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(54) Title: DESALINATION DEVICE AND PROCESS USING GAS DIFFUSION ELECTRODES

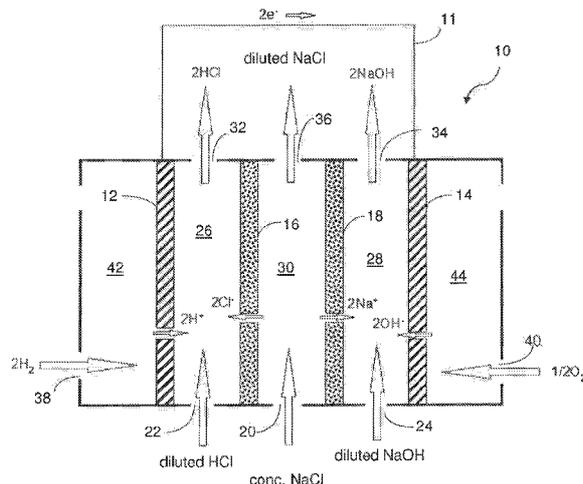


Fig. 1

(57) Abstract: The invention relates to a desalination device (10; 110) comprising a gas diffusion anode (12; 112) suitable to transform hydrogen $\frac{3}{4}$ into H^+ hydrogen ions; a gas diffusion cathode (14; 114) connected through an electrical connection (11) to said gas diffusion anode and suitable to transform oxygen O_2 into OH^- hydroxide ions; a system to feed said gas diffusion anode with hydrogen; a system to feed said gas diffusion cathode with oxygen; a cation exchange membrane (18; 118); and an anion exchange membrane (16; 116). The cathode (14; 114) is contained in a cathodic chamber (28; 128) suitable to contain or containing a catholyte. The anode (12; 112) is contained in an anodic chamber (26; 126) suitable to contain or containing an anolyte. The anodic chamber (26; 126) and the cathodic chamber (28; 128) are separated by the cation exchange membrane (18; 118) and by the anion exchange membrane (16; 116) which in turn are separated by a third chamber (30; 130) suitable to contain or containing an aqueous salt solution, where the cation exchange membrane (18; 118) is simultaneously a wall or a part thereof of the cathodic chamber (28; 128) and of the third chamber (30; 130) so that there can be a salt cation passage from the third chamber (30; 130) to the cathodic chamber (28; 128); and where the anion exchange membrane (16; 116) is simultaneously a wall or a part thereof of the anodic chamber (26; 126) and of the third chamber (30; 130) so that there can be a salt anion passage from the third chamber (30; 130) to the anodic chamber (26; 126). A related desalination process is also described.



WO 2016/120717 A1

DESALINATION DEVICE AND PROCESS USING GAS DIFFUSION ELECTRODES

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TECHNICAL FIELD

The present invention relates to a device and process for seawater and industrial brine desalination.

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STATE OF THE ART

Desalinization (also called desalination) is the process of removing dissolved salts in wafer, obtaining, as a result, freshwater from seawater or brackish water. In other words, desalinization refers to a technological process for the extraction of solvent (water) from salt solutions and the resulting freshwater production from seawater or industrial brines.

A desalinization device is known in the art by the application of distillation techniques or by reverse osmosis desalination or by means of electrodiaiysis desalinators. All three cases considered include a considerable energy source consumption, generally electrical energy in case of reverse osmosis and electrodiaiysis desalinators, or fuel for heating saline solution. Furthermore, in addition to the saline water supply inlet line and the freshwater or desalinated water outlet line, also the waste brine line is necessary.

Particularly, waste brines play a very important role in terms of environmental impact of existing desalinization techniques. These consist in saline solutions being too concentrated to be reprocessed by the system in an affordable way and are, therefore, managed as waste solutions. Given the increased salinity of these brines, their dispersion in the sea or soil demonstrated, over the years, the onset of a high environmental impact with the increase in relative salinity in dispersion areas and subsequent effects on flora and sea fauna or on drinking water availability from groundwater sources. Over the years, such environmental impact led to an exacerbation of the international legislations with regard to the possible application of such known technologies, leading to their substantial

inapplicability in the areas more affected by the need for freshwater supply from desalinization.

Notwithstanding the important advances in desalination technologies, seawater desalinization is still a technology with a higher energy consumption compared to
5 conventional technologies for freshwater treatment; this is the most relevant aspect that limits their commercial development. Furthermore, there are also strong concerns regarding potential environmental impacts of large seawater desalinization plants, since they produce waste (brine) that cannot be discharged into the sea. Such environmental drawback was found in all technologies
10 currently existing on the market.

