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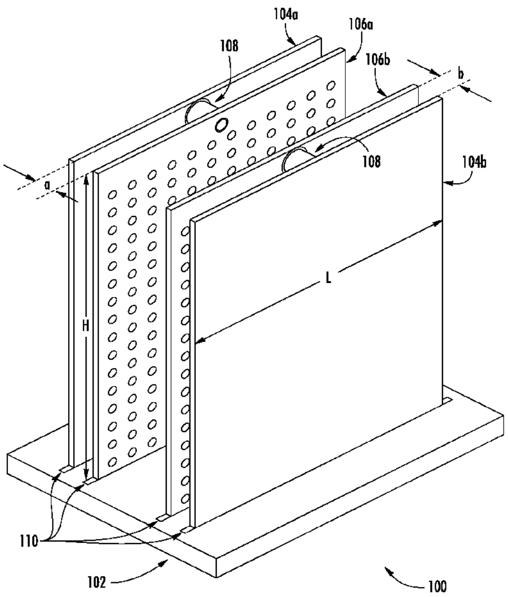

FIG. 1

(57) Abstract: Saltwater to freshwater conversion cells are provided. The saltwater to freshwater conversion cell includes a positive electrode; a negative electrode disposed opposite and parallel to the positive electrode; a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode; a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode; a power supply configured to generate an electric field between the positive electrode and the negative electrode; and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell. The positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

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SALTWATER TO FRESHWATER CONVERTER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and benefit of U.S. Provisional Patent Application No. 63/172,283, filed April 8, 2021, which is incorporated by reference herein in its entirety.

FIELD

[0002] The presently-disclosed invention relates generally to saltwater to freshwater converters and, more particularly, saltwater to freshwater conversion cells and systems and methods for converting saltwater to freshwater.

BACKGROUND

[0003] The need for freshwater is a global problem. Many countries have direct access to saltwater through oceans and seas, as well as brackish water in neighboring marshes. This saltwater, however, is not safe for human consumption. Various methods of converting saltwater to freshwater have been proposed and used for thousands of years, but many of these methods are not efficient and/or sanitary.

[0004] Accordingly, there still exists a need for devices, systems, and methods for cleanly and efficiently converting saltwater to freshwater.

BRIEF SUMMARY

[0005] One or more embodiments of the invention may address one or more of the aforementioned problems. Certain embodiments according to the invention provide saltwater to freshwater conversion cells. The saltwater to freshwater conversion cell includes a positive electrode; a negative electrode disposed opposite and parallel to the positive electrode; a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode; a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode; a power supply configured to generate an electric field between the positive electrode and the negative electrode; and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell. The positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

[0006] According to certain embodiments, the saltwater to freshwater conversion cell may further comprise a housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port, wherein the positive electrode, the negative electrode, the first plastic perforated plate, and the second plastic perforated plate may be disposed within the housing. In some embodiments, the saltwater stream may enter the housing via the saltwater entry port, the sodium-dense water channel may exit the housing via the sodium-dense water channel exit port, the chloride-dense water channel may exit the housing via the chloride-dense water channel exit port, and the desalinated water channel may exit the housing via the desalinated water channel exit port.

[0007] According to certain embodiments, the power supply may be disposed within the housing. In some embodiments, the power supply may be a direct current (DC) power supply. In other embodiments, the power supply may be an alternating current (AC) power supply.

[0008] According to certain embodiments, the positive electrode and the negative electrode may comprise stainless steel. In some embodiments, the positive electrode and the negative electrode may comprise surfaces having an electrical insulating plastic coating.

[0009] In another aspect, certain embodiments according to the invention provide saltwater to freshwater conversion systems. The saltwater to freshwater conversion system includes at least a first saltwater to freshwater conversion cell and a second saltwater to freshwater conversion cell. Each of the saltwater to freshwater conversion cells includes a positive electrode; a negative electrode disposed opposite and parallel to the positive electrode; a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode; a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode; a power supply configured to generate an electric field between the positive electrode and the negative electrode; and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell. The positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

[0010] According to certain embodiments, the system may comprise three saltwater to freshwater conversion cells. In other embodiments, the system may comprise four saltwater to freshwater conversion cells. In further embodiments, the system may comprise five saltwater to freshwater conversion cells.

[0011] According to certain embodiments, each saltwater to freshwater conversion cell may further comprise a housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port, wherein the positive electrode, the negative electrode, the first plastic perforated plate, and the second plastic perforated plate may be disposed within the housing. In other embodiments, at least the first saltwater to freshwater conversion cell and the second saltwater to freshwater conversion cell may be disposed in a housing, the housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port. In some embodiments, the sodium-dense water channel may exit the housing via the sodium-dense water channel exit port, the chloride-dense water channel may exit the housing via the chloride-dense water channel exit port, and the desalinated water channel may exit the housing via the desalinated water channel exit port. In further embodiments, the sodium-dense water channel exit port and the chloride-dense water channel exit port of each of the saltwater to freshwater conversion cells may drain into a wastewater collection unit, the desalinated water channel exit port of the first saltwater to freshwater conversion cell may drain into the saltwater entry port of the second saltwater to freshwater conversion cell, and the desalinated water channel exit port of the second saltwater to freshwater conversion cell may drain either into a freshwater collection unit or a saltwater entry port of a third saltwater to freshwater conversion cell.

[0012] According to certain embodiments, the power supply may be a direct current (DC) power supply.

[0013] In yet another aspect, certain embodiments according to the invention provide methods for converting saltwater to freshwater. The method includes providing a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions; flowing the saltwater stream through a saltwater to freshwater conversion cell, the saltwater to freshwater conversion cell comprising a positive electrode, a negative electrode, a first plastic perforated plate, and a second plastic perforated plate, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel; generating an electric field across the saltwater stream; collecting wastewater from the sodium-dense water channel and the chloride-dense water channel; and collecting freshwater from the desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel such that the plurality of positively charged sodium ions and the plurality of negatively charged chloride ions are substantially removed from water flowing through the desalinated water channel.

[0014] According to certain embodiments, the method may further comprise disposing the wastewater or recycling the wastewater through the saltwater to freshwater conversion cell. In further embodiments, the method may further comprise flowing the freshwater through one or more additional saltwater to freshwater conversion cells.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0015] Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0016] FIG. 1 is a perspective interior view of a saltwater to freshwater converter cell in accordance with certain embodiments of the invention;

[0017] FIG. 2 is a top perspective interior view of a saltwater to freshwater converter cell in accordance with certain embodiments of the invention;

[0018] FIG. 3 is a perspective exterior view of the front of a saltwater to freshwater converter in accordance with certain embodiments of the invention;

[0019] FIG. 4 is a perspective exterior view of the back of a saltwater to freshwater converter in accordance with certain embodiments of the invention;

[0020] FIG. 5 is a schematic view of a one cell saltwater to freshwater converter in accordance with certain embodiments of the invention;

[0021] FIG. 6 illustrates the effect of various electric field strengths on ion density in a saltwater to freshwater converter in accordance with certain embodiments of the invention;

[0022] FIG. 7 is a schematic view of a saltwater to freshwater conversion system in accordance with certain embodiments of the invention;

[0023] FIG. 8 illustrates the effect of the number of saltwater to freshwater conversion cells in a saltwater to freshwater conversion system on ion density in accordance with certain embodiments of the invention; and

[0024] FIG. 9 is a block diagram of a method for converting saltwater to freshwater in accordance with certain embodiments of the invention.

DETAILED DESCRIPTION

[0025] The invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the inventions are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout. As used in the specification, and in the appended claims, the singular forms “a”, “an”, “the”, include plural referents unless the context clearly dictates otherwise.

[0026] The invention includes, according to certain embodiments, converters and/or conversion cells, systems, and methods for converting saltwater to freshwater. The converters, systems, and methods are all based on a conversion cell that includes positive and negative electrodes, perforated plates positioned adjacent to the electrodes, and a power supply.

[0027] Saltwater is freshwater (H_2O) with salt (NaCl) crystals dissolved therein. The NaCl crystals are cubical and electrically neutral, which means that the number of Na^+ ions and the number of Cl^- ions in the water are substantially equal.

[0028] The force (F) on the ions in the water running through the conversion cell is influenced by the electrical field strength E=U/d in the water between the electrodes with the electrical potential difference (U) and the distance (d). Force (F) is calculated according to Formula 1:

$$F = Z * e * E \qquad (1)$$

where Z is the number of elementary charges of the ion, and e is the elementary charge of an electron ($1.60217653 * 10^{-19}$ coulombs). This force gives the Na^+ ions a velocity according to Formula 2:

$$v(Na) = u(Na) * E \qquad (2)$$

and gives the Cl^- ions a velocity according to Formula 3:

$$v(Cl) = u(Cl) * E \quad (3)$$

where the mobility of the Na^+ ions $u(Na) = 6.75 * 10^{-8} * m^2 * V^{-1} * s^{-1}$, and the mobility of the Cl^- ions $u(Cl) = 6.85 * 10^{-8} * m^2 * V^{-1} * s^{-1}$. The ions experience limited mobility due to the friction they encounter by moving in the water. As such, the velocity of the ions will not be higher than when the friction force is equal to the electric field force (E).

