Jan. 28, 1964 T. B. HOOVER 3,119,759

ROTATING ELECTROLYTIC CELL ASSEMBLY

Filed March 20, 1961 2 Sheets-Sheet 1

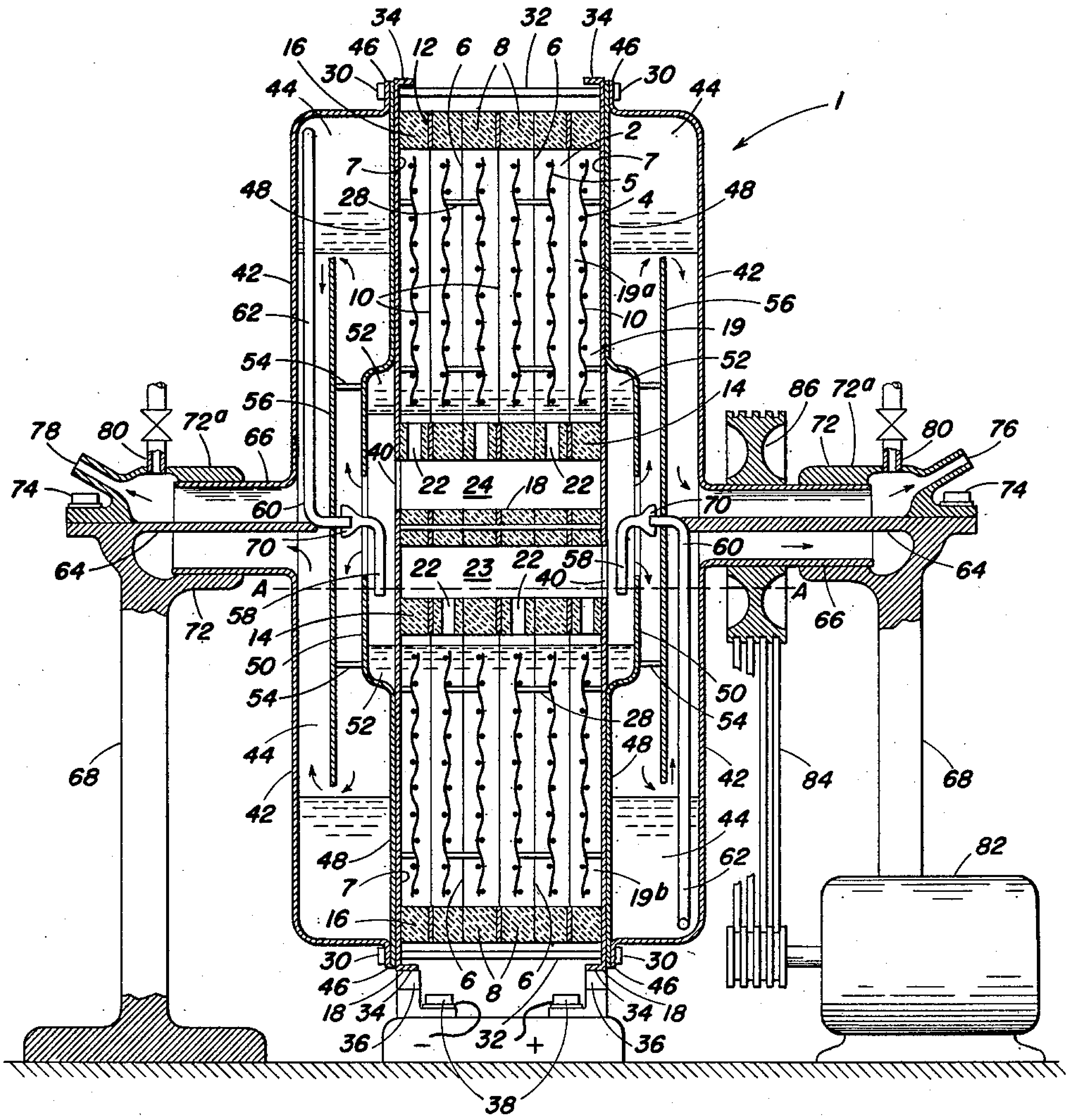

Fig. I.

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Fig. 2.

