

Aug. 20, 1968

R. S. STEFFANSON ETAL

3,398,080

MERCURY VERTICAL CATHODE ELECTROLYTIC CELL

Filed March 22, 1965

3 Sheets-Sheet 1

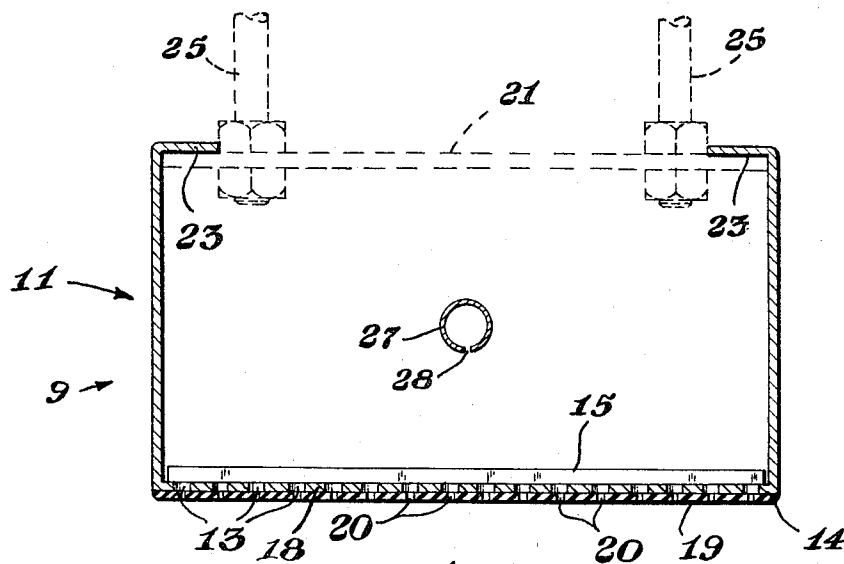


Fig. 2

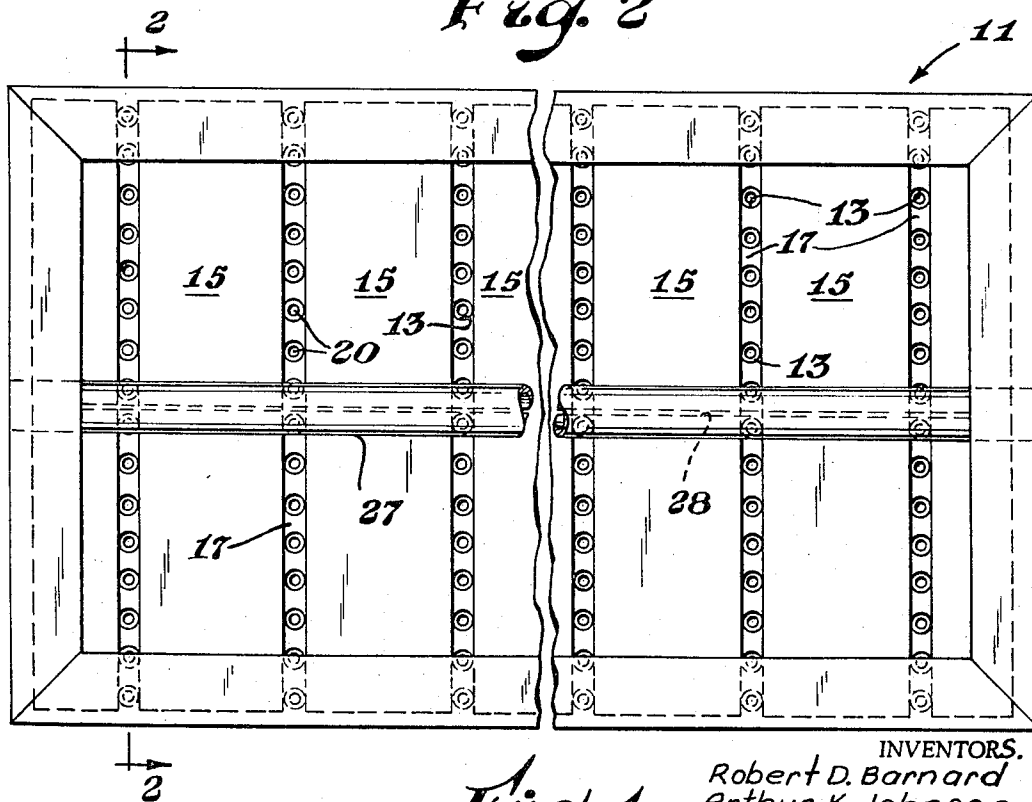


Fig. 1

INVENTORS.
Robert D. Barnard
Arthur K. Johnson
Robert S. Steffanson
BY C. Kenneth Bjork
AGENT