[0029] As a result of these forces, including the electric field force (E) in the water flowing between to the two electrodes connected to the power supply (e.g., DC power supply), Na^+ ions may be collected in one volume of water, and Cl^- ions may be collected in another volume of water. In particular, the Cl^- ionic density is higher in the water volume near the positive electrode, and the Na^+ ionic density is higher in the water volume near the negative electrode. When these two water volumes are drained out of the conversion cell, the water left in the middle of the conversion cell between the two electrodes has a lower density of dissolved NaCl than water entering the conversion cell. As discussed in more detail below, this water from the middle volume may be treated multiple (e.g., 3-4) times more to further decrease the NaCl density in the water (e.g., to about 6.25-12.5% of the original saltwater).

[0030] In this regard, the devices, systems, and methods disclosed herein are able to cleanly and efficiently convert saltwater to freshwater.

[0031] I. Saltwater to Freshwater Conversion Cells

[0032] Certain embodiments according to the invention provide saltwater to freshwater conversion cells. The saltwater to freshwater conversion cell includes a positive electrode; a negative electrode disposed opposite and parallel to the positive electrode; a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode; a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode; a power supply configured to generate an electric field between the positive electrode and the negative electrode; and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell. The positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

[0033] Turning now to FIG. 1, a saltwater to freshwater converter cell **100** is illustrated in accordance with certain embodiments of the invention. As shown in FIG. 1, the saltwater to freshwater converter cell **100** includes a positive electrode **104a** disposed on a baseplate **102**, a negative electrode **104b** disposed opposite and parallel to the positive electrode **104a** on the baseplate **102**, a first plastic perforated plate **106a** disposed adjacent to the positive electrode **104a** and between the positive electrode **104a** and the negative electrode **104b** on the baseplate **102**, and a second plastic perforated plate **106b** disposed adjacent to the negative electrode **104b** and between the positive electrode **104a** and the negative electrode **104b** on the baseplate **102**. Each of the positive electrode **104a**, negative electrode **104b**, first plastic perforated plate **106a**, and second plastic perforated plate **106b** may be secured to the baseplate **102** via grooves **110**.

[0034] According to certain embodiments, the positive electrode **104a** and/or the negative electrode **104b** may comprise stainless steel or any other suitable material for the electrodes that also conveys rust resistance as understood by a person of ordinary skill in the art. In such embodiments, the current flowing from a DC power supply may charge the electrodes to neutralize the approaching ions. In other embodiments, the positive electrode **104a** and/or the negative electrode **104b** may be painted with an electrical isolating plastic lacquer. In such embodiments, the power supply may only influence the conversion cell via the electric field strength.

[0035] In accordance with certain embodiments, and as with the first plastic perforated plate **106a** and the second plastic perforated plate **106b**, the baseplate **102** may also comprise plastic. In addition or in the alternative, the baseplate **102** may comprise any suitable nonconductive material as understood by a person of ordinary skill in the art.

[0036] In some embodiments, the positive electrode **104a** and the negative electrode **104b** may have the same thickness or different thicknesses. For example, in certain embodiments, the positive electrode **104a** and/or the negative electrode **104b** may comprise a thickness from about 0.1 mm to about 10 mm. In other embodiments, the positive electrode **104a** and/or the negative electrode **104b** may comprise a thickness from about 1 mm to about 5 mm. In further embodiments, the positive electrode **104a** and/or the negative electrode **104b** may comprise a thickness of about 2 mm. In this regard, the positive electrode **104a** and/or the negative electrode **104b** may comprise a thickness from at least about any of the following: 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, and 9.5 mm and/or at most about 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, and 0.5 mm (e.g., about 1-7 mm, about 0.5-5 mm, etc.).

[0037] Similarly, according to certain embodiments, the first plastic perforated plate **106a** and the second plastic perforated plate **106b** may have the same thickness or different thicknesses. For example, in certain embodiments, the first plastic perforated plate **106a** and/or the second plastic perforated plate **106b** may comprise a thickness from about 0.1 mm to about 10 mm. In other embodiments, the first plastic perforated plate **106a** and/or the second plastic perforated plate **106b** may comprise a thickness from about 1 mm to about 5 mm. In further embodiments, the first plastic perforated plate **106a** and/or the second plastic perforated plate **106b** may comprise a thickness of about 2 mm. In this regard, the first plastic perforated plate **106a** and/or the second plastic perforated plate **106b** may comprise a thickness from at least about any of the following: 0.1, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, and 9.5 mm and/or at most about 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, and 0.5 mm (e.g., about 1-7 mm, about 0.5-5 mm, etc.).

[0038] As can be seen in FIG. 1, the positive electrode **104a** and the first plastic perforated plate **106a** are separated by a non-zero distance **a**, and the negative electrode **104b** and the second plastic perforated plate **106b** are separated by a non-zero distance **b**. In some embodiments, for example, distance **a** may be equal to distance **b**. In other embodiments, for instance, distance **a** may be different from distance **b**. For example, in some embodiments, distance **a** and/or distance **b** may be from about 1 mm to about 10 mm. In other embodiments, distance **a** and/or distance **b** may be from about 2 mm to about 5 mm. In further embodiments, distance **a** and/or distance **b** may be about 4 mm. In this regard, distance **a** and/or distance **b** may be at least about any of the following: 1, 2, 3, 4, 5, 6, 7, 8, and 9 mm and/or at most about 10, 9, 8, 7, 6, 5, 4, 3, and 2 mm (e.g., about 1-7 mm, about 3-5 mm, etc.).

[0039] In certain embodiments, for example, as shown in FIG. 1, the positive electrode **104a** and the first plastic perforated plate **106a** may be separated by a spacer **108**, and the negative electrode **104b** and the second plastic perforated plate **106b** may similarly be separated by a spacer **108**. As with distances **a** and **b**, the spacers **108** may be the same length or different lengths.

[0040] In accordance with certain embodiments, the positive electrode **104a**, the negative electrode **104b**, the first plastic perforated plate **106a**, and/or the second plastic perforated plate **106b** may have a length **L**. In some embodiments, for example, the length **L** may be from about 100 mm to about 1000 mm. In other embodiments, the length **L** may be from about 200 mm to about 800 mm. In further embodiments, the length **L** may be from about 300 mm to about 500 mm. In certain embodiments, for instance, the length **L** may be about 400 mm. In this regard, the length **L** may be at least about any of the following: 100, 200, 300, 400, 500, 600, 700, 800, and 900 mm and/or at most about 1000, 900, 800, 700, 600, 500, 400, 300, and 200 mm (e.g., about 300-600 mm, about 200-400 mm, etc.).

[0041] According to certain embodiments, the grooves **110** may be only slightly thicker than each of the positive electrode **104a**, the negative electrode **104b**, the first plastic perforated plate **106a**, and the second plastic perforated plate **106b** such that each of the positive electrode **104a**, the negative electrode **104b**, the first plastic perforated plate **106a**, and the second plastic perforated plate **106b** snugly fit within the grooves **110**. As such, the thickness of each individual groove may be selected to be up to 1 mm thicker (e.g., 0.1mm, 0.5 mm, 0.8 mm, etc.) than the distance **a** or **b**. By way of example only, in certain embodiments in which the distance **a** and/or **b** is 2 mm, then the respective grooves **110** may be 2.1 mm thick. Similarly, the grooves **110** may be only slightly longer than each of the positive electrode **104a**, the negative electrode **104b**, the first plastic perforated plate **106a**, and the second plastic perforated plate **106b** such that each of the positive electrode **104a**, the negative electrode **104b**, the first plastic perforated plate **106a**, and the second plastic perforated plate **106b** snugly fit within the grooves **110**. As such, the length of each individual groove may be selected to be up to 1 mm longer (e.g., 0.1 mm, 0.5 mm, 0.8 mm, etc.) than the length **L**. By way of example only, in certain embodiments in which the length **L** is 400 mm, then the respective grooves **110** may be 400.1 mm long.

[0042] In accordance with certain embodiments, and as shown in FIG. 1, each of the positive electrode **104a**, the negative electrode **104b**, the first plastic perforated plate **106a**, and/or the second plastic perforated plate **106b** may have a height **H**. In some embodiments, for example, the height **H** may be from about 10 mm to about 400 mm. In other embodiments, the height **H** may be from about 50 mm to about 250 mm. In further embodiments, the height **H** may be from about 75 mm to about 150 mm. In certain embodiments, for instance, the height **H** may be about 100 mm. In this regard, the height **H** may be at least about any of the following: 10, 25, 50, 75, 100, 150, 200, 250, 300, and 350 mm and/or at most about 400, 350, 300, 250, 200, 150, 100, 75, 50, and 25 mm (e.g., about 50-150 mm, about 25-350 mm, etc.).

