ANION EXCHANGE ELECTROLYZER FLOW FIELD PLATE

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority to European patent application number EP24159614.7 filed on Febraury 26th, 2024, the entire contents thereof being herewith incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to a flow field plate and, in particular, an electrolyzer flow field plate, or electrolyzer flow field plate for two phase (liquid and gas) flow in a water electrolyzer. The present invention more particularly concerns an electrolyzer flow field plate for an anion exchange membrane water electrolyzer or for anion exchange membrane water electrolysis.

BACKGROUND

The escalating global demand for clean and renewable energy, catalyzed by the pressing issues of climate change, has generated significant interest in hydrogen as a promising solution for both energy storage and transportation, aiming to mitigate emissions from fossil fuels. Hydrogen boasts advantages such as its high energy density and clean-burning characteristics. However, it does not occur naturally on Earth and necessitates extraction from compounds like water and hydrocarbons, requiring diverse methods such as hydrocarbon reforming and water splitting.

In water splitting, an electric current is passed through water during electrolysis, causing it to separate into hydrogen and oxygen. By ensuring that the electricity comes entirely from renewable sources, the electrolysis process remains carbon-free, with no release of CO_2 or other greenhouse gases.

Water electrolyzers (WE) are gaining prominence recently due to various support strategies for clean hydrogen production. Prominently, two water electrolysis technologies have been proven to be scalable, namely - i) Proton Exchange Membrane Water Electrolyzers (PEMWE) ii) Alkaline Electrolyzers (AEL). The advent of anion exchange membrane water electrolyzers (AEMWE) combines the benefits of PEMWE and AEL, allowing the usage of non-platinum group metal catalysts. However, very minimal studies have been conducted towards optimizing the performance of AEMWE at the stack level.

ES2938279 discloses a flow field plate including a plurality of ribs in a fluid cavity. The plurality of ribs extend in an elongated manner parallel to the lateral walls of the flow field plate between the inlet and the outlet of the flow field plate.

KR1020040011286 discloses a flow field plate including a plurality of ribs in a fluid cavity. The length of each successive ribs is reduced for each of rib located between the inlet and outlet of the plate to form a tapered series of ribs.
Performance optimization gaps have been identified by the Inventors and include a two-phase (liquid and gas) study of flow fields necessary to evenly distribute current, temperature, pressure and fuel for electrolyzer performance.

Additionally, optimal or improved design of flow fields is important to evacuate generated gases effectively.

A goal of the present invention is to provide a solution to the above-mentioned inconveniences, and in particular, to provide a flow field design to improve and/or optimize two-phase flows in, for example, field flow plates or bipolar field flow plates designed, for example, for water electrolysis.

SUMMARY

It is therefore one aspect of the present disclosure to provide an electrolyzer flow field plate that addresses the above-mentioned inconveniences and needs. The electrolyzer flow field plate may comprise:
- a first flow entity configured to receive a fluid from at least one first flow entity fluid inlet and configured to communicate the fluid to at least one first flow entity fluid outlet;
- a second flow entity including at least one second flow entity fluid inlet and at least one second flow entity fluid outlet, the at least one second flow entity fluid inlet being configured to receive the fluid from the at least one first flow entity fluid outlet;
- an intermediate elongated rib located between and separating the first fluid flow entity and the second flow entity; and
- at least one further intermediate elongated rib delimiting or defining the at least one second flow entity fluid outlet, or an outlet support wall delimiting or defining the at least one second flow entity fluid outlet.

The first flow entity may include at least one fluid cavity delimited by at least one support wall of the electrolyzer flow field plate, the at least one fluid cavity comprising a fluid entrance

extremity and a fluid exit extremity, the first flow entity may further include a plurality of elongated channel ribs located inside the at least one fluid cavity, each elongated channel rib extending from the fluid entrance extremity to the fluid exit extremity to delimit a plurality of fluid channels for communicating the fluid to a first fluid passage extending between the at least one support wall of the electrolyzer flow field plate and the intermediate elongated rib, the first fluid passage being in fluid communication with the at least one first flow entity fluid outlet, each of the elongated channel ribs being located consecutively between the at least one support wall and the intermediate elongated rib.

The second flow entity may include at least one fluid cavity delimited by the intermediate elongated rib and the at least one further intermediate elongated rib or the outlet support wall, the at least one fluid cavity comprising a fluid entrance extremity and a fluid exit extremity, the second flow entity further including a plurality of elongated channel ribs located inside the at least one fluid cavity of the second flow entity, each elongated channel rib extending from the fluid entrance extremity to the fluid exit extremity to delimit a plurality of fluid channels for communicating the fluid to the at least one second flow entity fluid outlet, each of the elongated channel ribs being located consecutively between the intermediate elongated rib and the at least one further intermediate elongated rib or the outlet support wall.

Each elongated channel rib of the first flow entity may extend to an elongated channel rib tip located in the fluid exit extremity of the first flow entity, each elongated channel rib tip being located opposite a first side wall surface delimiting the at least one fluid cavity, the first side wall surface being defined by a first side wall of the electrolyzer flow field plate.

Each elongated channel rib tip may be located at a different distance from the first side wall surface, and the distance between the elongated channel rib tip and the first side wall surface consecutively increases for each consecutive elongated channel rib located consecutively between the at least one support wall and the intermediate elongated rib such that the first fluid passage widens between the at least one support wall and the intermediate elongated rib.

The support wall may, for example, include or define the first flow entity fluid inlet, and the first flow entity may include the support wall, the first side wall and a second side wall; wherein the first and second side walls may extend away from the support wall, and the first side wall surface of the first side wall and a second side wall surface of the second side wall delimit the at least one fluid cavity in which the plurality of elongated channel ribs are located between the first and second side wall surfaces. The first side wall surface may extend in a side wall

surface direction of extension and the elongated channel ribs may extend in an elongated direction that is different to the side wall surface direction of extension.

Each elongated channel rib of the second flow entity may extend to an elongated channel rib tip located in the fluid entrance extremity of the second flow entity and each elongated channel rib tip may be located opposite the first side wall surface.

Each elongated channel rib tip may be located at a different distance from the first side wall surface. The distance between the elongated channel rib tip and the first side wall surface may consecutively decrease for each consecutive elongated channel rib located consecutively between the intermediate elongated rib and the at least one further intermediate elongated rib or the outlet support wall such that a second fluid passage narrows between the intermediate elongated rib and the at least one further intermediate elongated rib or the outlet support wall. The second fluid passage may extend between the intermediate elongated rib and the at least one further intermediate elongated rib or the outlet support wall.

Other further advantageous features can be found in the dependent claims.

According to another aspect, the present disclosure also concerns an electrolyzer including at least one or a plurality of the electrolyzer flow field plates, or an anion exchange membrane water electrolyzer including at least one or a plurality of the electrolyzer flow field plates.

According to yet another aspect, the present disclosure also concerns an electrolysis method or anion exchange membrane water electrolysis method carried out using the electrolyzer or the anion exchange membrane water electrolyzer including at least one or a plurality of the electrolyzer flow field plates. The electrolyzer flow field plate may advantageously comprise or consist of Ni3P-coated stainless steel and be used in water electrolysis to improve electrolysis performance.

The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description with reference to the attached drawings showing some preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate the presently preferred embodiments of the invention, and together with the general description given above and the detailed description given below, serve to explain features of the invention.

Figure 1 schematically shows an exemplary electrolyzer flow field plate of the present disclosure.

Figure 2 schematically shows an enlarged view of the area of Figure 1 enclosed by the dashed frame.

Figures 3A and 3B schematically show further exemplary electrolyzer flow field plates of the present disclosure, the electrolyzer flow field plate of Figure 3A comprising nine entities or units and the electrolyzer flow field plate of Figure 3B comprising ten entities or units.

Figure 4 schematically shows further details of an entity or unit of an exemplary electrolyzer flow field plate of the present disclosure.

Figure 5A schematically shows the plate configuration or design of a known multi-parallel serpentine electrolyzer flow field plate.

Figure 5A schematically shows an exemplary electrolyzer flow field plate of the present disclosure comprising an improved multi-parallel serpentine configuration or design.

Figures 6A and 6B show the advantageous impact on the velocity distribution calculated at both an electrode surface (Figure 6A) and at a flow channel middle thickness (Figure 6B) of the electrolyzer flow field plate of the present disclosure compared to known multi-parallel serpentine electrolyzer flow field plates.

Figures 7A and 7B show a comparison of calculated fluid velocity profiles of the electrolyzer flow field plate of the present disclosure compared to known multi-parallel serpentine electrolyzer flow field plates having a straight design as well as those of standard parallel and 3 serpentine designs.

Figure 8 presents pressure drop values determined based on Two-Phase Flow Simulations for different flow field plate designs or configurations.

Figures 9A and 9B are schematic exemplary cross-sectional representations of the flow field plate illustrating some of the ribs and flow channels of the flow field plate as well as design parameters thereof.

Figure 10 schematically shows some further design parameters of elements such as rib length and flow field plate inner width for entities or units of the electrolyzer flow field plate of the present disclosure.

Figure 11 presents a calculated Reynolds number values of an average velocity in flow channels and at the electrode surface for different flow field plate designs or configurations.

Figure 12 schematically shows exemplary membrane-electrode assemblies and, more particularly, a cathode–membrane–anode configuration for which three different operating configurations can be performed for electrolysis to be carried out. Figure 12A shows a standard Anion Exchange Membrane Water Electrolyzer operating condition based on a classical alkaline electrolyzer mode of operation that is H_2O, aq. KOH fed to both the cathode and anode. Figure 12B shows minimum requirements for Anion Exchange Membrane Water Electrolyzer operation with H_2O, aq. KOH fed to the cathode only. Figure 12C shows an extended Anion Exchange Membrane Water Electrolyzer operation in which H_2O, aq. KOH is fed to the anode only.

Figure 13 schematically shows some further non-limiting exemplary dimensional details of an exemplary embodiment of an entity or unit of an exemplary electrolyzer flow field plate of the present disclosure.

Figures 14A and 14B schematically show an exemplary (AEMWE) stack assembly including a plurality of electrolyzer flow field plates of the present disclosure. Figure 14A is an assembled view, and Figure 14B is an exploded view. A first end plate of the system illustrated in Figure 14B is shown on the left side of Figure 14B and is shown located on the right side of Figure 14A.

Figure 15 shows measured results demonstrating that an implemented design of an AEMWE stack assembly having a 5-cell stack can reach >1.2kW performance.

Figure 16 shows measured performance results for an AEMWE stack assembly comprising stainless steel electrolyzer flow field plates according to the present disclosure compared to an AEMWE stack assembly comprising Ni_3P stainless steel electrolyzer flow field plates according to the present disclosure.

Figures 17A and 17B schematically show exemplary configurations including two membrane-electrode assemblies (MEA), each MEA arranged between a unipolar field flow plate and a bipolar field flow plate.

Herein, identical reference numerals are used, where possible, to designate identical elements that are common to the Figures. Also, the images are simplified for illustration purposes and may not be depicted to scale.

DETAILED DESCRIPTION OF SEVERAL EMBODIMENTS

Figures 1, 2, 3A to 3B, 4, and 5B schematically show an exemplary flow field plates 1 or electrolyzer flow field plates 1 of the present disclosure.

The flow field plate 1 includes a body 3 and a fluid flow structure, arrangement, or design 5. The fluid flow structure, arrangement, or design 5 is, for example, a fluid flow field pattern that directs or guides the flow of at least one fluid and/or gas/gases through the flow field plate 1. The body 3 comprises or defines the fluid flow structure, arrangement or design 5. The fluid flow structure, arrangement or design 5 is constructed or formed in the body 5, for example, by methods such as chemical etching, stamping, and/or Computer Numerical Control (CNC) milling. Material is, for example, removed from the body 3 to define or delimit elements in the body 3 that direct or guide the flow of at least one fluid and/or gas/gases through the flow field plate 1. The flowfield pattern can thus be machined onto the body 3 of the flow field plate 1.