Aug. 20, 1968

R. S. STEFFANSON ET AL

3,398,080

MERCURY VERTICAL CATHODE ELECTROLYTIC CELL

Filed March 22, 1965

3 Sheets-Sheet 2

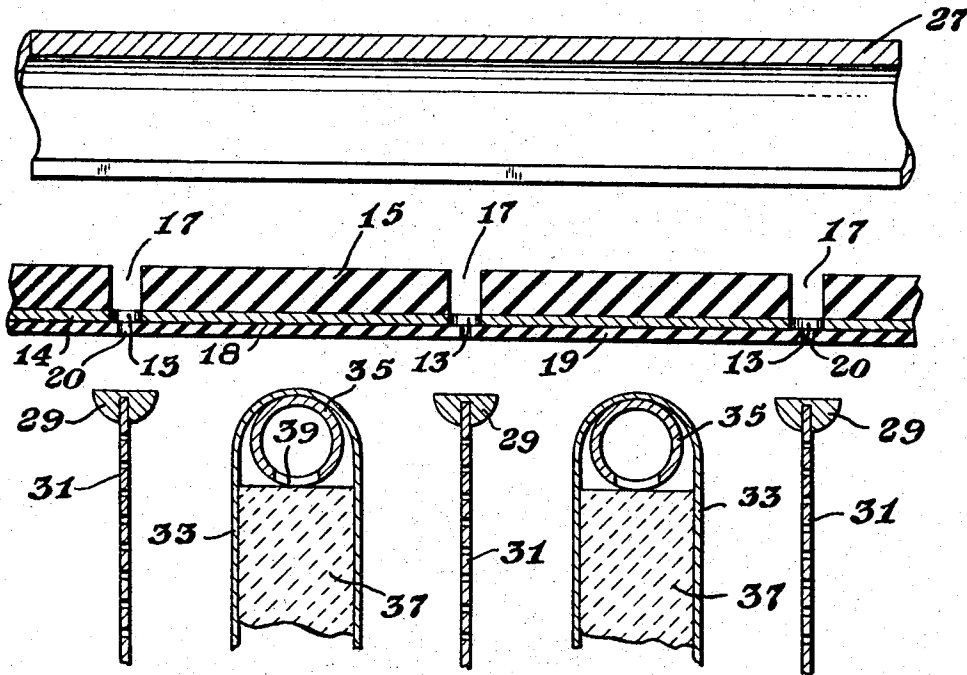
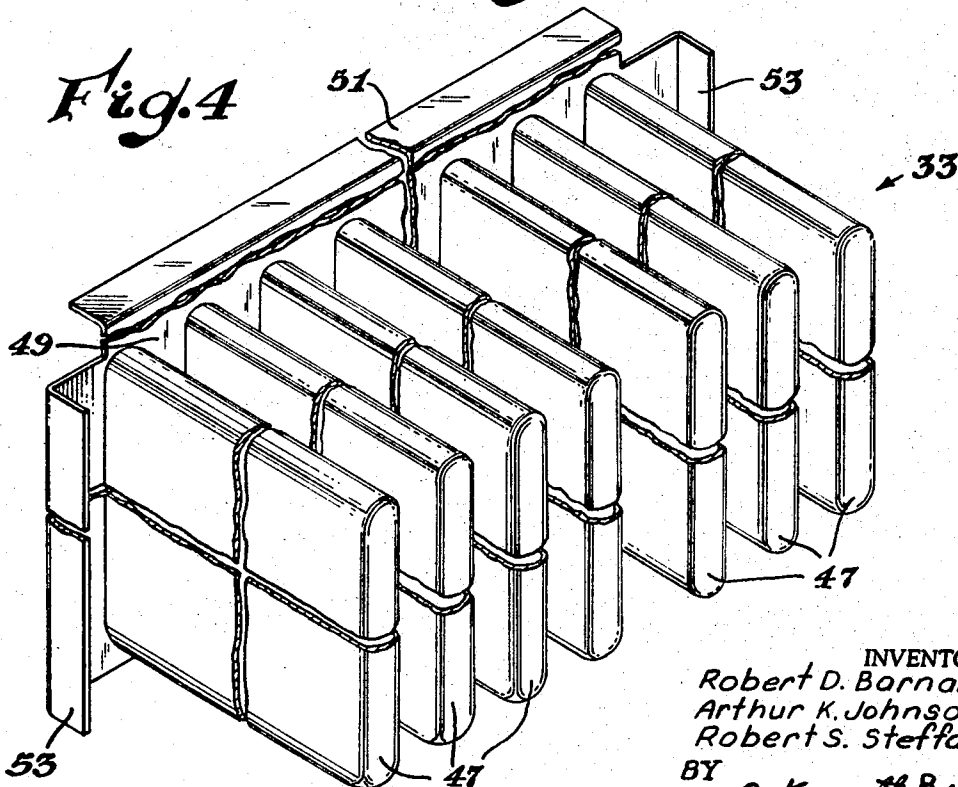