In addition to environmental impact generated from waste brine, a second critical point concerning presently known technologies is inherent to energy consumptions related to water desalinization activity for the production of drinking water. Over the last 20 years, most of the research was concentrated on this
15 aspect, in order to particularly optimize reverse osmosis and fractional distillation desalinization processes, nevertheless, energy consumptions mainly related to these two techniques are among the highest in the water treatment industry. By way of example, a reverse osmosis desalinization plant consumes approximately 3 kWh/m³, from which, considering about 0.20 US \$/kW, an energy cost of 0.60
20 US \$/m³ is derived, against a maximum value of 0.90 US \$/m³ of the produced water. On the other hand, concerning the evaporation processes, it is known that a vapour distillation of the turbine to the pressure of 6 bar subtracts enthalpy to the expansion in an amount equal to the theoretical production of about 5 kWh/m³ of desalinated wafer produced by evaporation. Such energy, known as latent
25 heat, is thus a non-recoverable energy consumption.

Today, as a consequence, the development of desalination technologies is entirely aimed at reducing energy consumption, while the desalination *post-*
treatment step, i.e. the disposal of *h*/per-saline waste, was not fully and
30 adequately addressed to date.

DISCLOSURE OF THE INVENTION

The invention has the object of overcoming the mentioned problems, and precisely proposes a new device and process for desalination that is simultaneously efficient and environmentally friendly in order to meet the increasingly more stringent environmental requirements, i.e. a device and
5 process for desalination that has low management and investment costs, able to avoid or chemically enhance waste (brine).

Thus, the object of the invention is the presentation of a device and a related process for the production of desalinated water from industrial brine or seawater, allowing first to solve the problem of waste brine production, and secondly to
10 optimize energy consumption per cubic metre of desalinated water.

A further object of the invention is to provide a desalination device and process able to provide a 99%-desalinated water, i.e. suitable for human consumption, with lower investment and operating costs compared to the known art and without producing waste (brine).

15 In a first aspect of the invention, the objects are achieved by a desalination device comprising:

- (a) a gas diffusion anode suitable to transform hydrogen H_2 into H^+ hydrogen ions;
- (b) a gas diffusion cathode connected through an electrical connection to said
20 gas diffusion anode and suitable to transform oxygen O_2 into OH^- hydroxide ions;
- (c) a system to feed said gas diffusion anode with hydrogen;
- (d) a system to feed said gas diffusion cathode with oxygen;
- (e) a cation exchange membrane;
- (f) an anion exchange membrane;

25 wherein

- (i) said cathode is contained in a cathodic chamber suitable to contain or containing a catholyte;
- (ii) said anode is contained in an anodic chamber suitable to contain or containing an anolyte;
- 30 (iii) said anodic chamber and said cathodic chamber are separated by said cation exchange membrane and by said anion exchange membrane which, in turn, are separated by a third chamber suitable to contain or containing an aqueous salt solution,

where

(a) said cation exchange membrane is simultaneously a wall or a part thereof of said cathodic chamber and of said third chamber, so that a salt cation passage is possible from the third chamber to the cathodic chamber;

5 (β) said anion exchange membrane is simultaneously a wall or a part thereof of said anodic chamber and of said third chamber so that a salt anion passage is possible from the third chamber to the anodic chamber.

The device, object of the invention, is able to treat industrial saline solutions or seawater in order to produce the extraction of ions dissolved in the aqueous
10 solution producing as a residue a solvent flow (deionized water) and two separate solutions, one containing anions and the other cations, previously dissolved in the saline solution, conveniently stabilized respectively by hydronium ion or (improperly) acidic proton and hydroxide or hydroxyl ion.

This device and a related process (to be later described), according to the
15 invention, chemically enhance waste (brine) through the production of basic chemical products and have a low investment cost.

The device and the desalinization process according to the invention are characterised by a coupled use of fuel cell technology and ion exchange membranes. Compared to a classical fuel cell, the separation of anodic and
20 cathodic chambers is realized through the interposition of a third chamber delimited by two ion exchange membranes.

Ion exchange membranes are known from various electrochemical and osmotic applications and are readily identifiable by a person skilled in the art. It is thus possible to omit a detailed description of the membranes.

25 The three chambers are separated from each other; liquid contents are not directly mixable; an exchange is permitted only within the scope of the ionic exchange through membranes.