The flow field plate 1 is, for example, a metallic plate comprising or consisting of stainless steel (for example, any grade of stainless steel), one or more transitional earth metals such as Nickel, iron, molybdynum, or spinel(s), or metals such as Nickel, iron, molybdynum, or spinel(s) coated on transition metals. This allows a most cost-efficient electrolyzer and electrolysis to be obtained compared to for example traditional titanium-based plates. The flow field plate 1 can, for example, have a length between 5 and 30 cm, a width between 5 and 10 cm and a thickness between 0.015cm and 1cm.

The flow field plate 1 may, for example, have a (generally) rectangular or square (outer peripheral) shape as, for example, illustrated in the non-limiting exemplary embodiment of

Figures 1 and 14. The flow field plate 1 may however have other shapes, for example, a circular (having, for example, a diameter between 5 and 30cm), or an oval shape.

The flow field plate 1 and/or the body 3 extend to define or delimit, for example, a planar structure or planar surfaces permitting stacking or a superposed accumulation of a plurality of the flow field plates 1 (see, for example, Figures 14A and 14B). The flow field plate 1 and/or the body 3 extend, for example, in a first direction (X direction) and a second direction (Y direction, see for example Figures 14A and 14B), the first direction and second direction being substantially perpendicular to a resulting or overall fluid and gas flow direction (Z direction), or an input fluid direction and/or an output fluid and/or gas flow direction of an electrolysis system 100 comprising the flow field plates 1.

The flow field plate 1 and/or the body 3 includes a plurality of entities or units 7 configured to direct or guide the flow of the fluid and/or gas/gases through the body 3 and through the flow field plate 1 to an outlet 9 of the body 3 (see Figure 1) through which the fluid and/or gas/gases exit the flow field plate 1.

The flow field plate 1 may include or be coated with at least one catalyst. According to one embodiment of the present disclosure, the catalyst may comprise or include Ni_3P. The catalyst is, for example, included or coated on the fluid flow structure 5 and/or the plurality of entities or units 7.

The flow field plate 1 and/or the body 3 includes an inlet 11 through which the fluid is provided to the plurality of entities or units 7 and/or to elements of the fluid flow structure, arrangement or design 5. The flow field plate 1 and/or the body 3 include, for example, an inlet fluid communication chamber 15 and an inlet canal or passage 16 arranged in fluid communication to provide fluid to the plurality of entities or units 7 and/or to elements of the fluid flow structure, arrangement or design 5. The inlet fluid communication chamber 15 comprises or is formed by, for example, a bore or through-hole extending fully through the body 3. This allows fluid to be communicated to a plurality of stacked flow field plates 1 by the fluid being passed through the aligned inlets 11 and inlet fluid communication chambers 15.

The flow field plate 1 and/or the body 3 includes, for example, an outlet fluid communication canal or passage 17 and an outlet fluid communication chamber 18 arranged in fluid communication to remove fluid and gas from the flow field plate 1 and/or the body 3, the fluid having been provided thereto through the plurality of entities or units 7 and/or elements of the fluid flow structure, arrangement or design 5. The outlet fluid communication chamber 18

comprises or is formed by, for example, a bore or through-hole extending fully through the body 3. This allows fluid to be communicated out of a plurality of stacked flow field plates 1 by the fluid being passed through the aligned inlets 9 and outlet fluid communication chambers 18. The outlet fluid communication canal or passage 17 and the outlet fluid communication chamber 18 may, for example, be arranged or located diagonally or at an opposite lateral side to that of the inlet 11 (see, for example, Figure 3A), or may, for example, be arranged or located laterally on the same side of the flow field plate 1 as the inlet 11 (see, for example, Figure 3B).

When a plurality of flow field plates 1 are stacked and assembled together, fluid can be provided through the plurality of inlet fluid communication passages 15 to provide fluid to the plurality of stacked flow field plates 1. Similarly, when a plurality of flow field plates 1 as stacked and assembled together, fluid can be removed via the plurality of outlet fluid communication passages 17 to remove fluid and/or gas/gases from the plurality of stacked flow field plates 1.

The flow field plate 1 and/or the body 3 includes a first side or face 19A and an opposing second side or face 19B located opposite first side 19A. The first side 19A may, for example, be a front side and the second side 19B may be a backside of the flow field plate 1 and/or the body 3.

The fluid flow structure, arrangement or design 5 may be included or located on only one side, either the first side 19A or the second side 19B, and in such a case the flow field plate 1 comprises or is a unipolar flow field plate. Alternatively, a fluid flow structure, arrangement or design 5 (which may, for example be substantially identical a fluid flow structures 5) may be included or located on both sides, that is on the first side 19A and the second side 19B, and the flow field plate 1 comprises or is a bipolar flow field plate. Alternatively, a bipolar flow field plate may be formed by two such unipolar flow field plates assembled or stacked back-to-back, for example, with the fluid flow structure-free sides placed or attached back-to-back.

Figures 14A and 14B schematically show an exemplary electrolysis stack assembly or electrolysis system 100 including a plurality of electrolyzer flow field plates 1 of the present disclosure. Figure 14A shows an assembled stack assembly or assembled system 100, while Figure 14B shows an exploded view of the stack assembly or system 100. A first end plate 107A of the system 100 is illustrated on the left side of Figure 14B while being illustrated to the right side of Figure 14A. The electrolysis stack assembly or electrolysis system 100 in one embodiment may be, for example, an Anion Exchange Membrane Water Electrolyzer AEMWE assembly 100 or Anion Exchange Membrane Water Electrolysis assembly 100.

The stack assembly or system 100 may in one embodiment be, for example, an anion exchange membrane water electrolysis stack assembly or system 100, or an anion exchange membrane water electrolyzer stack assembly or system 100.

The stack assembly or system 100 includes, for example, (see for example Figure 14B) a plurality of bipolar flow field plates 103 (for example, five bipolar flow field plates 103 as shown in Figure 14B) enclosed by or sandwiched between at least one first unipolar flow field plate 105A and at least one second unipolar flow field plate 105B.

The or each of the unipolar flow field plates 105A,105B and the or each of the bipolar flow field plates 103 are formed from or include the flow field plate 1 of the present disclosure, as explained above.

The stack assembly or system 100 also includes a first end plate 107A and a second endplate 107B between which the unipolar flow field plates 105A,105B and the bipolar flow field plates 103 are located or sandwiched. The stack assembly or system 100 further includes a first electrical insulator plate 109A located between the first end plate 107A and the first unipolar flow field plate 105A, and a includes a second electrical insulator plate 109B located between the second end plate 107B and the second unipolar flow field plate 105B. This allows to electrically isolate the end plates from the other elements of stack assembly or system 100, and in particular the cells 123 (see, for example, Figure 14A) of the of stack assembly or system 100.

The end plates 107A, 107B are, for example, metallic end plates comprising or consisting of stainless steel (for example, any grade of stainless steel), one or more transitional earth metals, or metals coated on transition metals. Alternatively, the end plates 107A, 107B are, for example, end plates comprising or consisting of one or more plastics.

The end plates 107A, 107B may comprise or consist of, for example, Nickel, Ni_3P, cast iron, Fe coated with Ni_3P, Stainless steel (for example, SS316L, SS304), Stainless steel coated with Ni_3P, HDPE, PE, PP, PTFE, or PEEK.

The end plate has, for example, a generally planar form of structure. The end plate is, however, not limited to any specific shape or size. The end plate can, for example, have a length between 15 and 50 cm, a width between 15 and 50 cm and a thickness between 2 and 20cm. The end plate may have a (generally) rectangular or square (outer peripheral) shape. The end plate may however have other shapes, for example, a circular or an oval shape.

The stack assembly or system 100 includes at least one or a plurality of membrane-electrode assemblies (MEA) 111. A membrane-electrode assembly (MEA) 111 is, for example, located between each set of two bipolar flow field plates 103. In the exemplary stack assembly or system 100 of Figures 14A and 14B, four membrane-electrode assemblies 111A, 111B, 111C, 111D are, for example, included located between the five bipolar flow field plates 103 of this exemplary system 100. The system 100 thus includes n-1 membrane-electrode assemblies where n is the total number of bipolar flow field plates 103. A membrane-electrode assembly (MEA) 111 is also, for example, located between each unipolar flow field plates 105A,105B and a bipolar flow field plates 103. A membrane-electrode assembly (MEA) 111E is, for example, located between the first unipolar flow field plate 105A and the closest neighboring bipolar flow field plate 103 to the first unipolar flow field plate 105A. A membrane-electrode assembly (MEA) 111F is, for example, located between the second unipolar flow field plate 105B and the closest neighboring bipolar flow field plate 103 to the second unipolar flow field plate 105B. A total of six membrane-electrode assemblies (MEA) 111 is thus included in the exemplary and non-limiting embodiment of Figures 14A and 14B.

The stack assembly or system 100 also includes a plurality of seals or sealing means 115 configured to block or prevent fluid leakage, for example, lateral fluid leakage or fluid leakage in the planar direction or X-Y directions to allow or to guide fluid and gas transport or displacement in or along the resulting or overall fluid and gas flow Z direction of an electrolysis system 100. The seal or sealing means 115 may, for example, comprise a gasket (for example, a flat or planar gasket) or an O-ring. The seal 115 may comprise or consist of polytetrafluoroethylene, or ethylene propylene diene monomer rubber. The seal material is not, however, limited to such materials, and any material tolerant to KOH, de-ionised and/or distilled water can be used.

A seal 115 may, for example, be located either side of a membrane-electrode assembly (MEA) 111, to enclose or sandwich the membrane-electrode assembly (MEA) 111 between two seals 115. A seal 115 may, for example, be located between the membrane-electrode assembly (MEA) 111 and the flow field plate 1, that is a bipolar flow field plate 103 or a unipolar flow field plate 105. The seal 115 may, for example, include both a gasket and an O-ring, that is, a gasket and an O-ring is, for example, located between the membrane-electrode assembly (MEA) 111 and the flow field plate 1. The gasket and the O-ring may, for example, in an embodiment comprise or consist of ethylene propylene diene monomer (EPDM) rubber.

The membrane-electrode assemblies (MEA) 111 may comprise, for example, an anion exchange membrane 117, a cathode electrode or hydrogen evolution reaction HER electrode 119 and an anode electrode 121 or oxygen evolution reaction electrode OER (see, for example Figure 12). The membrane 117 may comprise or consists of, for example, a polymeric anion exchange membrane, that is, for example, a solid polymer electrolyte membrane configured to conduct OH^- anions. The membrane 117 is configured to be impermeable to electrons and other reactants or products and configured to conduct OH^- anions. The membrane 117 may, for example, comprise oxidation-resistant fluorinated polymers, aromatic polymers derived from hydrocarbons, condensation polymers, and/or block polymers. The membrane 117 may, for example, in one embodiment be a polysulfone anion exchange membrane. Exemplary anion exchange membranes may be found, for example, in the publication by Cho Min Kyung, "A Review on Membranes and Catalysts for Anion Exchange Membrane Water Electrolysis Single Cells". In: J. Electrochem. Sci. Technol 8.3 (2017), pp. 183–196. DOI: 10.5229/JECST.2017.8.3.183, the full contents of which is incorporated herein by reference. The electrodes 119, 121 (cathode and anode electrodes) may, for example, be in direct contact with the membrane 117. The electrodes 119, 121 may, for example, comprise or consist of a transition metal, for example, Nickel or titanium.

A seal or sealing means (not shown) may, for example, also be located between the membrane 117 and one or both of the electrodes 119, 121. For example, a seal may be located between the membrane 117 and the cathode or HER electrode 119. The seal or sealing means includes, for example, a gasket (for example, a planar or flat gasket), the gasket may comprise or consist of, for example, polytetrafluoroethylene PTFE.