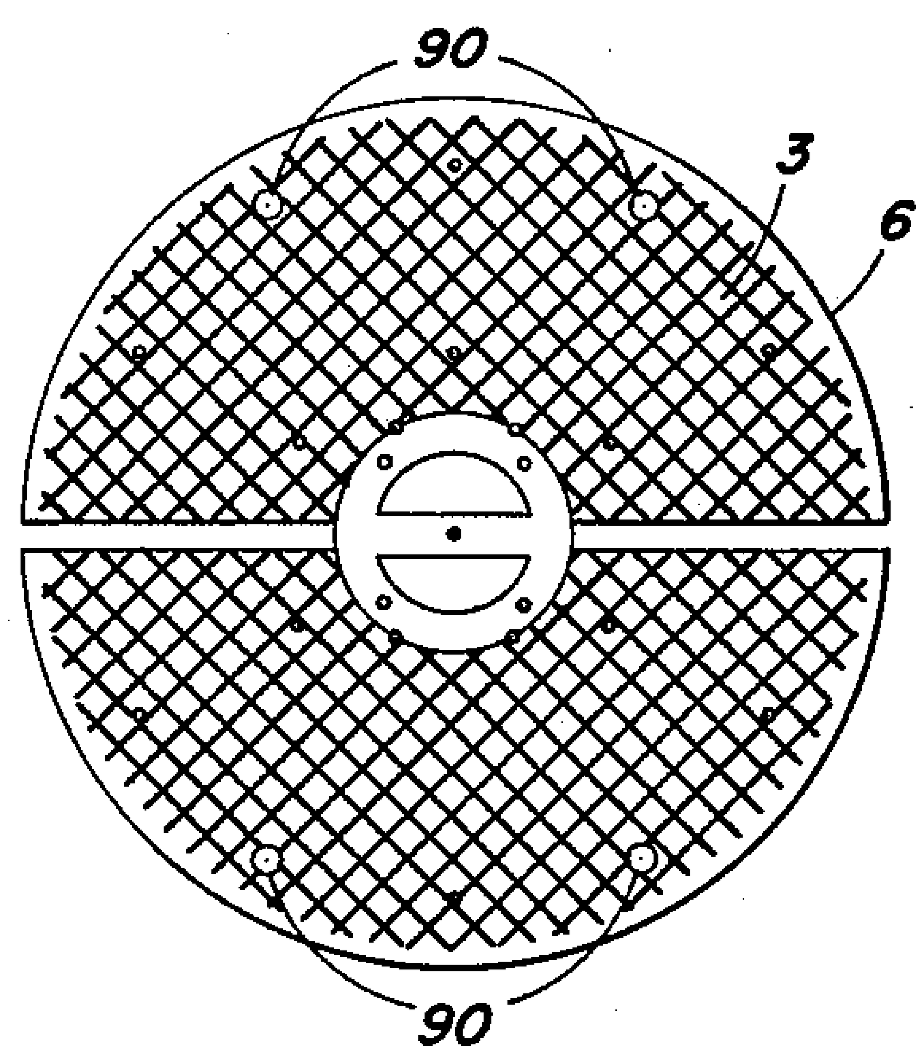
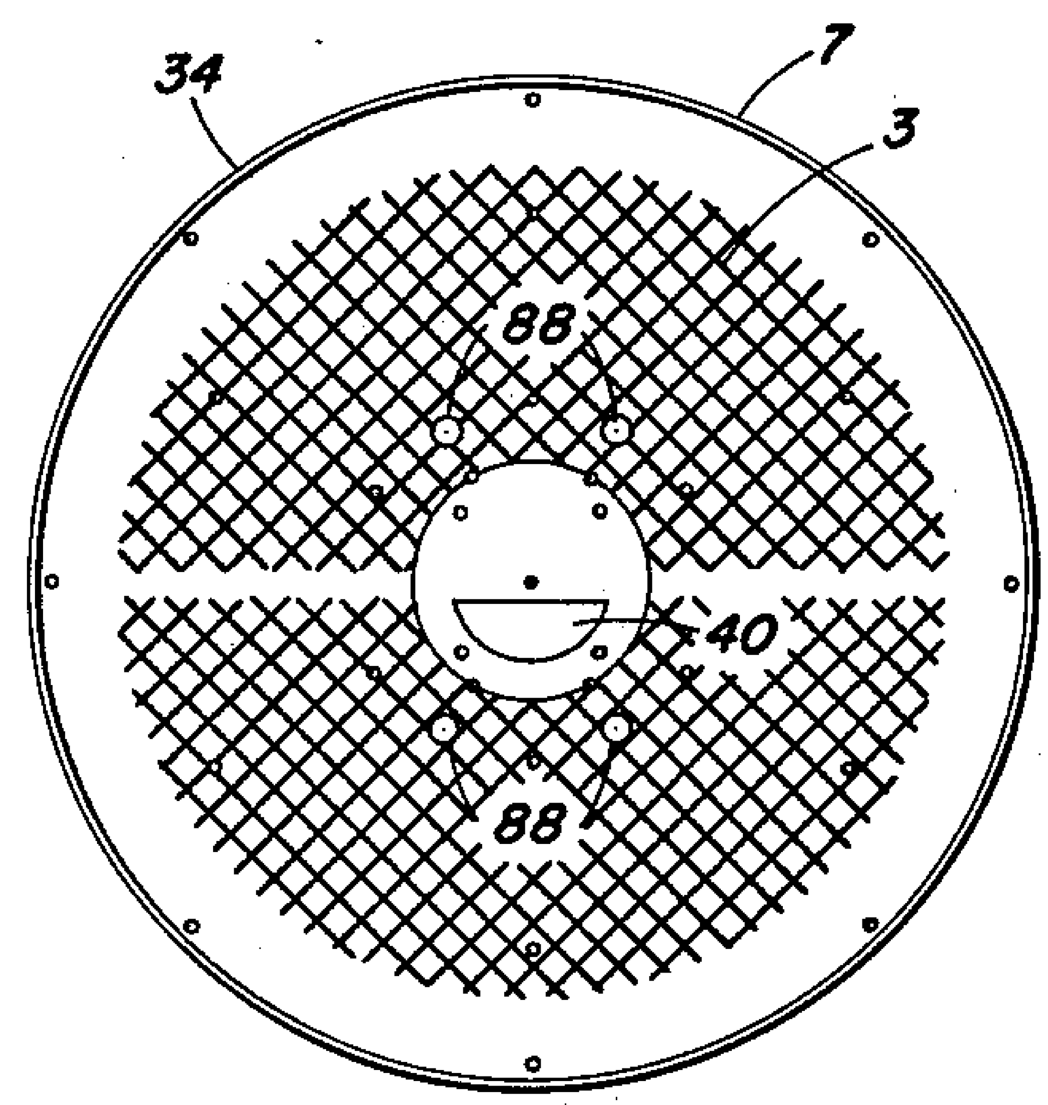


Fig. 3.