Fig. 3



INVENTORS.
Robert D. Barnard
Arthur K. Johnson
Robert S. Steffanson
BY C. Kenneth Byrle
AGENT

Aug. 20, 1968

R. S. STEFFANSON ETAL

3,398,080

MERCURY VERTICAL CATHODE ELECTROLYTIC CELL

Filed March 22, 1965

3 Sheets-Sheet 3

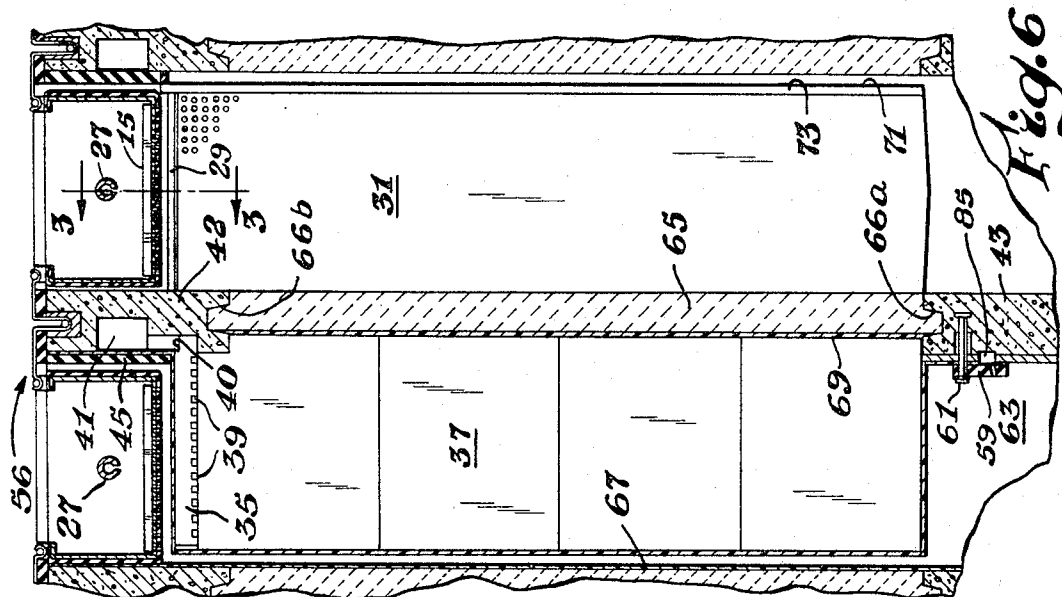
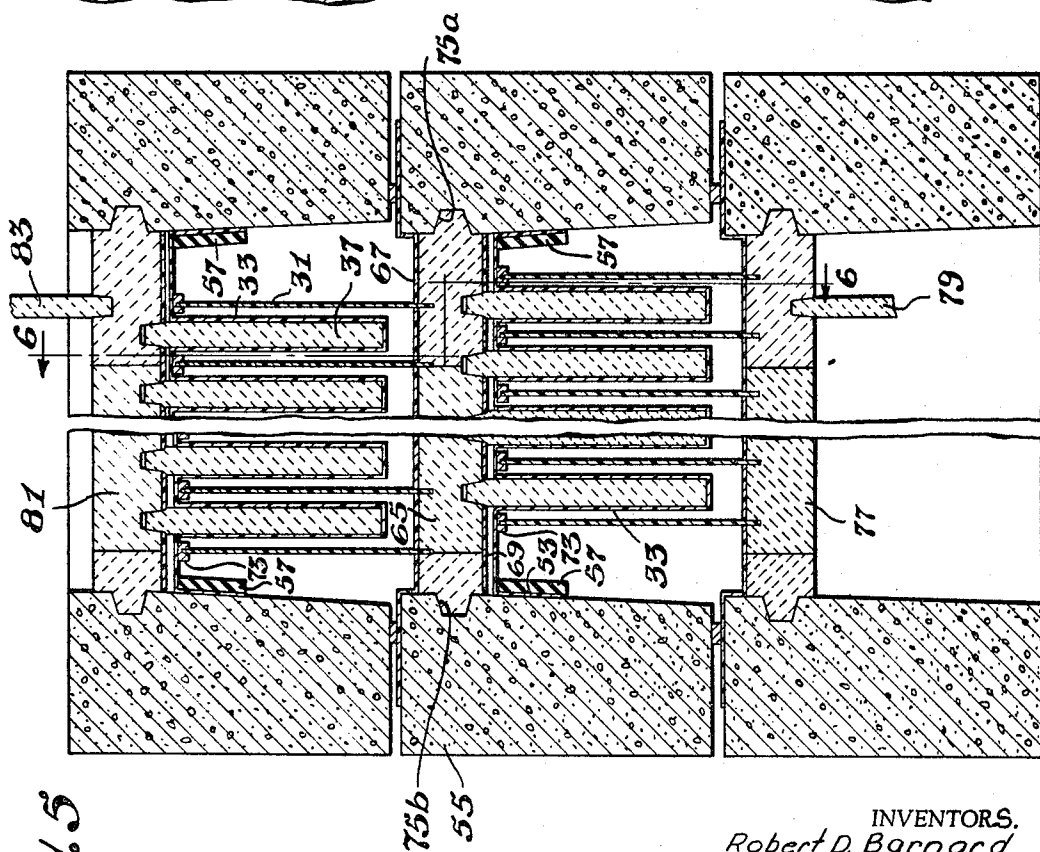