An exemplary stack of elements between field flow plates 1 (for example between two bipolar field flow plates, or between a bipolar field flow plate 103 and unipolar field flow plate 105) can be assembled, for example in an exemplary embodiment, in the following exemplary order:

i) gasket EPDM ii) O-ring EPDM iii) OER electrode 121 iv) Membrane 117 v) gasket PTFE vi) HER electrode 119 vii) Gasket EPDM viii) O-ring EPDM.

Optionally, the membrane-electrode assembly 111 may include a catalyst or catalyst layer provided on the cathode electrode 119, for example between the membrane 117 and the cathode electrode 119. Optionally, the membrane-electrode assembly 111 may include a catalyst or catalyst layer provided on the anode electrode 121, for example between the membrane 117 and the anode electrode 121.

Figures 17A and 17B schematically show, for illustration and explanatory purposes, an exemplary configuration including two membrane-electrode assemblies (MEA) 11, each membrane-electrode assembly 111 being arranged or located between a unipolar field flow plate 105 and a bipolar field flow plate 103. A membrane-electrode assembly MEA 111 can also be located or arranged between two bipolar field flow plates 103. As already mentioned above, in the exemplary embodiment of Figures 14A and 14B, there are two membrane-electrode assemblies 111 each located between a unipolar field flow plate 105 and a bipolar field flow plate 103, and four membrane-electrode assemblies 111 each located between bipolar field flow plates 103. The membrane-electrode assembly 111 is in contact with each of the field flow plates located either side of the membrane-electrode assembly 111.

The fluid flow structure 5 is schematically illustrated (see, for example, Figure 2) constructed or formed in the body 5 and includes ribs or protrusions 21 defining fluid channels 23 of the field flow plate 1, and of the the unipolar field flow plate 105 and the bipolar field flow plate 103.

Each flow field plate is configured to conduct electrons, and each ensemble of a membrane-electrode assembly 111 between two flow field plate (or an ensemble comprising a first and second flow flied plate and membrane-electrode assembly 111 located therebetween) forms a cell 123 of the system 100. The exemplary embodiment of the system 100 of Figures 14A and 14B includes six membrane-electrode assemblies 111A to 111F. The exemplary embodiment of the system 100 of Figures 14A and 14B includes six cells 123.

Figures 17A and 17B schematically show exemplary configurations of cells 123, each cell 123 includes a membrane-electrode assembly 111 arranged between a unipolar field flow plate 105 and a bipolar field flow plate 103. In comparison, the system 100 of the exemplary embodiment of Figures 14A and 14B additionally includes, for example, a plurality of sets of bipolar plates 103, each set having a membrane-electrode assembly 111 located between a first and second bipolar plate 103.

The stack assembly or system 100 includes a holder 125, or fixation 125 or attachment means 125 configured to hold the above elements that are the first electrical insulator plate 109A, the plurality of cells 123 (for example, the cell 123 comprising the membrane-electrode assembly 111 and the set of field flow plates 103, 105 as described above), and the second electrical insulator plate 109B between the first end plate 107A and the second end plate 107B.

The holder 125, fixation 125 or attachment means 125 may comprise, for example, a compression system CS (for example, a Spring-stud bolt compression system) including a bolt 125A, a spring 125B and a stud or nut 125C, and may as well include a bore or through hole BH located in each of the first end plate 107A and the second end plate 107B. The bolt 125A may for example include a nut or stud 125D. The stack assembly or system 100 includes a plurality of holders 125, fixations 125 or attachment means 125 such as compression systems CS arranged to hold the elements of the stack assembly or system 100 together, for which Figure 14A shows an exemplary embodiment.

In the system 100 of the exemplary embodiment illustrated in Figures 14A and 14B, the first electrical insulator plate 109A, the second electrical insulator plate 109B, the first end plate 107A and the second end plate 107B have a larger planar surface area than the cells 123 or field flow plates, and each include peripheral bores or through holes BH (Figure 14A) located around their periphery.

Amongst these peripheral bores or through holes BH, lateral peripheral bores or through holes BH1 to BH8 are located laterally in each of the end plates 107A, 107B such that a holder 125 or a compression system CS can extend through a lateral peripheral bore BH1…BH8 of the first end plate 107A (see, Figure 14B) and through a lateral peripheral bore BH1…BH8 of the second end plate 107B (see, Figure 14A) without passing through the cells 123. The peripheral bores or through holes BH also include central peripheral bores or through holes BH9 to BH12 (see for example Figure 14A) that are located centrally or between the lateral peripheral bores BH1…BH8. A holder 125 or compression system CS extends through each central peripheral bore BH9…BH12 of the first end plate 107A, through a bore or through hole BHF of the field flow plates 1 (unipolar 105, bipolar 103) located in alignment with the central peripheral bore BH9…BH12, and through a central peripheral bore BH9…BH12 of the second end plate 107B. For example, with reference to Figure 14B, a holder 125 or compression system CS would extend through the central peripheral bore BH9 of the first end plate 107A, a bore or through hole BHI of the first electrical insulator plates 109A, through bores or through holes BHF of the field flow plates, through a bore or through hole BHI of the second electrical insulator plates 109B and through the central peripheral bore BH10 of the second end plate 107B. In the exemplary embodiment of Figures 14A and 14B, each field flow plate 1 includes four bores or through holes BHF, each configured to receive a compression system CS.

As mentioned, the first and second electrical insulator plates 109A, 109B also include bore or through holes BHI through which a holder 125 or a compression system CS also extends

when extending between the first and second end plates 107A, 107B and through the bores or through holes BHF of the field flow plates (see, for example, Figure 14B).

The holders 125 or compression system CS (or Spring-stud bolt compression system) allows the cells 123 to be compressed/clamped together and the cells and the stack assembly or system 100 to be sealed to prevent or restrict unwanted fluid leakage from the cells 123, such as lateral fluid leakage. Each holder 125 or compression system CS is configured to allow the compression/clamping and sealing to be adjusted at different locations across the end plates 107A, 107B and across the stack assembly or system 100 and to obtain an even planar distribution of clamping force. The holders 125 or compression system CS are thus used for sealing the elements and materials of the stack assembly or system 100. The clamp force applied by each holder 125 or compression system CS is, for example, preferably greater than 0.1 kg cm^{-2}. The elements of the holder or compression system CS may, for example, be made from an electrical insulating plastic material such as glass fiber reinforced polyamide, EPDM, PTFE, HDPE, LDPE, PE, PEEK, or PP.

The second end plate 107B (see for example Figures 14A and 14B) includes a fluid inlet passage 127 and a fluid outlet passage 129. The second electrical insulator plate 109B (see for example Figure 14B) includes a fluid inlet passage 127B and a fluid outlet passage 129B aligned with those of the second end plates 107B.

In the exemplary embodiment, the fluid inlet passage 127 is configured to receive a fluid supply component or coupling 131 (see Figure 14A), such as standard Swagelok components, to supply fluid into the stack assembly or system 100. Fluid is communicated through the fluid inlet passages 127, 127B to the inlet fluid communication chambers 15 of the field flow plates 1 (unipolar 105, bipolar 103) and to the plurality of entities or units 7 and/or through the channels 23 and/or to elements of the fluid flow structure, arrangement or design 5 for electrolysis.

In the exemplary embodiment, the fluid outlet passage 129 is configured to receive a fluid evacuation component or coupling 133, such as a standard Swagelok component, to evacuate fluid from the stack assembly or system 100. Fluid and gas/gases exits the field flow plates 1 (unipolar 105, bipolar 103) via the outlet fluid communication chambers 18 or the outlets 9 and is communicated to the fluid outlet passage 129 of the second end plate 107B via the fluid outlet passage 129B of the second electrical insulator plate 109B.

To allow (water) electrolysis to be performed, the or each cathode electrode or hydrogen evolution reaction HER electrode 119 is configured to be connected to or is connected to a DC power source/supply (to the negative polarity or side of the DC power source/supply). The or each anode electrode or oxygen evolution reaction electrode 121 is configured to be connected to or is connected to the DC power source/supply (to the positive polarity or side of DC power source/supply).

This is, for example, done via the unipolar field flow plates 105 and the bipolar field flow plates 103. The or each unipolar field flow plate and the or each bipolar field flow plate can include, for example, a connection terminal to which the DC power source/supply is or can be connected. The cathode electrode(s) and the anode electrode(s) can thus be connected to the terminals of the DC power source/supply via one or more unipolar field flow plates 105, or via one or more unipolar field flow plates 105 and one or more bipolar field flow plates 103.

A non-limiting exemplary illustration and arrangement of such a connection configuration which is, for example, a series connection is shown in Figure 17A. Figure 17A shows first and second unipolar field flow plates 105A, 105B and one bipolar field flow plate 103 connected to the electrodes of the membrane-electrode assemblies 111. The positive polarity of the DC power source/supply is applied or is in electrical connection with the first unipolar field flow plate 105A, and the negative polarity of the DC power source/supply is applied or is in electrical connection with the second unipolar field flow plate 105B to form the series connection which allows (water) electrolysis to be performed. This principal can be similarly applied when multiple membrane-electrode assemblies 111 and multiple bipolar field flow plates 103 are present to provide electricity or an electric current to the anode and cathode electrodes for electrolysis to be performed, for example, in the exemplary configuration of the system 100 of Figures 14A and 14B.

Another non-limiting exemplary illustration of such a connection configuration which is, for example, a parallel connection is shown in Figure 17B also showing two unipolar field flow plates 105 and one bipolar field flow plate 103 connected to the electrodes of the membrane-electrode assemblies 111. One of the membrane-electrode assemblies 111 is oriented differently to the other so that the bipolar field flow plate is in electrical connection with the cathode electrodes 119 of each of the two membrane-electrode assembly 111 thus allowing the negative polarity of the DC power source/supply to be simultaneously in electrical connection with the cathode electrodes of each of the two membrane-electrode assemblies 111 via the bipolar field flow plate 103. Each of the unipolar field flow plates 105 are connected to one anode electrode 121 of one membrane-electrode assembly 111, and the positive

polarity of the DC power source/supply is, for example, in electrical connection with both unipolar field flow plates 105. This principal can be similarly applied when multiple membrane-electrode assemblies 111 and multiple bipolar field flow plates 103 are present to provide electricity or an electric current to the anode and cathode electrodes for electrolysis to be performed, for example, in the exemplary configuration of the system 100 of Figures 14A and 14B.

Figure 12 schematically shows exemplary membrane-electrode assemblies 111 and, more particularly, a cathode-membrane-anode configuration for which three different operating configurations can be performed for electrolysis to be carried out. Figure 12A shows a standard Anion Exchange Membrane Water Electrolyzer operating condition based on a classical alkaline electrolyzer mode of operation that is H_2O, aq. KOH fed to both the cathode and anode. Figure 12B shows minimum requirements for Anion Exchange Membrane Water Electrolyzer operation with H_2O, aq. KOH fed to the cathode only. Figure 12C shows an extended Anion Exchange Membrane Water Electrolyzer operation in which H_2O, aq. KOH is fed to the anode only.

The AEMWE assembly 100 may include a cathode-membrane-anode configuration 111 as shown in Figures 12A to 12C. The electricity is applied at the anode and cathode layers. Internally, the membrane 117 drives the ionic current with OH- as a charge carrier to complete the current loop. The anode and cathode layers may for example contain one or more transition metals such as Nickel or titanium, and alkali earth metal-based catalysts (such as those alkali earth metals disclosed above) and may or may not be symmetric in geometry. The reactions occurring at the cathode, anode and membrane electrode assembly 111 are shown in equations (1), (2) and (3), respectively. During water electrolysis, the membrane 117 separates the generated H_2 and O_2 gases.

$$4H_2O + 4e^- \longrightarrow 4OH^- + 2H_2 \quad (1)$$

$$4OH^- \longrightarrow +O_2 + 2H_2O + 4e^- \quad (2)$$

$$4H_2O \longrightarrow +O_2 + 2H_2O + 4H_2 \quad (3)$$

The liquid electrolyte comprises or consists of, for example, KOH and deionized (DI) water in the concentration range of, for example, 0 to 3 M. The type of electrolyte feed (with recirculation) can be changed based on the requirements.

