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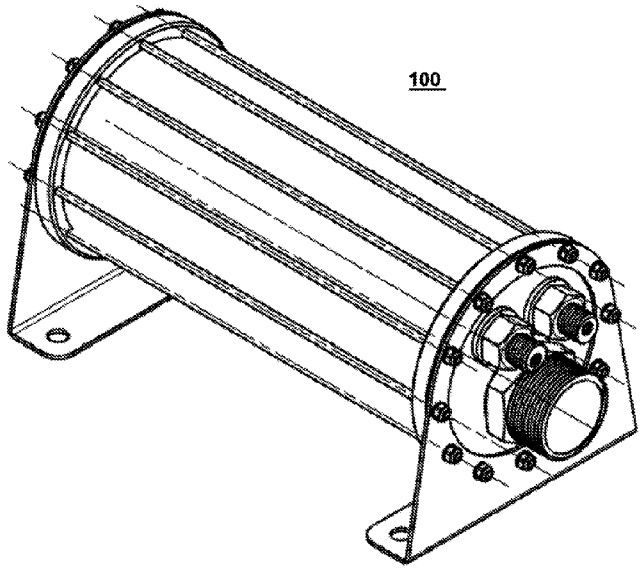


Figure 1

(57) Abstract: Electrochemical reactor comprising an electrode assembly, the electrode assembly including a plurality of electrode plates, at least two circular spacers, each having a central opening having a plurality of apertures/slots for receiving and spacing apart the plurality of electrode plates, and at least two lateral spacers inserted into the central openings of the at least two circular spacers, each having slots to engage with the at least two circular spacers. The electrochemical reactor can be applied for the in-line electrolytic treatment of water / wastewater and, more particularly, for maintaining or improving the water quality of drinking water supplies, swimming pools, ponds, irrigation waters, aquatic mammal tanks, spas, fountains, cooling towers and the like, and for the destruction of targeted contaminants (which can also be of microbiological nature) in water / wastewater streams.

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IN-LINE ELECTROCHEMICAL REACTOR

TECHNICAL FIELD

The present invention concerns an electrochemical reactor for the in-line treatment of aqueous solutions containing halides and, in particular, for the electrolytic treatment of drinking water.

BACKGROUND

Drinking water supplies are commonly disinfected with an oxidiser like chlorine or ozone. Drinking water and wastewater treatment plants may use on-site electrolytic generators to produce the oxidiser used for disinfection and/or as part of an advanced oxidation system for targeted organics destruction. Swimming pools, spas, water features such as ornamental fountains and the like are commonly sanitised using either electrolytic chlorination or ozonation.

Conventional apparatus used to sanitise water in pools and the like includes electrolytic chlorination systems, or "salt" chlorination systems. These systems utilise an electrolytic cell or "chlor-alkali" cell, typically comprising a submerged positively charged anode, a negatively charged cathode, and an electrical energy source for applying a current across the gap between the anode and cathode. The electrolytic cell is fed with a solution including a source of chlorides which, when oxidised, forms chlorine gas. Typically, the chloride source comprises an alkali metal chloride salt such as sodium chloride or potassium chloride, although other sources, such as hydrochloric acid and the like may also be used. When current is applied across the anode and cathode gap, the sodium and chloride ions disassociate with chloride ion concentrating in the solution nearby the anode and the sodium ion concentrating in the solution nearby the cathode. Chlorine and/or oxygen gas is generated on the anode surface and hydrogen gas is generated on the cathode surface, which is released back into the flowing water. The dissolved chlorine gas reacts with the water to create hydrochloric acid (HCl) and hypochlorous acid (HOCl). At concentrations greater than 1 ppm, hypochlorous acid minimises or prevents the growth of algae, bacteria, and other microorganisms. When a single-compartment electrolytic cell is used, the sodium

hydroxide and hypochlorous acid recombine to form sodium hypochlorite (bleach), which is the active oxidiser transported back into the main body of water to prevent microorganism growth. Typical examples of salt chlorination systems are disclosed in Kosarek (U.S. Pat. No. 4,361,471), Wreath and Keller (U.S. Pat. No. 4,613,415), Lynn et al. (U.S. Pat. No. 5,362,368), Bess and Smith (WO 2007/022572 A1), and Poyet (AU 2017/225104 B2), the entire disclosures of which are incorporated herein by this reference.

Conventional apparatus for sanitising water using ozonation typically comprises a high efficiency ozone generator and a venturi mixer or inductor port that injects ozone gas into the water to oxidise contaminants in the water. Exemplary ozonation systems which have been found to be particularly effective in pools and spas are disclosed in Martin and Lavelle (U.S. Pat. Nos. 6,500,332, 6,129,850 and 6,372,148), and Martin (U.S. Pat. No. 6,331,279). Other ozonation systems are disclosed in Karlson (U.S. Pat. No. 5,855,856), Morehead (U.S. Pat. No. 5,451,318), Engelhard (U.S. Pat. No. 5,709,799), and Karlson and Chamblee (U.S. Pat. No. 5,518,698). The entire disclosure of each of these patents is incorporated herein by this reference.

Ozone has been recognised by the FDA to be more than 200 times stronger than chlorine in microbial kill and can react at higher oxidation levels than can be achieved safely with chlorine. However, dissolved ozone can exist in water for only a very short period before it reacts and is converted back into oxygen gas. Thus, dissolved ozone is not an effective residual sanitiser, in contrast to chlorine which has relatively steady and consistent residual sanitisation properties.

To overcome the short residence time of ozone and the high vapor pressure of chlorine in hot spa water, spa and pool owners may add sodium bromide salt to the water. Bromine has a very low vapor pressure compared to chlorine, thus it does not vaporise as readily in aerated hot spa water. Dissolved ozone or sodium hypochlorite will react with the bromide ion to create the hypobromite ion in the water. Hypobromous acid or sodium hypobromite salt will oxidise ammonia to nitrogen gas without creating an intermediate amine compound like the chlorine oxidiser.

Attempts to combine the favourable properties of chlorination and ozonation are described in Tamir (U.S. Pat. No. 4,804,478) and Gargas (U.S. Pat. Nos. 6,517,713,

6,551,518 and 6,814,877 B2). The entire disclosure of each of these patents are incorporated herein by this reference.

Advanced oxidation processes (AOPs) are defined as those processes that optimise the production of hydroxyl radicals ($OH^{\bullet}$) and oxygen species without the addition of metal catalysts. In water treatment, AOPs refer specifically to processes where oxidation of organics by hydroxyl radicals ($OH^{\bullet}$) occurs specifically through processes that involve ozone (O_3), hydrogen peroxide (H_2O_2) and/or ultraviolet light (UV with wavelengths <300 nm), Fenton oxidation, and sonolysis. All AOP systems generate hydroxyl radicals via a pressure (cavitation), chemical reaction, electric field, or photon-based process, or combinations thereof. The ability of an oxidant to initiate chemical reactions is measured in terms of its oxidation potential. The end-product of complete oxidation (mineralisation) of organic compounds is carbon dioxide (CO_2) and water (H_2O). The oxidation potential of hydroxyl radicals at 2.8V is high relative to ozone at 2.1V and chlorine at ~1.4V.

Depending on the existing oxidants in the water and whether salts, anions, ozone and/or air are added to the water, a number of other oxidisers may be generated under AOP conditions including ozone, hydrogen peroxide, and several other peroxides (e.g., peroxomonosulphates, peroxo-disulphates, peroxycarbonates, peroxodiphosphates), which are all good disinfectants and oxidisers.

