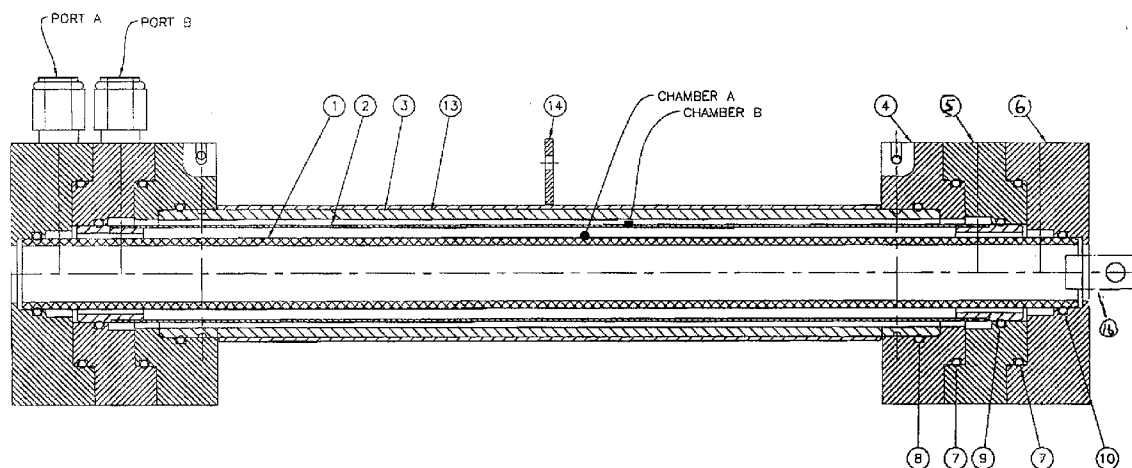


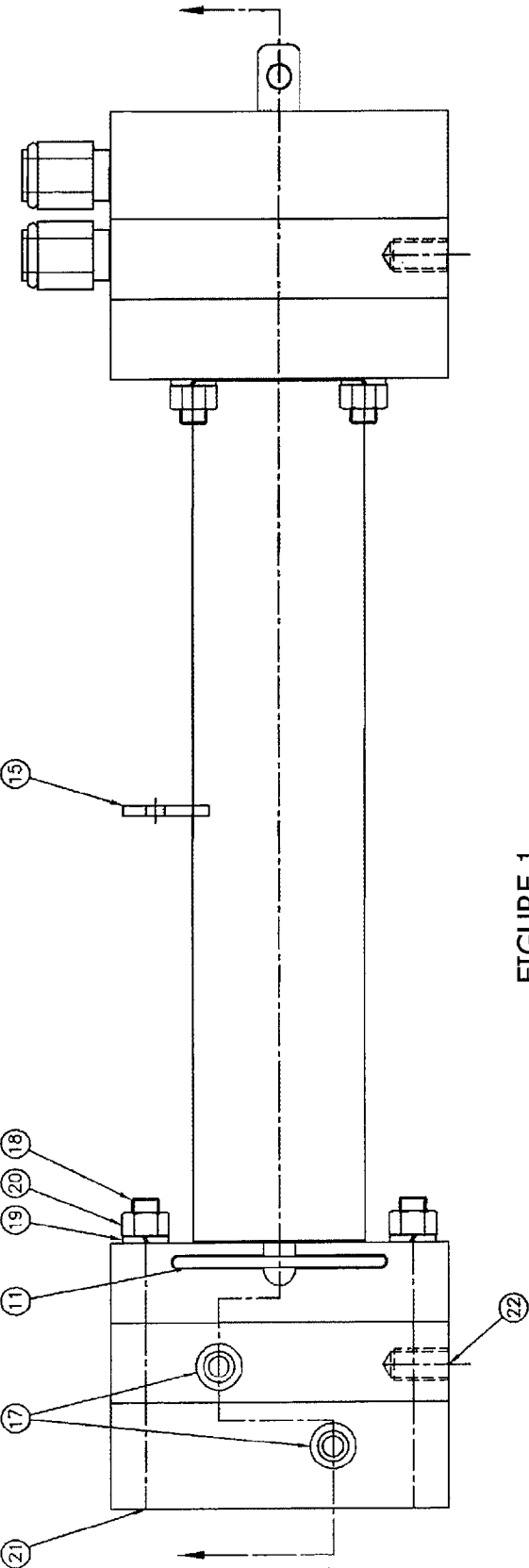


US 20130146472A1

(19) **United States**(12) **Patent Application Publication****Sullivan et al.**(10) **Pub. No.: US 2013/0146472 A1**(43) **Pub. Date: Jun. 13, 2013**(54) **APPARATUS AND METHOD FOR
GENERATING A STABILIZED SANITIZING
SOLUTION**(52) **U.S. Cl.**
USPC 205/347; 204/257(71) Applicant: **AQUAFOX INC.**, Rialto, CA (US)(57) **ABSTRACT**(72) Inventors: **Jay B. Sullivan**, Yoakum, TX (US);
Michel van Schaik, Loxahatchee, FL
(US)(73) Assignee: **AQUAFOX INC.**, Rialto, CA (US)(21) Appl. No.: **13/718,677**(22) Filed: **Dec. 18, 2012****Related U.S. Application Data**(63) Continuation-in-part of application No. 13/324,714,
filed on Dec. 13, 2011.**Publication Classification**(51) **Int. Cl.**
C25B 9/18 (2006.01)

The present invention provides a method utilizing Cylindrical Electrolysis cells for the generation of Hypochlorous Acid (HOCL) solutions having excellent sanitizing properties and a shelf life of 24 months when bottled. The electrolysis cells consist of at least two cylindrical electrodes with at least one cylindrical ion-selective membrane arranged co-axially between them. A cation-selective or anion-selective membrane separates the cathode chamber from the anode chamber allowing only selective ions to move from one chamber to another. A three section end piece facilitate the assembly of the cylindrical electrolysis cell and enables easy inspection and replacement of the ion-selective membranes. The method allows production of different concentrations of Hypochlorous Acid solutions with a pH value ranging from 3.5 to 7.5 and an Redox Oxidation Potential between +700 and +1200 mV when an aqueous sodium chloride or potassium chloride solution is treated.