The standard configuration (Figure 12A) supplies liquid for both cathodic and anodic reactions. The minimum required configuration to drive the water-splitting reaction, is liquid electrolyte feed at the cathode, as shown in Figure (12B), which results in humidified O_2 while having wet hydrogen. In such a case, the stack assembly or system 100 is configured to communicate fluid or liquid to only the flow field plates 1 and/or through the fluid flow structures 5 or channels 23 in contact or fluid communication with the cathode of the membrane electrode assembly 111. Similarly, the liquid electrolyte can be fed only at the anode in an extended configuration, as shown in Figure 12C, benefitting from the generation of humid hydrogen, simplifying the drying process. The water is delivered to the cathode due to diffusion. In such as case, the stack assembly or system 100 is configured to communicate fluid or liquid to only the flow field plates 1 and/or through the fluid flow structures 5 or channels 23 in contact or fluid communication with the anode of the membrane electrode assembly 111.

As previously mentioned, the flow field plate 1 and/or the body 3 includes the plurality of entities or units 7 configured to direct or guide the flow of the fluid and/or gas/gases through the body 3 and through the flow field plate 1 to the outlet 9 (see, for example, Figure 1) through which the fluid and/or gas/gases exit the flow field plate 1.

The design of the flow field plate 1 and the exemplary AEMWE system 100 of the present disclosure surpasses the standard parallel, serpentine, and multi-parallel serpentine flow channel designs by incorporating a curved or inclined shape profile within the flow field design of the flow field plate 1. This design enhancement significantly improves the homogeneity of the electrolysis reaction and substantially reduces the pressure drop. The flow field plate 1 of the present disclosure improves the multi-parallel serpentine design by enhancing the velocity profile and reducing the pressure drop. The improved multi-parallel serpentine design can be considered an inwardly inclined or ‘curved’ Multi-Parallel Serpentine (MPS) design and represents an advancement over the straight MPS design. Figure 5A schematically shows the straight MPS design and Figure 5B schematically shows an exemplary embodiment of the ‘curved’ Multi-Parallel Serpentine (MPS) design of the present disclosure.

The electrolyzer flow field plate 1 includes, for example, a plurality of flow entities or units 7. For example, the flow field plate 1 of the exemplary embodiment of Figure 1 includes flow entities or units 7A to 7I.

The electrolyzer flow field plate 1 comprises (see, for example, Figure 2) the first flow entity 7A, the second flow entity 7B, and an intermediate elongated rib or protrusion 25A located between and separating the first fluid flow entity 7A and the second flow entity 7B.

The electrolyzer flow field plate 1 may further comprise at least one further intermediate elongated rib or protrusion 25B, or a plurality of further intermediate elongated ribs or protrusions 25C, 25D, 25E, 25F…, and an outlet support wall 26 (see Figure 1) of the fluid flow structure, arrangement or design 5, the body 3, the electrolyzer flow field plate 1 or the flow entity 7.

In one particular embodiment, the electrolyzer flow field plate 1 may not comprise further intermediate elongated ribs or protrusions 25B and may comprise the outlet support wall 26 delimiting or defining a fluid outlet 33 of the second flow entity 7B. In such an embodiment, the electrolyzer flow field plate 1 contains only two flow entities 7 that are first and second flow entities 7A, 7B and the second flow entity fluid outlet 33 is delimited or defined by the outlet support wall 26 of the flow field plate 1.

The first flow entity 7A is configured to receive the fluid for electrolysis from a first flow entity fluid inlet 27 and configured to communicate the fluid to a first flow entity fluid outlet 29. The first flow entity fluid inlet 27 is in fluid communication with the inlet fluid communication chamber 15 and the inlet canal or passage 16. The first flow entity fluid inlet 27 is, for example, defined or delimited by the inlet canal or passage 16 defined or delimited by a support wall or inlet support wall 37 of the plate 1.

The support wall or inlet support wall 37 may include or define the fluid inlet 27, and/or the inlet fluid communication chamber 15 and/or the inlet canal or passage 16.

The inlet support wall 37 may, for example, be located opposite the outlet support wall 26 of the flow field plate 1. The inlet support wall 37 and the outlet support wall 26 may, for example, be located at opposite extremities of the flow field plate 1. A first lateral or side wall 39A and a second lateral or side wall 39B extend, for example, between the inlet support wall 37 and the outlet support wall 26. The inlet support wall 37 and the outlet support wall 26 may be elongated and may extend, for example, in an elongated direction that is the same elongated direction of extension as the one or more intermediate elongated ribs or protrusions 25 and/or the elongated channel ribs 21.

The first side wall 39A and the second side wall 39B may also be elongated and may extend, for example, in an elongated direction between the inlet support wall 37 and the outlet support wall 26, the elongated direction of extension being non-parallel or, for example, substantially

perpendicular to that of the one or more intermediate elongated ribs or protrusions 25 and/or the elongated channel ribs 21.

The inlet support wall 37 and the outlet support wall 26 may be transverse to the first side wall 39A and the second side wall 39B or an inner surface of the first side wall 39A and the second side wall 39B. The one or more intermediate elongated ribs or protrusions 25 and/or the elongated channel ribs 21 may extend transversely with respect to the first side wall 39A and the second side wall 39B or with respect to an inner surface of the first side wall 39A and the second side wall 39B.

It is noted that the above equally applies to all embodiments of the present the disclosure and not only to the particular embodiment of an electrolyzer flow field plate 1 that contains only two flow entities 7 that are first and second flow entities 7A, 7B.

The second flow entity 7B includes a second flow entity fluid inlet 31 and a second flow entity fluid outlet 33. The second flow entity fluid inlet 31 is in fluid communication with the first flow entity fluid outlet 29. The second flow entity fluid inlet 31 is configured to receive the fluid from the first flow entity fluid outlet 29 permitting the first flow entity 7A to communicate or transfer the fluid (and gas/gases) to the second flow entity 7B.

The intermediate elongated rib 25A is located between the first fluid flow entity 7A and the second flow entity 7B. The intermediate elongated rib 25A (partially) separates the first fluid flow entity 7A and the second flow entity 7B. The intermediate elongated rib 25A (or a surface thereof) defines or delimits (partially or at least partially) the first flow entity fluid outlet 29 and the second flow entity fluid inlet 31.

The intermediate elongated rib or each intermediate elongated rib extends outwards from the floor FL of the body 3 or of the plate 1 (for example, in the Z-direction).

The further intermediate elongated rib 25B delimits or defines (partially or at least partially) the second flow entity fluid outlet 33. In an embodiment including more than two flow entities or units 7, the second flow entity fluid outlet 33 may, for example, be in fluid communication with a flow entity fluid inlet of an additional flow entity that is, for example, a third flow entity 7C. Such embodiments are discussed further below. The immediate description relating to the two flow entity or unit 7 embodiment also, however, concerns embodiments including more than two flow entities or units 7.

The first flow entity 7A includes a fluid cavity 35A delimited by the intermediate elongated rib 25A (or a surface thereof), by the support wall 37 (or a surface thereof) as well as the first 39A and second 39B side walls (or surfaces thereof) of the fluid flow structure, arrangement or design 5, the body 3, the electrolyzer flow field plate 1 or first flow entity 7A. The support wall 37 of the electrolyzer flow field plate 1 is, for example, the flow field plate inlet wall delimiting or defining the first flow entity fluid inlet 27.

The fluid cavity 35A comprises a fluid entrance extremity FE1 and a fluid exit extremity FE2.

The first flow entity 7A includes the plurality of elongated channel ribs or protrusions 21 located inside the fluid cavity 35A. Each elongated channel rib 21 extends outwards from the floor FL of the fluid cavity 35A (or of the body 3 or the plate 1). Each elongated channel rib 21 extends, for example, in an elongated manner from the fluid entrance extremity FE1 to the fluid exit extremity FE2 to delimit or define the plurality of elongated fluid channels 23 for communicating the fluid to a first fluid passage or artery 41 located in or at the fluid exit extremity FE2 of the fluid cavity 35A.

Each elongated channel rib 21 extends from the fluid entrance extremity FE1 to the fluid exit extremity FE2 in a fluid flow direction towards a boundary surface delimiting the fluid cavity.

The fluid passage or artery is, for example, configured to redirect the fluid (and gas/gases) flow or to change a flow direction of the fluid received into the fluid passage or artery. The first fluid passage or artery 41, for example, redirects (lateral) fluid flow in a direction towards the lateral wall 39A and parallel to the elongation direction of extension of the fluid channel 23 to a direction of extension of the lateral wall 39A (or a surface S1 thereof), to redirect the fluid into a directly neighboring flow entity 7B and a fluid passage or artery thereof.

The elongated channel ribs 21 (or each elongated channel rib 21) extend traverse to the direction of extension of the first 39A and second 39B lateral/side walls (and/or the inner surfaces thereof) extending between the inlet 11 containing wall 37 and/or the outlet 9 containing wall 26.

The elongated fluid channels 23 (or each elongated fluid channel 23) extend, for example, traverse to the direction of extension of the first 39A and second 39B lateral/side walls (and/or the inner surfaces thereof) extending between the (i) the inlet containing extremity of the flow field plate 1 or wall and (ii) the outlet containing extremity of the flow field plate 1 or wall.

The fluid cavity 35, the inlets, the outlets, the fluid passage 41, the elongated channel ribs 21, the intermediate elongated ribs 25B and the fluid channels 23 are, for example, formed or constructed by removal of material of the body 3, such as by chemical etching, stamping, and/or Computer Numerical Control (CNC) milling), to define the flow pattern elements of the plate 1.

The first flow entity 7A includes, for example, the support wall 37 (or the inlet support 37), the first side wall 39A (or a portion thereof) and the second side wall 39B (or a portion thereof). As mentioned, the first side wall 39A and the second side walls 39B extend away from the support wall 37. A first side wall surface S1 (or a portion thereof) of the first side wall 39A and a second side wall surface S2 (or a portion thereof) of the second side wall 39B delimit or define the fluid cavity 35A in which the plurality of elongated channel ribs 21 are located. The plurality of elongated channel ribs 21 are located between the first side wall surface S1 (or a portion thereof) and the second side wall surface S2 (or a portion thereof).

The first side wall surface S1 extends in a side wall surface direction of extension (for example the Y-direction in the exemplary embodiment of Figure 2). The elongated channel ribs 21 extend in an elongated direction that is different to the side wall surface direction of extension.

The side wall surface direction of extension extends, for example, in an elongated manner and in a direction that is traverse to the elongated direction of extension of the elongated channel ribs 21, or traverse between the first side wall surface S1 and the second side wall surface S2.

The elongated channel ribs 21 extend, for example, in an elongated manner or direction between the first side wall surface S1 and the second side wall surface S2, and extend in an elongated direction traverse to the (elongated) direction of extension of the first side wall surface S1 and/or the second side wall surface S2.

The elongated channel ribs 21 extend, for example, in an elongated manner or direction that is non-parallel to the (elongated) direction of extension of the first side wall surface S1 and/or the second side wall surface S2.

A plurality of elongated channel ribs 21 are, for example, successively located, and/or are elongated transversely in the flow entity 7 and/or the fluid cavity 35A, between the inlet support wall 37 and the outlet support wall 26, and/or between the inlet canal 27 and the outlet canal 17 or the flow entity fluid outlet.

Each of the elongated channel ribs 21 of the flow entity 7 and/or the fluid cavity 35A extend to form or provide or define the elongated fluid channels 23, and each elongated fluid channel 23 of the flow entity 7 and/or the fluid cavity 35A is configured to communicate and/or guide the fluid (and gas/gases) from one side wall surface to the other side wall surface of the lateral walls, and/or to communicate and/or guide the fluid (and gas/gases) between opposing fluid passage or arteries of the flow entity 7 and/or the fluid cavity 35A (for example between the second fluid passage 43 and the first fluid passage 41 in the first the flow entity 7A).

