell 1_1. The first cell 1_1 rests on a metal current feeding plate 76, which is electrically connected to one of the terminals of a voltage source. The last cell of the stack of cells 1 is similarly in electric contact with another current feeding plate connected to the other terminal of the voltage source.

[0057] The first cell 1_1 includes a stack of material layers maintained between two bipolar plates 161, 141, for example made of titanium. Bipolar plate 161 is in contact with the metal current feeding plate 76 and thus only belongs to the first cell 1_1. Bipolar plate 141 is common to the first cell 1_1 and a second cell 1_2 (referenced figure 11) adjacent to the first cell 1_1.

[0058] The first cell 1_1 has a frame 12 that is clamped between the bipolar plates 141, 161. A first gasket 121 outlining the frame 12 is compressed between the frame 12 and the plate bipolar 141, and a second gasket 123 outlining the frame 12 is compressed between the frame 12 and the plate bipolar 161, to ensure the tightness of the first cell 1_1, whose anode and cathode compartments are crossed by water.

[0059] Inside the frame 12, the following successive material layers are superimposed on each other:

- a cathodic porous material 163, for example consisting of titanium particles or fibers sintered together, or consisting of carbon fibers,

- a proton exchange membrane 2, for example in Nafion ® or in a hydrocarbon material, and

- an anodic porous material 144, for example consisting of titanium particles or fibers sintered together.

[0060] Thus, the anodic compartment 14 of the first cell 1_1 includes the bipolar plate 141 and the anodic porous material 144. It also comprises a flow control device 142, integrated into the bipolar plate 141, as described further.

[0061] Similarly, the cathodic compartment 16 of the first cell 1_1 includes the bipolar plate 161 and the cathodic porous material 163. It also comprises a flow control device 162, integrated into the bipolar plate 161, as described further.

[0062] The frame 12 has a globally rectangular shape, whose inner edges receive the proton exchange membrane 2 and the anodic porous material 144. The proton exchange membrane 2 and the anodic porous material 144 are clamped on their end edges between the bipolar plate 141 and a sidewalk 126 of the frame 12. This sidewalk 126 extends inner edges of the frame 12 orthogonally to the stacking direction E, in a part of the frame 12 bordering the cathodic porous material 163. This arrangement allows a third gasket 22 outlining the sidewalk 126 to be compressed between on the one hand the sidewalk 126 and one the other hand the proton exchange membrane 2, the anodic porous material 144 and the bipolar plate 141, ensuring the tightness of the anodic compartment 14 of the first cell 1_1 with respect to the cathodic compartment 16 of the first cell 1_1.

[0063] Moreover, the bipolar plate 141 integrates reduction flow members 6a and 6b extending along parallel inner edges 127, 125 of the frame 12, and bordering the flow control device 142. These reduction flow members are pressed against corresponding end parts 144-1, 144-2 of the anodic porous material 144 as described further. That is to say, the flow control device 142 and the reduction flow members 6a, 6b do not extend on a surface of the frame 12.

[0064] End parts 144-1, 144-2 are integrally formed with the anodic porous material 144 or are made of a cheaper material than the rest of the anodic porous material 144, for example in PTFE (PolyTetraFluoroEthylene).

[0065] Furthermore, the bipolar plate 141 integrates distribution zones 4a and 4b extending respectively along reduction flow members 6a and 6b. These distribution zones 4a and 4b are pressed against an end face of the frame 12. The distribution zones 4a and 4b, the reduction flow members 6a and 6b and the flow control device 142 are confined in the volume delimited by joint 121, allowing a water circulation coming from an anode water inlet 129a (referenced figure 5) located in the frame 12 and opening on the end face of frame 12, to pass though these elements of the bipolar plate 141 without affecting the tightness of the first cell 1_1. Similarly, the flow control device 162 integrated in the bipolar plate 161 is confined in the volume delimited by joint 123, and pressed against the cathodic porous material 163. That is to say, the flow control device 162 does not extend on a surface of the frame 12.

[0066] Figure 5 now shows the end face of the frame 12, facing the bipolar plate 141 on the anode side of first cell 1_1. This end face extends along two orthogonal directions being a first direction L1 and a second direction L2, themselves orthogonal to the stacking direction E, the two parallel inner edges 127, 125 of the frame 12 extending in the first direction L1. A homogenous water circulation, represented by bolded arrows, uniformly pass through the inner edge 127 to the inner edge 125 inside the frame 12, in the second direction L2.

[0067] The water circulation is coming from the anode water inlet 129a crossing the frame 12 in the staking direction E and opening on the end face of the frame 12. The water first passes from the anode water inlet 129a through a transition zone 2a. In particular, the transition zone 2a is subject to a fast flow, confined between the frame 12 and the bipolar plate 141, the distance between which being mechanically maintained by support studs, guiding the flow towards the distribution zone 4a (referenced on figures 4 and 6). Between the transition zone 2a and the distribution zone 4a, support studs in the transition zone 2a form a plurality of thinner channels, oriented according to the second direction L2. These thinner channels create a pressure drop adjustment barrier. The cell pressure drop is thus adjusted by the friction created by the passage of the fluid through these thin channels. The studs also have the function of maintaining mechanical support for a gasket 123 located on the other side of the bipolar plate 141.

[0068] The water then flows from the transition zone 2a to the distribution zone 4a, created by studs 42, 44 stamped on the bipolar plate 141, as shown in figure 6.

[0069] The bipolar plate 141 has the same external dimensions as the end face of frame 12, that is to say its external edges superimpose to external edges of the end face of frame 12. Not surprisingly, the bipolar plate 141 has passage holes for water superimposed to water inlet or outlets of frame 12:

- the anode water inlet 129a of the frame 12 communicates with a passage hole 9a in the bipolar plate 141,
- an anode water and gas (O2) outlet 129b of the frame 12 communicates with a passage hole 9b in the bipolar plate 141,
- a cathode water inlet 128a of the frame 12 communicates with a passage hole 8a in the bipolar plate 141, and
- a cathode water and gas (H2) outlet 128b of the frame 12 communicates with a passage hole 8b in the bipolar plate 141.

[0070] The anode water inlet 129a and the anode water and gas (O2) outlet 129b are opening in the volume delimited by the gasket 121. The cathode water inlet 128a and the cathode water and gas (H2) outlet 128b are outside this volume but are each surrounded by a toroidal seal clamped between the frame 12 and the bipolar plate 141 or respectively between a frame 12 of the adjacent cell 1_2 and the bipolar plate 141. Several of this kind of seal used in module 70 are visible on figure 11 showing a cross-section of a part of module 70 according to A-A cutting plane (referenced figure 5).

[0071] Coming back to figures 5 and 6, the water flow coming from the transition zone 2a passes through a distribution zone 4a and then through a reduction flow member 6a integrated into the bipolar plate 141, before flowing uniformly through the flow control device 142.