The operation principle of the desalinization device according to the invention is comparable to the operation principle of a similar technology, i.e. the fuel cell. As
30 in fuel cells, in the device according to the invention, the oxidant and reducing gases are flowed through a gas diffusion electrode, for example a carbon electrode conveniently treated with platinum particles in order to catalyse the production of the H^+ ion from hydrogen and the OH^- ion from oxygen.

The electrochemical circuit is represented by an electrolyte consisting of a saline solution contained between the two membranes, that of the cationic type and that of the anionic type. In this case, the driving force that leads to the ion extraction from the solution is given by the principle of the electrical neutrality of solutions, which determines that cation (having positive charge) and anion (having negative charge) concentrations are related so that an increase in an ionic species is associated with an increase in the concentration of the other species having opposite charge, so that the solution maintains a global null electric charge. Due to the ability of ion exchange membranes to selectively transport positively or negatively charged ions and reject oppositely charged ions, it is possible not only to separate ions from the aqueous solution, but also to constrain them in separate chambers, neutralising them with appropriate H^+ or OH^- ions, in order to produce acidic or basic concentrated solutions.

In the hydrogen oxidation chamber, i.e. in the anodic chamber, in order to produce H^+ ions, a free electron is released on the electrode; conversely, in the reduction chamber, i.e. in the cathodic chamber, in order to obtain the production of OH^- ions from oxygen, a free electron is picked up. Correspondingly, a second external circuit, an electrical circuit, is realized through the electrical connection of two electrodes on which it advantageously generates a direct current. As described, thus, the present device is able to produce electrical energy during desalination as an essential phenomenon to the electrochemical circuit closure. Such electric current is exploitable as in fuel cells.

Secondly, advantageously, the described technology does not involve any thermal process or pressure processes or any type of fluid mechanical movement if not exclusively that given by the flows within the chambers.

In third analysis, the present desalination process, assimilable to an electrodialysis process, differs from it by the fact that it does not involve waste brine formation, since it does not proceed to the extraction of pure solvent portions from the solution but rather, conversely, to the direct extraction of ions from the solution. Moreover, the possibility of separately extracting and constraining positive and negative ions in separate chambers allows the realization of what may be defined a reverse acid-base neutralization reaction,

allowing to reproduce the respective concentrated acids and the respective concentrated bases from the saline solution.

In a preferred variant of the invention, in the desalinization device, each chamber is provided with an inlet and an outlet, and precisely:

- 5 (a) the anodic chamber is provided with an inlet for the diluted anolyte and an outlet for the concentrated acid;
- (b) the cathodic chamber is provided with an inlet for the diluted catholyte and an outlet for the concentrated base; and
- (c) the third chamber is provided with an inlet for the initial salt solution and an
10 outlet for the reduced-concentration salt solution.

This system allows a continuous device operation. There are three inlets for three different liquids (anolyte, catholyte and brine, wherein anolyte and catholyte do not correspond to brine) and three outlets for the production of three usable non-waste solutions: drinking water, acid and base.

- 15 Preferably, the cathode, the anode and membranes are plate-shaped and are essentially arranged in parallel therebetween. Such arrangement is simple and compact. Thus, in the device according to the invention, anode, anodic chamber, anion exchange membrane, third chamber, cation exchange membrane, cathodic chamber and cathode are in succession.

- 20 In an advantageous variant of the invention, the anolyte is an acid, the catholyte is a base and the salt solution is a salt solution composed of the anion of the acid and the cation of the base. This allows the production of concentrated acids and bases from their respective neutralization product, the salt. Most preferably, the anolyte is hydrochloric acid, the catholyte is sodium hydroxide and the salt
25 solution is a sodium chloride solution. In this constellation it is possible to desalinate seawater. Obviously, the device can also be used for the desalinization of other kind of concentrated salt solutions such as industrial process waste.

- Advantageously, the electrodes are carbon electrodes comprising catalyst
30 particles, in particular platinum. The presence of the catalyst simplifies hydrogen and oxygen transformation respectively into H^+ and OH^- . Other kind of electrodes, known from the art of fuel cells, are possible.

Preferably, the system to feed the gas diffusion anode with hydrogen is a methane-fed reformer. The use of such reformer allows the production of synthesis gas (H_2 and CO_2).

Advantageously, the system to feed said gas diffusion cathode with oxygen is a system that provides air. Air is a very economical choice and is available everywhere.