The first fluid passage 41 extends between the support wall 37 (or a surface thereof) of the electrolyzer flow field plate 1 and the intermediate elongated rib 25A and to the first flow entity fluid outlet 29, and the first fluid passage 41 is in fluid communication with the first flow entity fluid outlet 29. The first fluid passage 41 is delimited, for example, by the first side wall 39A (or a surface thereof). Each of the elongated channel ribs 21 is located consecutively between the support wall 37 (or a surface thereof) of the electrolyzer flow field plate 1 and the intermediate elongated rib 25A (or a surface thereof). That is, the elongated channel rib 21 are sequentially located in the fluid cavity 35A with one fluid channel 23 being located between two immediately neighboring elongated channel ribs 21.

Each elongated channel rib 21 of the first flow entity 7A extends to an elongated channel rib head or tip TP1 located in the fluid exit extremity FE2 of the first flow entity 7A. Each elongated channel rib tip TP1 is located opposite a first side wall surface S1 of the fluid cavity 35A or opposite the first side wall surface S1 or first inner side wall surface S1 that delimits the fluid cavity 35A.

The elongated channel rib head or tips TP1 may, for example, have a surface facing or opposite the first side wall surface S1 that is curved or rounded in form or shape, as for example seen in the exemplary embodiment of Figures 1 and 2.

The first side wall surface S1 is defined by a first side wall 39A of the fluid flow structure, arrangement or design 5, the electrolyzer flow field plate 1 or the first flow entity 7A.

The first inner side wall surface S1, and generally the inner side wall surfaces S, S1, S2 of the fluid flow structure 5, may extend for example (substantially) straight in, for example, the Y-direction or a direction of the other or neighboring flow entities 7 as illustrated in the exemplary embodiment of the Figures. Alternatively, the first inner side wall surface S1, and some or each the inner side wall surfaces S, S1, S2 of the fluid flow structure 5, may extend in a curved

manner (for example, a circular curve) that is curved outwardly or externally, for example, in a direction away from the geometric center of the flow field plate and towards the external surface of the flow field plate 1.

Each elongated channel rib tip TP1 is located at a different separation distance d1 from the first side wall surface S1. The separation distance d1 is, for example, the shortest distance between the elongated channel rib tip TP1 and the first side wall surface S1.

The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively increases for each consecutive elongated channel rib 21 located consecutively between the support wall 37 and the intermediate elongated rib 25A. The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively increases such that the first fluid passage 41 widens, or increases in size/volume between the support wall 37 and the intermediate elongated rib 25A. The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively increases such that the elongated channel rib tips TP1 and the first fluid passage 41 form an inwardly sloped profile (for example, inwardly of the plate 1) or inwardly inclined profile for the first fluid passage 41.

The tips of the elongated channel ribs 21 in the fluid exit extremity FE2 of the fluid cavity of the first flow entity 7A form a cascade profile or an inwardly inclined cascade profile.

Each elongated channel rib 21 of the first flow entity 7A also extends to a second elongated channel rib tip TP2 located in the fluid entrance extremity FE1 of the first flow entity 7A. A fluid passage 43 (second of the first flow entity 7A) is located in or at the fluid entrance extremity FE1 of the fluid cavity 35A. The fluid passage 43 extends between (i) the support wall 37 (or a surface thereof) and/or the first flow entity fluid inlet 27 and (ii) the intermediate elongated rib 25A (or a surface thereof). The fluid passage 43 is delimited by the second side wall 39B (or a surface thereof).

Each second elongated channel rib tip TP2 is located opposite a second side wall surface S2 of the fluid cavity 35A or opposite the second side wall surface S2 that delimits the fluid cavity 35A. The second side wall surface S2 is defined by the second side wall 39B of the body 3 and/or plate 1.

The elongated channel rib head or tips TP2 may, for example, have a surface facing or opposite the first side wall surface S2 that is curved or rounded in form or shape, as for example seen in the exemplary embodiment of Figures 1 and 2.

Each second elongated channel rib tip TP2 is located at a different distance d2 from the second side wall surface S2. The distance d2 between the second elongated channel rib tip TP2 and the second side wall surface S2 consecutively decreases for each consecutive elongated channel rib 21 located consecutively between the support wall 37 and the intermediate elongated rib 25A (for example, in a direction towards the intermediate elongated rib 25A).

The distance d2 between the second elongated channel rib tip TP2 and the second side wall surface S2 consecutively decreases such that the second fluid passage 43 narrows or decreases in size/volume between the support wall 37 and the intermediate elongated rib 25A. The distance d2 between the elongated channel rib tip TP2 and the second side wall surface S2 consecutively decreases in a direction from the support wall 37 towards the the intermediate elongated rib 25A such that the elongated channel rib tips TP2 and the fluid passage 43 form an outwardly (towards the exterior of the plate 1) sloped profile or outwardly inclined profile for the fluid passage 43. The distance d2 between the elongated channel rib tip TP2 and the second side wall surface S2 consecutively increases in a direction from the intermediate elongated rib 25A towards the support wall 37 such that the elongated channel rib tips TP2 and the fluid passage 43 form an inwardly sloped profile or inwardly inclined profile for the fluid passage 43.

The tips TP2 of the elongated channel ribs 21 in the fluid entrance extremity FE1 of the at least one fluid cavity of the first flow entity form a cascade profile.

The second fluid passage or artery 43, for example, redirects fluid flow flowing into the first flow entity 7a from the inlet canal 27 into a direction towards the lateral wall 39A and parallel to the elongation direction of extension of the fluid channel 23.

The intermediate elongated rib 25A is in contact with the second side wall 39B. The intermediate elongated rib 25A extends from the second side wall 39B of the electrolyzer flow field plate 1 towards the first side wall 39A and extends between the first fluid flow entity 7A and the second flow entity 7B. The second side wall 39B includes an elongated extension extending between the elongated channel ribs 21 of the first and second flow entities 7A, 7B, and the elongated extension defines the intermediate elongated rib 25A.

The intermediate elongated rib 25A delimits or defines an elongated fluid channel 23 of the first flow entity 7A located between the intermediate elongated rib 25A and the closest

neighboring elongated channel rib 21 of the first flow entity 7A. The intermediate elongated rib 25A may also delimit or define an elongated fluid channel 23 of the second flow entity 7B located between the intermediate elongated rib 25A and the closest neighboring elongated channel rib 21 of the second flow entity 7A.

The intermediate elongated rib 25A extends between the first fluid flow entity 7A and the second flow entity 7B and includes an intermediate elongated rib tip or head TPI located a distance d3 from the first side wall surface S1 to define or delimit the first flow entity fluid outlet 29, and/or the second flow entity fluid inlet 31.

The intermediate elongated rib tip TPI is, for example, located at a distance d3 from the first side wall surface S1 that is equal or substantially equal or less than the separation distance d1 of the closest neighboring elongated channel rib 21 of the first flow entity 7A and/or the second flow entity 7B from the first side wall surface S1. The intermediate elongated rib tip TPI is, for example, located at a distance d3 from the first side wall surface S1 that is substantially equal or less than the separation distance d1 of the elongated rib tip TP of the closest neighboring elongated channel rib 21 of the first flow entity 7A and/or the second flow entity 7B from the first side wall surface S1.

The intermediate elongated rib tip TPI is, for example, located at a distance d3 from the first side wall surface S1 that is equal or substantially equal or less than the separation distance d1 of each of the elongated channel ribs 21 of the first flow entity 7A and/or the second flow entity 7B from the first side wall surface S1. The intermediate elongated rib tip TPI is, for example, located at a distance d3 from the first side wall surface S1 that is (substantially) equal or less than the separation distance d1 of the elongated rib tip TP of each of the elongated channel ribs 21 of the first flow entity 7A and/or the second flow entity 7B from the first side wall surface S1.

Similarly, the second flow entity 7B also includes a fluid cavity 35B delimited or defined by the intermediate elongated rib 25A (or a surface thereof), the first 39A and second 39B side walls (or surfaces thereof), and the further intermediate elongated rib 25B (or a surface thereof).

In the above mentioned exemplary embodiment in which the electrolyzer flow field plate 1 may contain only two flow entities 7 that are first and second flow entities 7A, 7B and the second flow entity fluid outlet 33 is delimited or defined by the outlet support wall 26 of the flow field plate 1, the fluid cavity 35B of the second flow entity 7B is delimited or defined by the

intermediate elongated rib 25A (or a surface thereof), the first 39A and second 39B side walls (or surfaces thereof), and the outlet support wall 26 (or a surface thereof).

Similarly, the fluid cavity 35B comprises a fluid entrance extremity FE1 and a fluid exit extremity FE2, and a plurality of elongated channel ribs or protrusions 21 located inside the fluid cavity 35B with each elongated channel rib 21 extending from the fluid entrance extremity FE1 to the fluid exit extremity FE2 to delimit or define a plurality of elongated fluid channels 23 for communicating the fluid to the second flow entity fluid outlet 33 (or the outlet of the outlet support wall 26 in the above mentioned embodiment in which the electrolyzer flow field plate 1 contains only two flow entities 7).

The outlet support wall 26 delimits or defines the second flow entity fluid outlet 33 or the electrolyzer flow field plate outlet 9. The outlet support wall 26 may further include the outlet chamber 18 and the outlet canal 17 that is in fluid communication with the second flow entity fluid outlet 33 or the electrolyzer flow field plate outlet 9 to remove fluid from the electrolyzer flow field plate.

The fluid entrance extremity FE1 of fluid cavity 35B of the second flow entity 7B is directly in fluid communication with the fluid exit extremity FE2 of fluid cavity 35A of the first flow entity 7A. The fluid entrance extremity FE1 of fluid cavity 35B of the second flow entity 7B is located at an opposite end of the flow field plate 1 or flow entity to that of the fluid entrance extremity FE1 of fluid cavity 35A of the first flow entity 7A.

Each of the elongated channel ribs 21 is similarly also located consecutively, and located between the intermediate elongated rib 25A and the further intermediate elongated rib 25B.

Each elongated channel rib 21 of the second flow entity 7B also extends to an elongated channel rib tip TP1 located in the fluid entrance extremity FE1 of the second flow entity 7B, and each elongated channel rib tip TP1 is located opposite the first side wall surface S1.

Each elongated channel rib tip TP1 is located at a different distance d1 from the first side wall surface S1. The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively decreases for each consecutive elongated channel rib 21 located consecutively between the intermediate elongated rib 25A and the at least one further intermediate elongated rib 25B (or the outlet support wall 26). The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively decreases for each consecutive elongated channel rib 21 located consecutively in a direction from the

intermediate elongated rib 25A to the at least one further intermediate elongated rib 25B (or the outlet support wall 26).

The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively decreases such that a fluid passage 45 narrows or decreases in size/volume between the intermediate elongated rib 25A and the further intermediate elongated rib 25B (or the outlet support wall 26). The fluid passage 45 extends between the intermediate elongated rib 25A and the further intermediate elongated rib 25B (or the outlet support wall 26). The fluid passage 45 is delimited by the first side wall 39A (or the surface S1 thereof). The fluid passage 45 is in fluid communication with the first flow entity fluid outlet 29. The distance d1 between the elongated channel rib tip TP1 and the first side wall surface S1 consecutively decreases such that the elongated channel rib tips TP1 and the fluid passage 45 form an inwardly sloped profile or inwardly inclined profile for the fluid passage 45. For example, inwardly inclined in a direction from the further intermediate elongated rib 25B to the intermediate elongated rib 25A, or outwardly inclined in a direction from the intermediate elongated rib 25A to the further intermediate elongated rib 25B.

The tips of the elongated channel ribs 21 in the fluid entrance extremity FE1 of the fluid cavity of the second flow entity 7B form a cascade profile.