There still exists a need for an electrolytic water treatment system that can operate as a combined advanced oxidation process / residual oxidant generator for treatment of a wide range of water qualities and uses. Furthermore, there exists a need for such systems which can be manufactured simply and inexpensively, which can easily fit or be retrofitted into a conventional drinking water plant, industrial treatment plant, swimming pool, spa, cooling tower, irrigation channel, mining process, water feature or the like, and which requires relatively little maintenance.

SUMMARY OF THE INVENTION

The present invention relates to water / wastewater treatment systems and, more particularly, to systems and methods for maintaining the water quality of drinking water supplies, swimming pools, ponds, irrigation waters, aquatic mammal tanks, spas, fountains, cooling towers and the like, and for the destruction of targeted contaminants (which can also be of microbiological nature) in water / wastewater streams such as from municipal water / wastewater treatment plants, ground water streams, industrial water / wastewaters and water from larger bodies such as streams and rivers, and for the preparation of lixiviant solutions suitable for solution mining applications.

The present invention comprises an apparatus for generating a mixed oxidant stream containing oxidants such as: ozone, hydrogen peroxide and other peroxide species, hydroxyl radicals, as well as chlorine-based oxidants, the quantities and concentrations of which are determined by the quantity and type of compounds precursors that are fed into the electrochemical reactor, the water flow rate, the intensity of the current fed to the electrochemical reactor, and the electrode material.

In the particular case of drinking water treatment, the apparatus must be fit for purpose and comply with relevant regulations. In Australia, the Australian Building Codes Board manages and administers the so-called WaterMark Certification Scheme (*the Scheme*), which is a mandatory certification scheme for plumbing and drainage products to ensure they are fit for purpose and appropriately authorised for use in plumbing and drainage installations. For materials and products to be certified and authorised for use through *the Scheme*, specific standard tests must be passed. Currently, testing of products for use in contact with drinking water is standardised by AS/NZS 4020, which specifies requirements for the suitability of products for use in contact with drinking water, with regard to their effect on the quality of water. These products include pipes, fittings, components, and materials used in coating, protection, lining, jointing, sealing and lubrication applications in the water supply and plumbing industry. AS/NZS 4020 requires that products intended for use in contact with drinking water are tested by exposure to test water. Where appropriate, a scaling factor is applied to such tests to compensate for differences between laboratory and field conditions. In addition, WMTS-103 WaterMark Technical Specification sets out the minimum requirements for water treatment system componentry, other than those specified in AS/NZS 3497, for use on domestic drinking water supply (private or public).

It may be applied to systems used in commercial or industrial applications. Water treatment units and water sanitisers (including UV) are among the systems contemplated in WMTS-103, which prescribes the following requirements for the water system treatment:

- Products in contact with drinking water shall comply with AS/NZS 4020;
- When subjected to permanent hydrostatic pressure test of 2 +0.1, −0 MPa (or 20 bars) at the manufacturer's stated maximum operating temperature of 'x' +5, −0 °C for 60 min +10, −0 s, all components shall not leak (*Hydrostatic Pressure test*);
- All components shall be subjected to cyclic testing of 100,000 pressure cycles at a minimum pressure cycle frequency of 30 ±2 cycles/min at a temperature of 23 ±2 °C and a minimum and maximum pressure range of 0 to 1,034 kPa, or 10.34 bars (*Endurance test*);
- When tested at ambient temperature, components subjected to permanent hydrostatic pressure shall meet a minimum burst pressure of 3.5 MPa (or 35 bars) when tested at ambient temperature (*Burst Pressure test*).

According to the above requirements, the present invention concerns an electrochemical reactor able to pass the prescribed Hydrostatic Pressure test, Endurance test, and Burst Pressure test.

The present invention comprises an apparatus that can employ any number or combination of types of electrodes in an electrochemical cell(s) such as, but not limited to: dimensionally-stable electrodes, boron-doped diamond electrodes, ceramic titanium (Ebonex®) electrodes, glassy carbon or aerogel electrodes, lead-oxide electrodes, titanium, nickel, platinum, copper electrodes with specialty coatings, expendable electrodes such as iron or aluminium for electrocoagulation, or silica-based electrodes. The choice of electrode to be used in the present invention depends upon a large number of variables such as, but not limited to, the water treatment process(es) selected, the contaminants of interest, the influent water quality, the desired water quality, the efficiencies of the treatment processes, and costs associated with the treatment process.

In certain embodiments, the present invention includes an electrochemical reactor comprising an electrode assembly, the electrode assembly including a plurality of electrode plates; at least two circular spacers, each having a central opening having a plurality of apertures/slots for receiving and spacing apart the plurality of electrode plates; at least two lateral spacers inserted into the central openings of the at least two circular spacers, each having slots to engage with the at least two circular spacers.

DESCRIPTION OF THE FIGURES

Figure 1 shows a perspective elevation (isometric view) of an embodiment of the electrochemical reactor of the present invention;

Figure 2 shows a side view of the embodiment of the electrochemical reactor as shown in figure 1;

Figure 3 shows an end view of the embodiment of the electrochemical reactor as shown in figure 1

Figure 4 shows a section view of the electrochemical reactor of the present invention according to plan trace A-A in the terminal end view of figure 3;

Figure 5 shows a perspective elevation (isometric view) of the electrode assembly illustrating the spatial placement of the electrode stacks in accordance with the electrochemical reactor of figure 1;

Figure 6 is a first end view of the electrode assembly as shown in figure 5;

Figure 7 is a side view of the electrode assembly as shown in figure 5;

Figure 8 is an underside view of the electrode assembly as shown in figure 5;

Figure 9 is a perspective, exploded view of both the anode and cathode assemblies showing electrical and mechanical connectivity between the two assemblies in accordance with the electrode assembly of figure 5.

Figure 10 shows a perspective elevation (isometric view) of the spacer plate and lateral spacer, used to support and provide rigidity to the electrode assembly of figure 5;

Figure 11 is a separate perspective elevation (isometric view) of the circular spacer shown in figure 10;

Figure 12 is a separate perspective elevation (isometric view) of the lateral spacer shown in figure 10;

Figure 13 shows an exploded 2D view of the assembly between the current collectors and the related flanged fitting of the electrochemical reactor of the present invention; in this embodiment, an O-ring is illustrated as the means to prevent liquid leaks from the assembly between the flanged fitting and the hollow cylindrical element acting as the cell stack containment housing.

DETAILED DESCRIPTION

The present invention concerns an electrochemical reactor for the in-line treatment of water / wastewater or, more in general, aqueous solutions containing halides and, in particular, for the electrolytic treatment of drinking water with the aim of maintaining or improving the quality of water in water supplies, swimming pools, ponds, irrigation waters, aquatic mammal tanks, spas, fountains, cooling towers and the like, and for the destruction of targeted contaminants (which can also be of microbiological nature) in water / wastewater streams such as from municipal water / wastewater treatment plants, ground water streams, industrial water / wastewaters and water from larger bodies such as streams and rivers, and for the preparation of lixiviant solutions suitable for solution mining applications.

In one aspect, the invention comprises an apparatus for generating a mixed oxidant stream containing oxidants such as: ozone, hydrogen peroxide and other peroxide species, hydroxyl radicals, as well as chlorine-based oxidants, the quantities and concentrations of which are determined by the quantity and type of compounds precursors that are fed into the electrochemical reactor, the water flow rate, the intensity of the current fed to the electrochemical reactor, and the electrode material.