[0043] Moreover, as can be seen in FIG. 2, the positive electrode **104a** and the negative electrode **104b** are separated by a distance **d**. In some embodiments, for example, the distance **d** may be from about 10 mm to about 100 mm. In other embodiments, the distance **d** may be from about 25 mm to about 75 mm. In further embodiments, the distance **d** may be about 50 mm. In this regard, the distance **d** may be at least about any of the following: 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 65, 70, 75, 80, 85, 90, and 95 mm and/or at most about 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, and 15 mm (e.g., about 20-95 mm, about 35-80 mm, etc.).

[0044] In accordance with certain embodiments, the saltwater to freshwater converter cell may be disposed within a housing. For example, as shown in FIGs. 3 and 4, the saltwater to freshwater converter **200** may be disposed within a housing **202**. FIG. 3 illustrates the front of the housing **202**. As can be seen in FIG. 3, the front of the housing **202** may include a saltwater entry port **204** through which the saltwater stream **218** may enter the saltwater to freshwater converter **200**. FIG. 4 illustrates the back of the housing **202**, which is positioned opposite the front of the housing **202**. As can be seen in FIG. 4, the back of the housing **202** may include a desalinated water channel exit port **206** through which the desalinated water channel **226** may exit the housing **202**. The back of the housing **202** may also include a chloride-dense water channel exit port **208a** and a sodium-dense water channel exit port **208b** through which the chloride-dense water channel **220** and the sodium-dense water channel **222**, respectively, may exit the housing **202**. Moreover, in some embodiments, the power supply **214** may be disposed within the housing **202**. In other embodiments, however, the power supply **214** may be disposed outside the housing **202**.

[0045] FIG. 5 is a schematic view of a one cell saltwater to freshwater converter **200** in accordance with certain embodiments of the invention. As shown in FIG. 5, the saltwater to freshwater converter **200** may include a saltwater (e.g., seawater) source **210** that provides the saltwater stream **218** to the converter **200**. In some embodiments, the saltwater stream may comprise unprocessed saltwater **218**. In other embodiments, however, the saltwater stream may comprise processed saltwater **219** or a combination of unprocessed saltwater **218** and processed saltwater **219**.

[0046] According to certain embodiments, and as shown in FIG. 5, the converter **200** may include a pump **212** that pushes the unprocessed saltwater **218** through the converter **200** for processing. The pump **212** may be any suitable type and size of pump for pumping the saltwater **218** through the converter **200** as understood by a person of ordinary skill in the art. Indeed, the pump **212** must be capable of providing a water speed equal to the volume of the converter **200** divided by the amount of time required to move the distance **d** from one electrode to the other.

[0047] As shown in FIG. 5, the converter **200** also includes a power supply **214**. According to certain embodiments, the power supply **214** may be a direct current (DC) power supply. In some embodiments, the DC power supply may produce a voltage between the electrodes from about 50 V to about 500 V. In other embodiments, the DC power supply may produce a voltage between the electrodes from about 100 V to about 300 V. In further embodiments, the DC power supply may produce a voltage between the electrodes of about 200 V. In this regard, the DC power supply may produce a voltage between the electrodes of at least about any the following: 50, 100, 150, 200, 250, 300, 350, 400, and 450 V and/or at most about 500, 450, 400, 350, 300, 250, 200, 150, and

100 V (e.g., about 100-400 V, about 200-300 V, etc.). While in many embodiments it is preferable to use a DC power supply, in some embodiments the power supply **214** may be an alternating current (AC) power supply.

[0048] As the saltwater **218** moves through the converter **200**, the power supply **214** causes the positive sodium ions Na^+ and the negative chloride ions Cl^- in the saltwater **218** to dissociate such that the Cl^- ions move towards the positive electrode **104a** to form a chloride-dense water channel **220** between the positive electrode **104a** and the first plastic perforated plate **106a** and the Na^+ ions move towards the negative electrode **104b** to form a sodium-dense water channel **222** between the negative electrode **104b** and the second plastic perforated plate **106b**. In some embodiments, after traveling through length **L** of the converter **200**, which is the main body of the converter **200**, the chloride-dense water channel **220** and the sodium-dense water channel **222** may combine to form the processed saltwater **219**. The processed saltwater **219** may then flow into a wastewater collection unit **216** for disposal or further processing, as described herein. As the Na^+ ions and the Cl^- ions move towards the negative electrode **104b** and the positive electrode **104a**, respectively, the remaining water flowing through the converter **200** forms a desalinated water channel **226** between the first plastic perforated plate **106a** and the second plastic perforated plate **106b**. In some embodiments, this desalinated water channel **226** may then flow out of the converter **200** as processed freshwater, which may then be collected in a freshwater collection unit **250** or put through additional processing, as described herein.

[0049] FIG. 6 illustrates the effect of various electric field strengths on ion density in a saltwater to freshwater converter in accordance with certain embodiments of the invention. As shown in FIG. 6, when no electric field (E=0kV/m) is applied to the saltwater, the Na^+ and Cl^- ion densities remain the same as seawater. When a moderate electric field strength (e.g., E=2kV/m) is applied to the saltwater, the Cl^- ion density is highest at the positive electrode, the Na^+ ion density is highest at the negative electrode, and the desalinated water has a reduction in both Na^+ and Cl^- ion densities to greater than 50% but less than 100% of that of seawater (e.g., 60-75% of seawater). When a higher electric field strength (e.g., E=4kV/m) is applied to the saltwater, the Cl^- ion density is highest at the positive electrode, the Na^+ ion density is highest at the negative electrode, and the desalinated water has a reduction in both Na^+ and Cl^- ion densities such that the ion densities are less than 50% of that of seawater (e.g., 30-40% of seawater). As such, and without intending to be limited by theory, as the electric field strength increases, so does the reduction in Na^+ and Cl^- ion density in the desalinated water.

[0050] In this regard, the conversion cells are able to cleanly and efficiently convert saltwater to freshwater.

[0051] II. Saltwater to Freshwater Conversion Systems

[0052] In another aspect, certain embodiments according to the invention provide saltwater to freshwater conversion systems. The saltwater to freshwater conversion system includes at least a first saltwater to freshwater conversion cell and a second saltwater to freshwater conversion cell. Each of the saltwater to freshwater conversion cells includes a positive electrode; a negative electrode disposed opposite and parallel to the positive electrode; a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode; a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode; a power supply configured to generate an electric field between the positive electrode and the negative electrode; and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell. The positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

[0053] Turning now to FIG. 7, a saltwater to freshwater conversion system **300** is illustrated in accordance with certain embodiments of the invention. As shown in FIG. 7, the system **300** may include a plurality of saltwater to freshwater conversion cells. For example, in FIG. 7 the system **300** includes four conversion cells **310**, **320**, **330**, and **340**, but the system **300** is not so limited. In some embodiments, for instance, the system **300** may include three conversion cells, while in other embodiments, the system **300** may include five or more conversion cells.

[0054] Each conversion cell is largely the same as the converter **200** illustrated in FIG. 5, except the desalinated water channel may flow into another conversion cell for further processing rather than into a freshwater collection unit **250**. For example, conversion cell **310** may include a positive electrode **314a**, a negative electrode **314b**, a chloride-dense water channel **312** running between the positive electrode **314a** and the first plastic perforated plate (not shown), a sodium-dense water channel **313** running between the negative electrode **314b** and the second plastic perforated plate (not shown), and a desalinated water channel **316** flowing between the first plastic perforated plate and the second plastic perforated plate. Desalinated water channel **316** may then flow through conversion cell **320**. Conversion cell **320** may include a positive electrode **324a**, a negative electrode **324b**, a chloride-dense water channel **322** running between the positive electrode **324a** and the first plastic perforated plate (not shown), a sodium-dense water channel **323** running between the negative electrode **324b** and the second plastic perforated plate (not shown), and a desalinated water channel **326** flowing between the first plastic perforated plate and the second plastic perforated plate. Desalinated water channel **326** may then flow through conversion cell **330**. Conversion cell **330** may include a positive electrode **334a**, a negative electrode **334b**, a chloride-dense water channel **332** running between the positive electrode **334a** and the first plastic perforated plate (not shown), a sodium-dense water channel **333** running between the negative electrode **334b** and the second plastic perforated plate (not shown), and a desalinated water channel **336** flowing between the first plastic perforated plate and the second plastic perforated plate. Desalinated water channel **336** may then flow through conversion cell **340**. Conversion cell **340** may include a positive electrode **344a**, a negative electrode **344b**, a chloride-dense water channel **342** running between the positive electrode **344a** and the first plastic perforated plate (not shown), a sodium-dense water channel **343** running between the negative electrode **344b** and the second plastic perforated plate (not shown), and a desalinated water channel **346** flowing between the first plastic perforated plate and the second plastic perforated plate. Desalinated water channel **346** may then flow into the freshwater collection unit **250**. Similarly, the processed saltwater **219** may then flow into the wastewater collection unit **216**. While the system **300** is shown as having each desalinated water channel flow into the next conversion cell, any of the desalinated water channels may instead drain into a freshwater collection unit, such as freshwater collection unit **250**.