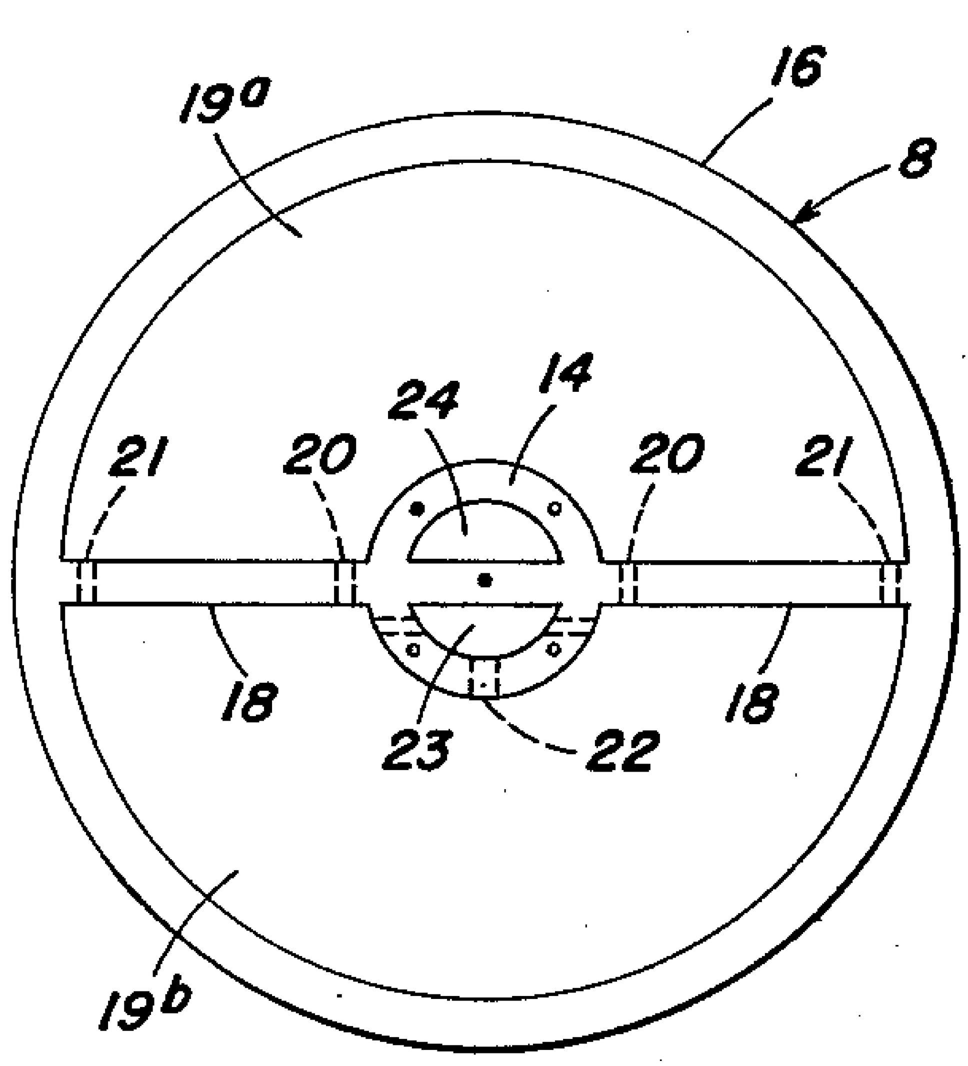


Fig. 4.