In another aspect, the invention provides an electrochemical reactor fit for purpose and able to pass the Hydrostatic Pressure test, Endurance test, and Burst Pressure test prescribed by the regulations relevant to drinking water (e.g., WMTS-103), with reference to the effect that materials and products may have on the quality of water. In particular, the electrochemical reactor of the present invention showed to be able to withstand a permanent hydrostatic pressure of 3.5 MPa (or 35 bars) when tested at ambient temperature, or a permanent hydrostatic pressure of 2.0 MPa (or 20 bars) when tested at 50 °C.

Under a further aspect, the present invention provides an electrochemical reactor which is capable of coping with the limited conductivity of drinking water, thanks to the extended electrode surface and limited distance between the electrode plates in the electrode assembly. Drinking water typically, and mostly, contains chloride ions and sodium ions; other chemical species may be sulphates, carbonates, calcium and magnesium ions; to a minor extent, also iron, manganese, phosphate and nitrate ions can be found, as well as dissolved gases including oxygen, carbon dioxide and nitrogen.

In describing preferred embodiments of the present invention illustrated in the figures, specific terminology is employed for the sake of clarity. The invention, however, is not intended to be limited to the specific terminology so selected, and it is to be understood that each specific element includes all technical equivalents that operate in a similar manner to accomplish a similar purpose.

As shown in Figure 1, the electrochemical reactor **100** of the present invention is an appliance that needs to be connected in-line to a source of water (not shown) by using inlet fitting **101a** and outlet fitting **101b**; however, it should be noted that it is also possible to reverse the flow direction of the fluid to be treated inside the reactor, i.e. using the fitting **101a** as an outlet and the fitting **101b** as an inlet. The electrochemical reactor **100** preferably is a hollow cylindrical element, having a cell stack containment housing **102** formed of electrically insulating material, such as unplasticized polyvinyl chloride ("uPVC") tubing, preferably obtained by cutting to size a Schedule 80 PVC pipe (i.e., a pipe for the distribution of pressurised liquids, compliant with ASTM D 1785 standard).

Figure 1-3 shows the cell stack containment housing **102** oriented horizontally, although it should be noted that the present invention can be mounted in any orientation, from horizontal to vertical. In a preferred embodiment of the present invention, the cell stack containment housing **102** is provided with flanged fittings **103** and **104**, or other suitable removable cap sufficient to support the electrode assembly **110**, preferably also made of uPVC. In order to withstand the high hydraulic pressure prescribed by the Hydrostatic Pressure test, Endurance test, and Burst Pressure test of WMTS-103, the electrochemical reactor **100** of the present invention is equipped with metal clamping rods **106** fixed to the flanged fittings **103** and **104**; to prevent liquid leaks, the flanged fittings **103** and **104** are also equipped with O-rings or gaskets. When O-rings are used, they are preferably inserted into a recess **138** created in the body of the flanged fitting, while in the case of the gaskets, they are housed between the flanged fitting and the hollow cylindrical element **102**. In a preferred embodiment of the present invention, the electrochemical reactor **100** of the invention is also equipped with a pair of metal supports **107a**,**107b** which, in addition to allowing the electrochemical reactor to be laid and fixed to the ground or on a wall, also allow a more uniform distribution of the tensions.

Figure 4 shows a sectional view of the electrochemical reactor **100**. A pair of metal current collectors **105a** and **105b** are mounted through the flange fitting **104**, which allow to connect stacks of electrodes **111a**,**111b** to a direct current power supply, through wires that are shown in Figure 13. Due to their similar construction, the current connectors **105a** and **105b** are described without reference to polarity, although it should be understood that, during operation, one current connector will be used as the cathode and the other current connector will be used as the anode.

Figures 5-8 and 9 illustrate the details of a preferred layout of the electrode assembly **110**, which comprises interlaced electrode stacks **111a** and **111b**. Electrical power is supplied to the electrode assembly **110** via current collector **105a**,**105b**. Electrodes in interlaced electrode stack **111a**,**111b** are additionally mechanically connected by metal threaded rod **118** by means of metal nuts **119**, as described in more detail below in association with Figure 9.

Figure 9 illustrates the construction of the electrode stacks **111a** and **111b**, of electrode assembly **110**. It should be noted that, where components are redundant, only one

component is described for clarity and simplicity. As shown, the electrode stack **111a**,**111b** consists of a plurality of metal plate electrodes **117**. All metal parts in contact with the fluid to be treated, and especially those comprised in electrode assembly **110**, are made of an electrically conducting material, metal, metal alloy or glassy carbon; it is preferable to use either titanium (pure or containing any impurity) or a metal alloy in which titanium is the major component; other valve metals can be considered (such as tantalum, zirconium or niobium), as well as nickel, copper or stainless steel. Regarding electrodes, the electrically conductive substrate can then be coated with a suitable catalyst, which typically includes those noble metals of the platinum family (Ir, Ru, Os, Rh, Pd, Pt), their oxides, either pure or blended with other oxides, and particularly with valve metal oxides as well as oxides of titanium, tantalum, zirconium, niobium and tin. Each electrode **117** has a thickness of between 0.1 mm and 4 mm, and preferably between 1 mm and 2 mm; net electrodes or perforated plate electrodes can also be considered.

In a preferred embodiment of the present invention, the metal plate electrodes are preferably formed of titanium, with those electrodes connected to the positive power supply being coated with a mixed oxide coating and those electrodes connected to the negative power supply being uncoated or coated with a mixed oxide coating. It will be recognised by those of ordinary skill in the art that the normal operating polarity just described may be electrically reversed in order to provide cleaning of the electrode assembly **110**. In a preferred embodiment of the present invention, the polarity is periodically reversed. This operation can be performed every hour, or every 10 minutes; more generally, the polarity can be reversed at time intervals between about 1 and 1440 minutes, said time interval being chosen according to the characteristics of the fluid to be treated, and the current fed to the electrochemical reactor.

Circular spacers **112a** and **112b** are made of insulating plastic material (e.g. PVC) and have a central opening provided with teeth/slots for receiving the electrode plates and keeping them uniformly separated and with seats that allow the coupling with the lateral spacers **113a** and **113b**, also made of insulating plastic material (e.g. PVC) and sized in such a way as to allow the assembly of the electrode holder structure **120** shown in Figure 10. The spacing between the electrode plates is generally comprised between 0.5 mm and 15 mm, yet preferably comprised between 1 mm and 3 mm. Once

assembled, the electrode holder structure **120** is locked in position by inserting the lateral electrode plates **114** and **115**, which are respectively inserted through the seats in a position adjacent to the lateral spacer **113a**,**113b**.

To provide electrical connectivity to the electrodes, a plurality of metal washers **116** are disposed between the electrodes **117** in correspondence with connection holes **117a**, as shown in Figure 9, so as to electrically connect the electrodes **117**, bridging and separating them. The thickness of the metal washers depends on the spacing between the teeth in the circular spacer **112a**,**112b** and on the thickness of the electrode plates; for example, using 1 mm thick electrode plates, and in order to obtain a 2 mm gap between the electrodes, the thickness of the metal washer **116** should be 5 mm; however, thinner metal washers are used in correspondence with the lateral spacer **113a**,**113b**. To provide further electrical connectivity between electrode plates in electrode assembly **110**, a metal current header connecting rod **118** threaded at the ends is passed into hole **117a** of the electrodes and tightened with metal nuts **119**. An additional metal washer **116a** can be located between the nut **119** and the lateral spacer **113a**,**113b** to allow for a more uniform distribution of the tensions. In a preferred embodiment, the mechanical and electrical configuration of the cathode assembly and the anode assembly will be essentially identical, each being a mirror image of one another.