Fig. 5

INVENTORS.
Robert D. Barnard
Arthur K. Johnson
Robert S. Steffanson
BY C. Kenneth Byrle
AGENT

1

3,398,080

MERCURY VERTICAL CATHODE ELECTROLYTIC CELL

Robert S. Steffanson, Concord, Robert D. Barnard, Walnut Creek, and Arthur K. Johnson, San Diego, Calif., assignors to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

Filed Mar. 22, 1965, Ser. No. 441,769

9 Claims. (Cl. 204-219)

This invention relates to an apparatus for effecting the electrolysis of aqueous electrolytes such as alkali metal halides and brines and more particularly relates to an improvement in a mercury cathode cell of the vertical type suitable for the electrolysis of brine.

In a vertical type mercury cathode cell assembly such as that described in co-pending application Ser. No. 112,847, filed May 26, 1961, now abandoned, in general the cell is constructed of two sections joined face to face with a fluid-tight seal along a vertical plane to form a box-like structure. Cathode supports having a mercury distribution system are attached to one of the sections. Graphite anodes are attached to the other. Electrolyte inlet and discharge means are provided as well as means to vent gases from the cell and to remove mercury from the cell. Means to impress an electrolytic current between the anodes and cathodes also is provided.

More specifically the mercury vertical cathode cell assembly disclosed and claimed in application Ser. No. 112,847 comprises a fluid-tight, two-section frame, or cell body, of an electrically non-conductive material, e.g., concrete, having an opening at the top. The bottom inner walls of this frame are substantially free from obstructions and slope inwardly and downwardly with respect to the horizontal axis to form a trough-shaped bottom. The trough-shaped bottom also is inclined with respect to the horizontal axis toward an outlet located in the bottom of the cell body.

A plurality of rectangular leaf-like cathode supports, each having a spreader bar on the top edge, are attached by at least one edge to one side of the frame by means of an electrically conducting cathode backing plate. The cathode supports project into the area enclosed by the frame and are spaced from the top and bottom of the frame. Preferably, each cathode support is a plate of ferrous material having a thickness of between about 1/4 inch and 1/2 inch. Also, each plate has an array of perforations which are staggered with respect to adjacent perforations but are substantially uniformly distributed over the side surfaces of the plates. The perforations have a diameter equal to between about 3/4 and 1 1/2 times the thickness of the plate and the area of the array is between 10 and 50 percent of the area of the side surface of the plate.