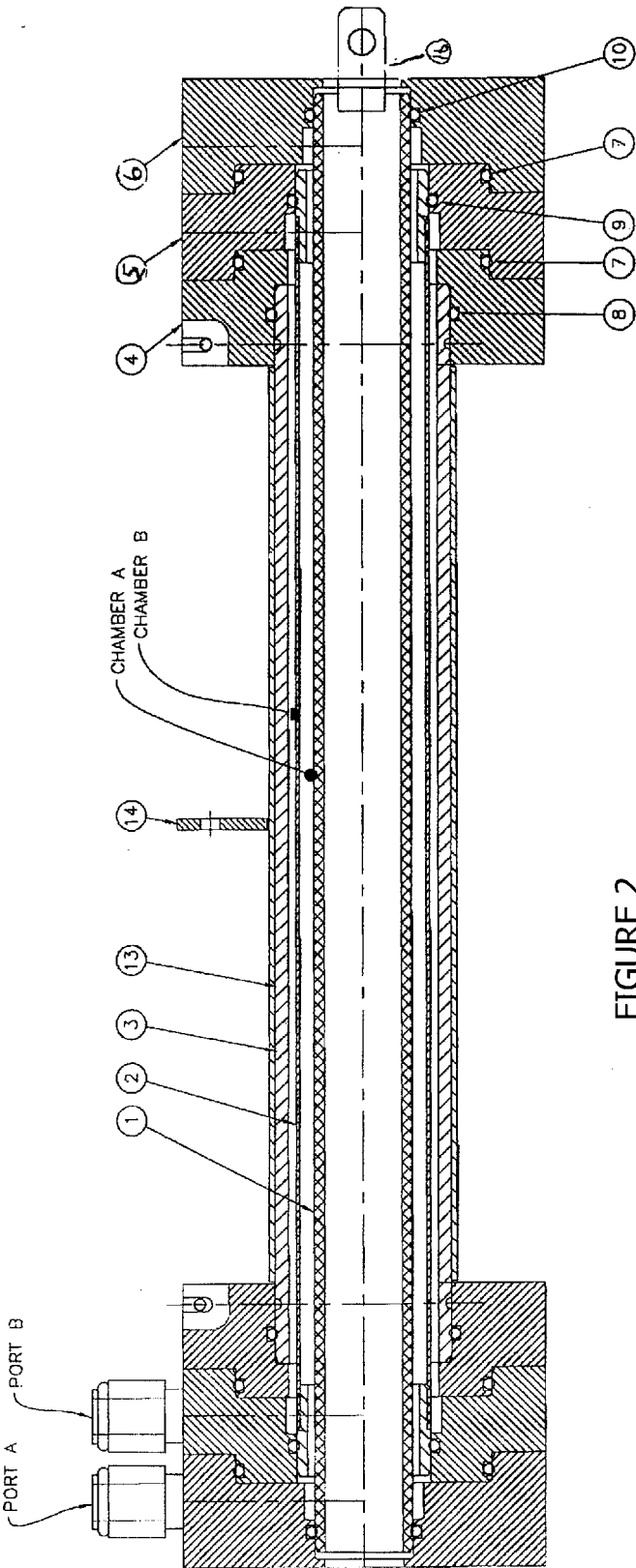
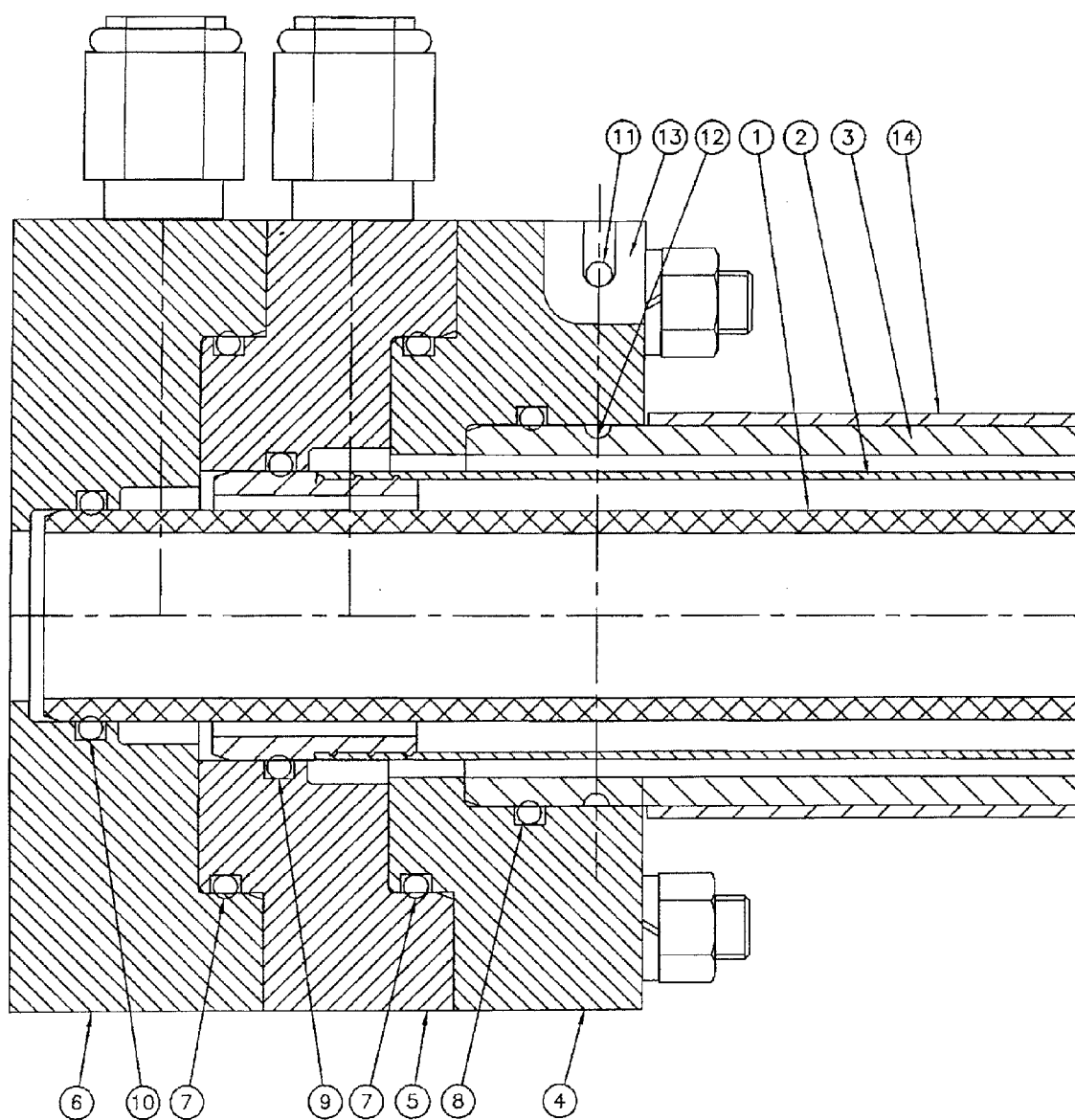