[0072] The distribution zone 4a extends along the second direction L2 between an edge 15 of the distribution zone 4a, adjacent to the transition zone 2a, and the reduction flow member 6a. The distribution zone 4a extends along the first direction L1 on a whole length of the inner edge 127, superimposed to the limit between the distribution zone 4a and the reduction flow member 6a. The reduction flow member 6a extends along an edge 11 of the flow control device 142, extending along the first direction L1. The lengths of this edge 11 of the flow control device 142 and the inner edge 127 of the frame 12 are equal.

[0073] When the water flow comes out of the flow control device 142, it passes through another reduction flow member 6b and another distribution zone 4b, integrated in the bipolar plate 141. The other distribution zone 4b guides the water flow towards another transition zone 2b on the frame 12, bringing the water into the anode water and gas (O2) outlet 129b of the frame 12. These other reduction flow member 6b, other distribution zone 4b and other transition zone 2b are respectively symmetric to the reduction flow member 6a, the distribution zone 4a and the transition zone 2a with respect to a symmetry axis separating the flow control device 142 in two equal parts in the first direction L1. The flow control device 142 extends along the second direction L2 between its edge 11 to an edge 13 parallel to edge 11 and of the same length, and along the first direction L1 between two parallel edges 18 superimposed to corresponding inner edges of the frame 12.

[0074] The other distribution zone 4b extends along the second direction L2 between an edge 17 of the other distribution zone 4b, adjacent to the other transition zone 2b, and the other reduction flow member 6b. The other distribution zone 4b extends along the first direction L1 on a whole length of the inner edge 125, superimposed to the limit between the other distribution zone 4b and the other reduction flow member 6b. The other reduction flow member 6b extends along the edge 13 of the flow control device 142, extending along the first direction L1.

[0075] The distribution zones 4a and 4b are confined between the frame 12 and the bipolar plate 141. These zones each include a plurality of studs 42, 44 formed into the bipolar plate 141, the studs 44 being of generally rectangular shape and arranged in a hydrodynamic way. These zones are subjected to the mechanical pressure exerted by on the one hand the water arriving in the cell 1_1 or leaving the cell 1_1 in the cathodic compartment 16 on the other face of the frame 12, and on the other hand the water arriving in the adjacent cell 1_2 or leaving this adjacent cell 1_2 in its cathodic compartment 16 on the other face of the bipolar plate 141, this water being at a higher pressure than in anodic compartments 14. These studs 42, 44 on the bipolar plate 141 therefore have the dual function of maintaining the distance between the frame 12 and the bipolar plate 141 despite the opposing forces and of creating fluid paths that can distribute the fluid along the flow control device 142 in the first direction L1. The number of rows of studs 42, 44 is determined so as to maintain a compromise between the roughness created by their presence resulting in a pressure drop and the distance between the studs 42, 44 allowed by the rigidity and strength of the frame 12 and the bipolar plate 141.

[0076] The distribution zones 4a and 4b each respectively contain a portion 5a, 5b extending the respective transition zones 2a, 2b in the second direction L2. This portions 5a, 5b are jet breaker zones. Indeed, most of the turbulent flow arriving at high speed after the inlet pressure drop adjustment barrier of transition zone 2a, must turn 90° to spread out in front of the reduction flow member 6a. As a result, one of the velocity components is greatly slowed, forming a local overpressure stop. The purpose of the plurality of studs 42 formed into the bipolar plate141 in the portion 5a is to contain this overpressure at a sufficient distance from the reduction flow member 6a. These studs 42 are characterized by the distance between them (5 to 7 mm between each stud 42), and by the fact that the total inlet cross-section in the portion 5a is as large as possible. Conversely, at the anode water outlet, most of the fluid must turn 90° to pass from the other distribution zone 4b to an outlet pressure drop adjustment barrier at the entrance of the other transition zone 2b. This causes a rapid increase in one of the velocity components and thus a venturi effect. This effect is contained by the portion 5b at a sufficient distance from the other reduction flow member 6b so that its operation is not disturbed. The studs 42 are thinner than studs 44, having for example a round section. Indeed, the studs 42 are used to fill a jet-breaking role, to distribute the water flow in a more laminar way, and to provide a good mechanical support. They are located in the same direction as the water flow to create enough hydraulic resistance without blocking the water flow.

[0077] Reduction flow members 6a, 6b connect the distribution zones 4a, 4b to the flow control device 142. They make the flow lines in the flow control device 142 uniform. As visible in figure 7, they are formed within the bipolar plate 141 by a plurality of channels 62 arranged orthogonally to the first direction L1. These channels 62 have a small hydraulic diameter allowing the regulation and the equitable distribution of the fluid flows upstream of the flow control device 142. The number and diameter of channels 62 are chosen so that the pressure drop they generate allows the flows to be balanced.

[0078] In this embodiment of the invention, channels 62 are formed by stamping of the bipolar plate 141. They are stamped between higher barriers 64 also stamped in the bipolar plates 141, these barriers 64 having a U-shape when seen in a plane P1 parallel to the main extension plane of the bipolar plate 141 and referenced figures 9 and 10. The bold arrows in figures 7 and 8 represent water flowing inside channels 62 of the reduction flow member 6a.

[0079] The water flows from a left side L to a right side R of figure 7, the reduction flow member 6a extending between the left side L and the right side R. It is to be noted that on figure 7, only the reduction flow member 6a is shown on the bipolar plate 141, regardless of the distribution zone 4a which is in fact located at the left side L and of the flow control device 142 which is in fact located at the right side R.

[0080] As shown in figure 7, each channel 62 contains two portions: a first portion 621 and a second portion 622, the second portion 622 being deeper than the first portion 621.

[0081] The first portion 621 faces the right side R and the second portion 622 faces the left side L. The second portions 622 extend between the bases of the U shaped by the barriers 64 while the first portions 621 are adjacent to the free ends of the U branches shaped by the barriers 64. Between these branches, a non-stamped zone 66 is in contact with the frame of the cell 1_2 adjacent to the first cell 1_1 and is dimensioned so that all these non-stamped zones 66 ensure a clamping force between the anodic porous material 144 and studs of a cathode side distribution zone of cell 1_2 's frame on the other side of the bipolar plate 141.

[0082] Symmetrically, each channel of the other reduction flow member 6b contain a first portion and a second portion, the second portion being deeper than the first portion and facing the other distribution zone 4b, while the first portion faces the flow control device 142. The second portions extend between the bases of the U shaped by the barriers of the other reduction flow member 6b while the first portions are adjacent to the free ends of the U branches shaped by these barriers. Between these branches, a non-stamped zone is in contact with the frame of the cell 1_2 adjacent to the first cell 1_1 and is dimensioned so that all these non-stamped zones ensure a clamping force between the anodic porous material 144 and studs of the cathode side distribution zone of cell 1_2 's frame on the other side of the bipolar plate 141. Similarly, the stamped branches of the U have a top wall transmitting a clamping force to the anodic porous material 144 and the third gasket 22 underneath the anodic porous material 144.