A mercury distribution system distributes mercury amalgam over the cathode supports. In one embodiment this mercury distributing means is a mercury carrying conduit having spaced apart perforations on the side facing the cathode support and centered above the spreader bar of the supports. These perforations are spread apart to such an extent and are of such a size that the pools of mercury formed upon the spreader bar by the impingement of individual streams of mercury discharging from the perforations upon the bar intercept each other to completely cover the spreader bar.

A plurality of rectangular leaf-like anode members, ordinarily of graphite, are attached to the side of the frame opposite the cathode supports being positioned in a similar manner as the cathode supports with respect to the top and bottom of the frame by means of an electrically conducting anode backing plate.

The anodes and cathode plates are attached to the

2

frame at a predetermined spatial relationship, usually parallel to each other, such that the cathode supports are interleaved between and spaced apart from the anodes.

A diaphragm is disposed between the cathode supports and anodes separating the cathode supports and the mercury distribution system from the anodes. The diaphragm assures that the cathode supports communicate with the bottom of the cell and the anodes communicate with the top of the cell.

Means to introduce electrolyte into the space at the bottom of the cell below the cathode supports, means to discharge electrolyte from the space at the top of the cell, means to vent gases from the cell, means to remove mercury from the bottom of the cell and means to impress an electrolysis current between said anode members and the vertical mercury cathodes complete the cell.

Efficient operation of such a mercury cathode electrolysis cell of the vertical type as set forth in application Ser. No. 112,847 requires that mercury pumping requirements be minimized. This in turn dictates that the flowing mercury must spread out into as thin a sheet as possible over the surfaces of the cathode supports so that the ratio of the mercury cathode surface array to mercury volume in the cell is maximized. In order to achieve this goal, the mercury is introduced uniformly along the upper borders of the mercury cathode support surface during operation of such a cell.

As shown and taught in the cell described in co-pending application Ser. No. 112,847, a uniform introduction of mercury onto the cathode is achieved by running the mercury through a narrow slit or preferably a plurality of perforations in the bottom of a distributor pipe within the cell mounted above and in alignment with the top edge of the cathode support. By this action mercury either impinges on the cathode support as a pre-formed thin sheet or as a plurality of streams which coalesce on a shaped support edge into such a thin sheet.

It has been found that when a continuous slit in a distributor pipe is employed for introducing mercury onto the cathode support the slit must be very narrow in order to discharge mercury in the required sheet form without having to pump excessively large volumes of the metal. During operation many times such narrow slits tend to become obstructed with particles of foreign matter that are present or become introduced into the mercury. This results in a non-uniform discharge of mercury onto the cathode support with disruption of the required thin sheet or even complete stoppage of the flow of mercury from the discharge pipe. The result of such action is hydrogen evolution at portions of the electrically conducting metal cathode support not covered by the mercury. This constitutes a loss of cell efficiency. If a plurality of perforations, i.e. small holes are used along the length of the mercury distributor pipe the chances of requiring excessive mercury volumes to maintain mercury requirements is lessened but plugging of the holes with its attendant detrimental effects as set forth hereinbefore is still an appreciable problem.

With such a closed pipe mercury distribution system within a cell, therefore, occasionally it is necessary to shut down operations and open the cells in order that the mercury distribution pipes can be removed from the system and cleaned or replaced.

Additionally, vertical mercury cathode cells heretofore have been fabricated such that anode and cathode support arrays are attached to separate electrode mounting plates mounted on opposite sides of an enclosing frame. To illustrate: In the vertical mercury cell described in application Ser. No. 112,847, the anode assembly consists of graphite anodes mounted on a graphite mounting plate and the cathode support assembly consists of per-

forated steel plates mounted on a separate steel backing plate.

In operation such cells are utilized in a side by side or abutting arrangement wherein electrical current is passed sequentially from the cathode assembly of one cell by means of intervening connectors to the anode assembly of the next adjacent cell. In such cells, therefore, the number of separate major structural elements required is three times the number of cells which have been ganged or joined together to give an operating cell assembly, i.e. each cell comprises two different electrode assemblies and an enclosing frame work plus electrical connector assemblies of a number only one less than the number of cells in the assembly.

It is a principal object of the present invention to provide an improvement in the mercury distribution system of a vertical mercury cathode electrolysis cell which system readily is accessible for inspection and can be freed of obstructions or foreign matter without interrupting cell operation.