FIGURE 2



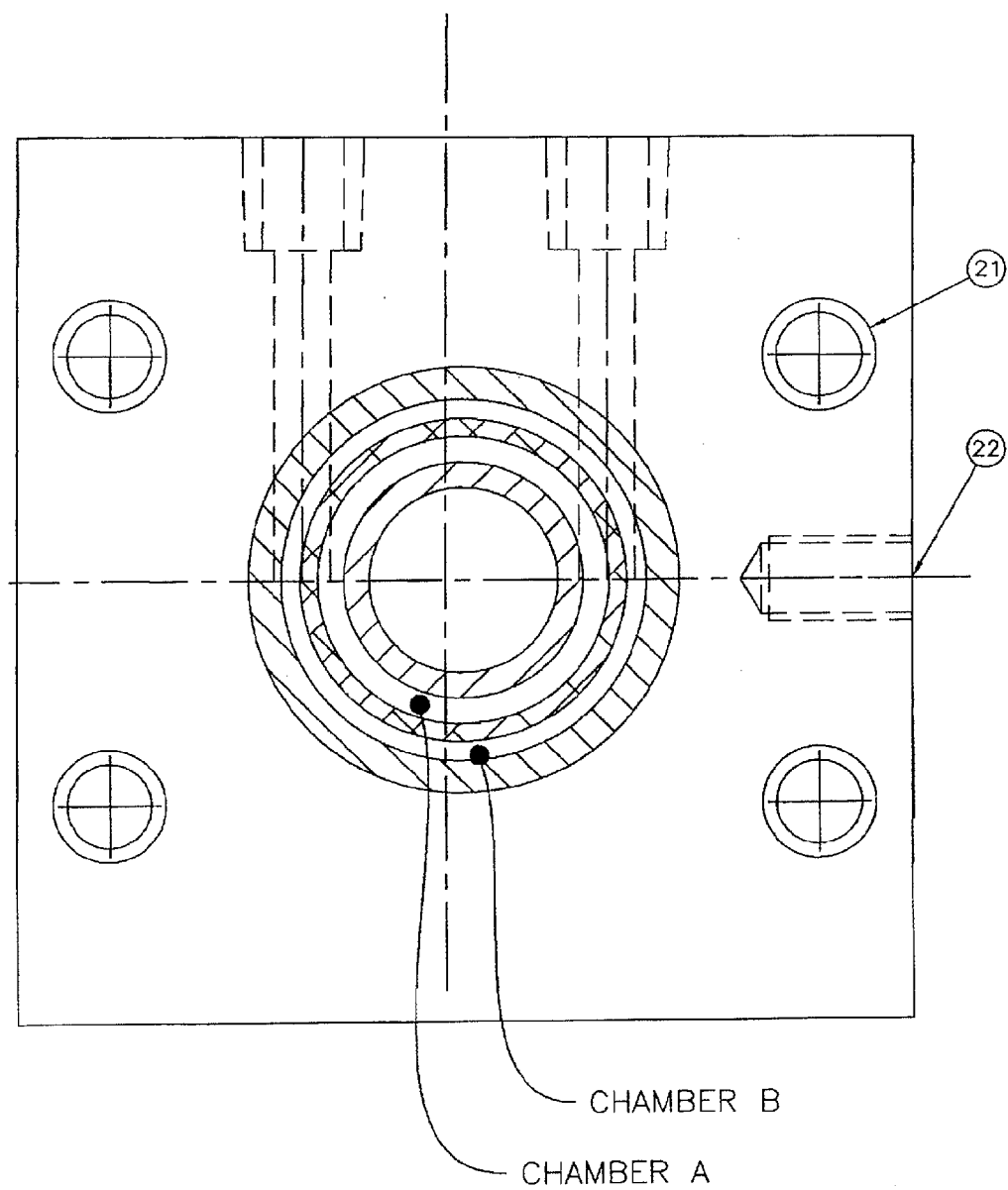


FIGURE 4

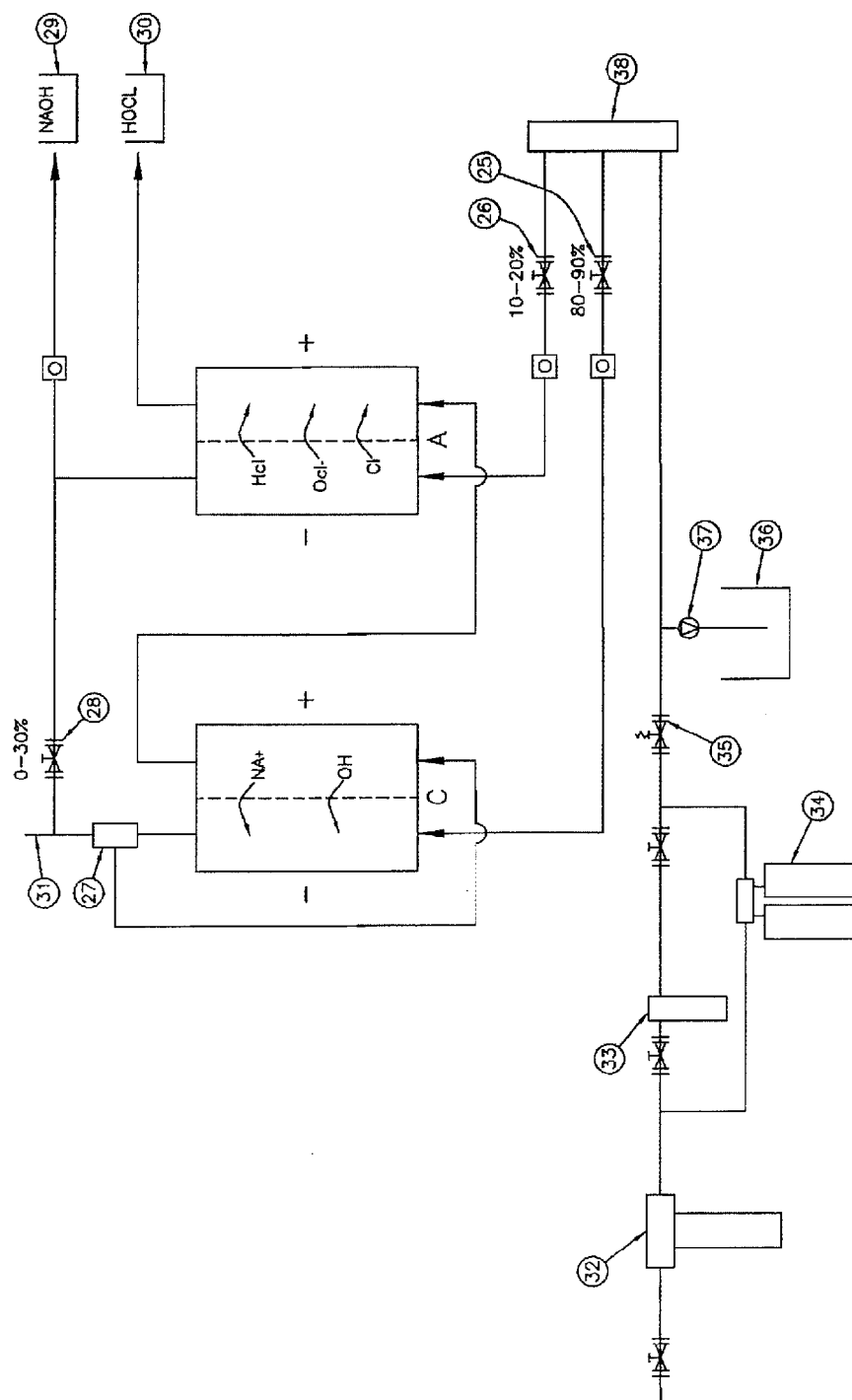


FIGURE 5

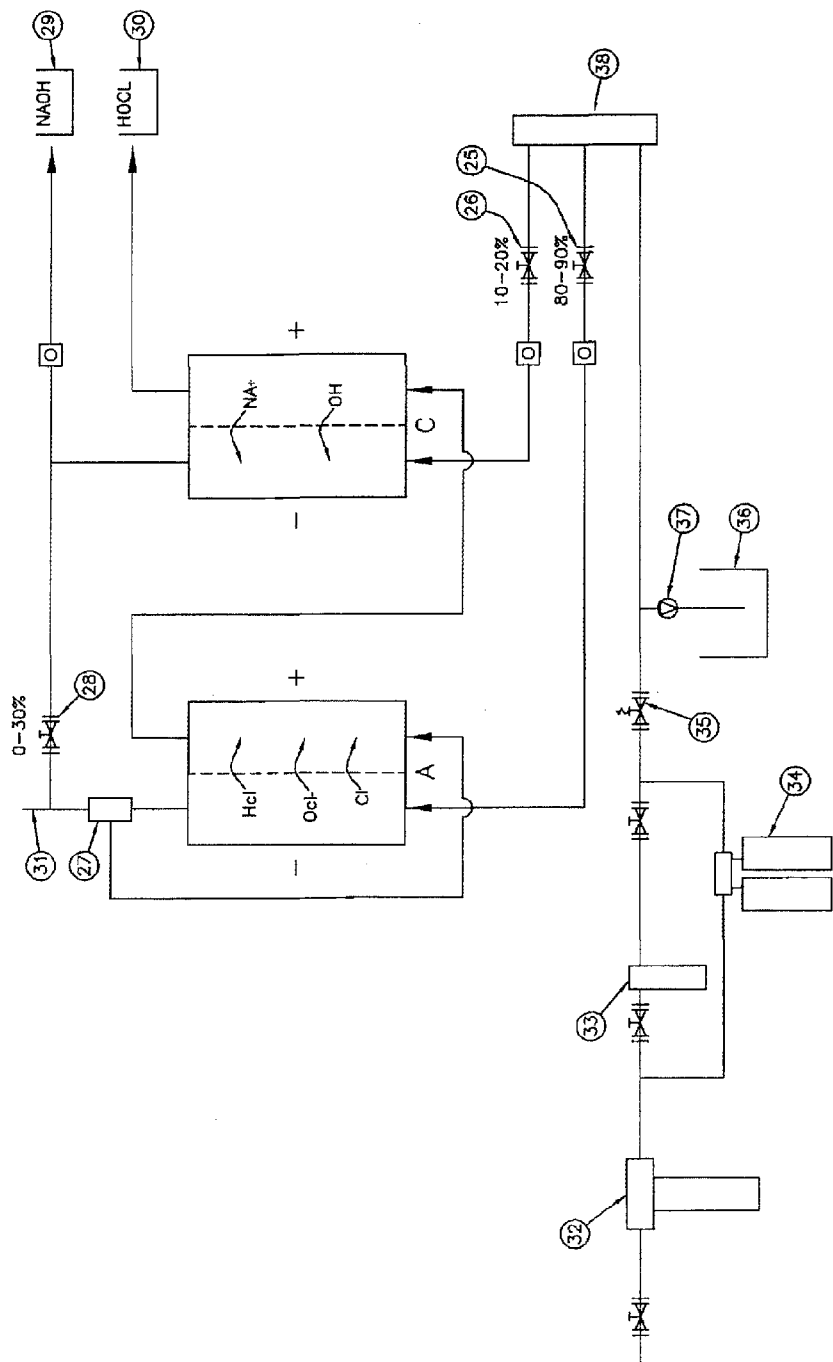


FIGURE 6

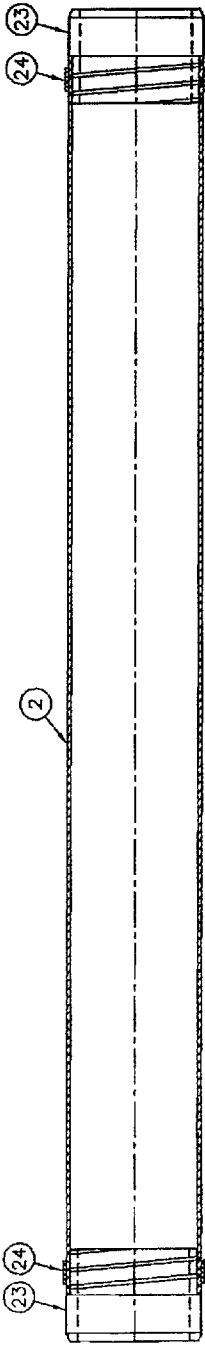


FIGURE 7

APPARATUS AND METHOD FOR GENERATING A STABILIZED SANITIZING SOLUTION

REFERENCE TO RELATED APPLICATIONS

[0001] In accordance with 37 C.F.R. 1.76, a claim of priority is included in an Application Data Sheet filed concurrently herewith. Accordingly, under 35 U.S.C. §119(e), 120, 121, and/or 365(c) the present invention claims priority, as a continuation-in-part of U.S. patent application Ser. No. 13/324,714, filed Dec. 13, 2011, entitled "DUAL DIAPHRAGM-ELECTROLYSIS CELL ASSEMBLY AND METHOD FOR GENERATING A CLEANING SOLUTION WITHOUT ANY SALT RESIDUES AND SIMULTANEOUSLY GENERATING A SANITIZING SOLUTION HAVING A PREDETERMINED LEVEL OF AVAILABLE FREE CHLORINE AND pH"; and is related to co-pending U.S. patent application Ser. No. _____, filed _____ and entitled "MESH ELECTRODE ELECTROLYSIS APPARATUS AND METHOD FOR GENERATING A SANITIZING SOLUTION"; the contents of the above referenced applications are incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates to the field of producing Hypochlorous Acid solutions and more specifically to the use of an apparatus and method to form a hypochlorous acid solution for use as a wound care product or usage as a hospital sanitizing solution, wherein the solution has a different pH, free-available-chlorine content, osmolality and shelf life for usage.

BACKGROUND OF THE INVENTION

[0003] Cylindrical electrolysis cells are known for use in the production of diluted Hypochlorous Acid solutions. The basic feature of these cells is two concentrically disposed cylindrical electrodes with a ceramic porous diaphragm separating a space between the two electrodes to define anode and cathode compartments. An electrolyte such as brine is passed through the anode and cathode compartments, separately or successively. When brine is electrolyzed in this way, under suitable conditions, it can produce a diluted Hypochlorous Acid solution.

[0004] Typically when an electrolyte solution passes through a single electrolyses cell having a porous ceramic diaphragm to separate the anode and cathode chambers, the diaphragm permits the diffusion of electrolytes between the anode and cathode. However, porous ceramic diaphragms are not ion specific and therefore at any time when negative ions are attracted to the positive anode and positive ions are attracted to the negative cathode, ions will move without limitations over the ceramic diaphragm.

[0005] While the primary function of such a ceramic diaphragm is to allow ions to move freely over the diaphragm, the ceramic diaphragm's secondary function is to retard the migration of electrolysis products at the anode and cathode from diffusing to each other. When utilizing a porous ceramic diaphragm, the effectiveness of preventing undesired side products moving over the diaphragm depends greatly on a pressure differential between both chambers. In various flow patterns, the flow of Hypochlorous Acid and Sodium Hydroxide is not equal in volume and pressure, as in most cases more Hypochlorous Acid than Sodium Hydroxide is required.

Therefore the volume of Sodium Hydroxide is mostly reduced to a minimum resulting in pressure differences between the anode and cathode chamber which significantly increases leakage of undesired products through the porous ceramic diaphragm.

[0006] A cylindrical three-chamber cell is described in co-pending U.S. Pat. No. _____ (Ser. No. 13/324,714) which addresses the undesired migration problem mentioned above, but the absence of any salt residues in the sanitizing solution limits the shelf life and the free-available-chlorine content of the generated Hypochlorous Acid solution. The pH and free-available-chlorine content of these diluted Hypochlorous Acid solutions, both acidic and neutral, generated from these three-chamber cells are less stable, lower in free-chlorine-content and although very suitable for onsite production and usage, it would be unsuitable for bottling and storage.

[0007] Passing a diluted brine solution through two cylindrical two-chamber electrolysis cells having a specific ion-exchange membrane instead through a single cylindrical two-chamber electrolysis cell having a porous ceramic diaphragm has the following merits. Migration of reductive species such as dissolved hydrogen gas produced in the cathode chamber into the anode chamber utilizing a porous ceramic diaphragm can be fully prevented using an anion-exchange membrane even at different pressure differentials. Migration of Oxidative species such as hydrogen ions formed on the anode toward the cathode is prevented at different pressure differentials using a cation-exchange membrane. Electrolyzing a diluted brine solution utilizing two cylindrical two-chamber electrolysis cells result in an increased salt conversion and thus generating a Hypochlorous Acid solution with a higher free-available-chlorine content having lower salt residues.