[0083] Figure 8 shows a realization of the reduction flow member 6a made by stamping the bipolar plate 141, and thus having rounded outlines. Only a little part of the reduction flow member 6a is shown.

[0084] Figure 9 shows this little part in the B-B cutting plane parallel to the first direction L1 and crossing the first portions 621 of channels 62. This cross-section shows that the reduction flow member 6a is bounded by the first plane P1, in contact with the anodic porous material 144, and by a second plane P2 parallel to the first plane P1 and in contact with the frame of the cell 1_2 adjacent to the first cell 1_1 on the other side of the bipolar plate 141. The barriers 64 extend from the first plane P1 to the second plane P2, blocking the water flow on a height d, while the first portions 621 of channels 62 allow the water flowing on a height h which is strictly less than the height d of barriers 64. The height h of a channel 62 extends from a bottom wall 623 of the channel, part of the bipolar plate 141, to the P1 plane. The height h also extends from a flat part of the bipolar plate 141 to the P1 plane. These heights are measured in the stacking direction E. Moreover, the first portions 621 of the channels 62 each have a width e measured in the first direction L1, such that this width e and this height h of these first portions 621 generate a predetermined pressure drop.

[0085] For example, the height h of a first channel portion 621 is between 20% to 90% lower than the height d of a barrier 64, and/or the cross-section area of a first channel portion 621 is between 2% to 10% of that of a repeating pattern of the reduction flow member 6a. This repeating pattern contains for example a unique barrier 64 and a unique channel 62, so that its cross-section area has a width f and a height equal to the distance between the first plane P1 and the second plane P2. Preferably, the cross-section area of the first portion 621 of a channel 62 is about 0,6mm^2, or different but between 0,15mm^2 and 2mm^2, or more preferably between

0,15mm^2 and 0,8mm^2. The height h of the first channel portion 621 is preferably between 0,1mm and 0,5mm.

[0086] Barriers 64 have a width, measured along the first direction L1, wider than that of a channel 62.

[0087] Figure 10 shows the part of the reduction flow member 6a of figure 7, in the C-C cutting plane parallel to the first direction L1 and crossing the second portions 622 of channels 62. These second portions 622 have the same height d as the barriers 64. They allow to support efficient transmission of compression forces between the cells 1.

[0088] Figure 11 shows in cross-section in a plane parallel to the stacking direction E and the second direction L2, a part of the first cell 1_1 and of the second cell 1_2 immediately adjacent to the first cell 1_1 in the water electrolysis module 70. This cross-section passes through the anode water inlet 129a and the cathode water outlet 128b. This cross-section makes apparent that, between the reduction flow member 6a and the other reduction flow member 6b, the bipolar plate 141 comprises integrally formed protruding patterns constituting the flow control device 142 interposed between the bipolar plate 141 and the anodic porous material 144 of the first cell 1-1 and constituting a flow control device 162 interposed between the bipolar plate 141 and a cathodic porous material 163 of the second cell 1_2. These protruding patterns are stamped on the bipolar plate 141. It is also apparent that frames 12 are simplified with respect to prior art, since frames 12 includes less studs than in prior art. They contain studs only on the transition zones 2a, 2b on the cathode side. Studs on the cathode side are creating a distribution zone between the bipolar plate 161 and the frame 12, are in contact with the non-stamping zones 66 and transmit a clamping force to the anodic porous material 144 via the reduction flow members 6a, 6b.

[0089] Alternatively, the distribution zones 4a, 4b and/or the reduction flow members 6a, 6b and/or the flow control devices 142, 162 may be stamped on one or several separate material strips which are then welded or soldered to the bipolar plate 141.

[0090] Such a realization of the distribution zones 4a, 4b, the reduction flow members 6a, 6b and the flow control devices 142, 162 integrated into the bipolar plate 141 reduces the number of components per cell, hence eases the assembly process and makes it more robust.

[0091] Moreover, the structure of the bipolar plate 141 improves the water flow distribution homogeneity over the active surface areas of the cells, hence optimizing their stable operation and their lifetime in service for stacks.

[0092] Furthermore, it decreases the cell thickness and reduces the interfaces between components, hence making the system more efficient.

[0093] Of course, the invention is not limited to the examples just described and many adjustments can be made to these examples without going beyond the scope of the invention. In particular the reduction flow member according to the invention and/or the distribution zones and/or the transition zones may not be integrated in the bipolar plate but may be made of additional pieces or integrated in the frame using another process than injection molding.

Claims

1. Reduction flow member (6b, 6a) for a water electrolysis cell (1), the reduction flow member (6b, 6a) comprising a first face lying in a first plane (P1), a second face lying in a second plane (P2) parallel to the first plane (P1), at least one first barrier (64) and a second barrier (64) extending between the first plane (P1) and the second plane (P2), at least one channel (62) being arranged between the first barrier (64) and the second barrier (64), wherein a height (h) of at least a portion of the channel (62), measured orthogonally to the first plane (P1) between a bottom wall of the channel (62) and the first plane (P1), is strictly less than a height (d) of the first or the second barrier (64), measured orthogonally to the first plane (P1).

2. Reduction flow member (6b, 6a) according to claim 1, wherein the height (h) of the channel portion (62) is 20% to 90% lower than the height (d) of the first or second barrier.

3. Reduction flow member (6b, 6a) according to claim 1 or 2, wherein a cross section area of the channel portion (62) is 2% to 10% of that of a repeating pattern of the reduction flow member, the pattern extending between the first plane (P1) and the second plane (P2).

4. Reduction flow member (6b, 6a) according to any one of claims 1 to 3, wherein each of the first and second barriers (64) have a U-shape when seen in the first plane (P1).

5. Reduction flow member (6b, 6a) according to the preceding claim, wherein the at least one portion of the channel (62) is a first portion (621) of the channel, the channel (62) comprising a second portion (622) of the channel in which the height of the channel (62) is strictly greater than the height (h) of the channel (62) in the first portion (621) of the channel (62), the second portion (622) of the channel (62) extending from the first portion (621) of the channel (62) to an end of one of the U-shapes, corresponding to a junction of branches of the U.

6. Reduction flow member (6b, 6a) according to any one of claims 1 to 5, wherein the reduction flow member (6a, 6b) is formed by stamping or hydroforming of a strip of metal material.

7. Bipolar plate (141) for a water electrolysis cell (1), the water electrolysis cell (1) comprising a stack of at least the bipolar plate (141), a flow control device (142) and a porous material (144, 163), the stack being bordered at least in part by a frame (12), the bipolar plate (141) being **characterized in that** the bipolar plate (141) comprises at least one reduction flow member (6b, 6a) according to any one of claims 1 to 6, allowing a circulation of water between, on the one hand, a distribution zone (4a) comprised between the frame (12) and the bipolar plate (141) and, on the other hand, the flow control device (142).