Figure 13 illustrates the assembly between the current collectors **105a**,**105b** and the related flanged fitting **104** of the electrochemical reactor of the present invention. Particularly advantageous for the present invention, the metal current collector **105a**,**105b** engages with a metal screw **131a**,**131b**, an optional metal washer **136a**,**136b**, and a flat tab cable metal lug **132a**,**132b** using a thread present inside the current collector **105a**,**105b**. The current collector **105a**,**105b** is secured to the flange fitting **104** by means of a metal flat washer **133a**,**133b**, and a metal nut **134a**,**134b**. A metal spring washer can be added between the metal flat washer and the metal nut to improve tightening. To prevent fluid leakage, especially under pressure, and to accommodate dimensional changes due to thermal cycling and resistive heating, the O-ring **135a**,**135b** is positioned between the current collector **105a**,**105b** and the flange fitting **104**. By tightening the metal nut **134a**,**134b**, the current collector **105a**,**105b** presses the O-ring **135a**,**135b** against the flanged fitting **104**, which provides the

required seal. Those skilled in the art will recognise that tightening the nut **134a**,**134b** can cause the current collector **105a**,**105b** to twist. Since each current collector **105a**,**105b** is firmly connected to the respective electrode stack **111a**,**111b**, any rotation of the current collector **105a**,**105b** would cause the corresponding electrode stack **111a**,**111b** to rotate at the same time, with consequent risk of bringing one electrode stack in contact with the other, and thus causing an internal short circuit. The authors of the present invention have discovered that the electrode holder structure **120** is indispensable for preventing an internal short circuit due to the rotation of the electrodes and/or of the current collector.

In a preferred configuration, the screw **131a**,**131b** and the flat tab cable lug **132a**,**132b** are made of brass; this also allows improving the electric conductivity of the current collector. In this embodiment, an O-ring **137** is illustrated as the means to prevent liquid leaks from the assembly between the flanged fitting **104** and the cell stack containment housing **102** (not shown). During the assembly of the electrochemical reactor **100**, the O-ring is inserted into the recess **138** created in the body of the flanged fitting **103**,**104**.

With reference to Figures 9 and 10, circular spacers **112a** and **112b** have not only the function of keeping separated the electrode plates **117** and of supporting the electrode holder structure **120** inside the cell stack containment housing **102**, but also of forcing the water / wastewater to be treated within the electrochemical reactor of the present invention to pass inside the electrode stacks **111a**,**111b**. In a preferred embodiment of the present invention, the diameter of the circular spacer **112a**,**112b** is equal to or just less than the internal diameter of the cell stack containment housing **102**.

In a preferred embodiment, the electrode assembly **110** comprises closely spaced and interlaced plate electrodes with all surfaces of the electrodes capable of being wetted by the fluid to be treated except those surfaces in contact with the insulating plastic material of the lateral spacers **113a**,**113b**, and represents both a passage for said fluid and an electrolysis chamber having a cross section at least as great as the cross section of the fluid inlet fitting (**101a**) and the fluid outlet fitting (**101b**) from the electrochemical reactor.

The features described above make the present invention more economical, efficient, and safer than other prior art devices, and therefore represent a clear advance over other prior art devices.

All references cited herein are incorporated by reference in their entireties.

The claims defining the invention are as follows:

1. Electrochemical reactor comprising an electrode assembly (**110**), the electrode assembly including a plurality of electrode plates (**117**), at least two circular spacers (**112a**,**112b**), each having a central opening having a plurality of apertures/slots for receiving and spacing apart the plurality of electrode plates (**117**), and at least two lateral spacers (**113a**,**113b**) inserted into the central openings of the at least two circular spacers (**112a**,**112b**), each having slots to engage with the at least two circular spacers (**112a**,**112b**).

2. Reactor according to claim 1, wherein the electrode assembly (**110**) comprises closely spaced and interlaced electrodes enclosed within an electrode holder structure (**120**) designed to force the water / wastewater to be treated to pass inside the electrode stacks (**111a**,**111b**).

3. Reactor according to any of the previous claims, wherein said reactor is able to withstand a permanent hydrostatic pressure of 3.5 MPa (or 35 bars) when tested at ambient temperature, or a permanent hydrostatic pressure of 2.0 MPa (or 20 bars) when tested at 50 °C.

4. Reactor according to any of the previous claims, wherein the electrode assembly (**110**) represents both a passage for the water / wastewater to be treated and an electrolysis chamber having a cross section at least as great as the cross section of the fluid inlet fitting (**101a**) and the fluid outlet fitting (**101b**) from the electrochemical reactor.

5. Reactor according to any of the previous claims, wherein said reactor is used for generating a mixed oxidant stream containing oxidants such as: ozone, hydrogen peroxide and other peroxide species, hydroxyl radicals, as well as chlorine-based

oxidants, the quantities and concentrations of which are determined by the quantity and type of compounds precursors that are fed into the reactor, the water flow rate, the intensity of the current fed to the reactor, and the electrode material.

6. Reactor according to any of the previous claims, wherein the mechanical and electrical configuration of the cathode assembly and the anode assembly are essentially identical, each being a mirror image of one another.

7. Reactor according to any of the previous claims, wherein said reactor is used for the electrolytic treatment of drinking water with the aim of maintaining or improving the quality of water in water supplies, swimming pools, ponds, irrigation waters, aquatic mammal tanks, spas, fountains, cooling towers and the like, and for the destruction of targeted contaminants (which can also be of microbiological nature) in water / wastewater streams such as from municipal water / wastewater treatment plants, ground water streams, industrial water / wastewaters and water from larger bodies such as streams and rivers, and for the preparation of lixiviant solutions suitable for solution mining applications.

8. Reactor according to any of the previous claims, wherein said reactor is installed in-line with the water / wastewater network to be treated.

9. Reactor according to any of the previous claims, wherein all metal parts in contact with the fluid to be treated, and especially those comprised in electrode assembly (**110**), are made of an electrically conducting material, metal, metal alloy or glassy carbon.

10. Reactor according to claim 9, wherein said metal parts are made of either titanium (pure or containing any impurity) or of metal alloys in which titanium, tantalum, zirconium or niobium are the major components.

11. Reactor according to any of the previous claims, wherein the electrodes (**117**) are coated with a suitable catalyst, which typically includes those noble metals of the platinum family (Ir, Ru, Os, Rh, Pd, Pt), their oxides, either pure or blended with other oxides, and particularly with valve metal oxides as well as oxides of titanium, tantalum, zirconium, niobium and tin.

12. Reactor according to claim 11, wherein the electrodes (**117**) have a thickness of between 0.1 mm and 4 mm, and preferably between 1 mm and 2 mm.

13. Reactor according to any of the previous claims, wherein the normal operating polarity is electrically reversed in order to provide cleaning of the electrode assembly (**110**).

14. Reactor according to claim 13, wherein the polarity is reversed at time intervals between 1 and 1440 minutes, said time interval being chosen according to the characteristics of the fluid to be treated, and the current fed to the reactor.

15. Reactor according to any of the previous claims, wherein said reactor is equipped with metal clamping rods (**106**) fixed to flanged fittings (**103**,**104**).

16. Reactor according to any of the previous claims, wherein said reactor is equipped with a pair of metal supports (**107a**,**107b**) that, in addition to allowing the reactor

to be laid and fixed to the ground or on a wall, also allow a more uniform distribution of tensions.

17. Reactor according to any of the previous claims, wherein said reactor is equipped with a pair of metal current collectors (**105a**,**105b**) mounted through the flange fitting (**104**), which allow to connect stacks of electrodes (**111a**,**111b**) to a direct current power supply.