The fluid passage 45 (first of the second flow entity 7B) is located in or at the fluid entrance extremity FE1 of the fluid cavity 35B. The fluid passage 45 extends between the second flow entity fluid inlet 29 and the further intermediate elongated rib 25B.

The fluid passage or artery 45, for example, redirects fluid flow flowing into the second flow entity 7b from the second flow entity 7b into a direction towards the second lateral wall 39B and parallel to the elongation direction of extension of the fluid channel 23.

Each elongated channel rib 21 of the second flow entity 7B extends to an elongated channel rib tip TP2 located in the fluid exit extremity FE2 of the second flow entity 7B. Each elongated channel rib tip TP2 is located opposite the second side wall surface S2 delimiting the fluid cavity 35B of the second flow entity 7B. The second side wall surface S2 is defined by the second side wall 39B.

Each elongated channel rib tip TP2 is located at a different distance d2 from the second side wall surface S2. The distance d2 between the elongated channel rib tip TP2 and the second side wall surface S2 consecutively increases for each consecutive elongated channel rib 21

located consecutively between the intermediate elongated rib 25A and the further intermediate elongated rib 25B (or the outlet support wall 26).

The distance d2 between the elongated channel rib tip TP2 and the second side wall surface S2, for example, consecutively increases for each consecutive elongated channel rib 21 located consecutively in a direction from the intermediate elongated rib 25A and to the further intermediate elongated rib 25B (or the outlet support wall 26).

The distance d2 between the elongated channel rib tip TP2 and the second side wall surface S2 consecutively increases such that a fluid passage 47 (second fluid passage of the fluid cavity 35B) widens or increases in size/volume between the intermediate elongated rib 25A and the further intermediate elongated rib 25B (or the outlet support wall 26). The distance d2 between the elongated channel rib tip TP2 and the second side wall surface S2 consecutively increases such that the elongated channel rib tips TP2 and the fluid passage 47 form an inwardly sloped profile or inwardly inclined profile for the fluid passage 47.

The tips of the elongated channel ribs 21 in the fluid exit extremity FE2 of the fluid cavity of the second flow entity 7B form a cascade profile or an inwardly inclined cascade profile.

The fluid passage 47 (second of the second flow entity 7B) is located in or at the fluid exit extremity FE2 of the fluid cavity 35B. The fluid passage 47 extends between the intermediate elongated rib 25A (or a surface thereof) and the further intermediate elongated rib 25B (or the outlet support wall 26). The fluid passage 47 is in fluid communication with the second flow entity fluid outlet 33 (or the outlet of the outlet support wall 26 in the above-mentioned embodiment in which the electrolyzer flow field plate 1 contains only two flow entities 7). The fluid passage 47 is delimited, for example, by the second side wall 39B (or the surface S2 thereof).

The fluid passage or artery 47, for example, redirects fluid flow flowing to the fluid exit extremity FE2 of the fluid cavity 35B of the second flow entity 7b into a direction towards and/or into the fluid outlet 33 which in one embodiment may be the fluid outlet of the plate 1.

In an alternative embodiment, such as illustrated in Figures 1 and 2, the fluid passage or artery 47redirects fluid flow flowing to the fluid exit extremity FE2 of the fluid cavity 35B of the second flow entity 7b into a direction towards and/or into the fluid outlet 33 and into a directly neighboring flow entity (7C) and a fluid passage or artery (49) thereof. In such a case, a third flow entity fluid inlet is in fluid communication with the second flow entity fluid outlet 33. The

third flow entity fluid inlet is configured to receive the fluid from the outlet 33 permitting the second flow entity 7B to communicate or transfer the fluid (and gas/gases) from the second flow entity 7B to the third flow entity 7C.

The further intermediate elongated rib 25B is in contact with the first side wall 39A. The further intermediate elongated rib 25B extends from the first side wall 39A of the electrolyzer flow field plate 1 towards the second side wall 39B. The first side wall 39A includes an elongated extension extending in the same direction as the elongated channel ribs 21 of the first and/or second flow entities 7A, 7B, and the elongated extension defines the further intermediate elongated rib.

The further intermediate elongated rib 25B extends towards the second side wall surface S2 and includes a further intermediate elongated rib tip TPI located a distance d4 from the second side wall surface S2. The further intermediate elongated rib tip TPI located opposite the second side wall surface S2 to define or delimit the second flow entity fluid outlet 33.

The first side wall surface S1 may be defined by the first side wall 39A of the first flow entity 7A or of the second flow entity 7B. The second side wall surface S2 may be is defined by the second side wall 39B of the first flow entity 7A or of the second flow entity 7B.

The above description describes details of two flow entities 7, that are the first and second flow entities 7A,7B. While the electrolyzer flow field plate 1 may contain only two flow entities 7A,7B in one exemplary embodiment, the electrolyzer flow field plate 1 may also include multiple flow entities 7, as for example shown in the exemplary embodiment of Figure 3A that shows the electrolyzer flow field plate 1 including a total of nine flow entities 7, and in the exemplary embodiment of Figure 3B that shows the electrolyzer flow field plate 1 including a total of ten flow entities 7. In such a case, the electrolyzer flow field plate 1 includes additional flow entities 7 similar or identical to the first and second flow entities 7A,7B. That is, a third flow entity 7C is similar or identical to the first flow entity 7A with the third flow entity fluid inlet 49 being connected in fluid communication to the second flow entity fluid outlet 33 of the second flow entity 7B. The fourth flow entity 7D is similar or identical to the second flow entity 7B with the fourth flow entity fluid inlet being connected in fluid communication to the third flow entity fluid outlet of the third flow entity 7B. The electrolyzer flow field plate 1 my thus include additional flow entities 7 such as third and fourth flow entities 7C,7D, or yet further flow entities 7 such as fifth and sixth flow entities 7E,7F, and so on, to include the desired number of total flow entities 7.

The third flow entity 7C includes a third flow entity fluid inlet 49 and a third flow entity fluid outlet 51. The third flow entity fluid inlet 49 is configured to receive the fluid from the second flow entity fluid outlet 33.

The fourth flow entity 7D includes a fourth flow entity fluid inlet and a fourth flow entity fluid outlet, and the fourth flow entity fluid inlet being configured to receive the fluid from the third flow entity fluid outlet 51.

The further intermediate elongated rib 25B is located between and separates the second fluid flow entity 7B and the third flow entity 7C. Yet a further intermediate elongated rib 25C is located between and separates the third fluid flow entity 7C and the fourth flow entity 7D. The plate 1 thus includes multiple intermediate elongated ribs 25 located between and separating the fluid flow entities (see, for example, Figure 1).

The exemplary embodiment of Figure 3B shows the electrolyzer flow field plate 1 including a total of ten flow entities 7 in which the flow entity fluid outlet of the tenth flow entity directly communicates with outlet fluid communication passage 17 of the outlet 9 to remove fluid and/or gas/gases from the flow field plate 1. The exemplary embodiment of Figure 3A (and Figure 1) shows the electrolyzer flow field plate 1 including a total of nine flow entities 7 in which the flow entity fluid outlet of the ninth flow entity directly communicates with outlet fluid communication passage 17 of the outlet 9 to remove fluid and/or gas/gases from the flow field plate 1.

The electrolyzer flow field plate 1 having an even number of flow entities 7 may thus further include at least one or a plurality of additional sets of the first and a second flow entities 7C, 7D in fluid communication with the first flow entity 7A and the second flow entity 7B, where the additional first flow entity (7C, 7E) of the set may be identical to the first flow entity 7A, and the additional second flow entity (7D, 7F) of the set may be identical to the second flow entity 7B. A further flow entity 7 that may be identical to the first flow entity 7A may be added to provide an electrolyzer flow field plate 1 having an odd number of flow entities 7.

As previously mentioned, the electrolyzer flow field plate 1 is, for example, for an anion exchange membrane water electrolyzer or for anion exchange membrane water electrolysis. The electrolyzer flow field plate is, for example, an anion exchange membrane water electrolyzer flow field plate or an anion exchange membrane water electrolysis flow field plate.

The innovative flow channel design implemented on the flow field plate FFP 1 offers a superior flow distribution characterised by homogeneity, minimal pressure drop, and favourable flow velocity, distinguishing it from other designs utilised in AELs as well as in other electrolysers / fuel cells technologies. Achieving a homogeneous flow distribution is important for optimising reactant dispersion and facilitating efficient removal of reaction products from the electrode's active area. This, in turn, promotes uniform reactions, resulting in increased reaction rate efficiency.

Simultaneously, the inclusion of a minimal pressure drop feature enhances the overall stack efficiency by reducing the power requirements for electrolytes recirculation. As a result, less energy is needed to facilitate the reaction of the same amount of fluid within the system. Consequently, this design enhancement contributes to the overall system's improved efficiency.

The novel design of the AEMWE system of the present disclosure surpasses the standard parallel, serpentine, and multi-parallel serpentine flow channel designs by incorporating the ‘curved’ shape within the flow field design. This design enhancement significantly improves the homogeneity of the reaction and substantially reduces the pressure drop.

The ‘curved’ Multi-Parallel Serpentine (MPS) design of the present disclosure represents an advancement over the straight MPS design. It features, for example, a cascade-shaped curvature between each repeating unit 7, as for example depicted in Figure 3A, which enhances fluid distribution and velocity profile. Notably, each entity 7 in the design exhibits two such cascade shapes; one at the inlet and another at the outlet. The ribs 21 within the entity 7 are strategically arranged in a cascade organization, forming for example a parallelogram or parallelogram peripheral form that promotes uniform fluid motion within each entity 7.

In accordance with further aspect of the present disclosure, the flow entity fluid outlet has a wider fluid flow opening than the flow entity fluid inlet to reduce a fluid flow velocity at the first flow entity fluid outlet relative to a fluid flow velocity at the second flow entity fluid inlet. This is schematically shown, for example, in Figure 4.

For example, the first flow entity fluid outlet 29 may have a wider fluid flow opening than the first flow entity fluid inlet 27 to reduce a fluid flow velocity at the first flow entity fluid outlet 29 relative to a fluid flow velocity at the first flow entity fluid inlet 27. The second flow entity fluid outlet 33 may have a wider fluid flow opening than the second flow entity fluid inlet 31 to reduce

a fluid flow velocity at the second flow entity fluid outlet 33 relative to a fluid flow velocity at the at least one second flow entity fluid inlet 31.

Similarly, this may be the same for other entities 7 or for each entity 7.

The design of the present disclosure thus incorporates an improved approach to optimize flow dynamics by using a smaller inlet and a larger outlet, effectively reducing flow velocity at the outlet while adhering to mass conservation principles. This intentional velocity reduction plays an important role in minimising turbulence and decreasing mixing between gas bubbles and the liquid 1M KOH, resulting in a more efficient and controlled flow pattern that enhances system performance. Figures 6A and 6B illustrate that the wider outlet of the 'curved' MPS design facilitates smoother fluid removal and reduces the likelihood of gas bubble-liquid mixing. Figure 4 also showcases the cascade-shaped ribs forming a parallelogram, ensuring better velocity uniformity compared to the straight MPS design in Figure 5A.

Another main distinction between the curved design of the present disclosure and the known straight MPS designs thus lies in the width of their inlet and outlet. While the straight design maintains equal widths for both, the curved MPS design features non-equal widths.

Additionally, as shown in Figures 5A and 5B, the ribs in the straight MPS design have a rectangular peripheral shape for each entity 7, whereas they may adopt a parallelogram peripheral shape in the curved MPS design of the present disclosure. As depicted in Figures 5A and 5B, the curvature of the ribs in the curved MPS design results in a more homogeneous velocity profile. Specifically, the curvature causes a reduction in velocity in the last channel, leading to a more uniform distribution across all channels within each repeating unit 7. It is worth noting that the y-axis of the graphs represents the normalization of the mixture mass velocity based on the maximum velocity found in the curved MPS design.

Figures 7A and 7B provide a comparison of the velocity profiles of the straight and curved MPS designs with those of the standard parallel and 3 serpentine designs. These profiles offer valuable insights into how the velocity evolves along the flow channels thanks to the two-phase simulation.