Another aspect of the invention relates to a desalinization process comprising the following steps:

- (a) providing a device according to the invention;
- 10 (b1) feeding of the anodic chamber with an anolyte, preferably a diluted acid;
- (b2) feeding of the cathodic chamber with a catholyte, preferably a diluted base;
- (b3) feeding of the third chamber with a concentrated salt solution;
- (C1) oxidation of hydrogen H_2 on the anode with formation of H^+ hydrogen ions that enter into the anodic chamber;
- 15 (c2) oxygen reduction on the cathode with formation of OH^- hydroxide ions that enter into the cathodic chamber;
- (d1) in reaction to the increase in H^+ ion concentrations in the anodic chamber, passage of salt anions from the third chamber to the anodic chamber;
- (d2) in reaction to the increase in OH^- ion concentrations in the cathodic chamber,
- 20 passage of salt cations from the third chamber to the cathodic chamber.

Advantageously, a concentrated acid is extracted from the anodic chamber, a concentrated base is extracted from the cathodic chamber and drinking water or water for irrigation use, preferably drinking water, is extracted from the third chamber. Thus, desalinated water and two basic chemical products, a concentrated acid and base, are obtained.

With the device and process according to the invention it is possible to:

- * produce electrical energy through hydrogen oxidation, for example generated through methane reforming, and oxygen reduction, for example of the oxygen contained in the air,
- 30 ® regenerate an acid, for example hydrochloric acid, and a base, for example sodium hydroxide, from a salt solution, such as sodium chloride, through salt component migration between cation and anion exchange

membranes. Accordingly, waste (brine) production will not occur, but basic chemical products are obtained.

The unique technology advantages according to the invention can be, *inter alia*, described with:

- 5 (a) production of drinking water;
(b) production of electrical energy (11 kWh /m³ of desalinated water); and
(c) production of basic chemicals, such as hydrochloric acid and sodium hydroxide.

10 The desalination principle according to the invention, may be described as a spontaneous pump ionic desalination (SPID) or as a spontaneous membrane ionic transfer (SMIT), the trade name chosen by the applicant for the technology according to the invention.

The features described for one aspect of the invention may be transferred *mutatis mutandis* to the other aspect of the invention.

15 Said objects and advantages will be better highlighted during the description of preferred embodiment examples of the invention given, by way of non-limiting example.

Variants of the invention are the object of the dependent claims. The description of preferred embodiments of the device and desalination process according to
20 the invention is given, by way of non-limiting example and not of limitation, with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates, in a schematic diagram, the desalination device and
25 process mode of operation according to the invention.

Fig. 2 illustrates, in an exploded view, an embodiment of the desalination device according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

30 With particular reference to figure 1, the device and process operation principle according to the invention is illustrated. The device generally referred to as 10 comprises two gas diffusion electrodes (GDE) 12 and 14 and, precisely, a gas diffusion anode 12 and a gas diffusion cathode 14. The two electrodes are

necessary for the oxidation and reduction of feeding gases, herein hydrogen and oxygen, of the fuel cell realized in the device 10. These electrodes 12 and 14 are separated by two membranes 16 and 18. Membrane 16 is an anion exchange membrane (AEM), while membrane 18 is a cation exchange membrane (CEM).

5 An inlet 20 connected to a salt water inlet line, an inlet 22 connected to an anolyte (diluted HCl) inlet line, and an inlet 24 connected to a catholyte (diluted NaOH) inlet line are further noted. The anolyte enters in a first chamber 26 formed between anode 12 and anion exchange membrane 16. The catholyte enters in a second chamber 28 formed between cathode 14 and cation exchange membrane

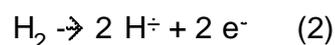
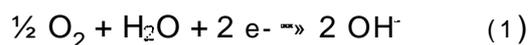
10 18. Finally, salt water enters in a third chamber 30 formed between the two ion exchange membranes 18 and 18. In each chamber 26, 28 and 30 an outlet is provided, and precisely in the first chamber 26 an outlet 32 for concentrated acids, in the second chamber an outlet 34 for concentrated bases and in the third chamber 30 an outlet 38 for drinking water or water for irrigation use.

15 Finally, the device 10 provides a hydrogen inlet 38 and an oxygen inlet 40 that are part, respectively, of a fourth and fifth chamber 42 and 44. Fourth chamber 42 is defined on one side by anode 12, while fifth chamber 44 is defined on one side by cathode 14. Electrodes 12 and 14 are permeable to hydrogen and oxygen. Electrodes 12 and 14 are connected through an electrical connection 11.