[0008] Thus what is lacking in the prior art is an apparatus and method of improving the stability and shelf life of on-site produced Hypochlorous Acid solutions.

SUMMARY OF THE INVENTION

[0009] Disclosed is a two cylindrical electrolytic cell device capable of producing various Hypochlorous Acid solutions whereas the pH, redox potential, free chlorine content, conductivity and osmolality can be adjusted. The invention is directed to a cylindrical ion-selective membrane electrolysis cell assembly comprising a cathode chamber and an anode chamber. The present invention provides an insulating end piece for a cylindrical electrolysis cell of the type comprising two cylindrical electrodes arranged coaxially one within the other with one ion-selective membrane arranged coaxially between them. The cylindrical ion-selective exchange membrane is construed from a polymer or a perfluorinated membrane sheet that is stretched, formed and sealed together to form a cylinder that can be leak free assembled in a cylindrical electrolyses cell by mounting the cylindrical ion-exchange membrane between two bushings or by mounting the cylindrical ion-exchange membrane on the inside or around a perforated porous tube.

[0010] An objective of the invention is to disclose an apparatus and method of improving the stability and shelf life of on-site produced Hypochlorous Acid solutions.

[0011] Another objective of the invention is to disclose the use of two cylindrical electrolysis cells constructed and arranged to provide a more stable Hypochlorous Acid solution suitable for bottling and storage up to 24 months can be generated.

[0012] Still another objective of the invention is to disclose how produced Hypochlorous Acid solutions can be used for wound care and hospital sanitation. The Hypochlorous Acid solutions are effective for sanitizing equipment, tools and surfaces, in particular after equipment, tools and surfaces have been cleaned with the generated Sodium Hydroxide solutions.

[0013] Another objective of the invention is to disclose Hypochlorous Acid and Sodium Hydroxide solutions having a long shelf life and a low salt residue which is in contrast with most generated Hypochlorous Acid and Sodium Hydroxide solutions produced by electrolysis of a brine solution in a single cell utilizing a ceramic diaphragm as separator between the anode and cathode.

[0014] Still another objective of the invention is to disclose various different sanitizing solutions can be produced utilizing the cylindrical electrolysis cells of the present invention, depending on the various flow patterns through the cells e.g. a neutral Hypochlorous Acid solution with a Ph between 6 to 7.5 and a long shelf life can be generated by dividing the diluted brine solution in a Product-flow (Hypochlorous Acid) and a Waste-flow (Sodium Hydroxide).

[0015] Yet still another objective of the invention is to disclose a diluted Sodium Hydroxide as cleaning solution suitable for cleaning all surfaces, including textiles, fabrics and carpets.

[0016] Still another objective of the invention is to disclose a diluted Hypochlorous Acid as sanitizing solution is suitable for wound care, hospital sanitation, water disinfection, but also suitable for sanitizing hands, food, (food contact) surfaces, air and fabrics.

[0017] Yet another objective of the invention is to disclose a generated cleaning and sanitizing solutions that contains limited salt residues due to the fact that the diluted brine solution passes two of more cells with ion-selective membranes whereas almost all sodium chloride or potassium chloride is efficiently converted into Hypochlorous Acid or Sodium Hydroxide.

[0018] Other objectives and further advantages and benefits associated with this invention will be apparent to those skilled in the art from the description, examples and claims which follow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is a plane view of the electrolyses cell;

[0020] FIG. 2 is a cross sectional view of the electrolyses cell;

[0021] FIG. 3 is a flow pattern to form hypochlorous acid solution with ph 6 to 7.5;

[0022] FIG. 4 is a flow diagram to form hypochlorous acid solution with ph 3.5 to 7;

[0023] FIG. 5 is an enlarged cross section view of an end piece;

[0024] FIG. 6 is a top view of the end piece; and

[0025] FIG. 7 is a side view of a cylindrical ion-selective exchange membrane.