Notably, the curved MPS design features a lower velocity in the last channel of each repeating unit 7 when compared to the straight MPS design. This more even distribution of velocity along the flow field can have a direct impact on the efficiency of the electrolyzer, as it results in a more homogeneous use of the electrode. This can lead to improved electrolysis performance.

Although the curved MPS design yields a less uniform velocity distribution than the parallel design, its higher velocity can more effectively remove the gas produced from the electrode surface, thus enabling a more efficient use of the electrode surface.

Furthermore, as mentioned previously, the pressure drop is an important parameter. As depicted in Figure 8, the curved MPS design exhibits the lowest pressure drop. Conventionally, literature asserts that parallel designs have the lowest pressure drop due to their shorter flow channels, which result in reduced friction along the channel walls and minimized energy loss. In contrast, the curved MPS design demonstrates an even lower pressure drop, enhancing the overall efficiency of the system. Notably, Figure 8's y-axis represents the normalized relative pressure, based on the pressure drop in the curved MPS design, to illustrate the pressure drop of the other designs.

As schematically shown in Figures 9A and 9B, the channel-to-rib width ratio (cr) and the channel-width to depth ratio (cc) are two further parameters of the plate 1 taken into consideration to assure improved or optimized electrolyzer operation.

Figures 9A and 9B provides a schematic representation of elements of the plate 1 and the system 100. The ribs 21, depicted in the diagram, are structural elements located on the flow field plate 1. They play an important role in conducting current throughout the system 100, ensuring efficient electrical flow. On the other hand, the flow channels 23 are passages within the plates 1 that enable the fluid, comprising both reactants and products, to flow through the system 100. Together, the ribs 21 and flow channels 23 form the essential elements for the proper functioning of the system 100.

The parameters that are the channel-to-rib width ratio (cr) and the channel-width to depth ratio (cc) are now further discussed.

Channel-to-Rib Widths Ratio: *cr*

$$cr\,[-] = \frac{\textbf{Channel Width}}{\textbf{Rib Width}} \qquad \frac{1}{3} \leq cr \leq 3$$

	Advantage(s)	Disadvantage(s)
$cr \leq 1$	Enhance more electronic conductivity	Decreases the flow distribution on the electrode active area, less reactions possible
$cr \geq 1$	More reactant participation at electrode surface	Reduces the area available for ribs, less efficient current distribution

The design considerations regarding rib width and flow channel width in a cell present a trade-off. Increasing the rib width enhances electronic conductivity, but reduces flow channel width, potentially impacting flow distribution and decreasing the electrochemical reaction rate. Conversely, widening the flow channel allows for more reactant participation at the electrode surface, but reduces the area available for ribs, leading to less efficient current conduction.

These factors highlight the importance of striking a balance between rib width and flow channel width in order to optimise the performance of the system 100. Finding the right combination ensures effective electronic conductivity while promoting uniform flow distribution and maximising reactant utilisation. Ultimately, achieving an optimal design that balances these factors is important for enhancing the overall efficiency and performance of the electrochemical system. As such, this design encompasses a range of *cr* ratios from 1/3 to 3, allowing for flexibility and adaptability in meeting the specific requirements of the system 100.

Channel Width to Depth Ratio: *cc*

$$cc\,[-] = \frac{\textbf{Channel Width}}{\textbf{Channel Depth}} \qquad \frac{1}{5} \leq cc \leq 5$$

	Advantage(s)	Disadvantage(s)
$cc \leq 1$	Decreases the flow resistance due to less frictions possible of the flow with the walls, lowering the pressure drop.	Decrease the contact of the flow with the electrode active area, less reaction possible. The use of additional material in the manufacturing process raises the cost of producing the bipolar component.
$cc \geq 1$	Improves the flow distribution, more uniform flow distribution, decrease the possibility of local regions with low reactant concentration, better overall reactant utilisation. Enhances a direct contact with the electrode surface, maximises the electrochemical reaction efficiency. Decreases the overall width of the bipolar plate, the ohmic losses in the overall system.	Weakens the electronic conductivity since it decreases the ribs area. Creates more pathways for the reactants to travel, could lead to more bypass in the sense that some regions of the electrode may not be used at their maximum capacity.

When considering the advantages and disadvantages of different channel dimensions, deeper channels 23 offer benefits such as enhanced mass transport, lower pressure drop, and increased electrode surface area. However, they may also result in drawbacks like uneven flow distribution, limited contact with the electrode surface, increased pressure drop potential, and potential manufacturing challenges. On the other hand, wider channels 23 provide advantages such as improved flow distribution, enhanced direct contact with the electrode surface, reduced pressure drop, and easier manufacturing. Nonetheless, wider channels 23 also have disadvantages, including reduced electrode surface area, weaker electronic conductivity, and an increased likelihood of reactant bypass. Careful evaluation of these factors is important to design flow field plates 1 that meet the specific requirements and conditions of the electrochemical system. This design accommodates flexibility and adaptability, enabling it to meet the specific needs of the system with varying requirements and conditions.

Another parameter taken into consideration is the flow field inlet to outlet width ratio *io*:

Flow field inlet to outlet width ratio:

$$\boldsymbol{io}[-] = \frac{\textbf{Inlet Width}}{\textbf{Outlet Width}} \qquad \boldsymbol{io} < \mathbf{1}$$

Figure 4 clearly demonstrates that the inlet and outlet of the flow field possess different widths, indicating a notable disparity. Consequently, a ratio, denoted as *io* (inlet to outlet widths), has been established to validate this design for any *io* value less than 1.

A further parameter taken into consideration is the number of channels 23 and ribs 21 per entity 7:

Number of channels and ribs per entity:

The number of channels (c) and the number of ribs (r) **per entity** (e) is for example:

$$\mathbf{1} \leq \mathbf{c} \leq \mathbf{20}$$

$$\mathbf{c\text{-}1} \leq \mathbf{r} \leq \mathbf{c+1}$$

$$\mathbf{1} \leq \mathbf{e} < \rightarrow \infty$$

The number of ribs per entity in the design can, for example, be determined based on the number of channels (c) as follows: c+1 and c-1 are the possible choices. This design is particularly useful when the number of channels per entity falls within the range of one to twenty. The upper limit of for example twenty is selected as it can be considered to represent

for example a maximum feasible number of channels per entity 7. This concept applies to designs that involve one entity 7 up to a number tending towards infinity.

To illustrate this concept, if one examines Figure 3A, which depicts a design consisting of a total of nine entities 7 for example, each containing, for example, five channels 23 and four ribs 21. This example helps to visualise the arrangement and configuration of channels 23, ribs 21 and entities 7 within the system.

A further parameter taken into consideration is the length of the ribs inside the flow field plate:

Length of the ribs inside the flow field, described by the rib length to flow field width ratio:

$$rf[-] = \frac{\textbf{Rib Length}}{\textbf{Flow Field Width}} \qquad 0 < rf < 1$$

As depicted in Figure 10, the length of the ribs 21 (between an outermost location of each of the tips TP1, TP2) is connected to the width of the flow field or the fluid cavity 35 of the fluid entity 7 between the surface S1 and the surface S2. Within each entity 7, the rib length is preferably always smaller than the flow field width to allow fluid flow between the ribs 21. Consequently, the ratio of rib length to flow field width (rf) should preferably be greater than zero and less than one.

A further parameter taken into consideration is the Reynolds number Re.

Reynolds number: Re

Re < 2300 at electrode surface: Laminar flow

The design shape discussed is preferably more suitable for Reynolds numbers below 2300 at the electrode surface, irrespective of the fluid being used. Maintaining laminar flow at the electrode surface offers several advantages. Firstly, it ensures a more uniform distribution of flow, promoting homogeneous reactions and maximizing surface area utilisation. Secondly, laminar flow provides a predictable and controlled environment for the reaction, in contrast to the uncertainties associated with turbulent conditions. Lastly, it facilitates efficient removal of reaction products from the active area in a smooth and regulated manner.

Figure 11 graphically represents the average speed at the electrode surface and the average speed in the overall flow channels, considering the density and dynamic viscosity of 1M KOH.

This illustration provides insight into the flow characteristics within the system and helps understand the relationship between flow velocities at different locations within the comparison. Figure 9 provides an illustrative example showcasing the results obtained from four distinct flow field designs, each featuring a 100cm^2 electrode active area. With the Reynolds number being calculated with ρ being the density, W being the flow channel width, U the averaged mixture (liquid 1M KOH and O_2 gas bubbles) velocity, μ being the dynamic viscosity.

The following provides a summary of the design parameters to be considered given in dimensionless numbers:

Name	Acronym	Range	Description
Channel-to-Rib Widths Ratio	cr	$\frac{1}{3} \leq cr \leq 3$	Ratio of the fluid flow to the current conduction
Channel Width to Depth Ratio	cc	$\frac{1}{5} \leq cc \leq 5$	Impacts the fluid pathway on the flow field plate as well as its thickness
Flow Field Inlet to Outlet Width Ratio	io	$io \leq 1$	The outlet width of the flow field is larger or equal to the width of the inlet
Channel	c	$1 \leq c \leq 20$	Number of channel(s) per entity
Rib	r	$c-1 \leq r \leq c+1$	Number of rib(s) per entity
Entity	e	$1 \leq e < \rightarrow \infty$	Number of possible entities per flow field
Rib Length to Flow Field Width Ratio	rf	$0 < rf < 1$	Length of the ribs are always smaller than the flow field width
Reynolds Number	Re	< 2300	Aim is to keep laminar flow

In addition, it should be noted that the general shape of the design remains valid and invariant under any type of homeomorphism possible. Bearing in mind that a homeomorphism is a way to change the shape of an object while preserving its fundamental properties (e.g.: number of holes, connectedness and continuity).

An exemplary representative system including a 5-cell membrane electrode assembly (MEA) stack was built by the Inventors using exemplary SS316L endplates. The flow field pattern as shown in Figure 1 was machined onto the metallic plates 1 (bipolar plates) of the system. Flat gaskets and Orings made up of PTFE and EPDM were used as seals. Each membrane electrode assembly (MEA) stack was assembled in the following order: i) gasket EPDM ii) O-ring EPDM iii) OER electrode iv) Membrane v) gasket PTFE vi) HER electrode vii) Gasket EPDM viii) O-ring EPDM. Figure 15 shows measured results demonstrating that an implemented design of the plates 1 of the present disclosure in an AEMWE stack assembly having a 5-cell stack can reach >1.2kW performance.

A commercial cathode-membrane-anode was tested at 60 °C, 1 M KOH to validate the implemented design. The performance of 1 A cm^{-2} was reached at 10 V, 1 kWe consumption, at a HHV efficiency of 74%. The HHV efficiency was defined assuming 100% Faradaic efficiency, as shown in equation (4).

$$\eta_{HHV} = \frac{1.48}{V_{cell}} \quad (4)$$

where, V_{cell} is the average cell voltage of the stack.

A high power of 1.43 kWe was consumed to produce an H_2 flow rate of 7.7 m3 / day at 72% HHV efficiency without reaching the mass transfer region, proving the effectiveness of the newly designed flow fields.

As mentioned previously, the flow field plate 1 may include or be coated with at least one catalyst. According to one embodiment of the present disclosure, the catalyst may comprise or include Ni_3P.

The testing of this Ni_3P coating was done in a standard two-electrode setup at room temperature and 1 M KOH. The setup was ir-corrected to compare a bare stainless steel SS316 exemplary embodiment and the Ni_3P-coated SS316 exemplary embodiment. The performance of the Ni_3p-SS316 was 7.5% higher than the bare stainless steel SS316, as seen in Figure 16.

A further aspect of the present disclosure concerns an electrolyzer or an anion exchange membrane water electrolyzer including at least one or a plurality of the electrolyzer flow field plates 1. The electrolyzer flow field plate 1 may be an electrolyzer unipolar flow field plate, or an electrolyzer bipolar flow field plate.