[0055] As with the converter **200** shown in FIG. 5, the system **300** may include a seawater source **210**, a pump **212**, and a power supply **214**. While the system **300** is shown as including one pump **212** and one power supply **214**, the system **300** is not so limited. For example, the system **300** may include a plurality of pumps and power supplies, and in some embodiments, each conversion cell may be paired with its own pump and power supply.

[0056] As discussed above with respect to the converter **200**, in some embodiments each saltwater to freshwater conversion cell may include a housing. In this regard, when multiple conversion cells are used, such as in the system **300**, each conversion cell may be disposed in its own housing. In such embodiments, some or all of the housings may be connected to each other such that the desalinated water channel from a first conversion cell and housing will flow directly into a second conversion cell and housing. In other embodiments, however, the plurality of housings may not be directly connected to each other. In such embodiments, the desalinated water channel from a first conversion cell may be collected upon its exit from the housing and then transported to a second conversion cell and housing. In other embodiments, however, some or all of the conversion cells may be positioned within the same housing. For example, for system **300**, all four conversion cells **310**, **320**, **330**, **340** may be positioned within the same housing such that saltwater **218** enters the housing and the desalinated water channel **348** and processed saltwater **219** exit the housing.

[0057] As discussed previously herein, the system **300** may include multiple (e.g., three, four, five, etc.) conversion cells. FIG. 8 illustrates the effect of the number of saltwater to freshwater conversion cells in a saltwater to freshwater conversion system on ion density (and, therefore, salt content) in the water being processed. As shown, in FIG. 8, as the number of conversion cells increases, the ion density of the water decreases, largely exponentially. Indeed, as shown in FIG. 8, by way of example only, unprocessed saltwater had an ion density of 100%, saltwater processed with one cell had an ion density of about 50%, saltwater processed with two cells had an ion density of about 25%, saltwater processed with three cells had an ion density of about 12.5%, saltwater processed with four cells had an ion density of about 6.25%, and saltwater processed with five cells had an ion density of about 3.15%.

[0058] In this regard, the system is able to cleanly and efficiently convert saltwater to freshwater.

[0059] **III. Methods for Converting Saltwater to Freshwater**

[0060] Certain embodiments according to the invention provide methods for converting saltwater to freshwater. The method includes providing a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions; flowing the saltwater stream through a saltwater to freshwater conversion cell, the saltwater to freshwater conversion cell comprising a positive electrode, a negative electrode, a first plastic perforated plate, and a second plastic perforated plate, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel; generating an electric field across the saltwater stream; collecting wastewater from the sodium-dense water channel and the chloride-dense water channel; and collecting freshwater from the desalinated water channel. The electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel such that the plurality of positively charged sodium ions and the plurality of negatively charged chloride ions are substantially removed from water flowing through the desalinated water channel.

[0061] FIG. 9, for example, is a block diagram of a method **400** for converting saltwater to freshwater in accordance with certain embodiments of the invention. As shown in FIG. 9, the method **400** includes the following steps:

Step **410**: Providing a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions;

Step **420**: Flowing the saltwater stream through a saltwater to freshwater conversion cell, the saltwater to freshwater conversion cell comprising a positive electrode, a negative electrode, a first plastic perforated plate, and a second plastic perforated plate, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel;

Step **430**: Generating an electric field across the saltwater stream, wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel such that the plurality of positively charged sodium ions and the plurality of negatively charged chloride ions are substantially removed from water flowing through the desalinated water channel;

Step **440**: Collecting wastewater from the sodium-dense water channel and the chloride-dense water channel; and

Step **450**: Collecting freshwater from the desalinated water channel; and, optionally:

Step **460a**: Disposing the wastewater;

Step **460b**: Recycling the wastewater through the saltwater to freshwater conversion cell; or

Step **460c**: Flowing the freshwater through one or more additional saltwater to freshwater conversion cells.

[0062] In this regard, the method is able to cleanly and efficiently convert saltwater to freshwater.

[0063] Example

[0064] A one-cell converter was constructed such that the distance d between the two electrodes was 0.05 m, the height H of the cell was 0.1 m, and the length L was 0.4 m, providing a 2 liter cell volume. The voltage between the electrodes was 200 V DC.

[0065] As such, based on Formulas 2 and 3 discussed above, the velocities of the ions were as follows:

$$v(Na) = 6.75 * 10^{-8} * m^2 * V^{-1} * s^{-1} * (200\ V/0.05\ m) = 0.27\ mm/s$$
$$v(Cl) = 6.85 * 10^{-8} * m^2 * V^{-1} * s^{-1} * (200\ V/0.05\ m) = 0.30\ mm/s$$

[0066] As such, an individual Na^+ ion needs approximately 185 seconds to move the distance from one electrode to the other, and an individual Cl^- ion needs approximately 167 seconds to move the distance from one electrode to the other. To ensure that all ions in the conversion cell would have enough time to reach their attracting electrodes, the pump was required to provide a water speed of 2 liters / 185 seconds = 0.011 l/s = 40 l/h.

[0067] The following exemplary embodiments are provided, the numbering of which is not to be construed as designating levels of importance or relevance.

[0068] Embodiment 1 provides a saltwater to freshwater conversion cell comprising a positive electrode, a negative electrode disposed opposite and parallel to the positive electrode a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode, a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode, a power supply configured to generate an electric field between the positive electrode and the negative electrode, and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel, and wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

[0069] Embodiment 2 provides the saltwater to freshwater conversion cell according to Embodiment 1, further comprising a housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port, wherein the positive electrode, the negative electrode, the first plastic perforated plate, and the second plastic perforated plate are disposed within the housing.

[0070] Embodiment 3 provides the saltwater to freshwater conversion cell according to any one of Embodiments 1-2, wherein the saltwater stream enters the housing via the saltwater entry port, the sodium-dense water channel exits the housing via the sodium-dense water channel exit port, the chloride-dense water channel exits the housing via the chloride-dense water channel exit port, and the desalinated water channel exits the housing via the desalinated water channel exit port.

[0071] Embodiment 4 provides the saltwater to freshwater conversion cell according to any one of Embodiments 1-3, wherein the power supply is disposed within the housing.

[0072] Embodiment 5 provides the saltwater to freshwater conversion cell according to any one of Embodiments 1-4, wherein the power supply is a direct current (DC) power supply.

[0073] Embodiment 6 provides the saltwater to freshwater conversion cell according to any one of Embodiments 1-5, wherein the power supply is an alternating current (AC) power supply.

[0074] Embodiment 7 provides the saltwater to freshwater conversion cell according to any one of Embodiments 1-6, wherein the positive electrode and the negative electrode comprise stainless steel.

[0075] Embodiment 8 provides the saltwater to freshwater conversion cell according to any one of Embodiments 1-7, wherein the positive electrode and the negative electrode comprise surfaces having an electrical insulating plastic coating.

[0076] Embodiment 9 provides a saltwater to freshwater conversion system comprising at least a first saltwater to freshwater conversion cell and a second saltwater to freshwater conversion cell, each of the saltwater to freshwater conversion cells comprising a positive electrode, a negative electrode disposed opposite and parallel to the positive electrode, a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode, a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode, a power supply configured to generate an electric field between the positive electrode and the negative electrode, and a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel, and wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

[0077] Embodiment 10 provides the system according to Embodiment 9, wherein the system comprises three saltwater to freshwater conversion cells.

[0078] Embodiment 11 provides the system according to any one of Embodiments 9-10, wherein the system comprises four saltwater to freshwater conversion cells.

[0079] Embodiment 12 provides the system according to any one of Embodiments 9-11, wherein the system comprises five saltwater to freshwater conversion cells.

[0080] Embodiment 13 provides the system according to any one of Embodiments 9-12, wherein each saltwater to freshwater conversion cell further comprises a housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port, wherein the positive electrode, the negative electrode, the first plastic perforated plate, and the second plastic perforated plate are disposed within the housing.

[0081] Embodiment 14 provides the system according to any one of Embodiments 9-13, wherein the sodium-dense water channel exits the housing via the sodium-dense water channel exit port, the chloride-dense water channel exits the housing via the chloride-dense water channel exit port, and the desalinated water channel exits the housing via the desalinated water channel exit port.

[0082] Embodiment 15 provides the system according to any one of Embodiments 9-14, wherein the sodium-dense water channel exit port and the chloride-dense water channel exit port of each of the saltwater to freshwater conversion cells drain into a wastewater collection unit, the desalinated water channel exit port of the first saltwater to freshwater conversion cell drains into the saltwater entry port of the second saltwater to freshwater conversion cell, and the desalinated water channel exit port of the second saltwater to freshwater conversion cell drains either into a freshwater collection unit or a saltwater entry port of a third saltwater to freshwater conversion cell.

[0083] Embodiment 16 provides the system according to any one of Embodiments 9-15, wherein at least the first saltwater to freshwater conversion cell and the second saltwater to freshwater conversion cell are disposed in a housing, the housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port.

[0084] Embodiment 17 provides the system according to any one of Embodiments 9-16, wherein the power supply is a direct current (DC) power supply.