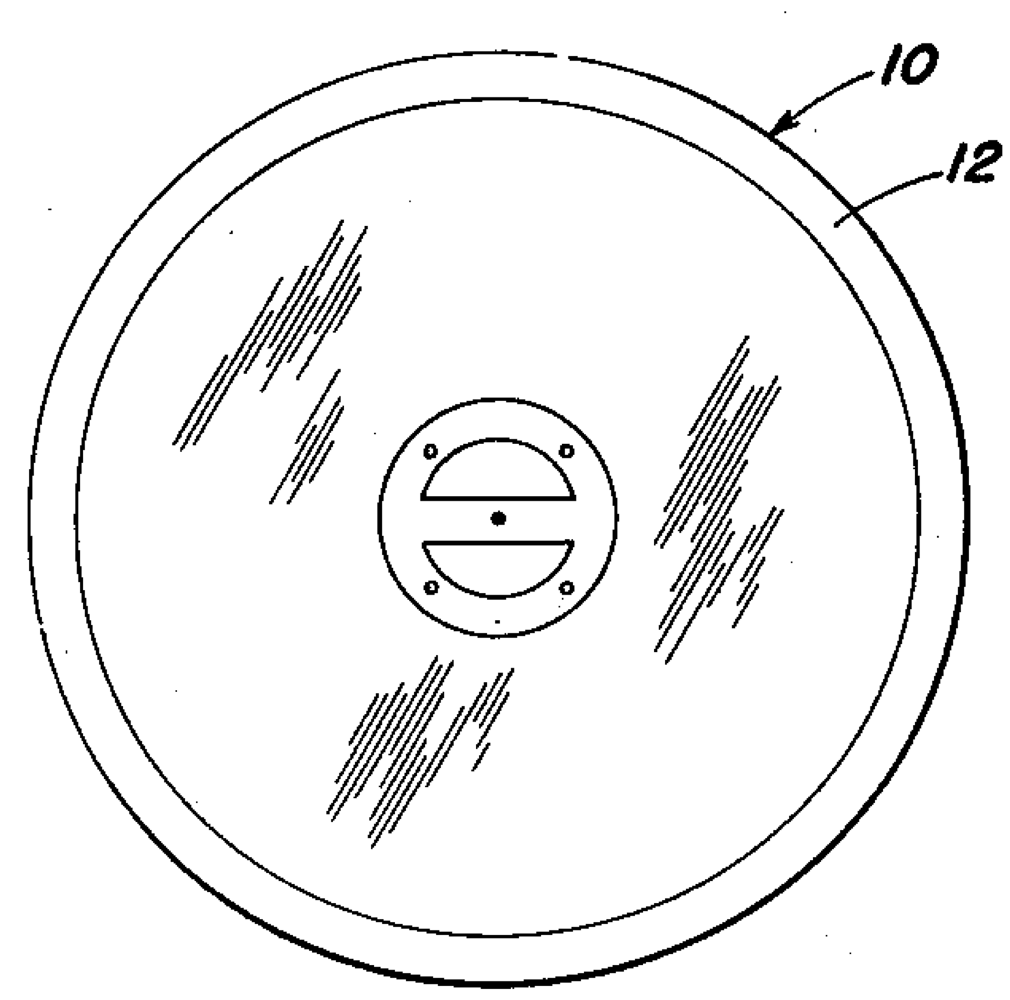


Fig. 5.

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ROTATING ELECTROLYTIC CELL ASSEMBLY

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8 Claims. (Cl. 204—212)

This invention relates to improvements in process and apparatus for effecting electrolysis. More particularly, the present invention relates to an electrolytic cell apparatus for the production of oxygen and/or hydrogen from aqueous solutions in environments where said apparatus must function free or substantially free of gravity.

Electrolytic cells known heretofore, while having been developed to a high degree of efficiency for the commercial production of gases such as hydrogen and oxygen, have been dependent upon normal gravitational force for separation of these and like gases from liquid electrolyte. Such devices are therefore not adapted to functioning at altitudes and in environments where gravitational forces are substantially non-existent.

Accordingly, it is an objective of the present invention to provide an electrolytic process and apparatus which is capable of producing gases such as oxygen and hydrogen in efficacious amounts independent of such gravitational force, and indeed, whether such forces are present or absent.

Electrolytic cells normally employed in commerce fall into two broad classifications: tank type and bipolar or filter-press type. The latter type is normally preferred in the practice of the present invention due to its more compact structure and requirement of less space for an equivalent productive capacity. It is particularly preferred to employ the compact and significantly lighter cell apparatus described and claimed by the inventor herein in application Serial No. 29,670 filed May 17, 1960, now abandoned, for modification in accordance with the practice of this invention.

The principles of electrolytic decomposition carried on in these apparati whether of the tank or bipolar type of assembly, however, have been known for an extended period of time. Electrolysis thus involves the splitting of compounds such as water into ionic charged components of hydrogen and hydroxyl moieties. These ions, carrying respectively, positive and negative charges, are identified, sequentially, as cations and anions. These ions are induced to migrate in a controlled manner in an electrolytic cell under the influence of an impressed electrical potential which is created between paired electrodes, that is a positively charged anode and a negatively charged cathode. In this procedure, the negative ions (anions) are attracted to the anode, and the positively charged ions (cations) migrate to the cathode. In order to provide a high concentration of ions of a low electrical resistance through the assembly, it is customary to use as the electrolyte a 15 to 30 weight-percent solution of sodium hydroxide or potassium hydroxide. The sodium hydroxide or potassium hydroxide is not consumed in the process, the over-all effect of which is the decomposition of water into its elements, hydrogen and oxygen. For efficient quantitative production of the desired elements, a plurality of paired electrodes are normally provided in commercially employed cell assemblies and are so employed in the apparatus described hereinafter.

Thus, the present invention provides an apparatus in which the electrolytic function proceeds in concert with a rotary motion induced therein to insure efficient separation of the liquid and gas phases. Accordingly, the liquid electrolyte is thrown toward the periphery of the apparatus while the product gases are withdrawn along the axis of rotation. The apparatus thus devised provides

for conducting the gases through a region of maximum centrifugal force for the purpose of removing entrained droplets of liquid electrolyte which would otherwise be carried along by the flowing stream of gas, and for the continuous recycling of any liquid so removed.

The present invention, however, both as to its organization and mode of operation, together with further features and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a cross-sectional view of an electrolytic cell assembly prepared in accordance with the practice of the invention;

FIGURE 2 is an elevational view of electrode elements and an internal plate member in association therewith in accordance with the present invention;

FIGURE 3 is an elevational illustration of an end plate of the cell apparatus of the present invention together with electrode members positioned thereon;

FIGURE 4 is an elevational view of a spacer element of the cell assembly;

FIGURE 5 is an elevational view of a diaphragm member of the cell assembly of the invention.