DETAILED DESCRIPTION OF THE INVENTION

[0026] The present invention is directed to method of producing a stable Hypochlorous Acid solution suitable for bottling and storage utilizing two optimized cylindrical electrolysis cells having two cation-exchange membranes as separator between the anode and cathode or a cation-ex-

change membrane and a anion-exchange membrane as separator between the anode and cathode.

[0027] Now referring to FIGS. 1-4 in general, the two chamber electrolysis cell is illustrated where an inner electrode [1] is positioned within a cylindrical ion-selective exchange membrane [2] which is positioned within an outer electrode [3] by the use of two end pieces which consist of an tube cap [4] having a stainless steel clip [11] to lock tube cap [4] with the outer electrode [3], port A cap [6] and port B cap [5].

[0028] The design of the three sections of the end piece permits the orientation and sealing of the entire assembly. Tube cap [4] seals the outer electrode [3] with the end piece using an O-ring [8]. The tube cap [4] is locked on the outer electrode [3] using a stainless steel clip [11]. The outer electrode tube-ends facilitate a groove [12] that fits the stainless steel clip [11] which is pushed through two holes formed in the tube cap [4].

[0029] Port B cap [5] features port B for direction of the flow of a diluted brine solution through port B ending in fittings [17] into the chamber B defined by the spaces between the outer electrode [3] and the cylindrical ion-selective exchange membrane [2] and out of chamber B through port B ending in fittings [17] of the opposite port B cap [5].

[0030] Port A cap [6] features port A for direction of the flow of a diluted brine solution through port A ending in fittings [17] into chamber B defined by the spaces between the inner electrode [1] and the cylindrical ion-selective exchange membrane [2] and out of chamber A through port A ending in fittings [17] of the opposite port A cap [6]. The three sections of end piece are compressed on each other using O-rings [7] to seal the sections on each other.

[0031] The tube cap [4] is clamped on the outer electrode [3] using an O-ring [8] and a stainless steel clip [11] that fits a groove [12] manufactured on the outside of the outer electrode [3]. Port B cap [5] is pressed on the tube cap [4] whereas the tube cap [4] facilitated a groove for an O-ring [7] and whereas port B cap [5] is pressed on the tube cap [4]. Port A cap [6] is pressed on port B cap [5] whereas the port B cap [5] facilitated a groove for an O-ring [7] and whereas the port A cap [6] is pressed on port B cap [5].

[0032] The tube cap [4], port A cap [6] and port B cap [5] are bolted together using four stainless steel bolts [18], washers [19] and nuts [20]. In each section of the end piece, there are four holes [21] to facilitate the stainless steel bolts [18], washers [19] and nuts [20]. The seal between each section of the end piece is achieved by compressing the sections of the end piece onto each other, in a manner such that the compressive force can be applied slowly and smoothly without the introduction of torque such that a reliable seal is produced without damaging the cylindrical ion-selective exchange membrane [2].

[0033] Either of the electrodes [1] and [3] can act as the anode with the other acting as the cathode. The choice can be made by considerations of the ease of manufacture or requirements of the nature of the electrolysis process to be performed which can favor the anode or cathode chamber preferentially being the outer chamber. These considerations include the desired spacing between the electrodes and the diaphragms, the desired space between the cylindrical ion-selective exchange membrane [2] and the relative volume requirements for the balance of flows of the electrolyte solution in chamber A and chamber B.

[0034] The inner electrode [1] and outer electrode [3] tubes are constructed of an electrically conductive material, preferably titanium. The metal electrode tubes are coated with a mixed metal oxide on the face of the tube directed toward the cylindrical ion-selective exchange membrane [2]. The metals of the two electrodes can be titanium or stainless steel. Both metals can be coated with a mixed metal oxide. The cathode can be an uncoated metal, but the anode has to be a mixed metal oxide coated metal. A preferred arrangement has the outer electrode [3] as the anode internally coated with a mixed metal oxide and the inner electrode tube [1] as the cathode and not coated.

[0035] The outer electrode [3] has an electrical connector [15] welded to the outside of the outer electrode [3] tube. The inner electrode [1] has an electrical connector [16] on its end that is part of the inner electrode [1] and extends out of the outside of the upper end piece. Although not necessary for the function of the assembly, the outside of the outer electrode [3] is insulated by a rubber sleeve [14] that is heat-shrunk over the outer electrode [3] and cut to length. Optionally an insulating sheath or tube can be glued to the outside of the outer electrode [3].

[0036] The anode and cathode are separated by a cylindrical ion-selective exchange membrane [2]. The cylindrical ion-exchange membrane is made of a polymer or a perfluorinated sheet reinforced with or without polytetrafluoroethylene. The thickness of the cylindrical ion-exchange membrane may vary between 0.025 mm and 0.5 mm depending whether the ion-selective exchange membrane is mounted between two bushings [23] as is seen in FIG. 7 or whether the ion-selective exchange membrane is mounted on the inside or around a perforated porous tube [24] which tube-ends are not perforated and not porous over a length of 1 inch from each tube-end. When mounted on a perforated porous tube [24], the ion-selective membrane sheet can be thinner as it is stretched and sealed on the surface of the perforated porous tube [24]. The ion-selective exchange membrane [2] can be mounted on the inside or around a perforated porous tube [24] depending on the flow pattern and pressure differential between the anode and cathode chamber. The assembly of the ion-exchange membrane [2] starts with cutting soaked, stretched ion-exchange membrane sheets to length. Then the ion-exchange sheets are sealed together using a hotwire sealing device, melting the edges of the ion-exchange membrane sheet together. Either two bushings [23] are screwed on both ends of the formed cylindrical ion-exchange tube to form a leak free seal or the formed cylindrical ion-exchange membrane tube is pushed over or inside a perforated porous tube [24]. The bushings [23] or the perforated porous tube [24] are assembled into port B cap [5] whereas a groove is manufactured to facilitate an O-ring [9]. The bushings [23] or tube [24] is compressed between both port B caps [5] whereas the O-ring [9] forms a leak free seal with the bushings [23] or the perforated porous tube [24]. The inner electrode [1] is sealed in Port cap A [6] whereas a groove is manufactured to facilitate an O-ring [10]. The inner electrode [1] is compressed into the O-ring [10] to form a leak free seal with Port cap A [6].

[0037] The relative diameter of the outer electrode [3], inner electrode [1], the cylindrical ion-selective exchange membrane [2] can vary within the single requirement that outer electrode [3] must be of greater diameter than the cylindrical ion-selective exchange membrane [2]. The cylindrical ion-selective exchange membrane [2] is greater than the inner electrode tube [1]. The actual diameters can vary depending

upon the desired features of the electrolysis cell assembly. To this end the diameters can be varied to optimize the rate of electrolysis, rate of flow through the cell assembly, and other needs of the system to which the assembly will be used. Likewise, the relative length of the electrodes [1] and [3] and the cylindrical ion-selective exchange membrane [2] can vary within the single requirement of this embodiment that the outer electrode [3] must be shorter than the cylindrical ion-selective exchange membrane [2] and the cylindrical ion-selective exchange membrane [2] shorter than inner electrode [1]. The lengths of the electrodes [1] and [3] and the length of the cylindrical ion-selective exchange membrane [2] can be determined by factors such as ease of construction and geometries to optimize the performance of the electrolysis cell assembly in the system it which it is to perform.

[0038] The upper and lower end pieces are interchangeable and constructed of an insulating material, preferably Polyvinyl Chloride. Each end piece consists of three sections, the tube cap [4], port A cap [6] and port B cap [5]. The bushings [23] and perforated porous tube [24] are constructed of an insulating material, preferably Polyvinyl Chloride.

[0039] The three sections of the end piece can be formed by molding or machining. Ports [17] are for introduction or exit of diluted brine solution to chamber A as well to chamber B. All sections of the end piece consists three or more holes to accept three or more stainless steel bolts [18], washers [19] and nuts [20] by which the three sections of the end piece are compressed together.