[0085] Embodiment 18 provides a method for converting saltwater to freshwater, the method comprising providing a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, flowing the saltwater stream through a saltwater to freshwater conversion cell, the saltwater to freshwater conversion cell comprising a positive electrode, a negative electrode, a first plastic perforated plate, and a second plastic perforated plate, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel, generating an electric field across the saltwater stream, wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel such that the plurality of positively charged sodium ions and the plurality of negatively charged chloride ions are substantially removed from water flowing through the desalinated water channel, collecting wastewater from the sodium-dense water channel and the chloride-dense water channel, and collecting freshwater from the desalinated water channel.

[0086] Embodiment 19 provides the method according to Embodiment 18, further comprising disposing the wastewater or recycling the wastewater through the saltwater to freshwater conversion cell.

[0087] Embodiment 20 provides the method according to any one of Embodiments 18-19, further comprising flowing the freshwater through one or more additional saltwater to freshwater conversion cells.

[0088] Modifications of the invention set forth herein will come to mind to one skilled in the art to which the invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

THAT WHICH IS CLAIMED:

1. A saltwater to freshwater conversion cell comprising:

a positive electrode;

a negative electrode disposed opposite and parallel to the positive electrode;

a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode;

a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode;

a power supply configured to generate an electric field between the positive electrode and the negative electrode; and

a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell,

wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel, and

wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

2. The saltwater to freshwater conversion cell according to claim 1, further comprising a housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port, wherein the positive electrode, the negative electrode, the first plastic perforated plate, and the second plastic perforated plate are disposed within the housing.

3. The saltwater to freshwater conversion cell according to claim 2, wherein the saltwater stream enters the housing via the saltwater entry port, the sodium-dense water channel exits the housing via the sodium-dense water channel exit port, the chloride-dense water channel exits the housing via the chloride-dense water channel exit port, and the desalinated water channel exits the housing via the desalinated water channel exit port.

4. The saltwater to freshwater conversion cell according to claim 1, wherein the power supply is disposed within the housing.

5. The saltwater to freshwater conversion cell according to claim 1, wherein the power supply is a direct current (DC) power supply or an alternating current (AC) power supply.

6. The saltwater to freshwater conversion cell according to claim 1, wherein the positive electrode and the negative electrode comprise stainless steel.

7. The saltwater to freshwater conversion cell according to claim 1, wherein the positive electrode and the negative electrode comprise surfaces having an electrical insulating plastic coating.

8. A saltwater to freshwater conversion system comprising:

at least a first saltwater to freshwater conversion cell and a second saltwater to freshwater conversion cell, each of the saltwater to freshwater conversion cells comprising:

a positive electrode;

a negative electrode disposed opposite and parallel to the positive electrode;

a first plastic perforated plate positioned adjacent to the positive electrode and between the positive electrode and the negative electrode;

a second plastic perforated plate positioned adjacent to the negative electrode and between the positive electrode and the negative electrode;

a power supply configured to generate an electric field between the positive electrode and the negative electrode; and

a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions, the saltwater stream flowing through the conversion cell,

wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel, and

wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel.

9. The system according to claim 8, wherein the system comprises three or more saltwater to freshwater conversion cells.

10. The system according to claim 8, wherein each saltwater to freshwater conversion cell further comprises a housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port, wherein the positive electrode, the negative electrode, the first plastic perforated plate, and the second plastic perforated plate are disposed within the housing.

11. The system according to claim 10, wherein the sodium-dense water channel exits the housing via the sodium-dense water channel exit port, the chloride-dense water channel exits the housing via the chloride-dense water channel exit port, and the

desalinated water channel exits the housing via the desalinated water channel exit port.

12. The system according to claim 10, wherein the sodium-dense water channel exit port and the chloride-dense water channel exit port of each of the saltwater to freshwater conversion cells drain into a wastewater collection unit, the desalinated water channel exit port of the first saltwater to freshwater conversion cell drains into the saltwater entry port of the second saltwater to freshwater conversion cell, and the desalinated water channel exit port of the second saltwater to freshwater conversion cell drains either into a freshwater collection unit or a saltwater entry port of a third saltwater to freshwater conversion cell.

13. The system according to claim 8, wherein at least the first saltwater to freshwater conversion cell and the second saltwater to freshwater conversion cell are disposed in a housing, the housing having a saltwater entry port, a sodium-dense water channel exit port, a chloride-dense water channel exit port, and a desalinated water channel exit port.

14. A method for converting saltwater to freshwater, the method comprising:

providing a saltwater stream comprising a plurality of positively charged sodium ions and a plurality of negatively charged chloride ions;

flowing the saltwater stream through a saltwater to freshwater conversion cell, the saltwater to freshwater conversion cell comprising a positive electrode, a negative electrode, a first plastic perforated plate, and a second plastic perforated plate, wherein the positive electrode and the first plastic perforated plate define a chloride-dense water channel, the negative electrode and the second plastic perforated plate define a sodium-dense water channel, and the first plastic perforated plate and the second plastic perforated plate define a desalinated water channel;

generating an electric field across the saltwater stream, wherein the electric field is configured to cause the plurality of negatively charged chloride ions in the saltwater stream to move through the first plastic perforated plate and into the chloride-dense water channel and the plurality of positively charged sodium ions in the saltwater stream to move through the second plastic perforated plate and into the sodium-dense water channel such that the plurality of positively charged sodium ions and the plurality of negatively charged chloride ions are substantially removed from water flowing through the desalinated water channel;

collecting wastewater from the sodium-dense water channel and the chloride-dense water channel; and

collecting freshwater from the desalinated water channel.

15. The method according to claim 14, further comprising disposing the wastewater or recycling the wastewater through the saltwater to freshwater conversion cell.