8. Bipolar plate (141) for a water electrolysis cell (1) according to the preceding claim, wherein the reduction flow member (6b, 6a) is stamped or hydroformed and integrally formed with the bipolar plate (141).

9. Bipolar plate (141) for a water electrolysis cell (1) according to claim 7 or 8, wherein the distribution zone (4a) comprises studs (44, 42) extending through a thickness of the bipolar plate (141).

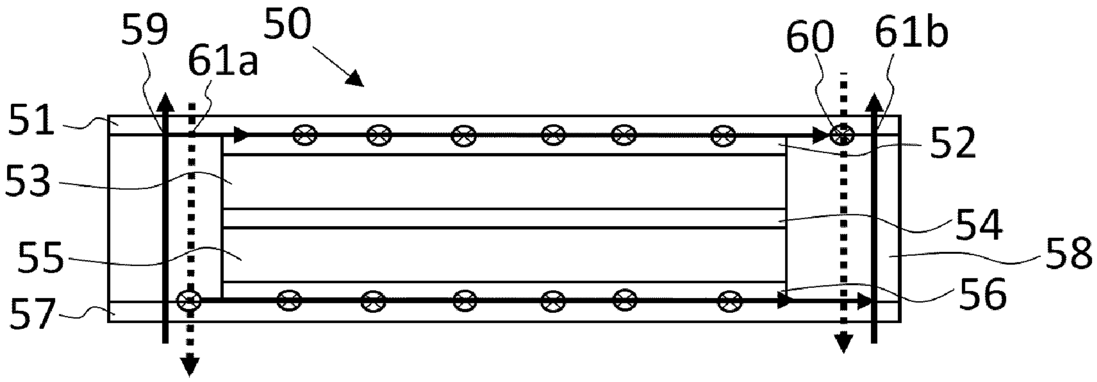
10. Bipolar plate (141) for a water electrolysis cell (1) according to claim 9, wherein the distribution zone (4a) comprises a portion (5a) in which the studs are oblong in shape and extend mainly parallel to the water circulation, said portion (5a) being comprised between a water flow inlet zone (2a) and the reduction flow member (6b, 6a).

11. Bipolar plate (141) for a water electrolysis cell (1) according to anyone of claims 7 to 10, wherein the bipolar plate (141) comprises integrally formed protruding patterns constituting the flow control device (142).

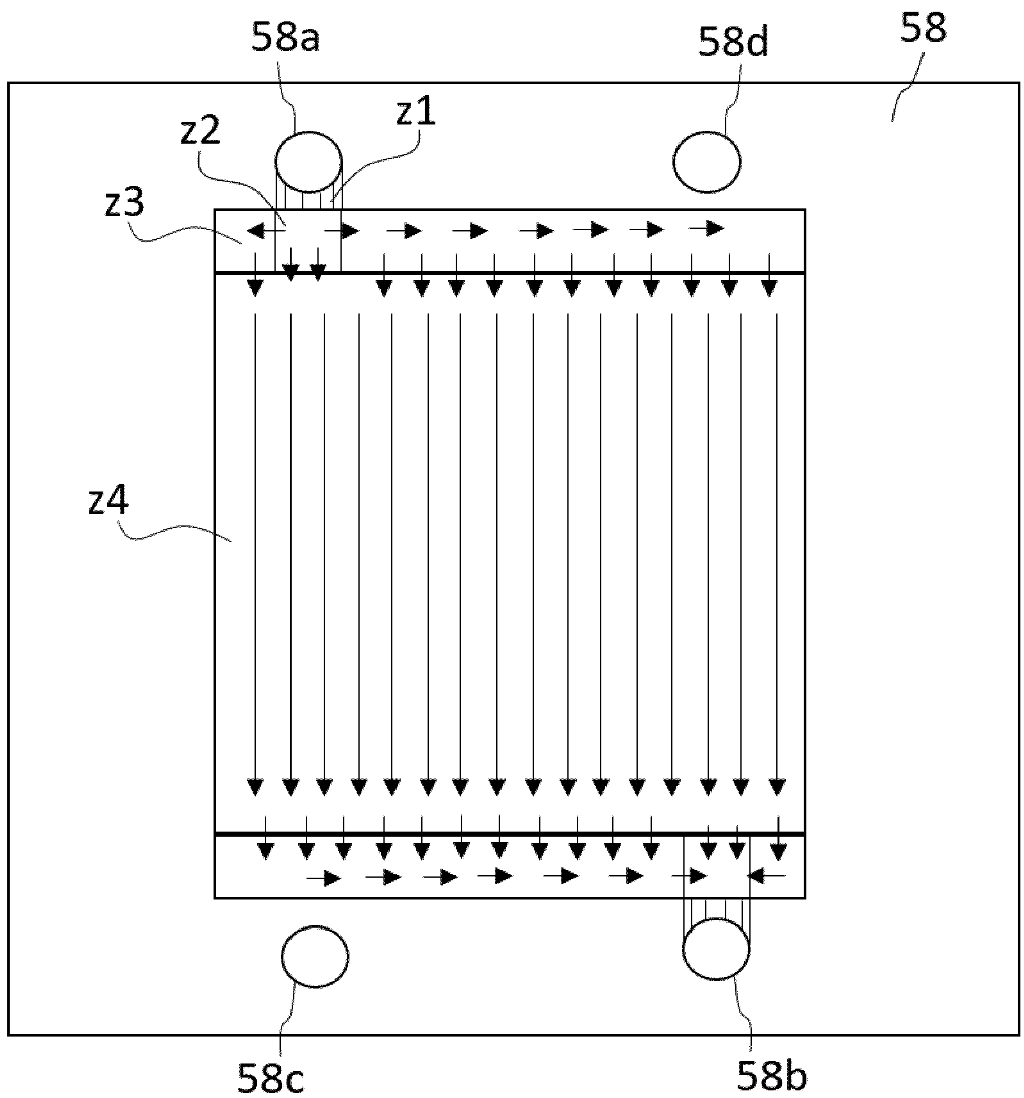
12. Water electrolysis cell (1) comprising a stack of at least one bipolar plate (141), a flow control device (142), a cathodic porous material (163), a separator (2) and an anodic porous material (144), the water electrolysis cell (1) having a frame (12) bordering the stack, the frame (12) having at least one inlet (129a) and one outlet (129b) configured to allow a circulation of water within an anode of the water electrolysis cell (1), and the water electrolysis cell (1) including a distribution zone (4b) capable of supplying water from the inlet (129a) to the flow control device (142) interposed between the bipolar plate (141) and the anodic porous material (144) of the water electrolysis cell (1),
the water electrolysis cell (1) being **characterized in that** it comprises at least one reduction flow member (6a) according to any of claims 1 to 6, arranged between the water distribution zone and the flow control device.