Referring now more particularly to the drawings, the invention involves a multi-cellular bi-polar or filter-press electrolytic generator assembly indicated in its entirety by the numeral **1**. This apparatus **1** comprises a plurality of unit cells **2**, clamped into a compressed face-to-face relationship along a common axis. Three complete cell units are illustrated in FIGURE 1. The unit cells **2** are, in turn, made up of two mesh screen electrodes **3**, an anode **4**, and a cathode **5** (see FIGURES 2 and 3) positioned between steel plates, either two internal plate members **6**, or an internal plate member **6** and an end plate **7**. These latter plate members **7** are more rigidly constructed and of somewhat larger diameter. Separating the two electrodes **4** and **5** of opposite polarity in each unit cell are two spacers **8** of the type shown in FIGURE 4. These spacers or spacer frames **8** are formed of a light-weight material such as plastic and specifically polyethylene, for example. Positioned between the spacers **8** in each instance is a diaphragm **10** formed of asbestos or the like having bonded to its periphery the sealing gasket means **12** formed desirably of rubber.

The spacers or frames **8** serve to maintain in proper spatial relationship to each other the electrodes **4** and **5**, the steel internal and end support plates **6** and **7** of each cell, and the porous asbestos diaphragm **10** positioned therebetween which serves to prevent mixing of the gases evolved at the respective electrodes. The spacers **8** also serve as containers for the electrolyte wherein the aforesaid anode and cathode are positioned; and, in addition, define the passages for the circulation and removal of electrolyte and product gases.

Each spacer element **8** is formed of two concentric rings **14** and **16** and radial arms **18** passing from the common center point of said rings to the other and greater of the rings **16**. Thus the arms **18** support and connect the inner ring **14** and the outer ring **16**. These arms **18** are continuous with each other and as seen in FIGURE 4 describe, in effect, an equal division of the area within the aforesaid rings on either side thereof. The outer ring **16** defines, in actuality, the outer wall of the cell anode or cathode chamber **19** as described above. It is thus solid and uninterrupted. The inner ring **14** in turn defines the inner wall of the anode or cathode chamber. The radial arms **18** thus serve, in traversing the distance between the inner ring **14** and the outer ring **16**, in dividing the electrode chambers **19** as seen in FIGURE 1 into upper and lower sub-chambers **19***a* and **19***b* respectively which are, however, connected by the ducts or orifices 20 and 21. The channels 20 and 21 are disposed in parallel alignment across the width of the aforesaid radial arms 18 between the inner ring 14 and the outer ring 16. The ports 20 are positioned immediately adjacent the inner ring 14 and transmit evolved gases to the ducts 22. The ports 21, positioned adjacent the outer ring or wall 16 transmit electrolyte across the radial arms 18.

The inner ring 14 serves a second function as the wall bordering and forming substantially the passages indicated by the numerals 23 and 24 (see FIGURE 1). These passages are between and interior to the cell assembly wherein the gases evolved in the electrode chambers are initially introduced in the course of their passage from said chambers to complete removal from the cell apparatus. The aforesaid orifices 22 connect the interior of the electrode chamber between the inner and outer rings 14 and 16 respectively with one of the internal semi-circular orifices of each of the spacers 8 which contribute to the passages 23 and 24 in the assembled state. These orifices are limited to one side of the inner ring 14. This is so that the chamber 19 situated within the walls or rings 14 and 16 of any single spacer communicates only with a single channel 23 or 24. In the assembled state the spacers 8 forming anode (4)-containing chambers 19 are thus uniformly arranged to connect with, for example, the channel 23 and to transmit in a substantially exclusive manner, oxygen thereto. By rotating similarly disposed spacers 8 forming the chambers 19 containing the cathodes 5, one-hundred and eighty degrees (180°), the orifices 22 will now connect these latter chambers exclusively with the passage 24 and pass only hydrogen thereinto in substantial amounts.

The unit cells 2 are assembled, as is evident from accompanying FIGURE 1, so that the nickel anodes 4 and steel cathodes 5 alternate throughout the entire assembly 1. Each anode 4 and cathode 5 of adjacent cell units 2, separated by an internal plate member 6, are electrically and mechanically connected by means of the metallic support members 28. Thus the internal plates 6 as well as the end plates 7 also serve to position the attached electrodes 4 and 5 within the body of each cell unit 2 by means of said support elements 28 and to prevent mixture of the gases evolved from each electrode. It is noted that each end plate 7 has mounted thereon a single support element or member 28 and, of course, supports in each instance only a single electrode.