It is another object of the present invention to provide improved cell construction employing bi-polar electrode containing half cell units which markedly reduce the number of major structural elements from that employed in conventional vertical mercury cathode cells.

It is also an object of the present invention to provide a mercury distribution system for vertical mercury cathode electrolysis cells which permits the incorporation of vertical mercury cathode electrolysis cells having repeating half cell units embodying bi-polar electrode structures into the ganged cell construction.

It is a further object of the present invention to provide novel improvements in a mercury cathode cell of the vertical type as disclosed and claimed in application Ser. No. 112,847.

In general, the improvement to vertical mercury cathode electrolysis cells of the present invention provides a novel mercury distribution system comprising an open box, inert to brine and mercury, mounted above an alternating array of anodes and cathode supports and also comprising a common electrode backing plate on opposite faces of which are mounted graphite anodes encased in a permeable diaphragm and ferruginous cathode supports.

The invention will be more completely understood from the detailed description in the specification when read in conjunction with the figures of the drawings. In the drawings it is to be understood that like numbers in the different figures relate to the same elements.

In the drawings:

FIGURE 1 is a top view of one embodiment of the mercury distribution system of the present invention.

FIGURE 2 is a cross-sectional view of the mercury distribution system of the present invention taken along line 2—2 of FIGURE 1.

FIGURE 3 is a fragmentary sectional view showing the mercury distribution system of FIGURES 1 and 2 and its relationship to the anode-cathode arrays of a vertical mercury cathode electrolysis cell.

FIGURE 4 is an isometric view of the diaphragm used in the cell.

FIGURE 5 is a sectional plan view of an operating cell assembly when viewed from the top employing three ganged cells utilizing the novel improvement of the present invention.

FIGURE 6 is a vertical sectional view taken along the line 6—6 of FIGURE 5.

The embodiment of the mercury distribution system 9 shown in FIGURES 1-3 comprises an open top box-like member 11 having a multiplicity of spaced perforations 13 arranged in series of rows at spaced apart intervals along the length of the bottom 14 of box member 11, each row extending substantially across the width of the bottom 14 of the box 11. Each row of perforations 13 is arrayed so as to be aligned with the top edge of a cathode support 31 when the open top distributor box 11 is positioned in operating position in a cell. Inert block-like

members 15 are positioned at intervals across the inside of the bottom 14 of the box 11 in such a manner so as to provide an open channel 17 above each row of perforations 13 in the bottom 14 of the box 11. Each channel 17 can range in width from about $\frac{1}{2}$ of the diameter up to about twice the diameter of a perforation 13 although ordinarily it is slightly larger than the diameter of perforation 13. The members 15 are of a length so as to be slightly shorter than the width of the box 11 thereby assuring communication between each of the channels 17 and establishment of the same depth of mercury throughout the system. The block-like members 15 are fabricated from a material inert to brine or mercury, for example, rubber or a polymer resin such as an acrylonitrile-butadiene-styrene copolymer and are firmly attached to the bottom 14 of the box 11 as by an adhesive and/or lock-bars or the like. The outer face 18 of the bottom 14 of box member 11 has attached thereto a coating 19 also inert to brine or mercury, such as rubber or a fluorocarbon resin, this coating having perforations 20 substantially equal in number to perforations 13 and the centers of which are concentric with the centers of openings 13 in the bottom of the box 11. Perforations 20 actually serve as the metering means for mercury distribution onto the cathode supports.

The inert blocks 15 and coating 19 cover the metal bottom 14 of the box 11 to such an extent that no metal except mercury is exposed to the brine in the cell below or above.

As shown in the depicted embodiment, the perforations 13 in the bottom 14 of the box 11 are of a smaller diameter than the width of the channels 17 which feed mercury to these perforations 13. This is preferred although by no means critical. Perforations 20 at a maximum are of the same diameter as perforations 13, but ordinarily, as shown in the figure, these are of a diameter smaller than perforations 13. The actual size of perforations 20 is predetermined for a given cell assembly to assure that the proper and requisite mercury volume is distributed to the cathode support.