13. Water electrolysis module comprising a plurality of water electrolysis cells (1) according to the preceding claim, the water electrolysis cells (1) being stacked on top of each other, a first cell (1_1) and a second cell (1_2) of the plurality of water electrolysis cells (1) sharing the same at least one bipolar plate (141), the bipolar plate comprising integrally formed protruding patterns constituting a flow control device (142) interposed between the bipolar plate and an anodic porous material (144) of the first cell (1_1), and constituting a flow control device (162) interposed between the bipolar plate (141) and a cathodic porous material (163) of the second cell (1_2).

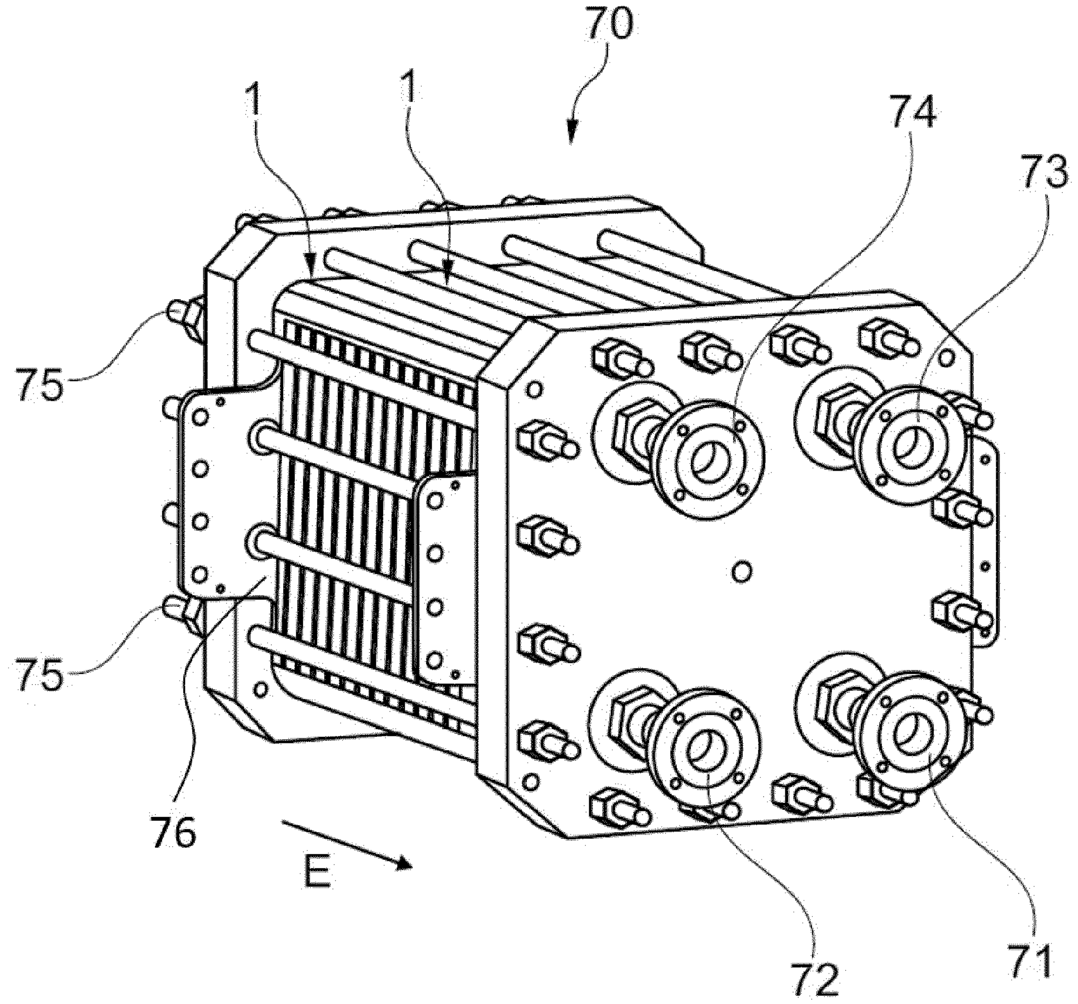
[fig 1]



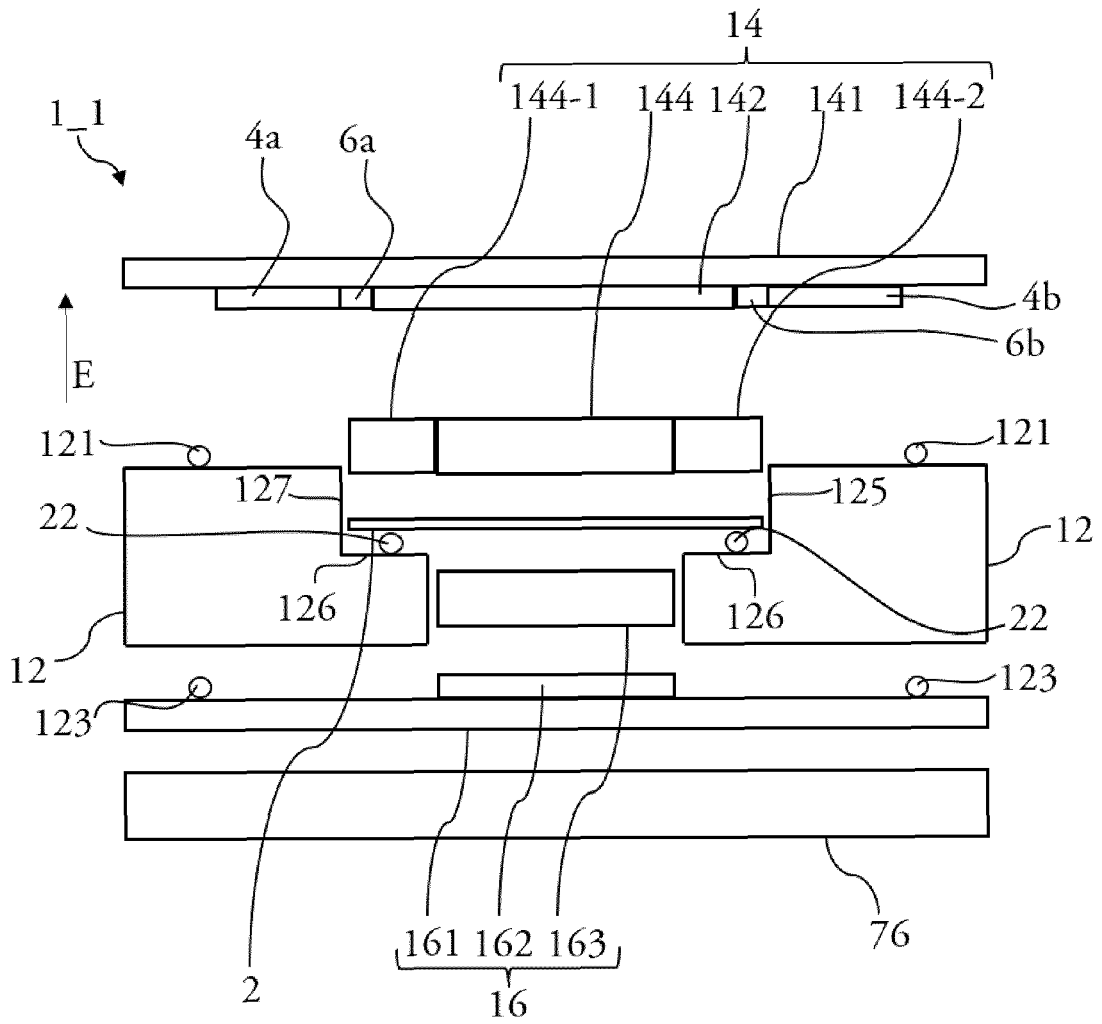
[fig 2]