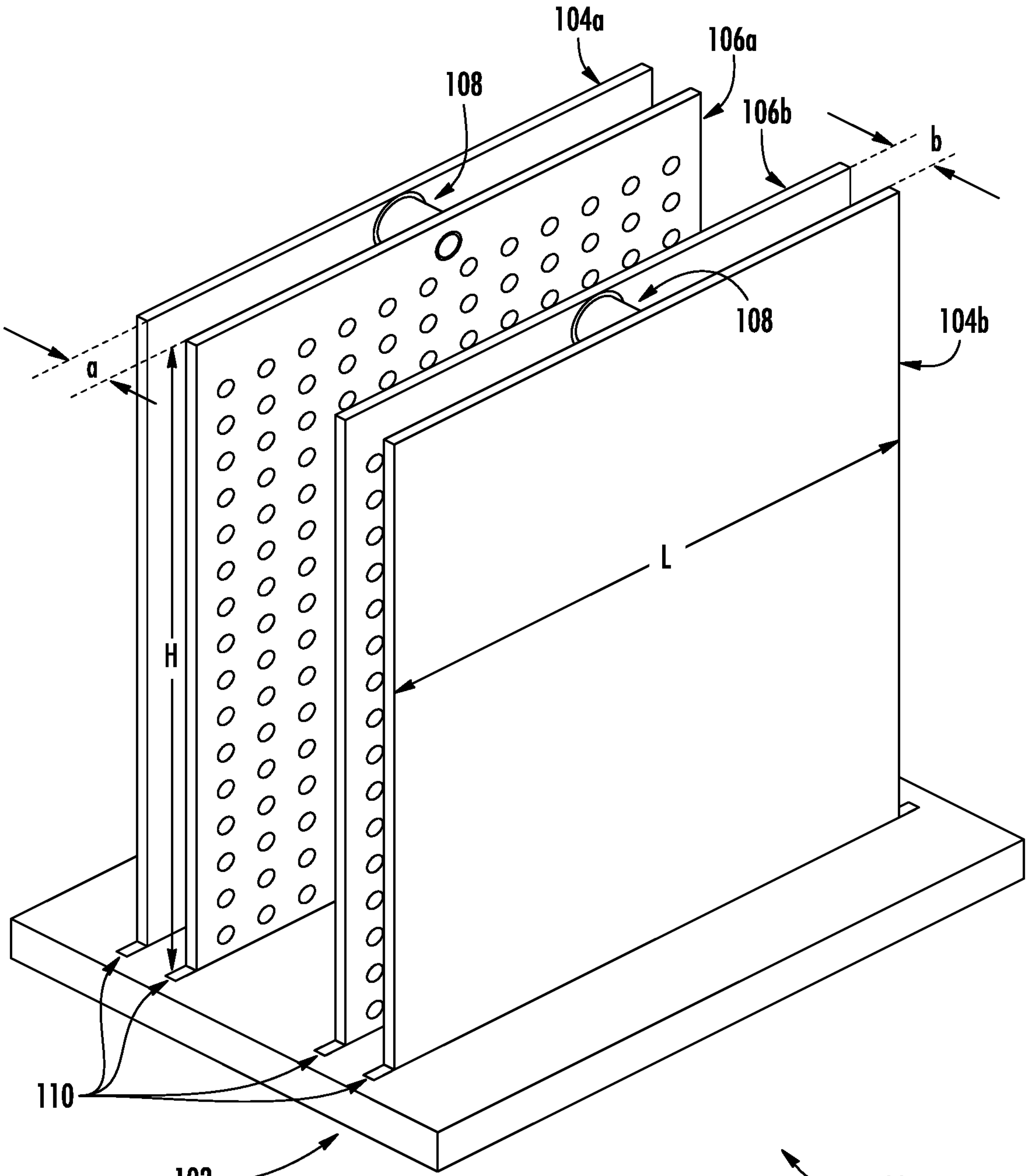


FIG. 1

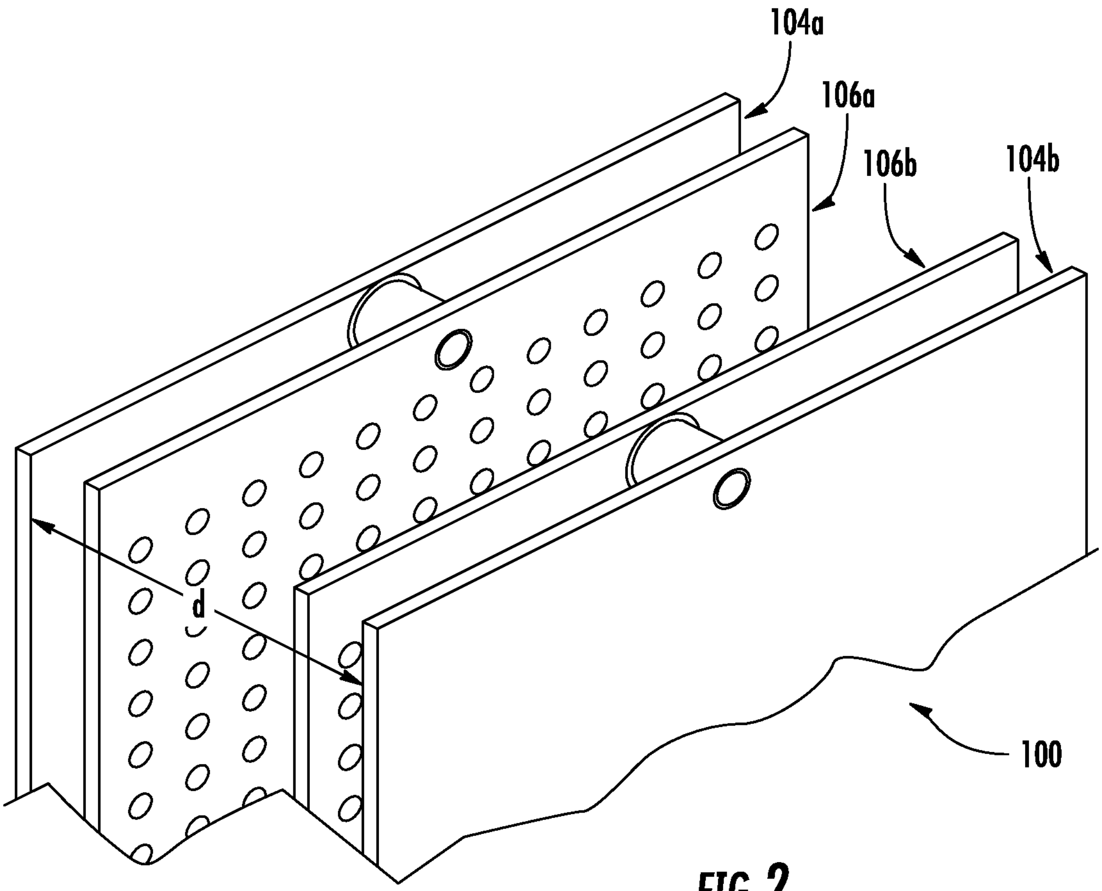


FIG. 2

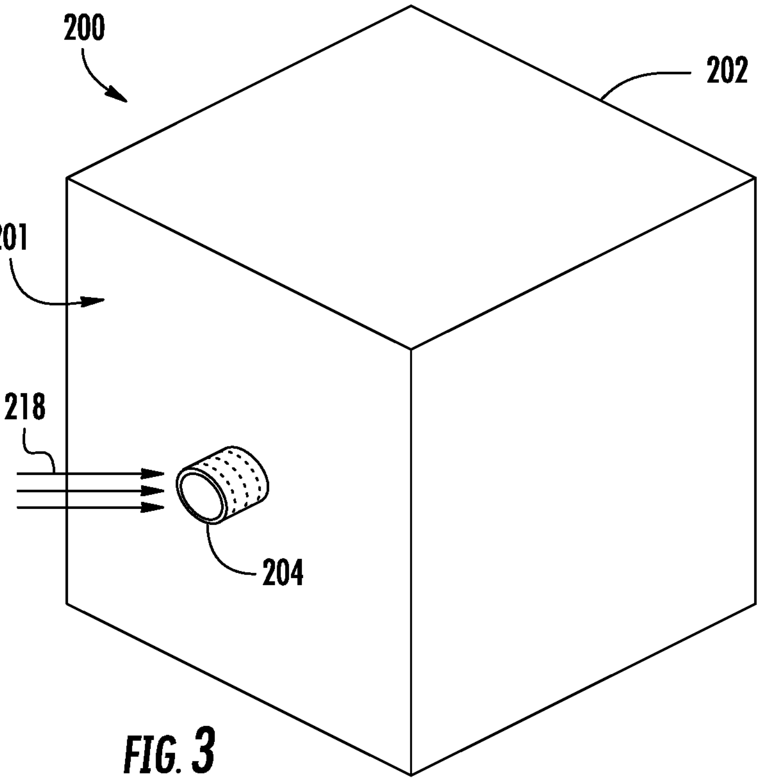


FIG. 3

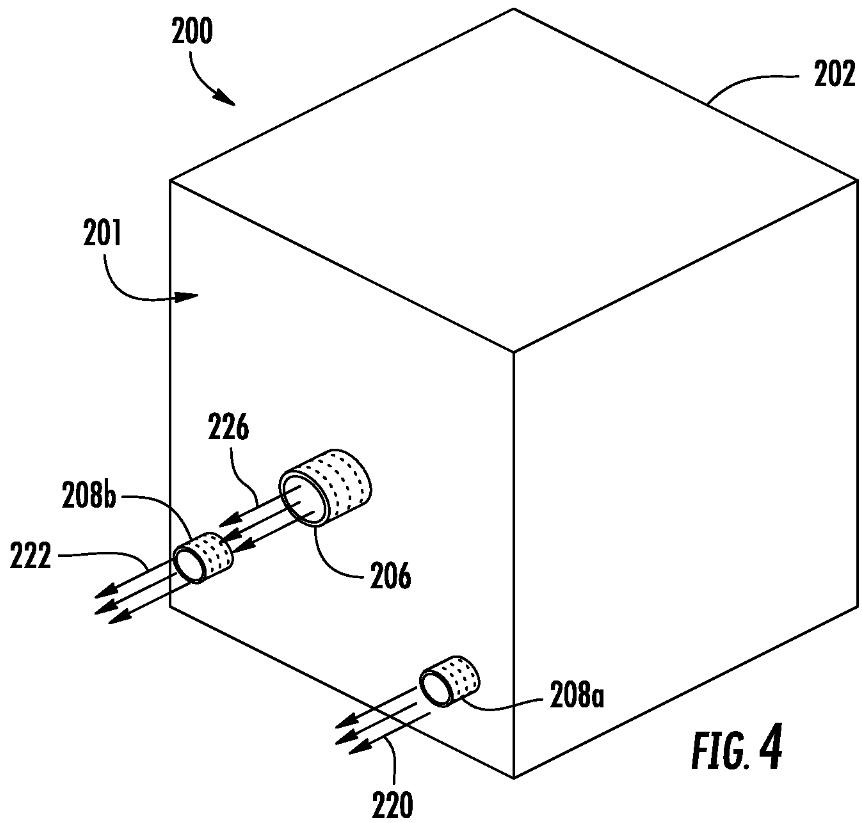
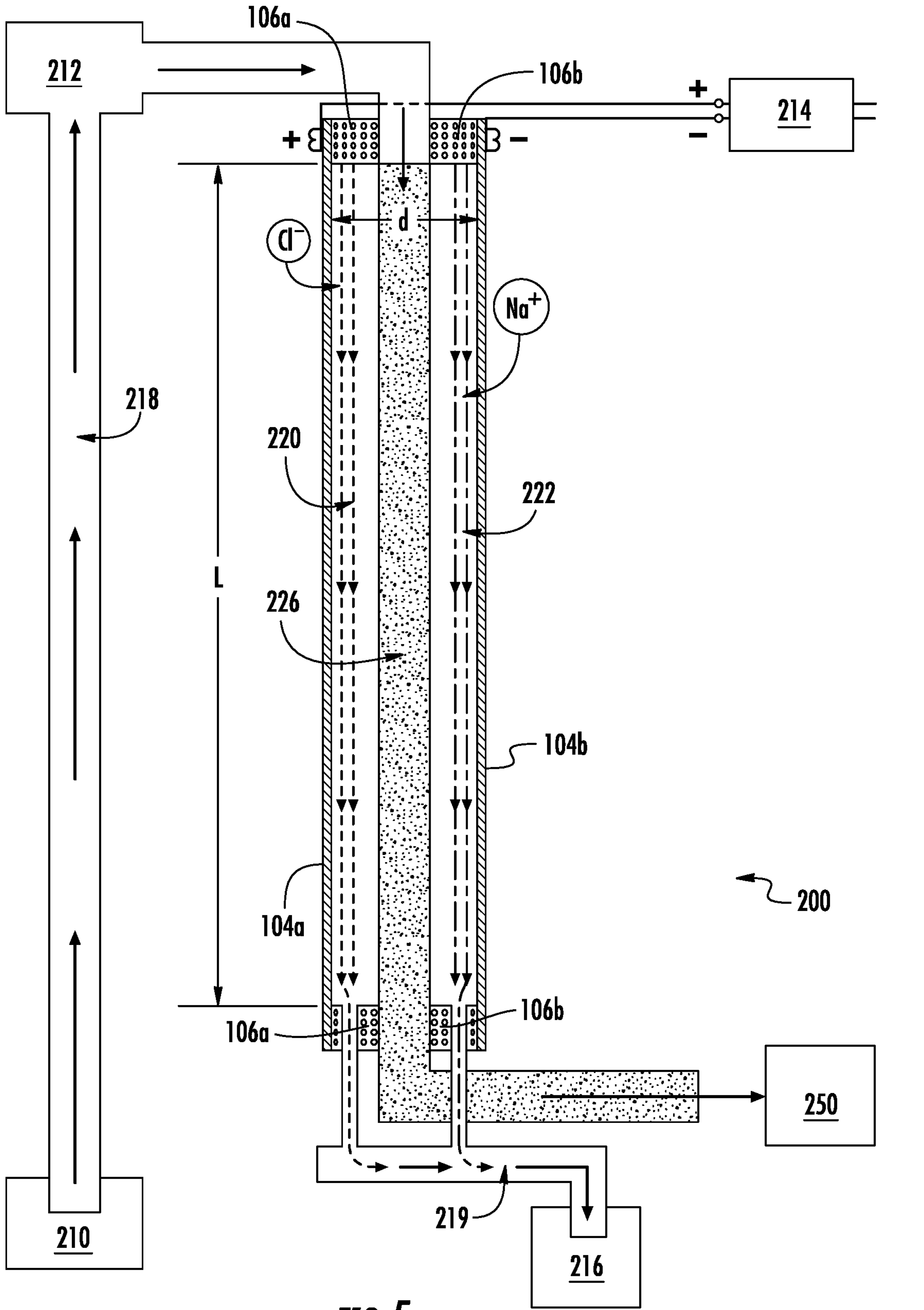