Ordinarily as employed in a vertical mercury cathode cell the box 11 is fitted with a readily removable metal plate-like cover 21. This cover is positioned such that its end portions overlap and contact the under side of indented shoulders 23 of the top of the box member 11. As shown cover 21 is fitted with assemblies 25 which connect or are fastened to hangers or structural connectors, not shown. It is to be understood that this cover member 21 is not critical for operation of the present novel mercury distributor assembly but serves primarily to assure that undesirable foreign matter from the atmosphere does not get into the mercury supply as well as to minimize the escape of mercury vapor to the atmosphere. The hanger assemblies 25 provide a ready means of positioning the novel mercury distributor assembly. A conduit 27 having a continuous perforation 28 along its length on its lower side extends the length of the box-like member 11 above the blocks 15 communicating through the ends of this member 11 with the mercury supply. The box is adapted to join in sealing arrangement with the cell body by means of an emplacement near the top of the concrete frame.

This novel mercury distributing assembly, because of its design provides if required for ready unplugging of the perforations, as by an inert rod, without having to dismantle the cell or even halt operation.

It is to be understood that this box-like mercury distributing system can be fabricated entirely from a brine and mercury resistant material. Also, if desired, the mercury distributing system can be cast or otherwise formed as a single integral unit. However, ordinarily for ease of construction the mercury distributing system is fabricated in accordance with the depicted embodiment.

The inclusion of the spacer blocks 15 in the depicted assembly serves to eliminate the need for a heavy weight, i.e. large inventory, of mercury in the box 11. However,

it is to be understood that if a larger mercury inventory is employed, the spacer blocks 15 can be eliminated from the assembly.

The mercury distribution system is positioned in a cell above the perforated conducting cathode supports 31 such that each row of holes or perforations 13 and 20 is aligned with the mercury spreader bar 29 on the top of the cathode support 31 directly below a given row of perforations 13 and 20. Preferably the perforations 13 and 20 in a given row are aligned so as to be directly above the center of the spreader bar 29 beneath this row. This spreader bar 29 as shown in the depicted embodiment in cross-section is in the shape of a hemisphere having its flat side facing the mercury distributing system. This is a preferred form. However, it is to be understood that the mercury spreader bar 29 can have a triangular cross-section or other cross-sectional configuration.

With this mercury distributing system, to assure operability, a brine permeable diaphragm 33 is used to cover tubular collector members 35 and the graphite anode members 37. This diaphragm 33 encases the anodes 37 and tubular collector members 35 serving as a brine permeable bag. As depicted a tubular collector member 35 is positioned on top of each anode 37. In a preferred embodiment the collector member 35 is an open ended cylinder having a series of spaced apart slots 39 across the bottom along its length and communicates at one end with a header channel 41 through a slot 40. The header channel 41 serves to remove vent gases from the cell along with electrolyte. The diaphragm 33 covering each of the anodes 37 in a given assembly is affixed to a concrete frame of the cell by means of conventional bar clamps or plastic cleats. In actual fabrication of the depicted diaphragm embodiment of FIGURE 4, the diaphragm 33 is not fabricated so as to cover a single anode but conveniently is fabricated in the form of a series of pockets 47 in a common planar sheet base 49 whereby all of the anodes in a unit are simultaneously covered. The top end of the sheet 49 provides flange 51 and each side provides a flange 53 whereby the diaphragm 33 is held tightly against the corresponding portions of the cement frame at the top, and each side by plastic cleats 45, 59 and 57, respectively.

More particularly as shown in FIGURE 4, the diaphragm 33 is a rectangular unitary structure made of a porous material having a sheet-like planar base 49. Pocket-like members 47 of substantially equal height and length and of a number equal to the anodes 37 in a given cell unit are positioned at intervals along the sheet, corresponding in placement to the position of the anodes 37 in a given unit cell. Each pocket 47 is of such a size so as to totally enclose a given anode 37 and its tubular member 35. The upper end of the planar base 49 is bent at an angle of 90° to provide a flange 51. The edge of each side wall of the base 49 is curled into a lip or flange 53.

The flange 51 provides a means for attaching the diaphragm 33 to the top concrete frame member 42 and flanges 53 provide a means for attaching the diaphragm 33 to the concrete side frame members 55 of the cell. The flange 51 at the top of the cell is held in place by a lock-bar spring-type restraining means 56 while the flanges 53 are held by a vertical plastic cleat assembly 57 fastened to the concrete side wall 55 of the cell assembly. At the bottom the planar sheet 49 is held against the bottom concrete member 43 of the cell frame, being held in place by means of a plastic cleat 59 which in turn is secured by a bolt assembly 61 which passes through the cleat 59, bottom of planar sheet 49 and is fastened into the wall 43 of the concrete frame. The diaphragm 33 completely envelopes each anode 37 in a given cell compartment and separates the anodes 37 from the cathode supports 31. This diaphragm 33 also partitions the interior of the cell into anode and cathode compartments. The cathode compartments communicate directly with space 63, i.e. bottom of the cell, and the anode compartments communicate through the tubular member 35 by means of slot 40 with

header channel 41 integral to the concrete framework 42 at the top of the cell.