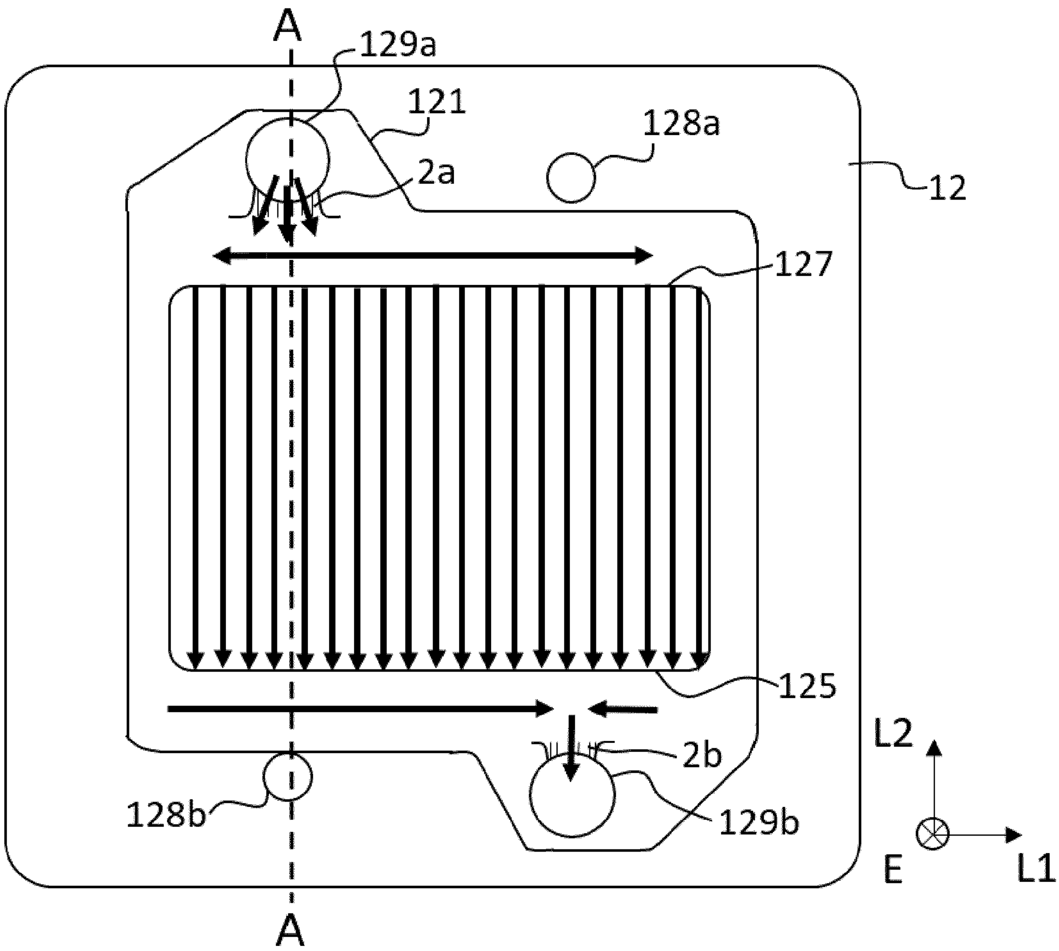
[fig 3]



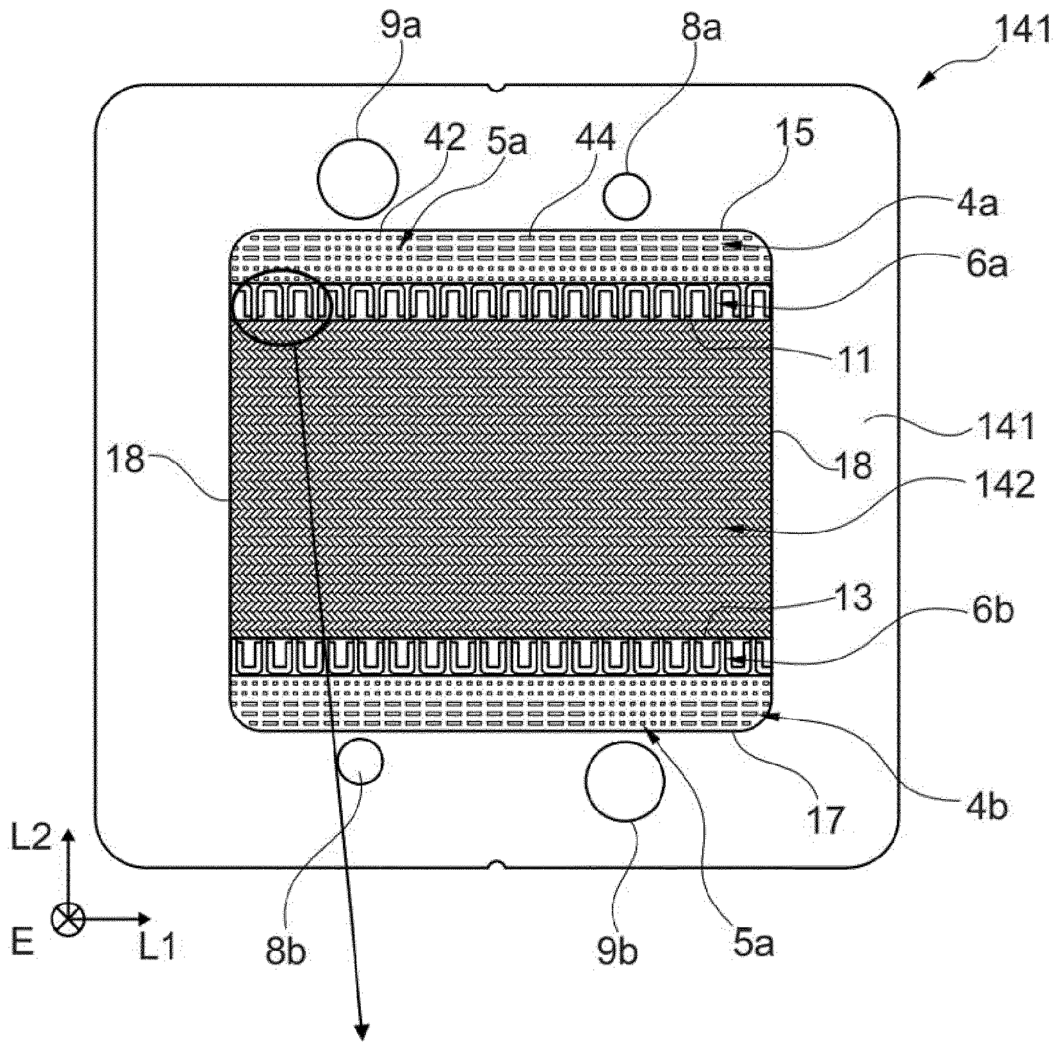
[fig 4]