Assemblies of such cell units 2 of substantially cylindrical conformation are compressed together with a system of nuts 30 mounted on tie-rods 32 which latter elements pass through evenly spaced orifices positioned about the perimeter of the end plates 7 and extend between mated orifices in each of said end plates 7 which are of greater diameter than the other cell elements. The outer margin of each of said end plates 7 bears a flange 34 which serves as a slip ring bearing against a brush 36 which communicates in turn with the terminals 38 of an external electrical power source (not shown), thus establishing a circuit for conduction of electricity through the cell electrodes 4 and 5. Each end plate 7 presents a single semi-circular aperture 40. These end plates are so disposed at each end of the assembled cell units 2 that the aperture 40 of one end plate 7 faces the unopen face of the opposite end plate. Thus, in effect, each of the end plates is 180° out of phase with the other. As a result, the passages 23 and 24 are each closed at one end and open at the other; the open end in one coinciding with the closed terminus of the other; as seen in FIGURE 1. Thus, it is provided, to continue the earlier illustration appearing hereinabove, that the gaseous oxygen emanating from the anode (4)-containing chamber 19 is not intermixed with the hydrogen received from the cathode (5)-containing chamber upon the passage of these gases through and from the channels 23 and 24 respectively, as described hereinafter.

Positioned at each end of the assembly of cell units 2 are the shells 42 forming the outer walls of the cell assemblies and providing the chambers 44. These shells 42 are supported by means of flanges 46 on the insulating tie rods 32 by the nuts 30; the tie rods passing through suitable orifices defined in the aforesaid flanges 46.

Also supported by said tie rods 32 and enclosed by said nuts 30 and positioned, specifically, between the terminal flanges of the housings or shells 42 and the end plates 7 are the outer edges of the insulating deflector plates 48. The inner surfaces of these plates 48 are in contact with the end plates 7 across the greater portion of the outer surface thereof but diverge outwardly therefrom as they approach the central axis of the cell assembly and terminate prior to crossing said axis, providing the deflectors 50 which, in combination with the outer walls of the end plates 7, provide the containers 52. Supports 54 mounted upon the outer walls of the deflectors 50 serve to position and maintain the baffles 56, which as shown in the illustration of FIGURE 1 are flat plates disposed across the central axis of rotation of the assembly at either end thereof within the housing 42.

Entering the chambers 52 formed by the deflectors 50 at opposite ends of the assembled cell units 2 are the terminal ends of the short arms 58 of the siphons 60. These siphons define a passage through the baffles 56 and curve outwardly to form a longer arm 62 the outer tip of which is, in each instance, curved parallel to and opposing the direction of rotation of the cell assembly. Each of the outer and longer arms 62 of the siphons 60 extends to an opposite side of the cylindrical housing 42. The siphons 60 are maintained in stationary position and supported upon the shafts 64 extending inwardly through the bearings 66 from the supporting frames 68. These siphons 60 serve to return electrolyte, which has escaped from the unit cells 2 with the evolved product gases from the periphery of the chambers 44 formed within the housings 42 to the containers formed by the deflectors 50 for re-use. The couplings 70 positioned about the siphons 60 at the point where these latter conduits pass through the baffles 56 are provided to facilitate assembly and dismantling of the apparatus, and to minimize the passage of gas through the orifice formed in each of the baffles 56 at this point as the baffles rotate in operation of the cell apparatus.

Continuous with the housing members or shells 42 are the outwardly disposed hollow bearings and conduits 66 referred to above about the central axis of rotation of the cell apparatus. These bearings 66 positioned at opposite ends of the cell apparatus rotate within the stationary bearings 72 of the stationary supporting frames 68. The bearings 72 of the stationary frames 68 are split horizontally to permit facile assembly or dismantling of the apparatus. The upper halves 72*a* of these stationary bearings 72 are affixed to the supporting frame 68, in each instance, by means of bolts 74. These upper bearing members 72*a* are modified to provide the ducts 76 and 78 through which oxygen and hydrogen are thus removed individually and simultaneously from the cell apparatus at opposite ends thereof via the aforesaid hollow bearings or conduits 66. Also disposed in the upper stationary bearing elements 72*a* are the ports for the valve actuated electrolyte feed lines 80.

Rotation of the assembly 1 is accomplished by suitable means such as the motor 82 attached by means of the belts 84 to the pulley 86 which is affixed to the outer cylindrical walls of the rotatable bearing members 66.

In operation, the assembly of cells contains sufficient electrolyte, preferably 30 percent potassium hydroxide solution, to cover the electrodes 3 while the apparatus is rotating but not so much that the liquid phase enters the ports 22 in the spacers 8. In the process of the invention the rotational velocity is controlled so as to produce approximately one gravitational unit of centrifugal acceleration at the liquid interface. Thus, illustratively, if the inner radius of the electrodes 4 and 5 is 6 cm., a rotational speed of 120 r.p.m. will be adequate. When a D.C. potential of approximately 2 volts per unit cell is supplied to the terminals 38 the cathodes 5 acquire a negative potential and the anodes 4 acquire a positive potential. Hydrogen ions in the electrolyte are attracted to the cathodes 5 where they are discharged, forming hydrogen gas. Since the electrodes 3 are in close proximity to the diaphragm 10 the gas accumulates in the space between each of the electrodes 3 and the adjacent internal plate 6 or end plate 7. Similarly, hydroxyl ions are attracted to the anodes 4 where they are discharged with the liberation of oxygen gas. Under the influence of the centrifugal force field the gases are transported toward the axis of rotation, becoming disengaged from the liquid electroltye and passing through the ports 22 in the spacers 8 into the blind ducts or passages 23 and 24. As noted above, successive spacers 8 are turned 180° so that those providing chambers 19 for the cathodes 5 communicate, for example, only with the duct 24 and pass hydrogen gas thereinto by means of the aforesaid ports 22; while the alternate spacers 8, which form the anode (4) chambers 19, communicate only with the channel 23 by means of the ports 22 and transmit oxygen thereto.