20 Hydrogen H₂ and oxygen O₂ oxygen are oxidised and reduced respectively on anode 12 and cathode 14 to form H⁺ hydrogen ions and OH⁻ hydroxide ions. These ions leave the respective electrodes to enter into the first chamber 26 and second chamber 28.

Hydrogen oxidation (anodic process) and oxygen reduction (cathodic process)

25 processes are represented by the following equations (1) and (2):



The driving force of the system is the electrical neutrality principle, which determines that cation (having positive charge) and anion (having negative

30 charge) concentrations are related to each other so that an increase in the concentration of one ionic species is associated with an increase in the

concentration of the other species having opposite charge. Since the used membranes have the ability to selectively transport positively (membrane 18) or negatively (membrane 16) charged ions and reject oppositely charged ions, it is possible to separate, remove and concentrate electrolytes. In the specific case illustrated in figure 1, the increase in the H^+ ion concentration in chamber 28 causes the compensation of the positive charges introduced with the entrance of Cl^- ions from chamber 30 through the anion exchange chamber 16, while the increase in the OH^- ion concentration in chamber 28 causes the compensation of the negative charges introduced with the entrance of Na^+ ions from chamber 30 through the cation exchange membrane 18. These processes cause an increase in hydrochloric acid HCl concentration in chamber 26, an increase in sodium hydroxide $NaOH$ concentration in chamber 28 and, finally, a decrease in salt $NaCl$ concentration in chamber 30. In chambers 26 and 28, H^+ and Cl^- (forming hydrochloric acid) and OH^- and Na^+ (forming sodium hydroxide) are respectively combined together.

Accordingly, hydrochloric acid and sodium hydroxide may be regenerated by the sodium chloride solution using a cell 10 at three chambers or compartments 26, 28 and 30 defined by two electrodes 12 and 14 and by two ion exchange membranes 16 and 18.

In summary, the device provides an inlet 20 connected to the saline solution feeding line (not represented), two inlets containing the anolyte and catholyte diluted solutions 22 and 24, two hydrogen and oxygen feeding inlets 38 and 40, electrodes 12 and 14 for feeding gases oxidation and reduction, appropriate ion exchange membranes 16 and 18, an outlet 36 for drinking desalinated water or water for irrigation use, a concentrated acid outlet 32, a basic concentrated solution outlet 34.

Figure 2 illustrates, in an exploded view, a device 110 8 (a cell) embodiment example according to the invention.

On the external sides of the device 110 there are some perforated walls 146 and 148 defining cell 110. Proceeding from cell sides 110 towards the inside, two perforated gaskets 154 and 156 are noticed. Between the wall 146 and the gasket

154 a gas compartment (arrow A) is inserted (not represented), as well as (arrow B) between the wall 148 and the gasket 156. A gas diffusion cathode 114 and a gas diffusion anode 112, supported by perforated walls 152 and 150, respectively follow. Electrodes 112 and 114 are followed by perforated gaskets 166 and 168.

5 Two chambers 128 and 128 in respective perforated walls 174 and 176 are associated. On each side, a perforated gasket 178 and a non-perforated gasket 180 follow, then there are a cation exchange membrane 118 and a perforated anion exchange membrane 116. Finally, there are a perforated gasket 186 and a non-perforated gasket 188, one on each side; these gaskets define a third

10 chamber 130 housed in a perforated wall 192. The presence or absence of said holes and the alignment or non-alignment therebetween determine defined channels for liquid passage, such as the diluted and concentrated anolyte and catholyte and the salt and desalinated water.

Chambers 126, 128 and 130, electrodes 112 and 114 and membranes 116 and

15 118 correspond to chambers 26, 28 and 30, electrodes 12 and 14 and membranes 16 and 18 of figure 1.

One of the holes 194 of wall 148 is used as an inlet for the anolyte passing through the respective holes aligned with it into chamber 126 where it concentrates and exits from a set of aligned holes through the outlet

20 corresponding to one of the holes 196 of wall 148. Chamber 126 is defined by anode 112 and by the anion exchange membrane 116. Anolyte flow is represented by arrows C.

One of the holes 198 of wall 146 is used as an inlet for the catholyte passing through the respective holes aligned with it into chamber 128 where it

25 concentrates and exits from a set of aligned holes through the outlet corresponding to one of the holes 200 of wall 146. Chamber 128 is defined by cathode 114 and by the cation exchange membrane 118. Catholyte flow is represented by arrows D.