14
144-1
144
142
141
144-2
1_1
4a
6a
4b
6b
E
121
121
127
125
22
12
126
126
22
12
123
123
161 162 163
16
2
76

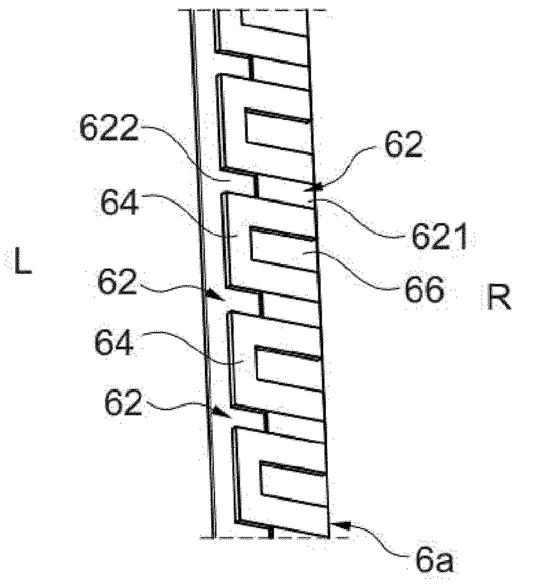
[fig 5]



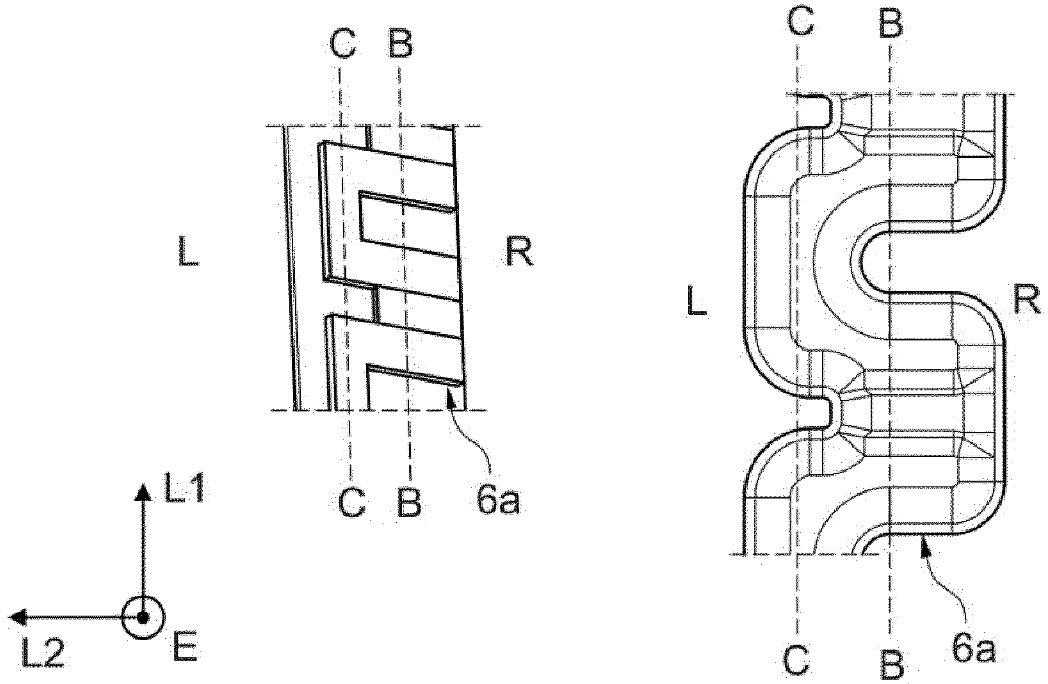
[fig 6]


9a
8a
141
42
5a
44
15
4a
6a
11
141
18
18
142
13
6b
17
4b
L2
E
L1
8b
9b
5a

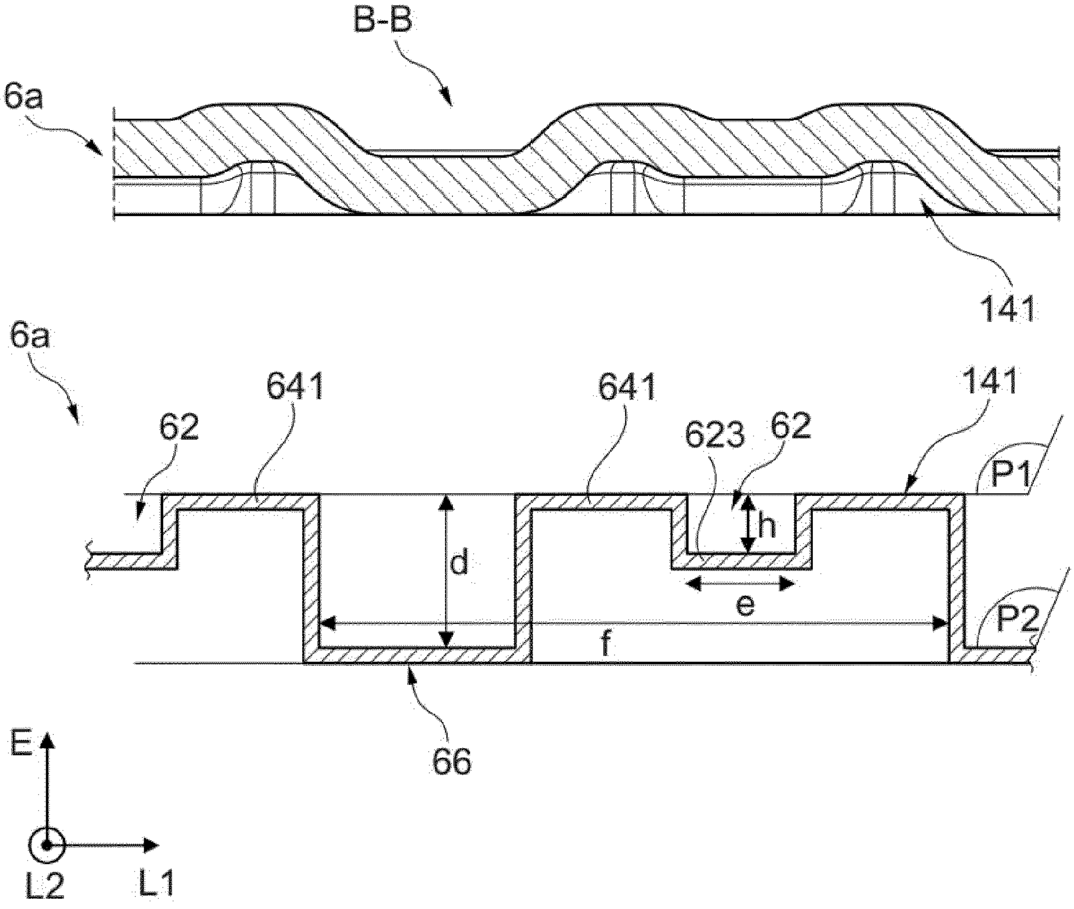
[fig 7]