Yet a further aspect of the present disclosure concerns an electrolysis method or anion exchange membrane water electrolysis method. The method, for example, includes providing the above electrolyzer or anion exchange membrane water electrolyzer; providing a liquid electrolyte, for example, comprising water or deionized (DI) water and KOH to the electrolyzer; providing an electrical current to the membrane electrode assemblies (MEA) or cells 123 and carrying out water electrolysis.

The exemplary system 100 as described herein may be used to carry out water electrolysis. Ni_3P-coated flow field plates may, for example, be used during the water electrolysis method.

While the invention has been disclosed with reference to certain preferred embodiments, numerous modifications, alterations, and changes to the described embodiments, and equivalents thereof, are possible without departing from the sphere and scope of the invention. Accordingly, it is intended that the invention not be limited to the described embodiments and be given the broadest reasonable interpretation in accordance with the language of the appended claims. The features of any one of the above-described embodiments may be included in any other embodiment described herein.

CLAIMS

1. Anion exchange membrane water electrolyzer flow field plate (1) comprising:

- a first flow entity (7A) configured to receive a fluid from at least one first flow entity fluid inlet (27) and configured to communicate the fluid to at least one first flow entity fluid outlet (29);

- a second flow entity (7B) including at least one second flow entity fluid inlet (31) and at least one second flow entity fluid outlet (33), the at least one second flow entity fluid inlet (31) being configured to receive the fluid from the at least one first flow entity fluid outlet (29);

- an intermediate elongated rib (25A) located between and separating the first fluid flow entity (7A) and the second flow entity (7B); and

- at least one further intermediate elongated rib (25B) delimiting or defining the at least one second flow entity fluid outlet (33), or an outlet support wall (26) delimiting or defining the at least one second flow entity fluid outlet (33);

the first flow entity (7A) including at least one fluid cavity (35A) delimited by at least one support wall (37) of the electrolyzer flow field plate (1), the at least one fluid cavity (35A) comprising a fluid entrance extremity (FE1) and a fluid exit extremity (FE2), the first flow entity (7A) further including a plurality of elongated channel ribs (21) located inside the at least one fluid cavity (35A), each elongated channel rib (21) extending from the fluid entrance extremity (FE1) to the fluid exit extremity (FE2) to delimit a plurality of fluid channels (23) for communicating the fluid to a first fluid passage (41) extending between the at least one support wall (37) of the electrolyzer flow field plate (1) and the intermediate elongated rib (25A), the first fluid passage (41) being in fluid communication with the at least one first flow entity fluid outlet (29), each of the elongated channel ribs (21) being located consecutively between the at least one support wall (37) and the intermediate elongated rib (25A);

the second flow entity (7B) including at least one fluid cavity (35B) delimited by the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B)

or the outlet support wall (26), the at least one fluid cavity (35B) comprising a fluid entrance extremity (FE1) and a fluid exit extremity (FE2), the second flow entity (7B) further including a plurality of elongated channel ribs (21) located inside the at least one fluid cavity (35B) of the second flow entity (7B), each elongated channel rib (21) extending from the fluid entrance extremity (FE1) to the fluid exit extremity (FE2) to delimit a plurality of fluid channels (23) for communicating the fluid to the at least one second flow entity fluid outlet (33), each of the elongated channel ribs (21) being located consecutively between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B) or the outlet support wall (26);

each elongated channel rib (21) of the first flow entity (7A) extending to an elongated channel rib tip (TP1) located in the fluid exit extremity (FE2) of the first flow entity (7A), each elongated channel rib tip (TP1) being located opposite a first side wall surface (S1) delimiting the at least one fluid cavity (35A), the first side wall surface (S1) being defined by a first side wall (39A) of the electrolyzer flow field plate (1),

wherein each elongated channel rib tip (TP1) is located at a different distance (d1) from the first side wall surface (S1), and the distance (d1) between the elongated channel rib tip (TP1) and the first side wall surface (S1) consecutively increases for each consecutive elongated channel rib (21) located consecutively between the at least one support wall (37) and the intermediate elongated rib (25A) such that the first fluid passage (41) widens between the at least one support wall (37) and the intermediate elongated rib (25A);

wherein the support wall (37) includes or defines the first flow entity fluid inlet (27), and the first flow entity (7A) includes the support wall (37), the first side wall (39A) and a second side wall (39B); wherein the first and second side walls (39A, 39B) extend away from the support wall (37), and the first side wall surface (S1) of the first side wall (39A) and a second side wall surface (S2) of the second side wall (39B) delimit the at least one fluid cavity (35A) in which the plurality of elongated channel ribs (21) are located between the first and second side wall surfaces (S1, S2), wherein the first side wall surface (S1) extends in a side wall surface direction of extension and the elongated channel ribs (21) extend in an elongated direction that is different to the side wall surface direction of extension;

wherein each elongated channel rib (21) of the second flow entity (7B) extends to an elongated channel rib tip (TP1) located in the fluid entrance extremity (FE1) of the second flow entity (7B), each elongated channel rib tip (TP1) being located opposite the first side wall surface (S1);

wherein each elongated channel rib tip (TP1) is located at a different distance (d1) from the first side wall surface (S1);

and characterized in that the distance (d1) between the elongated channel rib tip (TP1) and the first side wall surface (S1) consecutively decreases for each consecutive elongated channel rib (21) located consecutively between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B) or the outlet support wall (26) such that a second fluid passage (45) narrows between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B) or the outlet support wall (26), the second fluid passage (45) extending between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B) or the outlet support wall (26).

2. Anion exchange membrane water electrolyzer flow field plate (1) according to claim 1, wherein the intermediate elongated rib (25A) extends between the first fluid flow entity (7A) and the second flow entity (7B) and includes an intermediate elongated rib tip (TPI) located at a distance (d3) from the first side wall surface (S1) to define or delimit the at least one first flow entity fluid outlet (29), and/or the at least one second flow entity fluid inlet (31).

3. Anion exchange membrane water electrolyzer flow field plate (1) according to claim 1 or 2, wherein the intermediate elongated rib (25A) extends between the first fluid flow entity (7A) and the second flow entity (7B) and includes an intermediate elongated rib tip (TP1) located at a distance (d3) from the first side wall surface (S1) that is equal or less than a separation distance (d1) of the closest neighboring elongated channel rib (21) of the first flow entity (7A) and/or the second flow entity (7B) from the first side wall surface (S1).

4. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, wherein each elongated channel rib (21) of the second flow entity (7B) extends to an elongated channel rib tip (TP2) located in the fluid exit extremity (FE2) of the second flow entity (7B), each elongated channel rib tip (TP2) being located opposite a second side wall surface (S2) delimiting the at least one fluid cavity (35B) of the second flow entity (7B), the second side wall surface (S2) being defined by a second side wall (39B) of the electrolyzer flow field plate (1), and

wherein each elongated channel rib tip (TP2) is located at a different distance (d2) from the second side wall surface (S2), and the distance (d2) between the elongated channel rib tip (TP2) and the second side wall surface (S2) consecutively increases for each consecutive elongated channel rib (21) located consecutively between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B) or the outlet support wall (26) such that a third fluid passage (47) widens between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (26B) or the outlet support wall (26), the third fluid passage (47) extending between the intermediate elongated rib (25A) and the at least one further intermediate elongated rib (25B) or the outlet support wall (26).

5. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, wherein each elongated channel rib (21) of the first flow entity (7A) extends to an elongated channel rib tip (TP2) located in the fluid entrance extremity (FE1) of the first flow entity (7A), each elongated channel rib tip (TP2) being located opposite the second side wall surface (S2), and

wherein each elongated channel rib tip (TP2) is located at a different distance (d2) from the second side wall surface (S2), and the distance (d2) between the elongated channel rib tip (TP2) and the second side wall surface (S2) consecutively decreases for each consecutive elongated channel rib (21) located consecutively between the at least one support wall (37) and the intermediate elongated rib (25A) such that a fourth fluid passage (43) narrows between the at least one support wall (37) and the intermediate elongated rib (25A), the fourth fluid passage (43) extending between the at least one support wall (37) and the intermediate elongated rib (25A).

6. Anion exchange membrane water electrolyzer flow field plate (1) according to the previous claim, wherein the at least one further intermediate elongated rib (25B) extends towards the second side wall surface (S2) and includes a further intermediate elongated rib tip (TPI) located a distance (d4) from the second side wall surface (S2) to define or delimit the at least one second flow entity fluid outlet (33).

7. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, the at least one further intermediate elongated rib (25) extends from the first side wall (39A) of the electrolyzer flow field plate (1) towards the second side wall (39B) of the electrolyzer flow field plate (1), and the at least one intermediate elongated rib (25A) extends from the second side wall (39B) of the electrolyzer flow field plate (1) towards the first side wall (39A) of the electrolyzer flow field plate (1).

8. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, wherein the tips (TP2) of the elongated channel ribs (21) in the fluid entrance extremity (FE1) of the at least one fluid cavity (35A) of the first flow entity (7A) form a cascade profile, and the tips (TP1) of the elongated channel ribs (21) in the fluid exit extremity (FE2) of the at least one fluid cavity (35A) of the first flow entity (7A) form a cascade profile;
and the tips (TP1) of the elongated channel ribs (21) in the fluid entrance extremity (FE1) of the at least one fluid cavity (35B) of the second flow entity (7B) form a cascade profile, and the tips (TP2) of the elongated channel ribs (21) in the fluid exit extremity (FE2) of the at least one fluid cavity (35B) of the second flow entity (7B) form a cascade profile.

9. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, wherein the at least one first flow entity fluid outlet (29) has a wider fluid flow opening (wo) than an opening (wi) of the at least one first flow entity fluid inlet (27) to reduce a fluid flow velocity at the at least one first flow entity fluid outlet (29) relative to a fluid flow velocity at the at least one first flow entity fluid inlet (27),
and wherein the at least one second flow entity fluid outlet (33) has a wider fluid flow opening (wo) than an opening (wi) of the at least one second flow entity fluid inlet (31) to reduce a

fluid flow velocity at the at least one second flow entity fluid outlet (33) relative to a fluid flow velocity at the at least one second flow entity fluid inlet (31).

10. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, further including a third flow entity (7C) including at least one third flow entity fluid inlet (49) and at least one third flow entity fluid outlet (51), the at least one third flow entity fluid inlet (49) being configured to receive the fluid from the at least one second flow entity fluid outlet (33);
and further including a fourth flow entity (7D) including at least one fourth flow entity fluid inlet and at least one fourth flow entity fluid outlet, the at least one fourth flow entity fluid inlet being configured to receive the fluid from the at least one third flow entity fluid outlet (51);

wherein the at least one further intermediate elongated rib (25B) is located between and separating the second fluid flow entity (7B) and the third flow entity (7C), and a further intermediate elongated rib (25C) is located between and separating the third fluid flow entity (7C) and the fourth flow entity (7D).

11. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims 1 to 9, further including at least one additional set of a first and a second flow entities in fluid communication with the first flow entity (7A) and the second flow entity (7B), the at least one additional first flow entity (7C) being identical to the first flow entity (7A), and the at least one additional second flow entity (7D) being identical to the second flow entity (7B).

12. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, wherein the anion exchange membrane water electrolyzer flow field plate (1) is an anion exchange membrane water electrolyzer unipolar flow field plate or is an anion exchange membrane water electrolyzer bipolar flow field plate.

13. Anion exchange membrane water electrolyzer flow field plate (1) according to any one of the previous claims, wherein the anion exchange membrane water electrolyzer flow field

plate (1) is a Ni_3P-coated stainless steel anion exchange membrane water electrolyzer flow field plate (1).

14. Anion exchange membrane water electrolysis method including the steps of:

- providing an anion exchange membrane water electrolyzer including at least one or a plurality of the anion exchange membrane water electrolyzer flow field plates (1) according to any one of the previous claims; and

- carrying out water electrolysis.