Through a third hole 202 of the holes of wall 148 the concentrated salt solution

30 enters and passes through the respective holes aligned with it into chamber 130 where its salt concentration decreases and exits from a set of aligned holes

through the outlet corresponding to another hole 204 of the holes of wall 148. Chamber 130 is defined by cathode exchange membrane 118 and by anion exchange membrane 116. Salt/desalinated solution flow is represented by arrows E.

5 In an application example of the invention for freshwater production from seawater, the plant is composed of a methane-fed reformer for the production of synthesis gas, containing hydrogen and carbon dioxide and a cell as described above. Such plant is preceded by a normal seawater pre-treatment plant, comprising subsequent filtration steps for organic compound and algae removal
10 and for turbidity stabilization, up to an ultrafiltration step, aimed at the removal of divalent ions dissolved in the solution. The water flow feeding the cell is predominantly composed of water and monovalent ions, including predominantly chlorine and sodium. The reformer is fed with hydrogen or with other liquid fuels and provides hydrogen supply for cell feeding. For each m³ of treated water 0.9
15 m³ of drinking water are produced, with a methane consumption of about 3.7 m³ per cubic meter of treated water and a subsequent production of 11 kg of NaOH and 19 kg of NCl.

The present invention solves the problems presented above and provides a device and a related process useful for seawater and industrial brine desalination
20 without producing concentrated salt solutions and producing electrical energy and basic chemical products.

The device according to the invention is a fuel cell electrochemical device able to produce electrical energy during the desalinization process, to consume different forms of fossil fuels, to produce desalinated water and finally to reduce salts
25 dissolved in basic chemicals, which can be economically exploited, avoiding brine production.

During implementation, further embodiment modifications or variants of the desalinization device and desalinization process of the invention, not described herein, may be implemented. If such modifications or such variants should fall
30 within the scope of the following claims, they should all be considered protected by the present patent.

CLAIMS

- 1) Desalinization device (10; 110) comprising:
- (a) a gas diffusion anode (12; 112) suitable to transform hydrogen H_2 into H^+ hydrogen ions;
 - 5 (b) a gas diffusion cathode (14; 114) connected through an electrical connection (11) to said gas diffusion anode and suitable to transform oxygen O_2 into OH^- hydroxide ions;
 - (c) a system to feed said gas diffusion anode with hydrogen;
 - (d) a system to feed said gas diffusion cathode with oxygen;
 - 10 (e) a cation exchange membrane (18; 118);
 - (f) an anion exchange membrane (16; 116);
- wherein
- (i) said cathode (14; 114) is contained in a cathodic chamber (28; 128) suitable to contain or containing a catholyte;
 - 15 (ii) said anode (12; 112) is contained in an anodic chamber (26; 126) suitable to contain or containing an anolyte;
 - (iii) said anodic chamber (28; 126) and said cathodic chamber (28; 228) are separated by said cation exchange membrane (18; 118) and by said anion exchange membrane (16; 116) which in turn are separated by a third chamber
 - 20 (30; 130) suitable to contain or containing a salt aqueous solution,
- where
- (a) said cation exchange membrane (18; 118) is simultaneously a wall or a part thereof of said cathodic chamber (28; 128) and of said third chamber (30; 130) so that there can be a salt cation passage from the third chamber (30; 130) to the
 - 25 cathodic chamber (28; 128);
 - (β) said anion exchange membrane (16; 116) is simultaneously a wall or a part thereof of said anodic chamber (26; 126) and of said third chamber (30; 130) so that there can be a salt anions passage from the third chamber (30; 130) to the anodic chamber (26; 126).
- 30
- 2) Desalinization device according to claim 1, characterized in that each of said chambers (26, 28, 30; 126, 128, 130) is provided with an inlet (20, 22, 24; 194, 198, 202) and an outlet (32, 34, 36, 196, 200, 204), and precisely:

- (a) that the anodic chamber (26; 126) is provided with an inlet (194) for the diluted **anolyte** and an outlet (196) for the concentrated acid;
- (b) that the cathodic chamber (28; 128) is provided with an inlet (198) for the diluted catholyte and an outlet (200) for the concentrated base; and
- 5 (c) that the third chamber (30; 130) has an inlet (202) for the starting salt solution and an outlet (204) for the reduced concentration salt solution.
- 3) Desalinization device according to claim 1 or 2, characterized in that said cathode (14; 114), said anode (12; 112) and said membranes (16, 18; 116, 118)
- 10 are plate-shaped and are essentially arranged in parallel therebetween.
- 4) Desalinization device according to any of claims 1 to 3, characterized in that said anolyte is an acid, said catholyte is a base and said salt solution is a salt solution composed of the anion of said acid and of the cation of said base.
- 15 5) Desalinization device according to claim 4, characterized in that said anolyte is hydrochloric acid, that said catholyte is sodium hydroxide and that said salt solution is a sodium chloride solution.
- 20 6) Desalinization device according to any of claims 1 to 5, characterized in that electrodes (12, 14; 112, 114) are carbon electrodes comprising catalyst particles, in particular platinum.
- 25 7) Desalinization device according to any of claims 1 to 6, characterized in that said system to feed said gas diffusion anode with hydrogen is a methane-fed reformer.
- 30 8) Desalinization device according to any of claims 1 to 7, characterized in that said system to feed said gas diffusion cathode with oxygen is a system that provides air.
- 9) Desalinization process comprising the following steps:
- (a) providing a device (10; 110) according to any of the previous claims;

- (b1) feeding the anodic chamber (26; 126) with an anoiyte, preferably a diluted acid;
- (b2) feeding the cathodic chamber (28; 128) with a cathoiyte, preferably a diluted base;
- 5 (b3) feeding the third chamber (30; 130) with a concentrated salt solution;
- (c1) oxidation of hydrogen H_2 on the anode (12; 112) with formation of H^+ hydrogen ions that enter into the anodic chamber;
- (c2) oxygen reduction on the cathode (14; 114) with formation of OH^- hydroxide ions that enter into the cathodic chamber;
- 10 (d1) in reaction to the increase in H^+ ion concentrations in the anodic chamber (26; 126), passage of salt anions from the third chamber (30; 130) to the anodic chamber (26; 126);
- (d2) in reaction to the increase in OH^- ion concentrations in cathodic chamber (28; 128), passage of salt cations from the third chamber (30; 130) to the cathodic
- 15 chamber (28; 128).

10) Process according to claim 9, characterized in that a concentrated acid is extracted from said anodic chamber (26; 126), a concentrated base is extracted from said cathodic chamber (28; 128) and drinking water or water for irrigation

20 use, preferably drinking water, is extracted from said third chamber (30; 130).

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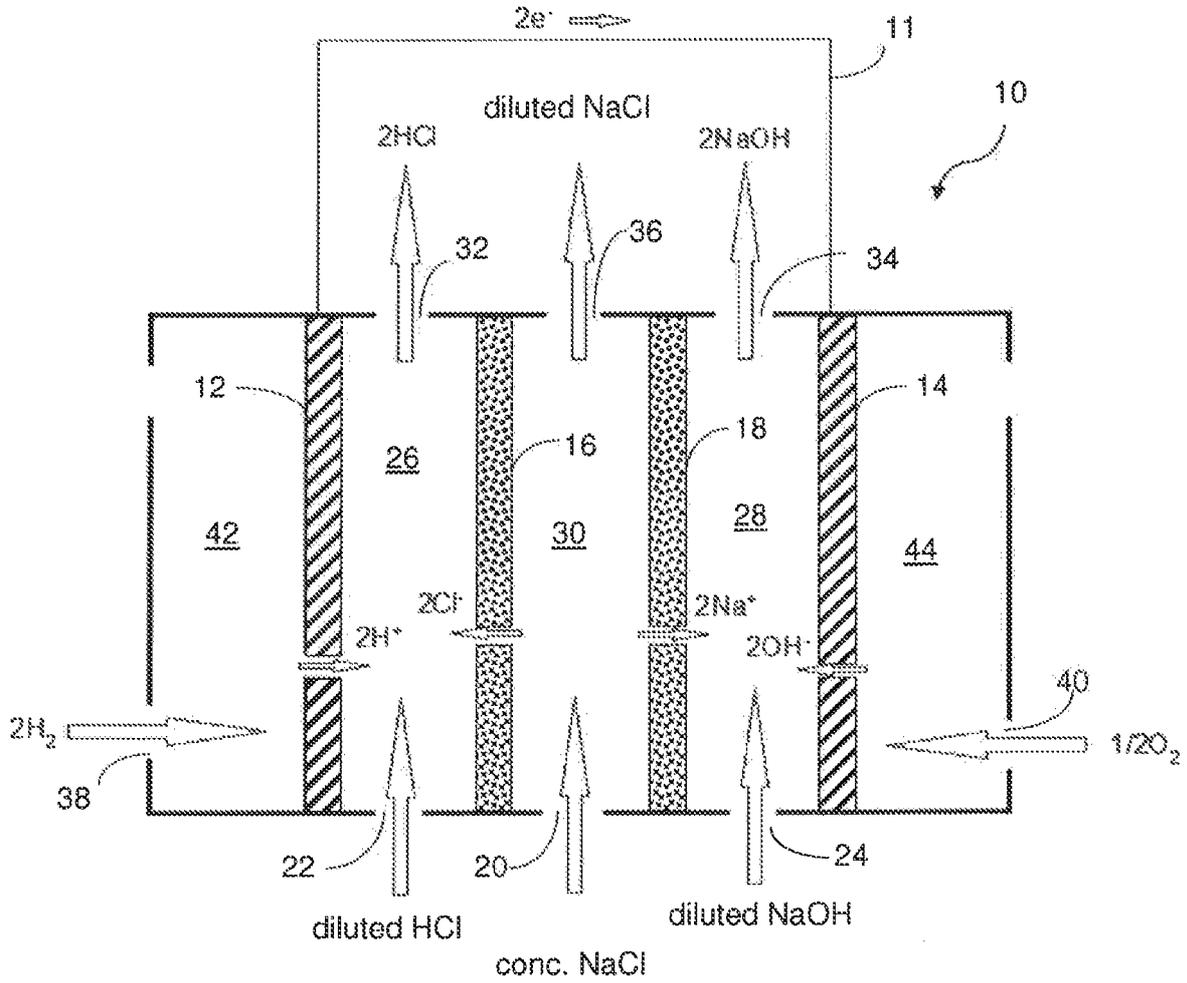