622
62
64
621
L
62
66
R
64
62
6a

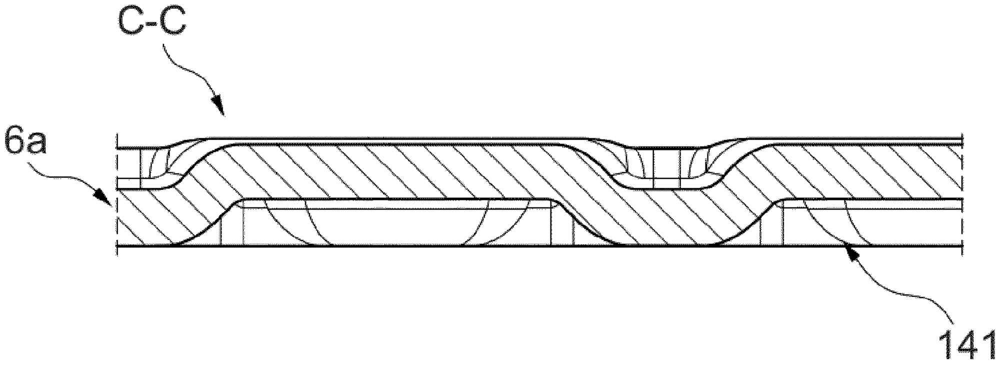
[fig 8]

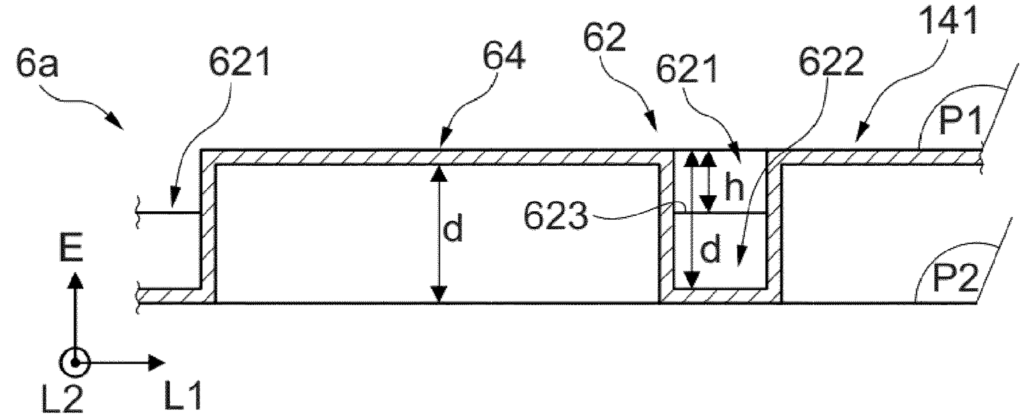


[fig 9]

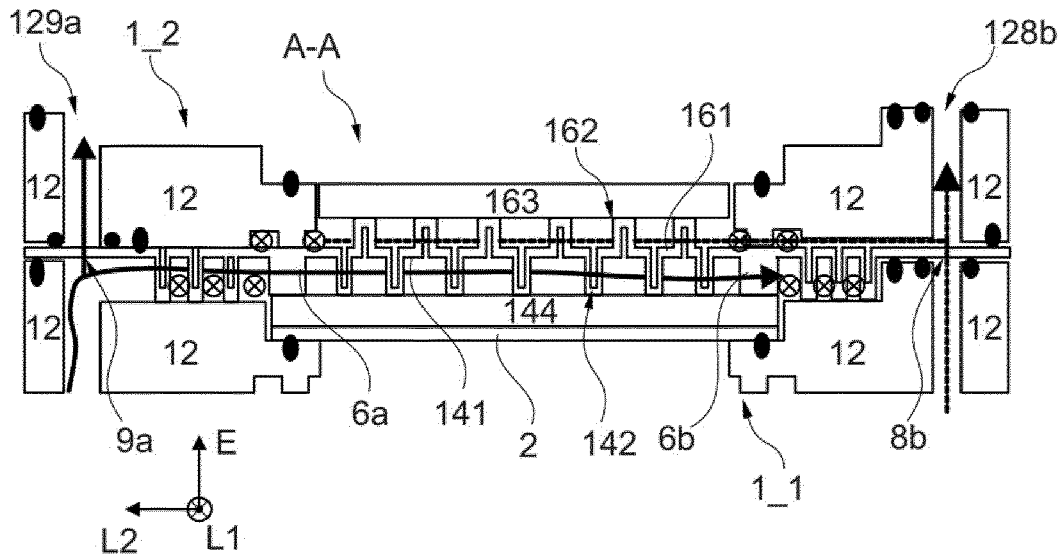


[fig 10]


C-C
6a
141


6a
621
64
62
621
622
141
P1
h
d
623
d
P2
E
L2
L1

[fig 11]


129a
1_2
A-A
128b
162
161
12
12
163
12
12
12
144
12
12
12
9a
6a
141
2
142
6b
8b
1_1
E
L2
L1

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EUROPEAN SEARCH REPORT

Application Number
EP 23 16 7785

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	* the whole document * -----	12,13	
X	US 2022/243348 A1 (BEKKEDAHL TIMOTHY A [US] ET AL) 4 August 2022 (2022-08-04)	1-11	
Y	* the whole document * -----	12,13	
X	CHEN XI ET AL: "Performance study on a stepped flow field design for bipolar plate in PEMFC", ENERGY REPORTS, vol. 7, 8 January 2021 (2021-01-08), pages 336-347, XP093098017, ISSN: 2352-4847, DOI: 10.1016/j.egyr.2021.01.003	1-11	
Y	* the whole document * -----	12,13	
Y	US 2006/068266 A1 (HANLON GREG A [US]) 30 March 2006 (2006-03-30) * the whole document * -----	12,13	
			TECHNICAL FIELDS SEARCHED (IPC)
			C25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	6 November 2023	Ritter, Thomas

CATEGORY OF CITED DOCUMENTS

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06-11-2023

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