18. Reactor according to any of the previous claims, wherein the spacing between the electrode plates is comprised between 0.5 mm and 15 mm.

19. Reactor according to any of the previous claims, wherein a plurality of metal washers (**116**) are disposed between the electrodes (**117**) in correspondence with connection holes (**117a**), so as to electrically connect said electrodes (**117**), bridging and separating them.

20. Reactor according to claim 19, wherein the thickness of the metal washers (**116**) depends on the spacing between the teeth in the circular spacer (**112a**,**112b**) and on the thickness of the electrode plates (**117**).

21. Reactor according to any of the previous claims, wherein O-rings (**135a**,**135b**) are positioned between the current collectors (**105a**,**105b**) and the flange fitting (**104**) in order to prevent fluid leakage, especially under pressure.

22. Reactor according to any of the previous claims, wherein an electrode holder structure (**120**) is used to prevent an internal short circuit due to the rotation of the electrodes (**117**) and/or of the current collectors (**105a**,**105b**).

23. Reactor according to any of the previous claims, wherein an O-ring (**137**) is inserted into a recess (**138**) created in the body of the flanged fitting (**103**,**104**) to prevent liquid leaks from the assembly between the flanged fitting (**104**) and the cell stack containment housing (**102**).

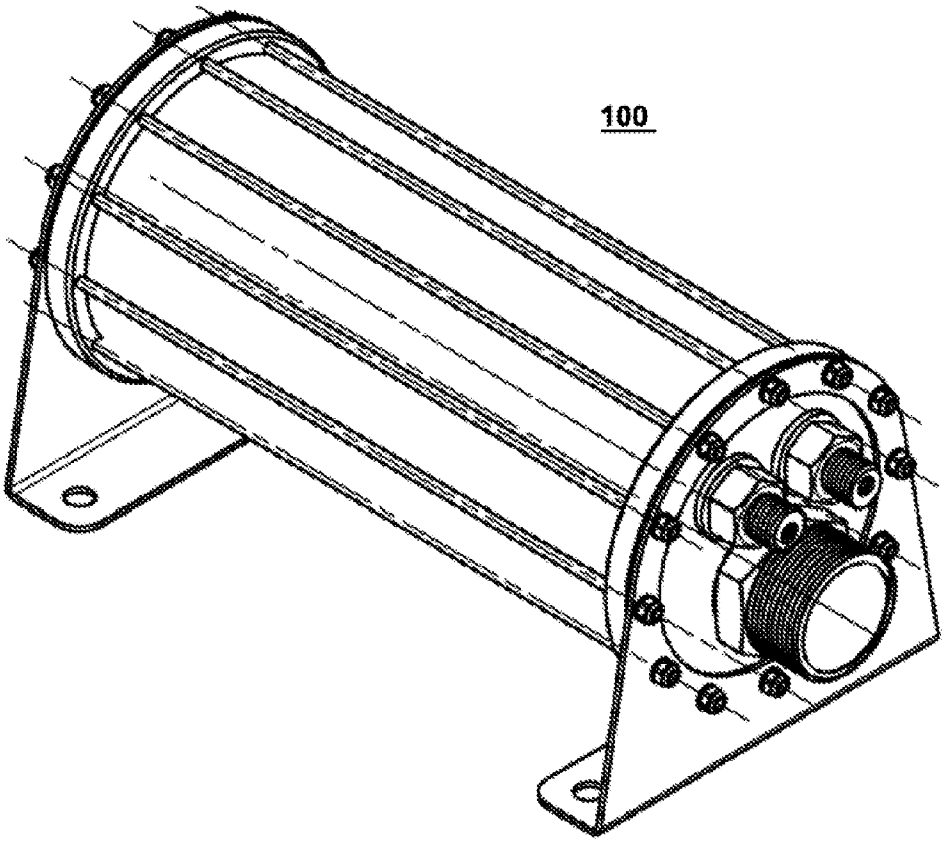


Figure 1

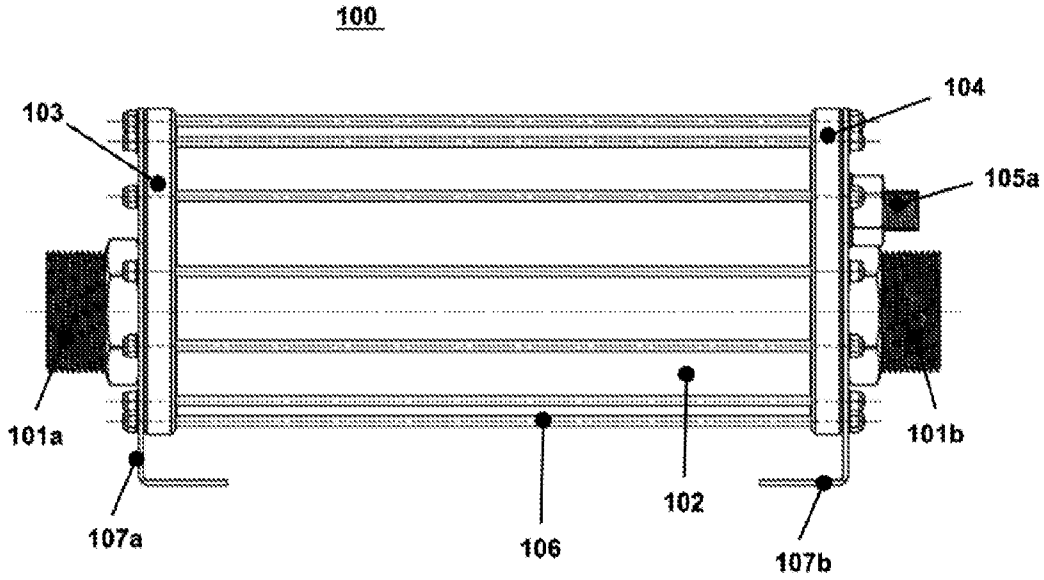


Figure 2

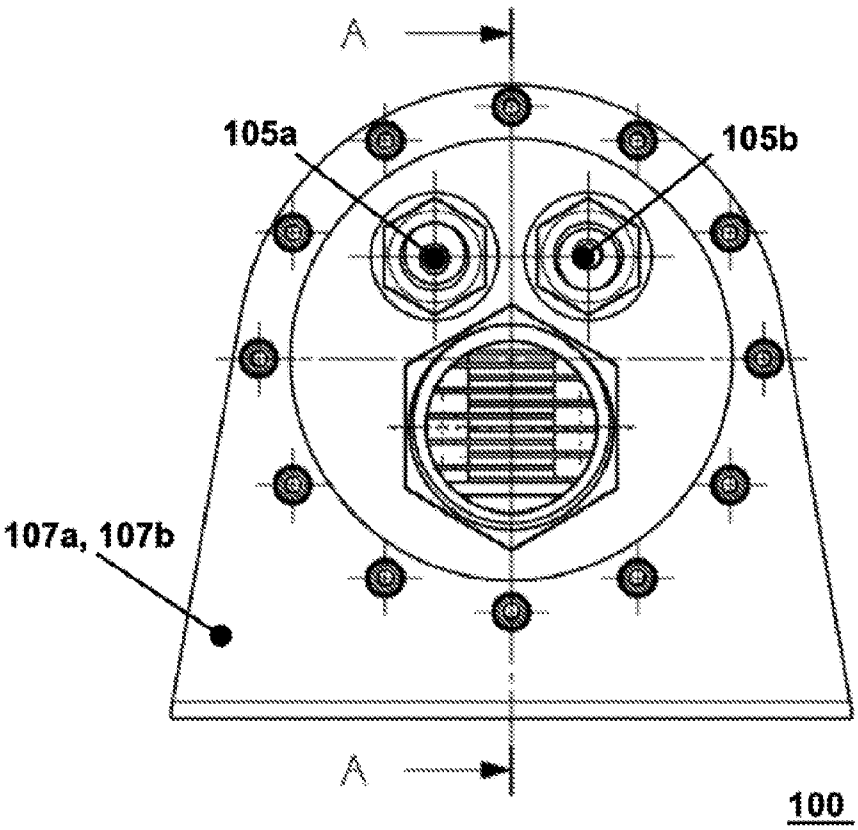


Figure 3

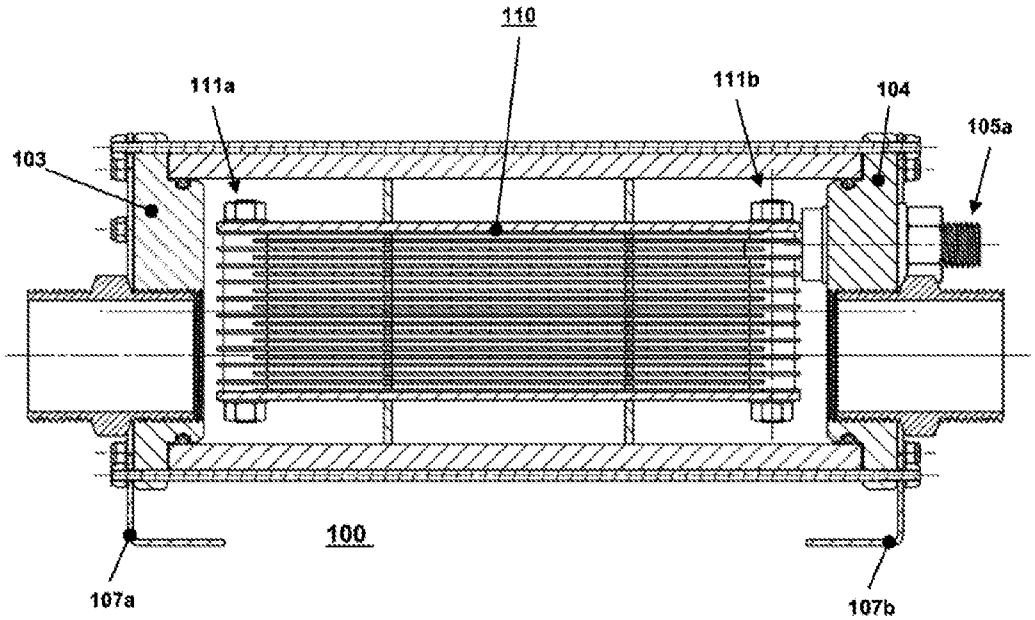


Figure 4

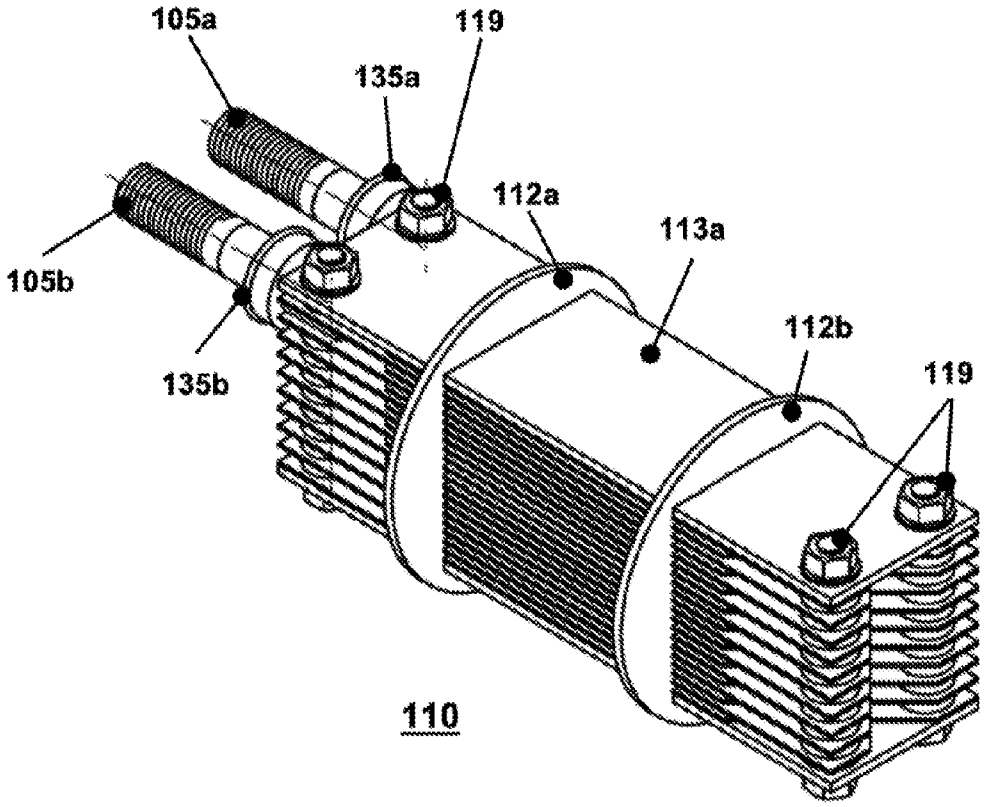


Figure 5

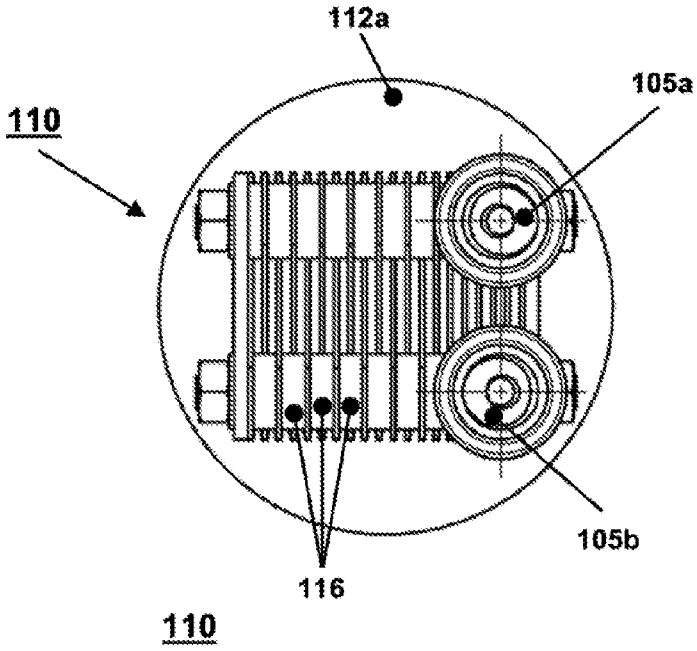


Figure 6

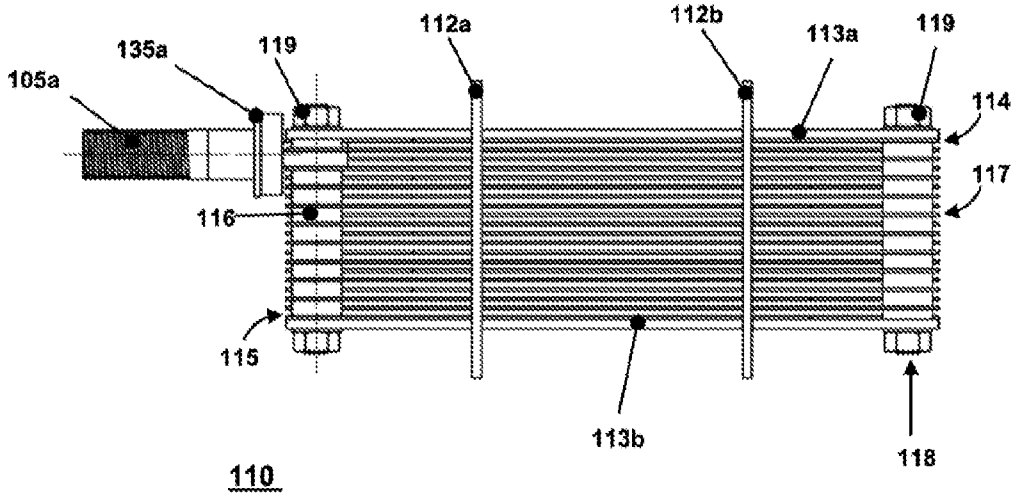


Figure 7

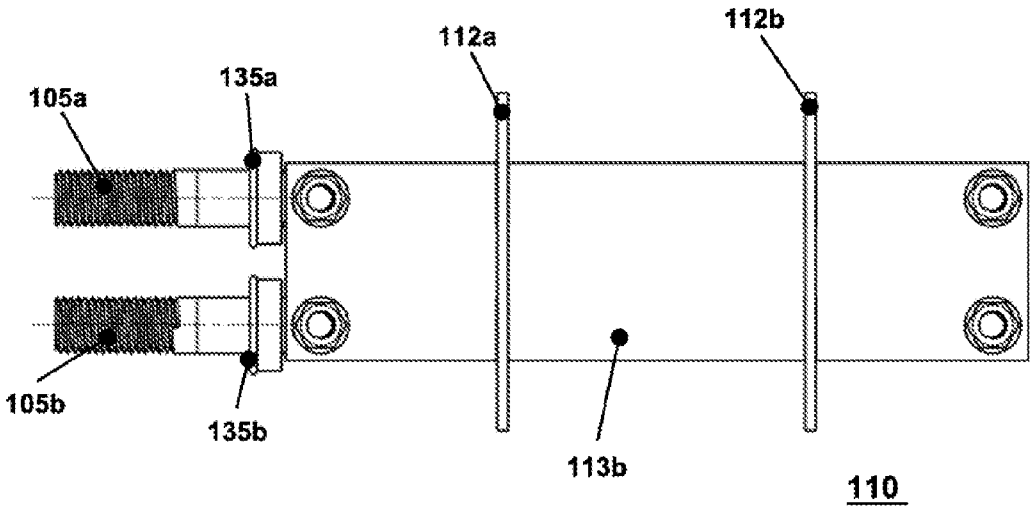


Figure 8

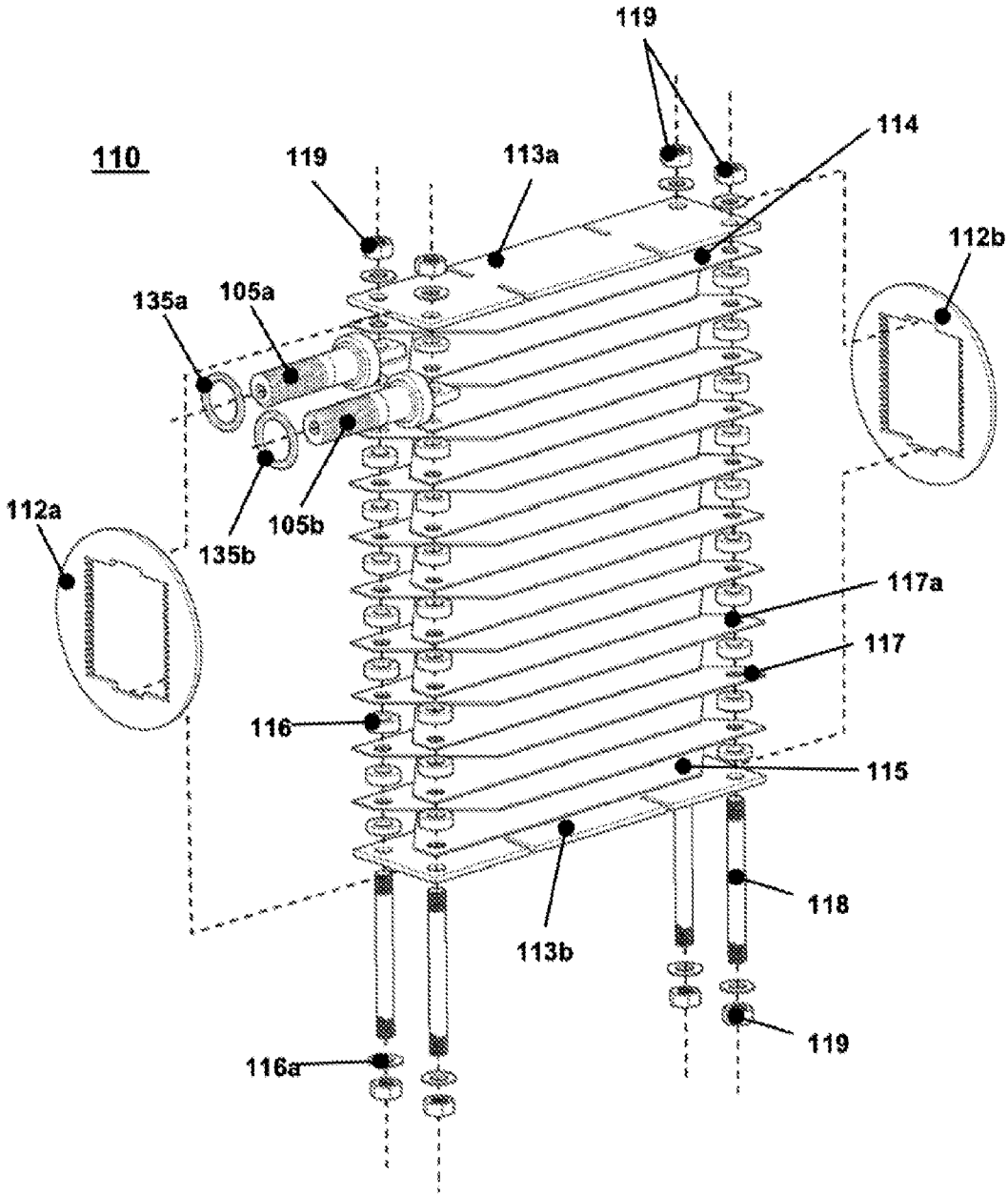

110
119
119
113a
114
112b
135a
105a
105b
135b
112a
117a
117
116
115
118
113b
119
116a