[0040] Two sections [4] and [5] of the end piece have a groove to facilitate O-ring [7] to form the seals between the end piece sections. When the tube cap [4] is clamped on the outer electrode [3] using a stainless steel clip [11] that fits in a groove [12] made on the outside of electrode [3] and stainless steel bolts [18], washers [19] and nuts [20] are used, then the four bolts provide the structural integrity of the assembly. Two holes [22] with female thread are made in the port B cap [5] at both opposite sides. This allows mounting the assembly on a plate or bracket. This plate or bracket may be a plastic or stainless steel as long as the metal is insulated from one or both of the electrodes. A preferred fabrication of a mounting plate or bracket is a machined sheet of Polyvinyl Chloride, which is commercially available as PVC.

[0041] One critical feature of the end piece is that the inside diameter of all sections of the end piece closely match the outside diameters of the three tubes [1], [2] and [3] so that a good seal can be achieved. When clamping the tube cap [4] on the outer electrode [3] with stainless steel clip [11] and when the other sections of the end piece are compressed on each other, it is important that the O-ring [8], [9] and [10] forms a good seal between the tubes [1], [2] and [3] and the three end caps [4], [5] and [6] form a seal between the three sections themselves using O-ring [7]. It is necessary that upon assembly the length of the cell assembly is defined by the length imposed by the outer electrode [3]. The cylindrical ion-selective exchange membrane [2] must be long enough to seal at either the bushings [23] or the perforated porous tube [24] is sealed in port B cap [5] by O-ring [9] even if one end of the ion-selective exchange membrane [2] is resting on port B cap [5] and port A cap [6].

[0042] A second critical feature of the end caps is the presence of two ports. Port A begins at fitting [17] on an outside surface of port A [6] permits the flow of a diluted brine solution through chamber A defined by the outside of the inner electrode tube [1] and the inside of the cylindrical

ion-selective exchange membrane [2]. Port B begins at fitting [17] on an outside surface of port B cap [5] and permits the flow of a diluted brine solution through chamber B defined by the outside of the cylindrical ion-selective exchange membrane [2] and the inside of outer electrode [3]. The outside of port A and port B is a fitting [17] which accepts a tube for introduction or exit of a fluid to the cell assembly.

[0043] These fittings [17] can be a compression fitting, a hose barb, or some other coupling which is appropriate for the system within which the electrolysis cell assembly is to function. The orientation of the ports is necessarily to promote a tight spiral flow around the inner electrode tube [1], the cylindrical ion-selective exchange membrane [2] and the outer electrode [3] between the spaces in chamber A and chamber B.

[0044] The end pieces can have other configurations as long as the configuration permits for the sealing of the assembly where the compressive force is imposed upon the outer electrode [3] and no significant compressive force is imposed on the cylindrical ion-selective exchange membrane [2]. The different types of end pieces can be combined in any combination as long as the appropriate lengths of tubing are chosen and as long as the sections of the end piece are sealed together by compression. While the preferred end piece has been illustrated and described, it will be clear that the invention is not so limited. Modifications, changes, variations, substitutions and equivalents will occur to those skilled in the art without departing from the spirit and scope of the present invention as described in the claims.

[0045] Another critical feature of this invention is the construction of the cylindrical ion-selective exchange membrane [2]. Firstly, a tube is made from an ion-selective membrane sheet by soaking a sheet prior to cutting a sheet to length and seal the edges of the sheet with a hotwire device together so that the polymer or fluorinated material melts together. Then either the ion-selective exchange tube [2] is either stretched and sealed on the inside or around a perforated porous tube [24] whereas the tube ends are solid and not porous or two bushings [23] are screwed in the tube ends of the cylindrical ion-selective tube [2] to form a leak free seal. It is important that the length of the ion-exchange sheet is cut at the right length as the ion-selective exchange sheet need to be stretched to fit around a perforated porous tube [24] or has to stretch to allow the bushings [23] to be screwed in the ion-selective exchange tube [2]. Soaking prior to cutting is necessary to allow the sheet to expand prior to cutting and melting the edges together leaving enough stretching capability so that the cylindrical ion-selective exchange membrane [2] can slide inside or around the perforated porous tube [24] or over the two bushings [23]. To establish a firm seal and thus preventing leakages between the ion-selective exchange membrane [2] and the perforated porous tube [24] or the two bushings [23], it is important to soak the sheet at least 24 hours in hot water (40 C) and form a cylindrical ion-selective exchange membrane [3] with a diameter marginally larger as the diameter of perforated porous tube [24] or the two bushings [23]. In case the ion-selective exchange membrane [2] is mounted on the inside of the perforated porous tube [24], the diameter of the cylindrical ion-selective exchange membrane [2] is marginally smaller than the diameter of the perforated porous tube [24].

[0046] This two chamber cylindrical electrolysis cell can be used with different flow patterns allowing changing of the pH, free-available chlorine content, redox potential, conduc-

tivity and osmolality of the dilute Hypochlorous Acid solution. A typical flow pattern as seen in FIGS. 5 and 6 permits approximately 70 to 90% of the diluted brine solution to pass successively through cathode and anode chambers to generate a stable Hypochlorous Acid solution and approximately 10 to 30% of the diluted brine solution to pass through one or more the cathode chambers to generate a Sodium Hydroxide solution. The volume of diluted brine solution that passes the electrolysis cells and separately and successively the cathode and the anode chambers can be restricted by closing product valve [25] and waste product valve [26] which are mounted prior to the inlets of the anode or cathode chambers of one of the two electrolysis cells. The volume of diluted brine solution from the outlet of the cathode chamber and that is re-directed to the inlet of the anode chamber can be restricted by closing a drain valve [28] that is mounted after the diluted brine solution passed a degassing chamber [27] assembled in the outlet tube of the cathode chamber. Different Hypochlorous Acid solutions are produced using the same flow pattern whereas both electrolysis cells consist of a cation-selective exchange membrane or whereas one electrolysis cell consist of a cation-exchange membrane and the other of an anion-exchange membrane. To produce a neutral Hypochlorous Acid solution approximately 80 to 100% of the electrolyzed solution that exits the cathode chamber is re-directed to the inlet of one of the anode chambers and whereas 0 to 20% of the electrolyzed liquid is collected in a Sodium Hydroxide storage container [29] or drained as waste or used as an effective cleaning solution. This flow pattern whereas 80 to 100% of the electrolyzed solution is collected in a Hypochlorous Acid storage container [30] is preferred when there is no or little usage of the waste flow and whereas the volume of the product flow is maximized. A preferred alternative flow pattern is to a diluted brine solution first through the cathode chamber, where in the outlet tube a degassing chamber [27] is mounted to release hydrogen gases and allow some of the diluted sodium hydroxide to flow to a storage container [29] and approximately 80 to 90% of the diluted sodium hydroxide is re-entered in the anode chamber. The result of this preferred alternative flow pattern is that approximately 80% of the diluted brine solution has undergone cathodic electrolysis followed by anodic electrolysis to generate a neutral pH sanitizing solution. Depending on the whether a cation-selective or an anion-selective exchange membrane is used, re-entering more diluted Sodium Hydroxide into the anode chamber will normally increase the pH of the diluted Hypochlorous Acid and re-entering less diluted Sodium Hydroxide will normally reduce the pH of the diluted Hypochlorous Acid. The volume of the diluted Sodium Hydroxide that enters the anode chamber is regulated by a drain valve [28] that is mounted after the degassing chamber [27] in the outlet tube of the cathode chamber between the tee and the Sodium Hydroxide storage container [29]. Degassed hydrogen is vented and thus dispersed in fresh air through a vent [31] that is located above the electrolysis cells.

[0047] As is illustrated in FIG. 6, prior to electrolysis of a diluted brine solution, the incoming water is filtered using a 10 micron filter [32]. After pre-filtration the incoming water is further treated either using a dual resin ion-exchange softener [33] or using a reverse-osmoses installation [34]. After treatment of the incoming water, pressure is reduced to maximum 50 psi using a pressure reducing valve [35]. A saturated brine solution is made using a brine container [36] whereas granular salt or salt pellets are saturated and a saturated brine

solution is pumped into the treated water using a peristaltic pump [37]. After the saturated brine is injected into the treated water, a mixing chamber [38] ensures that all saturated brine is completely mixed with the treated water ensuring a constant quality of diluted brine solution.

[0048] In the product-flow a flow-meter and an automatic control valve (product-valve [25]) regulates the flow between 70-90% of the total flow. in the other stream (waste-flow) a flow-meter and an automatic valve (waste-valve [26]) regulates the flow between 10-30% of the total flow, never closing the flow.

[0049] The product-flow passes through the following electrolytic chambers:

[0050] a) The product-flow passes through the cathode chamber of a two-chamber electrolytic cell (cell 1) whereas a cation-selective exchange membrane is the separator between the anode and the cathode.