The ducts 20 provide for passage of evolved product gases across the radial arms 18 of the spacers 8 from that portion of the electrode-containing chambers remote from the ports 22 to passage therethrough into the ducts 23 or 24, depending, as noted above, upon the position assumed by the spacer 8, and thus the ports 22 thereof, with relation to the aforesaid ducts 23 and 24. The ports 21 as noted heretofore permit circulation of electrolyte across the radial arms 18 between the chambers 19*a* and 19*b*.

The gaseous flow of oxygen and hydrogen outwardly through the ducts 23 and 24 is indicated by the arrows in FIGURE 1. This gas is drawn outwardly past the system of baffle plates 56 to the chambers 44 formed by the housings 42 at either end of the cell assembly 1. The gases are then conveyed to the periphery of the housing chambers 44 and thence through the hollow bearings or conduits 66 into the ducts 76 and 78 employed for carrying off the separate gases, oxygen and hydrogen, respectively.

Vacuum pressure is exerted through the ducts 76 and 78 for removal of the gases from the cell units 2 as it forms.

The function of the baffles 56 is to conduct the product gases through a region of high centrifugal force in order to remove entrained electrolyte. As the gases are evolved from the electrodes 3 they tend to carry along droplets of liquid electrolyte as a mist. For baffles 56 which are 30 cm. in radius with a rotational speed of 120 r.p.m. the centrifugal force to which the gas stream is subjected is approximately five gravitational units. The electrolyte withdrawn by this centrifugal force is collected at the outer periphery of the shell or housing chambers 44 and is continually collected and returned to the body of the cell assembly by means of the siphons 60. These siphons as noted above are stationary. The kinetic energy of the rotating electrolyte within the shell or housing 42 is converted in these stationary siphons 60 to potential energy as the liquid enters therein and flows along each of the arms thereof towards the axis of rotation of the cell assembly. It is discharged through each of the short arms 58 of the siphons 60 into the deflectors 50 from which it passes through the opening 88 in the end plates 7 and the corresponding orifices 90 in the internal plate members 6 to each of the electrolytic cell units 2.

It is noted that to avoid admixture of evolved product gases from the electrode chambers 3, that is, illustratively, of the hydrogen and oxygen evolved, the level of electrolyte within the electrode chambers 19 should be maintained above that of the aforesaid orifices 88 and 90 during operation of the cell apparatus.

The electrolyte is initially introduced and renewed in the cell assembly 1 by transmittal thereof, when the cell assembly is at rest, from the valve actuated feed lines 80 through the conduits 66 and thence to the periphery of the chambers 44. The electrolyte is then received into the cell units 2 in the manner and through the siphons and related containers and passages described above. Introduction of new electrolyte feed into the cell apparatus is normally accomplished only when the appartus is at rest.

Liquid will accumulate within the shell chambers 44 to a depth of approximately one-third (⅓) of the radius thereof since the centrifugal potential energy of a unit mass rotating at a given radial distance will be greater than its kinetic energy of rotation. The kinetic energy at the periphery of the shell 42 and at the inlet of the siphon 60 will become sufficient when the liquid has attained this level to overcome the potential energy at the gas-liquid interface and any additional liquid will be returned to the cell assembly 1 in the manner described hereinabove.

This apparatus can also be operated under conditions of normal gravitational force when, with the assembly at rest, electrolyte is introduced through the feed lines 80 until the lower half of the cell units 2 and associated shell chambers 44 are filled to the level indicated by the interrupted line A—A in FIGURE 1. Upon rotation at sufficient velocity to produce a centrifugal force greater than the gravitational force at all gas-liquid interfaces, the siphons will drain excess liquid from the shell or housing chambers 44 into the electrolysis chambers 19 and operation of the assembly will proceed with evolution of the product gases initiated and sustained at zero gravity conditions.

What is claimed is:

1. An apparatus for effecting electrolytic decomposition which comprises a cell assembly including at least one cell unit composed of elements which include plate members, which form the opposite extremities thereof; two electrodes, an anode and a cathode positioned between and supported by said plate members in each of said cell units; said electrodes being disposed within the chambers formed by a plurality of spacer frames, and each of said spacer frames having a rigid perimeter, said spacer frames being positioned between said plate members and in contiguous relation with the borders of the planar surfaces thereof; a diaphragm positioned between said anode and said cathode, and between said spacer frames; a plurality of tie rods defining a passage about the periphery of said cell assembly transverse thereto and through the terminal plate members posed at opposite ends of the assembly of cell units; suitable means positioned on each of said tie rods and adapted to exert a compressive force on said plate members and any cell units positioned therebetween; said cell assembly being adapted to rotate about an axis central and transverse thereto; dual channels defining a passage through said cell assembly parallel to and adjacent said central axis; each of said channels defining a single terminal orifice at opposite ends of said cell assembly; apertures connecting the anode chamber of said cell assembly with one of said channels; and an aperture connecting the cathode chamber of said cell assembly with the other of said channels; terminal chambers positioned at opposite ends of the cell assembly with which the aforesaid terminal orifices of said channels communicate; baffles positioned in said terminal chambers exterior to the terminal orifice of each said channels and adapted to force effluent gases emitted from said channels to the periphery of said terminal chambers; means for withdrawing said effluent gases from said terminal chambers; and means for supporting and rotating said cell assembly including said terminal chambers about the aforesaid central axis.