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/000067

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 H01M

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/140103 AI (GILLIAM RYAN J [US] ET AL) 10 June 2010 (2010-06-10) paragraphs [0018] , [0019] , [0027] , [0028] , [0029] , [0030] figure 1	1-10
A	US 2010/270158 AI (LOGAN BRUCE [US]) 28 October 2010 (2010-10-28) paragraphs [0002] , [0043] figure 1	1-10
	----- -/- .	

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

* Special categories of cited documents :

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"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

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Date of the actual completion of the international search 12 May 2016	Date of mailing of the international search report 19/05/2016
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Janssen , Camiel
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/000067

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>KIROS Y ET AL: "Oxygen reduction electrodes for electrolysis in chlor-alkali cells", ELECTROCHIMICA ACTA, ELSEVIER SCIENCE PUBLISHERS, BARKING, GB, vol. 51, no. 16, 10 April 2006 (2006-04-10), pages 3346-3350, XP025168368, ISSN: 0013-4686, DOI: 10.1016/J.ELECTACTA.2005.10.024 [retrieved on 2006-04-10] the whole document</p> <p>-----</p>	1-10
A	<p>US 2009/314718 A1 (SPARROW BENJAMIN STUART [CA] ET AL) 24 December 2009 (2009-12-24) the whole document</p> <p>-----</p>	1-10
A	<p>YOU-PENG QU ET AL: "Simultaneous water desalination and electricity generation in a microbial desalination cell with electrolyte recirculation for pH control", BIORESOURCES TECHNOLOGY, ELSEVIER BV, GB, vol. 106, 12 November 2011 (2011-11-12), pages 89-94, XP028123906, ISSN: 0960-8524, DOI: 10.1016/J.BIORTECH.2011.11.045 [retrieved on 2011-11-25] the whole document</p> <p>-----</p>	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/IB2016/000067
--

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010140103 A1	10-06-2010	AU 2009290161 A1	03-02-2011
		CN 102239590 A	09-11-2011
		EP 2324528 A1	25-05-2011
		US 2010140103 A1	10-06-2010
		US 2011308964 A1	22-12-2011
		WO 2011008223 A1	20-01-2011

US 2010270158 A1	28-10-2010	US 2010270158 A1	28-10-2010
		WO 2010124079 A2	28-10-2010

US 2009314718 A1	24-12-2009	AU 2009261893 A1	30-12-2009
		CA 2649873 A1	08-04-2009
		CN 102066268 A	18-05-2011
		EP 2303784 A1	06-04-2011
		IL 209702 A	31-08-2015
		JO 2809 B	15-09-2014
		JP 5229756 B2	03-07-2013
		JP 2011525420 A	22-09-2011
		KR 20110034006 A	04-04-2011
		US 2009314718 A1	24-12-2009
		US 2011068008 A1	24-03-2011
		WO 2009155683 A1	30-12-2009