[0051] b) After the product-flow passed the cathode chamber, it enters into a gas-separation chamber whereas gaseous hydrogen is released through a vent [31] and a sodium hydroxide solution is drained from the product-flow. The volume of drained solution is measured with a flow-meter and regulated with an automatic valve (drain-valve [28]). Approximately 0-15% of the Product-flow is drained and flows into a Sodium Hydroxide storage container [29].

[0052] c) The remaining 85-100% of the product-flow flows into and passes through the anode chamber of the same electrolytic cell (cell 1).

[0053] d) After the (reduced) product-flow leaves the anode chamber of cell 1, it flows into and passes through the anode chamber of a second two-chamber electrolytic cell (cell 2) whereas an anion-selective exchange membrane is the separator between the anode and cathode.

[0054] e) After the (reduced) product-flow leaves the anode chamber of cell 2, it flows into a Hypochlorous Acid storage container [30].

[0055] f) Simultaneously the 10-30% waste-flow passes through the cathode chamber of cell 2 after it flows into a Sodium Hydroxide storage container [29].

[0056] The product-flow undergoes first cathode electrolysis whereas cations are attracted to the cathode. Secondly, the product-flow undergoes anode electrolysis whereas cations are donated to the cathode chamber, passing through the cation ion-exchange membrane. Thirdly the product-flow undergoes a second anode electrolysis in cell 2, whereas anions from the waste-flow are donated to the product-flow passing through the anion ion-exchange membrane and accepted in the anode chamber by the product-flow. This flow configuration can be labeled as cathode to anode whereas part of the cathode product is drained. the waste-flow undergoes only cathode electrolysis in cell 2 whereas it donates anions to the product-flow. A the aqueous brine solution stream flow from a cell with cation ion-exchange membrane to a second cell with an anion ion-exchange membrane, this flow configuration can be labeled as cation to anion.

[0057] The pH of the Hypochlorous Acid can be effectively and accurately controlled by regulating the drain-valve [28] as well regulating simultaneously the waste-valve [26] and product-valve [25]. By opening the drain-valve, initially hydrogen gas, but when opening more also sodium hydroxide solution is stripped (drained) from the product-flow. pH of the hypochlorous acid solution will be the highest when the drain-valve is closed. by opening the drain-valve [28] the

volume of the product-flow is reduced allowing it more time to pass successively through the two anode chambers whereas no hydrogen gas-bubbles are passing with the product-flow thus not interfering the anode electrolysis of the (reduced) product-flow. Absence of gas bubbles and less volume result in a lower pH of the hypochlorous Acid.

[0058] Independently, the volume of the waste-flow and product-flow can be adjusted. reducing the waste-flow (and increasing the product-flow) changes the donor-acceptor relation within cell 2. Less waste-flow means that less anions are fed into the cathode chamber of cell 2, which means that less anions are donated to the anode chamber and thus less anions pass through the anion ion-exchange chamber. More waste-flow will increase the ph of the hypochlorous acid solution.

[0059] Another neutral hypochlorous acid solution with a ph between 3.5 and 7 and a long shelf life can be generated by dividing the diluted brine solution in a product-flow (hypochlorous acid) and a waste-flow (sodium hydroxide). a stable hypochlorous acid solution is generated by having the product-flow pass through the following electrolytic chambers:

[0060] a) The product-flow passes through the cathode chamber of a two-chamber electrolytic cell (cell 1) whereas an anion-selective exchange membrane is the separator between the anode and the cathode.

[0061] b) After the product-flow passed the cathode chamber, it enters into a gas-separation chamber whereas gaseous hydrogen is released through a vent and a sodium hydroxide solution is drained from the product-flow. The volume of drained solution is measured with a flow-meter and regulated with an automatic valve (drain-valve [28]). Approximately 0-15% of the product-flow is drained and flows into a sodium hydroxide storage container [29].

[0062] c) The remaining 85-100% of the product-flow flows into and passes through the anode chamber of the same electrolytic cell (cell 1).

[0063] d) After the (reduced) product-flow leaves the anode chamber of cell 1, it flows into and passes through the anode chamber of a second two-chamber electrolytic cell (cell 2) whereas a cation-selective exchange membrane is the separator between the anode and cathode.

[0064] e) After the (reduced) product-flow leaves the anode chamber of cell 2, it flows into a hypochlorous acid storage container [30].

[0065] f) The 10-30% waste-flow passes through the cathode chamber of cell 2 after it flows into a sodium hydroxide storage container [29].

[0066] The product-flow undergoes first cathode electrolysis whereas anions are attracted to the anode. secondly, the product-flow undergoes anode electrolysis whereas anions are donated to the anode chamber, passing through the anion-selective exchange membrane. Thirdly the product-flow undergoes a second anode electrolysis in cell 2, whereas cations from the product-flow are donated to the waste-flow passing through the cation-selective exchange membrane and accepted in the cathode chamber by the waste-flow. This flow configuration can be labeled as cathode to anode to anode whereas part of the cathode product is drained. The waste-flow undergoes only cathode electrolysis in cell 2 whereas it accepts cations to the waste-flow. as the aqueous brine solution stream flow from a cell with an anion-selective exchange

membrane to a second cell with a cation-selective exchange membrane, this flow configuration can be labeled as anion to cation anion.

[0067] The pH of the hypochlorous acid can be effectively and accurately controlled by regulating the drain-valve **[28]** as well regulating simultaneously the waste-valve **[26]** and product-valve **[25]**. By opening the drain-valve, initially hydrogen gas is released through the vent, but when opening more also sodium hydroxide solution is stripped (drained) from the product-flow. pH of the hypochlorous acid solution will be the lowest when the drain-valve is closed. By opening the drain-valve the volume of the product-flow is reduced allowing it more time to pass successively through the two anode chambers whereas no hydrogen gas-bubbles passing with the product-flow thus not interfering the anode electrolysis of the (reduced) product-flow. Absence of hydrogen gas bubbles and less volume result in a higher pH of the Hypochlorous Acid.

[0068] Independently, the volume of the waste-flow and product-flow can be adjusted. Reducing the waste-flow (and increasing the product-flow) changes the donor-acceptor relation within cell **2**. Less waste-flow means that less cation can be accepted into the cathode chamber of cell **2**, which means that less cations are donated to the cathode chamber and thus less cations pass through the cation-selective exchange chamber. More waste-flow will decrease the pH of the hypochlorous acid solution.

[0069] The Free Available Chlorine (FAC) can be accurately monitored and controlled by:

[0070] a) Changing the voltage (V) across the two electrolytic cells.

[0071] b) Changing the salinity (S) and conductivity (EC) of the aqueous brine solution.

[0072] c) Changing the volume of the product-flow and waste-flow. By changing the total flow, product-flow, waste-flow, voltage and current, stable hypochlorous acid solutions can be generated between pH 3.5 and 7.5 having a free-available-chlorine content of 90 to 900 ppm.

[0073] One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objectives and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiments, methods, procedures and techniques described herein are presently representative of the preferred embodiments, are intended to be exemplary and are not intended as limitations on the scope. Changes therein and other uses will occur to those skilled in the art which are encompassed within the spirit of the invention and are defined by the scope of the appended claims. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in the art are intended to be within the scope of the following claims.

We claim:

1. An apparatus for generating a stabilized sanitizing solution comprising: two cylindrical electrolysis cells having an outer cylindrical electrode separated from an inner cylindrical electrode by a cylindrical ion-selective membrane arranged coaxially one within the other to create a cathode chamber and an anode chamber; a pair of end pieces to each of said cells where a space between said inner cylindrical

electrode and said cylindrical ion-selective membrane and a space between the ion-selective membrane and the outer cylindrical electrode defines anode and cathode chambers; wherein one of said electrodes functions as an anode and the other electrode functions as a cathode to form a stabilized sanitizing solution having an extended shelf life from a diluted brine drawn through said electrolysis cells.

2. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said anode and cathode are constructed from a titanium base activated with a mixed metal oxide coating structure including a mixture of ruthenium, iridium, titanium, tantalum, and rhodium.

3. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said ion-selective membrane in said electrolysis cells consists of a cylindrical cation-selective membrane made of polymer or perfluorinated membrane sheet reinforced with or without polytetrafluoroethylene.

4. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said ion-selective membrane in said electrolysis cells consists of a cylindrical anion-selective membrane made of polymer or perfluorinated membrane sheet reinforced with or without polytetrafluoroethylene.

5. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said cylindrical ion-selective membranes are mounted on a bushing that thread into said cylindrical ion-selective membrane to form a non leaking seal.

6. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said cylindrical ion-selective membrane is construed from ion-selective membrane sheet that is stretched and sealed to form a cylinder that is capable of sustaining up to 50 psi pressure.

7. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said the ion-selective membrane sheet is sealed around the outside or inside of a perforated porous tube to form a leak free seal with the tube, said tube fits into an O-ring or gasket to form a non leaking seal with the end piece of said electrolysis cell.

8. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said end piece comprises three stackable sections of complimentary topography with at least one seal forming feature at every interface between adjacent sections wherein said seal is selected from the group of a compressible ridge, a gasket, or an O-ring.

9. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein said tubes and end pieces are selected from the group of Polyvinyl Chloride (PVC), Acetal, Nylon or Poly Carbonate.

10. The apparatus for generating a stabilized sanitizing solution according to claim **7** wherein said gaskets and O-rings are selected from the group of Ethylene Propylene (EPDM), Nitrile (BUNA-N), Fluorocarbon (FKM) or combination of a plastic and a rubber.

11. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein changing the sequence of the electrolyses stages generates a solution with different pH, free available chlorine content, redox-potential, conductivity, osmolality and shelf life.

12. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein aqueous sodium chloride or potassium chloride solution is supplied to the cathode chambers and anode chambers at a lower end piece of the

electrolysis cells and cleaning solutions (NaOH) and sanitizing solutions (HOCL) are obtained from an upper end piece of the electrolysis cells.

13. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein a spiral feed of the aqueous brine is fed to the anode and cathode chambers using tangential inlet and outlet ports.

14. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein the current is a direct current applied across the electrodes.

15. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein free available chlorine content is regulated by altering voltage, volume and electrical conductivity of aqueous sodium chloride or potassium chloride solution by controlled injection of a saturated brine solution into softened water prior to passing a dilute brine solution through the anode chambers and cathode chambers and whereas the current across the electrodes is at least 20 amps.

16. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein the cathode chamber comprises an inlet fitting connected to a tube that passes tangentially through a specific section of the lower end piece to communicate with the cathode chamber through an aperture and wherein the anode chamber comprises an inlet fitting connected to a tube that passes tangentially through a specific section of the lower end piece to communicate with the anode chamber through an aperture

17. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein the cathode chamber comprises an outlet fitting connected to a tube that passes tangentially through a specific section of the upper end piece to communicate with the cathode chamber through an aperture and wherein the anode chamber comprises an outlet fitting connected to a tube that passes tangentially through a specific section of the upper end piece to communicate with the anode chamber through an aperture.

18. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein ports address spaces through said end pieces or through said electrode tubes adjacent to the site of insertion of said electrode tubes into said end pieces.

19. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein entrance ports direct the flow of said fluid at an angle of 0 to 15 degrees relative to the plane of seats of said end pieces.

20. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein solution is a diluted hypochlorous acid.

21. The apparatus for generating a stabilized sanitizing solution according to claim **1** wherein solution is sodium hydroxide.

22. A method for generating a stabilized sanitizing solution having an extended shelf life, said method comprising the steps of:

- arranging two cylindrical electrolysis cells having an outer cylindrical electrode separated from an inner cylindrical electrode by a cylindrical ion-selective membrane arranged coaxially one within the other to create a cathode chamber and an anode chamber;

- providing a pair of end pieces to each of said cells where a space between said inner cylindrical electrode and said cylindrical ion-selective membrane and a space between the ion-selective membrane and the outer cylindrical electrode defines anode and cathode chambers;

- introducing a diluted brine solution into one said end piece wherein one of said electrodes functions as an anode and the other electrode functions as a cathode to form a stabilized solution having a prolonged shelf life.

23. The method for generating a stabilized sanitizing solution according to claim **22** wherein said diluted brine solution is a saturated chloride solution injected into softened water to make a aqueous chloride solution and wherein the concentration of the chloride solution passing through cathode and anode chambers is maximal 15 g/L.

24. The method for generating a stabilized sanitizing solution according to claim **23** wherein said saturated chloride solution is sodium chloride.

25. The method for generating a stabilized sanitizing solution according to claim **23** wherein said saturated chloride solution is potassium chloride.

26. The method for generating a stabilized sanitizing solution according to claim **23** wherein the concentration of the chloride solution is controlled by measurement of the electrical conductivity of the diluted brine solution or the current measured across the electrodes in the electrolysis cells using a variable speed peristaltic pump.

27. The method for generating a stabilized sanitizing solution according to claim **22** wherein 5 to 15% of the liquid is an alkaline cleaning solution consisting of Sodium Hydroxide and having a negative redox potential ranging from -700 to -900 mV.

28. The method for generating a stabilized sanitizing solution according to claim **22** wherein 85% to 95% of the liquid is a neutral sanitizing solution consisting of Hypochlorous Acid having a free-active-chlorine content of 90 to 900 ppm and a positive redox potential ranging from +700 to +1200 mV.

29. The method for generating a stabilized sanitizing solution according to claim **22** wherein free available chlorine content is regulated by altering voltage, volume and electrical conductivity of the solution by controlled injection of a saturated brine solution into softened water prior to passing a dilute brine solution through the anode chambers and cathode chambers and whereas the current across the electrodes is at least 20 amps.

30. A method for generating a stabilized sanitizing solution comprising the steps of: constructing several electrolysis stages for converting a diluted brine solution into a stabilized Hypochlorous Acid solution by passing and electrolyzing a diluted brine solution through one cathode chamber and two anode chambers of two cylindrical electrolyses cells; applying a current across the electrodes of said electrolysis cells; forming a sealing engagement between an end piece to said chamber, a cylindrical electrodes and an ion-selective membrane wherein said end piece has a lateral inlet through an outer wall thereof, said inlet being provided with a fitting for tangential feeding of the brine solution to the inside of the end piece, and wherein two pairs of ports for entrance or exit of fluid are situated in an upper and lower end piece comprising an external fitting for attachment of a hose or pipe, wherein said first pair of ports at opposite ends of said assembly internally addresses a space between said outer electrode tube and the ion-selective membrane and said second pair of ports at opposite ends of said assembly internally addresses a space between said ion-selective membrane and said inner electrode tube.

31. The method of claim **30**, wherein diluted Hypochlorous Acid solutions are generated with different pH, free available

chlorine content, redox-potential, conductivity, osmolality and shelf life by changing the flow patterns through the electrolyses cells and thus changing the sequence of the electrolyses stages that the diluted brine solution undergoes.

32. The method of claim **31**, wherein a saturated sodium chloride or potassium chloride solution is injected into softened water to make a aqueous sodium chloride or potassium chloride solution and wherein the concentration of the sodium chloride or potassium chloride solution passing through cathode and anode chambers is maximal 15 g/L.

33. The method of claim **32**, whereas the concentration of the sodium chloride or potassium chloride solution is controlled by measurement of the electrical conductivity of the diluted brine solution or the current measured across the electrodes in the electrolysis cells using a variable speed peristaltic pump.

34. The method of claim **30**, wherein 5 to 15% of the liquid is an alkaline cleaning solution consisting of Sodium Hydroxide and having a negative redox potential ranging from -700 to -900 mV.

35. The method of claim **30**, wherein 85% to 95% of the liquid is an neutral sanitizing solution consisting of

Hypochlorous Acid having a free-active-chlorine content of 90 to 900 ppm and a positive redox potential ranging from +700 to +1200 mV.

36. The method of claim **30**, wherein aqueous sodium chloride or potassium chloride solution is supplied to the cathode chambers and anode chambers at a lower end piece of the electrolysis cells and cleaning solutions (NaOH) and sanitizing solutions (HOCL) are obtained from the upper end piece of the electrolysis cells.

37. The method of claim **30**, wherein a spiral feed of the aqueous sodium chloride or potassium chloride solution is fed to the anode and cathode chambers using tangential inlet and outlet ports

38. The method of claim **30**, wherein the current is a direct current is applied across the electrodes.

39. The method of claim **30**, wherein the free available chlorine content is regulated by altering the voltage, volume and electrical conductivity of aqueous sodium chloride or potassium chloride solution by controlled injection of a saturated brine solution into softened water prior to passing a dilute brine solution through the anode chambers and cathode chambers and whereas the current across the electrodes is at least 20 amps.

* * * * *