Figure 9

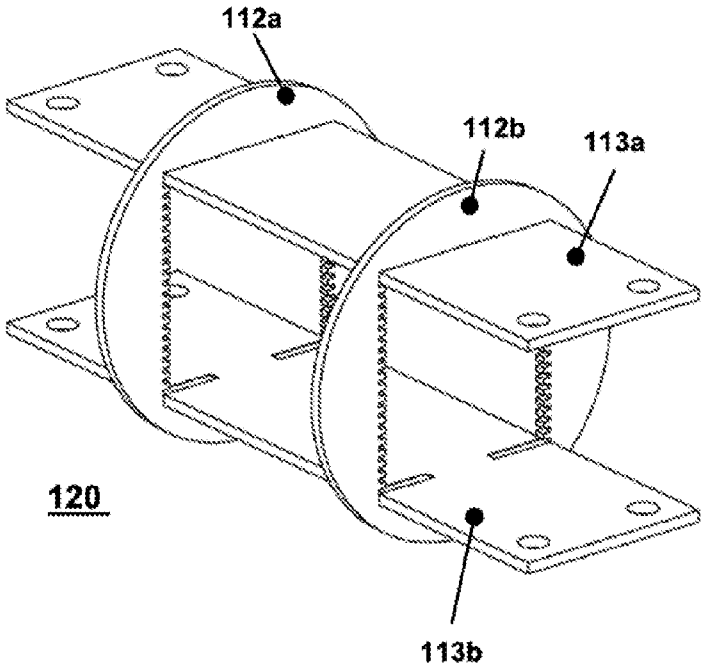


Figure 10

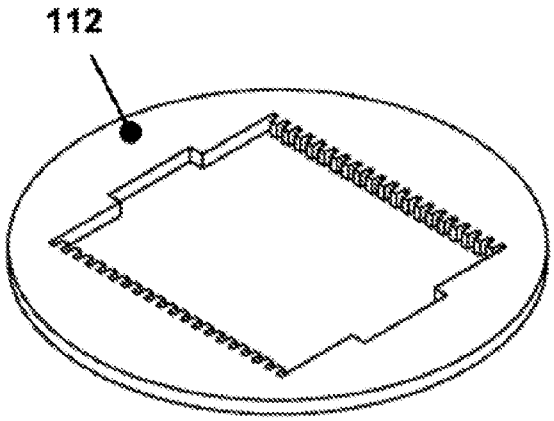


Figure 11

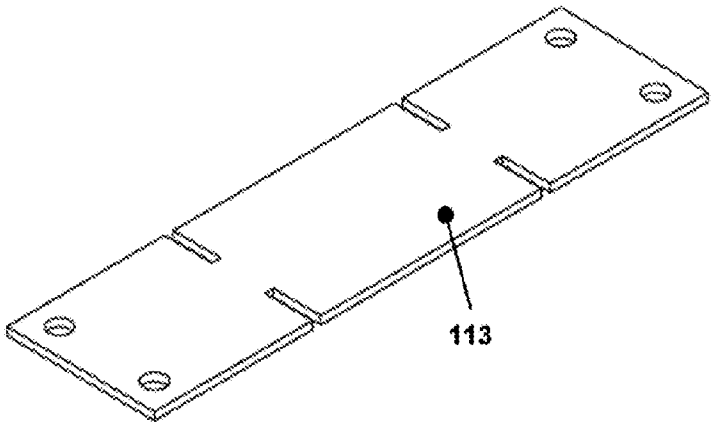


Figure 12

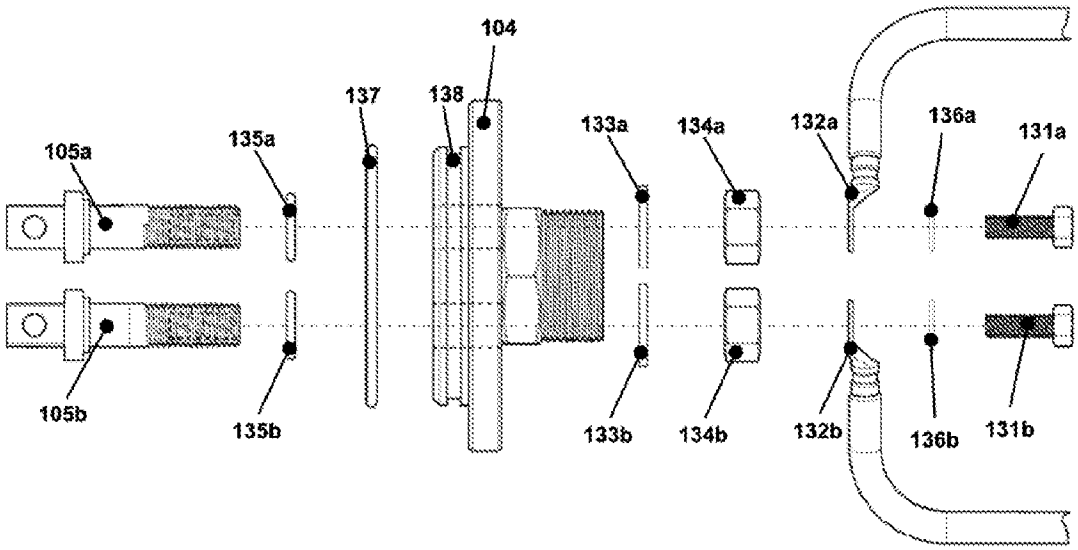


Figure 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2022/050439

A. CLASSIFICATION OF SUBJECT MATTER

C02F 1/467 (2006.01) C02F 1/76 (2006.01) C25B 9/63 (2021.01) C25B 13/00 (2006.01)

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)

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)

EPOQUE X-FULL: Databases: TXPEA, TXPEB, TXPEC, TXPEE, TXPEF, TXPEH, TXPEI, TXPEP, TXTPEPEA, TXTPEPEB, TXPES, TXPEU, TXPEY, TXPUSE0A, TXPUSE1A, TXPUSEA, TXPUSEB, TXPWOEA, WPIAP, EPODOC; Keywords: C02F1/72/LOW, C02F2201/78/LOW, C02F2201/32/LOW, C02F1/46/LOW, C02F2201/461/LOW, C02F1/4672/LOW, C25B9/63/LOW, C25B13, C02F1/46109/LOW; Keywords: electrode, multiple, spacer, slot, plate, electrooxydation, and like terms. Google Patent search: Keywords: water treatment, oxidant, electrochemical, electrode plate, plurality, spacer, and like terms. Applicant and inventor names searches in Espacenet, AusPat, and internal databases provided by IP Australia: Applicant name: TTD GLOBAL; Inventor names: VALLELONGA, Daniel; FERRO, Sergio; Keyword: electrode.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] 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

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

"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	20 June 2022

Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Hong Yu AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262837946

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2022/050439**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/0026335 A1 (FIELDS) 12 February 2004 Abstract, Figures, para. [0036], [0042], [0044]	1-23
X	JP H01266977 A (DAIDO STEEL CO LTD) 24 October 1989, English Abstract retrieved from Espacenet English translation of Abstract, specification page 1 retrieved from Espacenet and EPOQUE, Figures	1-23
X	US 2019/0276942 A1 (PROCESS SOLUTIONS, INC.) 12 September 2019 Abstract, Figures, para. [0003], [0049]-[0052], [0057]	1-23
X	KR 102054624 B1 (DESOL CO LTD) 12 December 2019, English Abstract retrieved from Espacenet English translation of Abstract, specification pages 1, 3, claims retrieved from Espacenet and Google Patent, Figures	1-23

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2022/050439**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2004/0026335 A1	12 February 2004	US 2004026335 A1	12 Feb 2004
		US 2005000905 A1	06 Jan 2005
JP H01266977 A	24 October 1989	JP H01266977 A	24 Oct 1989
US 2019/0276942 A1	12 September 2019	US 2019276942 A1	12 Sep 2019
		US 10975479 B2	13 Apr 2021
		WO 2019173696 A1	12 Sep 2019
KR 102054624 B1	12 December 2019	KR 102054624 B1	12 Dec 2019

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.