FIG. 4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106b
214
+
−
+
−
d
Cl⁻
Na⁺
L
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220
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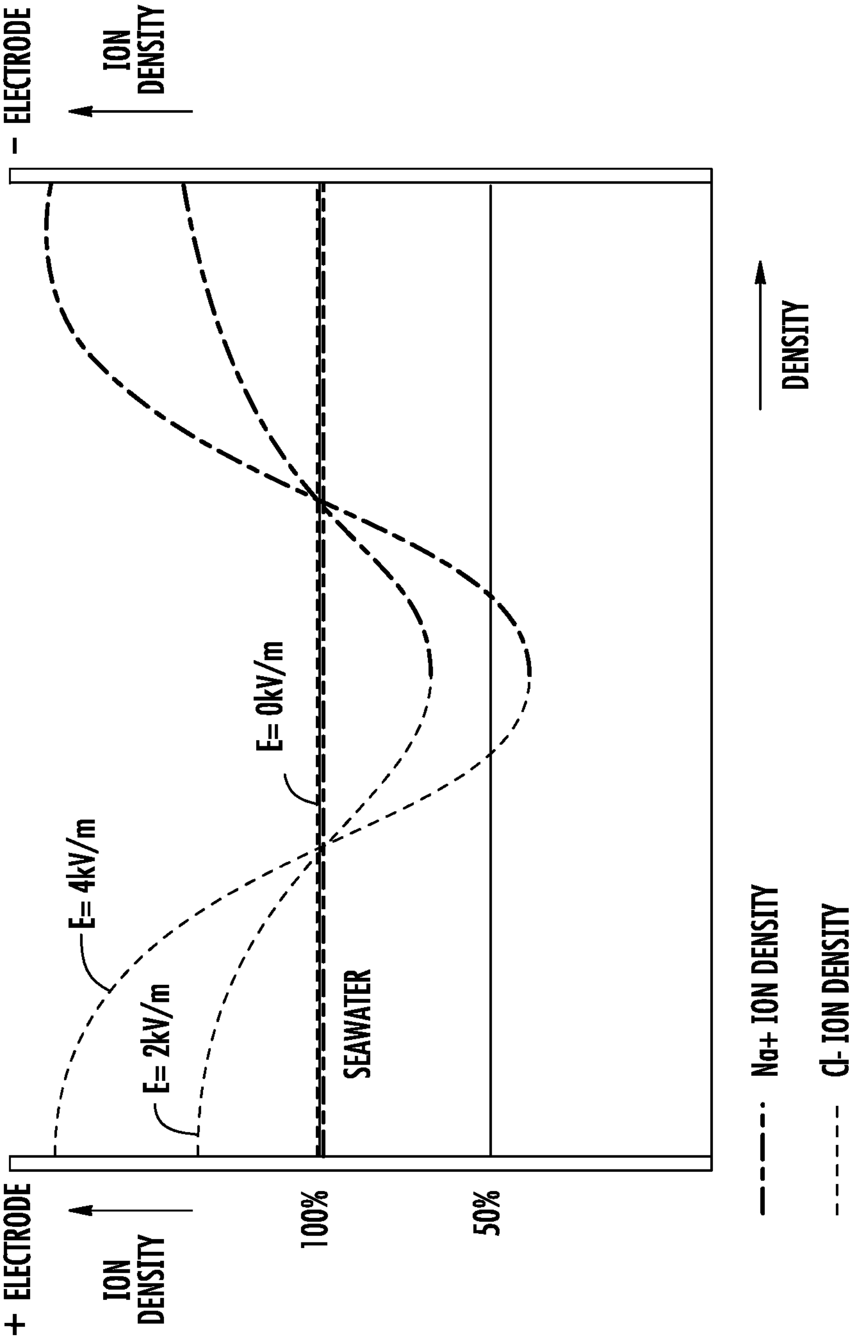
226
104b
104a
200
106a
106b
250
219
216
210

FIG. 5



– ELECTRODE
ION DENSITY
+ ELECTRODE
ION DENSITY
100%
50%
E= 4kV/m
E= 2kV/m
E= 0kV/m
SEAWATER
DENSITY
Na+ ION DENSITY
Cl- ION DENSITY