2. An apparatus for effecting electrolytic decomposition that comprises a cell assembly including a plurality of cell units composed of elements which include plate members which form the opposite extremities thereof; two electrodes, an anode, and a cathode positioned between and supported by plate members in each of said cell units;

each of said electrodes being disposed within a chamber formed by a spacer frame, and each of said spacer frames being positioned between said plate members and in contiguous, air-tight engagement with the borders of the planar surfaces thereof; a diaphragm positioned between each of said anode and said cathode; and between said spacer frames; a plurality of tie rods defining a passage about the periphery of said cell assembly transverse thereto and through the terminal plate members positioned at opposite ends of the assembly of cell units; suitable fastening means positioned on each of said tie rods and adapted to exert a compressive force on said plate members and the cell units positioned therebetween, said cell assembly being adapted to rotate about an axis central and transverse thereto; said terminal plate members and the plate members of each of said cell units being formed of electrically conductive material, said terminal plate members being connected to an electrical source; dual channels defining a passage through said cell assembly parallel to and adjacent said central axis; each of said channels defining a single terminal orifice at opposite ends of said cell assembly; apertures connecting the anode chamber of said cell assembly with one of said channels; and apertures connecting the cathode chamber of said cell assembly with the other of said channels; terminal chambers positioned at opposite ends of the cell assembly with which the aforesaid terminal orifices of said channels communicate; baffles positioned in said terminal chambers exterior to the terminal orifice of each of said channels and adapted to force effluent gases emitted from said channels toward the periphery of said terminal chambers; means for withdrawing said effluent gases from said terminal chambers; means for supporting and rotating said cell assembly including said terminal chambers about the aforesaid central axis; and siphons extending to the periphery of said terminal chambers and adapted to withdraw liquid from the periphery thereof and return it to the electrode chambers of said cell units of said cell assembly.

3. In an electrolytic cell assembly the improvements comprising, in combination, means for separating substantially the gaseous products of electrolysis from the electrolyte in said cell assembly; means for inducing rotation of said cell assembly about an axis transverse and central thereto; and chamber means exterior of said cell but integral with said cell assembly for inducing passage of said gases through a region of centrifugal force produced by said rotation to remove entrained electrolyte therefrom.

4. In an electrolytic cell assembly capable of producing the gaseous products of electrolysis independent of gravitational forces, the improvements comprising; means for producing and isolating the gaseous components of electrolytic decomposition; means for inducing rotation of said cell assembly about an axis transverse and central thereto; and chamber means exterior to the unit cells of said cell assembly for inducing passage of said gases through the region in said assembly of maximum centrifugal force produced by said rotation to remove entrained electrolyte therefrom.

5. In an electrolytic cell assembly, the improvements comprising, in combination, means for recovering substantially the gaseous products of electrolysis from the electrolyte in said cell assembly; means for inducing rotation of said cell assembly about an axis central and

transverse thereto; and chamber means exterior to the unit cells of said cell assembly for inducing passage of said gases through the region of maximum centrifugal force produced by said rotation to remove the residue of electrolyte entrained therein; the recovery of said gases and removal of said residual electrolyte therefrom being attained thereby substantially independently of gravitational forces.

6. In an electrolytic cell assembly, the improvements comprising, in combination, means for recovering substantially gaseous hydrogen and oxygen produced by electrolysis from the electrolyte of said cell assembly; means for inducing rotation of said cell assembly about an axis central and transverse thereto; and chamber means exterior to the unit cells of said cell assembly for inducing passage of said gases through the region of maximum centrifugal force produced by said rotation to remove the residue of electrolyte entrained therein; the recovery of said gases and removal of said residual electrolyte therefrom being attained thereby substantially independent of gravitational forces.

7. In an electrolytic cell assembly, the improvements comprising, in combination, means for recovering, substantially, the gaseous products of electrolysis from the electrolyte in said cell assembly; means for inducing rotation of said cell assembly about an axis central and transverse thereto; chamber means exterior to the unit cells of said cell assembly for inducing passage of said gases through the region of said cell assembly wherein maximum centrifugal force is produced by said rotation to effect removal of the residue of electrolyte entrained therein; and means for effecting the recovery and redisposition of said residual electrolyte in the unit cells of said assembly; the recovery of said gases and removal, recovery and redisposition of said residual electrolyte thus being attained substantially independently of gravitational forces.

8. In an electrolytic cell assembly, the improvement comprising, in combination, means for recovering substantially, gaseous hydrogen and oxygen produced by electrolysis of water from the electrolyte present in said cell assembly; means for inducing rotation of said cell assembly about an axis central and transverse thereto; chamber means exterior to the unit cells of said cell assembly for inducing passage of said gaseous components discretely and simultaneously through regions wherein maximum centrifugal force is produced by said rotation to effect removal of residual electrolyte entrained therein; and means for effecting the recovery and redisposition of said residual electrolyte in the unit cells of said assembly; the recovery of said gaseous components, hydrogen and oxygen; and the removal, recovery and redisposition of said residual elecetrolyte thus being attained substantially independently of gravitational forces.

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