FIG. 6

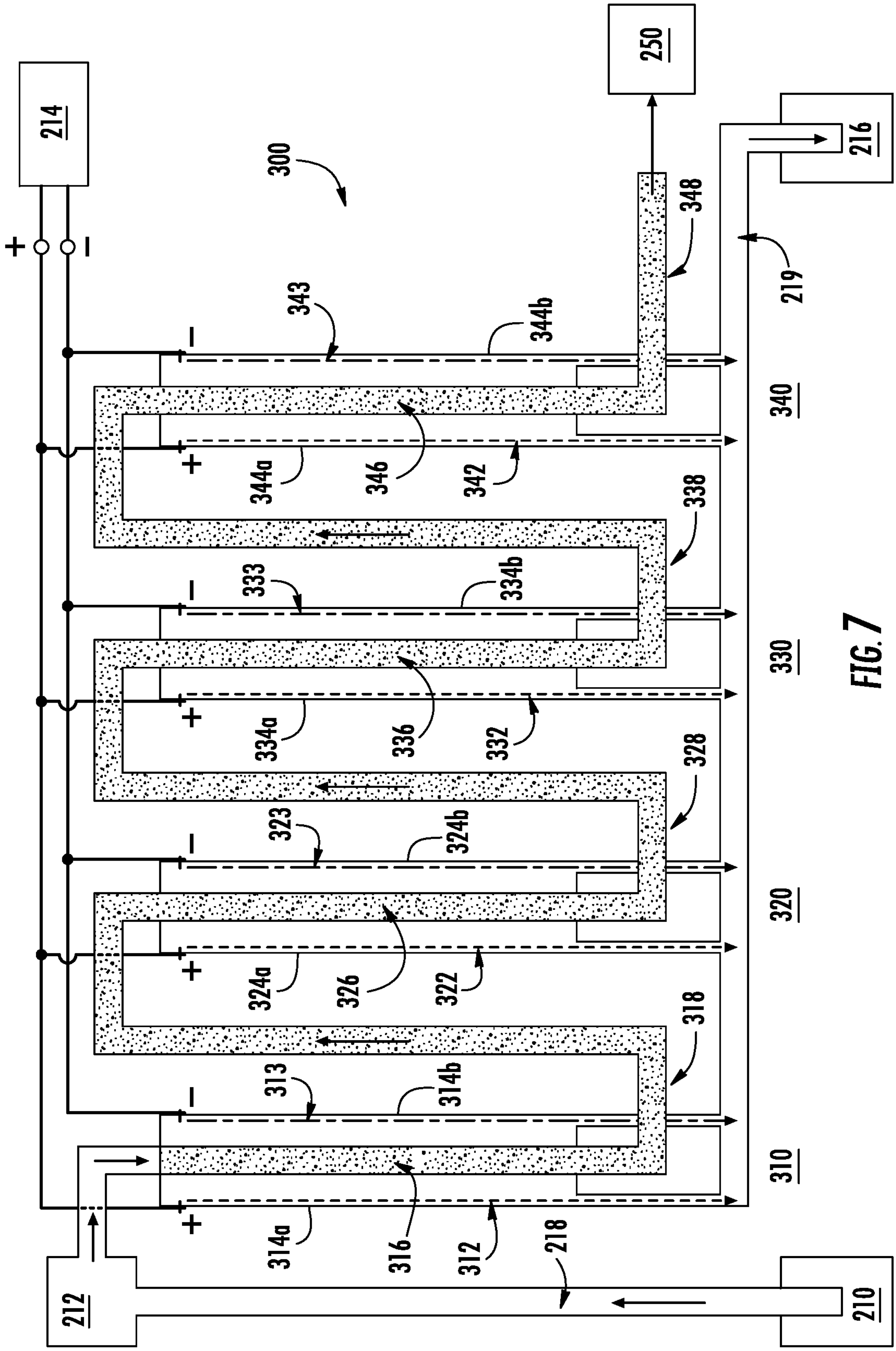

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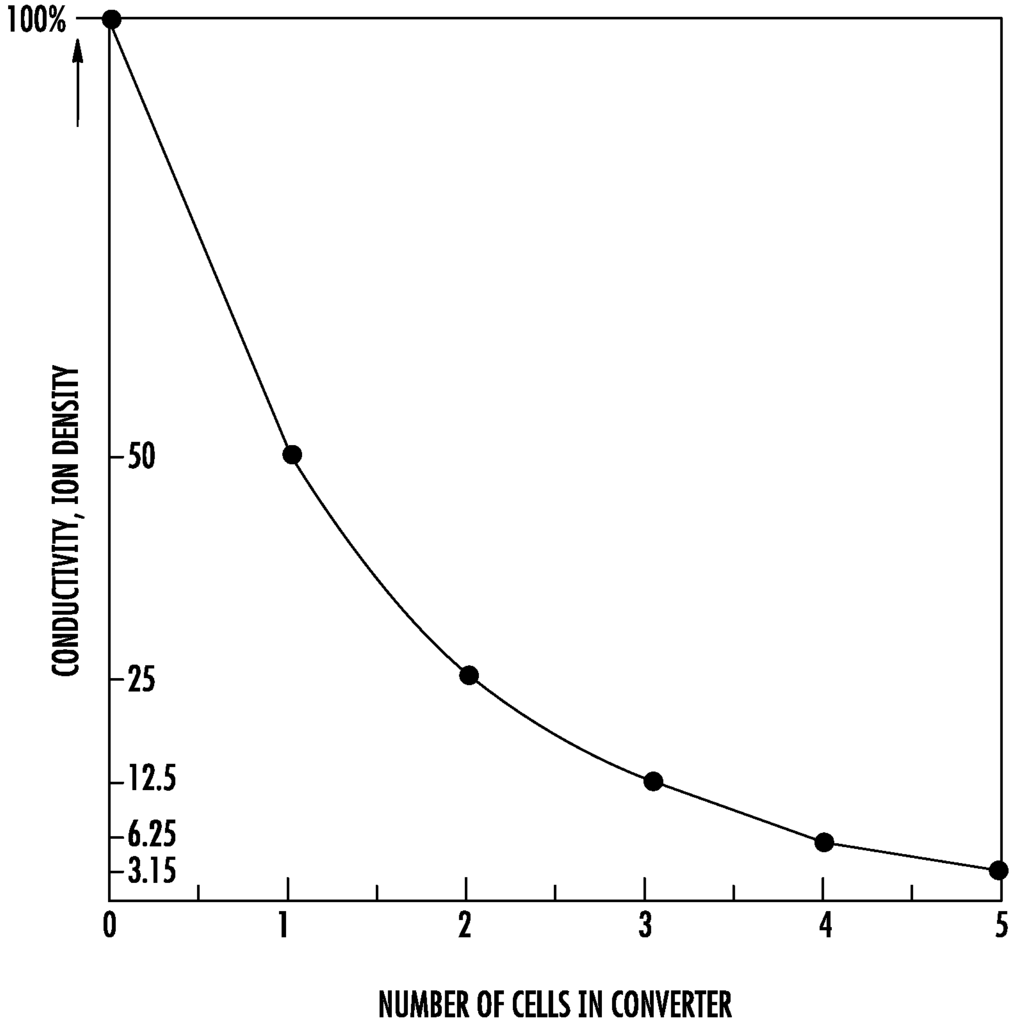
FIG. 7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50
25
12.5
6.25
3.15
CONDUCTIVITY, ION DENSITY
0
1
2
3
4
5
NUMBER OF CELLS IN CONVERTER

FIG. 8

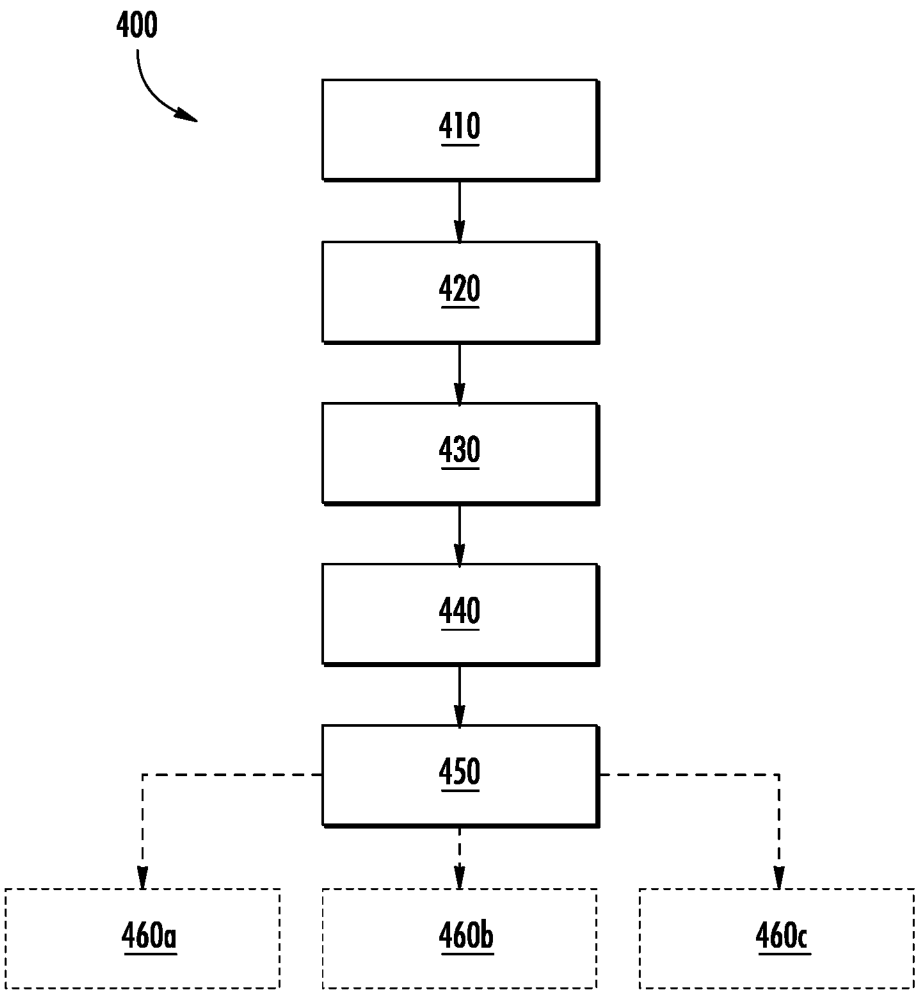

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2022/053231

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F1/46 C02F1/461
ADD. C02F103/08

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C02F C25B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/305765 A1 (TROUVE EMMANUEL [FR] ET AL) 26 October 2017 (2017-10-26) paragraphs [0001], [0021] - [0038], [0096], [0114], [0120]; figure 5 paragraphs [0040] - [0093]; figure 1A -----	1-15
X	US 2017/088445 A1 (YAZDANBOD AZAROGHLY [CA]) 30 March 2017 (2017-03-30) paragraphs [0002], [0013], [0025] - [0028], [0093] paragraphs [0101] - [0107]; figures 10, 11 -----	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 June 2022	13/07/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Vaz, Miguel

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2022/053231

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2017305765 A1	26-10-2017	CY 1121016 T1	11-12-2019
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		WO 2012054871 A2	26-04-2012