The diaphragm 33 generally is made of a porous material such as a polyvinyl chloride fabric but if desired it can be constructed of other non-conducting materials such as Teflon tetrafluoroethylene resins.

During operation of the cell, the diaphragm 33 is held closely against the anode backing plate 65 by the brine head required for brine flow through the diaphragm 33. This brine head also collapses and holds the diaphragm 33 closely around the anodes 37 and tubular members 35 thereby assuring that no contact occurs between the cathodes 31 and the diaphragm 33.

In fabricating a given cell the anodes 37 and cathode supports 31 are mounted into a notched common electrically conducting backing plate 65 e.g. graphite, to provide a bipolar electrode structure which is then set into corresponding notches 66a-66b in the top 42 and bottom 43 of the concrete frame of the cell. As shown in the depicted embodiment, the anodes 37 and cathode supports 31 are attached by one edge to opposite faces of the common backing plate 65 and extend outwardly from the plate. Ordinarily, as shown the anodes 37 and cathode supports 31 mounted along a given backing plate 65 are spaced apart and parallel. This provides for ease in formation of a multi-cell assembly where the anodes 31 mounted in one backing plate 65 and the cathode supports 31 for a second backing plate 65 are interleaved as shown in FIGURE 5. An inert coating, such as a layer of epoxy resin 67 ordinarily then is applied to this backing plate 65 on one side between the cathode supports 31 and extends into the top member 42 and bottom member 43 of the concrete frame. On the other face of the backing plate 65 a layer of a phenolic resin 69 is applied to the backing plate 65 between the graphite anodes 37 in the unit cell.

The epoxy resin coating 67 assures that the brine does not contact any material having a lower hydrogen voltage than mercury thus avoiding hydrogen formation on the cathode side of the cell.

The phenolic resin 69 prevents chlorine evolution anywhere except on an anode surface 37 above which the chlorine means, i.e. collector tube 35 is provided.

Ordinarily the outwardly projecting edge 71 of the cathode support 31 is fitted with a plastic edge cover 73. This edge cover 73 assures that the edge of the cathode support 31 does not touch the diaphragm 33.

In assembling a plurality of the bi-polar electrodes of the present invention into a multi-unit cell, a notched backing plate 65 is fitted into the corresponding notches 66a-66b in the top 42 and bottom 43 of the frame. Likewise, this backing plate 65 also is notched on both sides so as to meet with mating indentation 75a-75b in the concrete side frame member 55. In completing a multi-unit cell, one of the end units is comprised of an electrically conducting plate member 77 fitted internally of the cell with cathode supports 31 only and fitted externally with a conventional electrically conducting terminal assembly 79. The other end unit is a second electrically conducting plate member 81 fitted with anodes 37 contained within a diaphragm 33. This end plate 81 also is fitted externally with an electrically conducting terminal assembly 83. In these end units, the cathode supports or anodes are so positioned that the anodes in one end plate interleave in spaced apart relationship with the cathode supports of an adjacent bi-polar electrode structure and the cathode supports of the other end plate interleave in spaced apart relationship with the anodes of an adjacent bi-polar electrode structure. Ordinarily a plurality of the terminal connections is made on each side of the terminal cells, those from the cathode terminal cell being connected in parallel and those from the anode cell likewise being connected in parallel.

For purposes of illustration in the depicted embodiment only one intermediate cell having the bi-polar electrode cathode assembly has been shown. However, it is to be understood that a plurality of the intermediate cells hav-

ing the bi-polar duplex cathode-anode structure can be employed. In such an assembly, the bi-polar cathode-anode structures are positioned such that the cathode supports 31 from a given cell and the anodes 37 from the next adjacent cell are present in an alternating comb-like assembly. With such cells, the end plates are the same as set forth hereinbefore.

As depicted in the figures, the improvements to the vertical mercury cathode cell of the present invention are employed in the cell so that there is a mercury outlet 63 at the bottom, a brine inlet and distribution channel 85 near the bottom of the anode and a combination gas vent and brine outlet header 41 at the top.

The frame fabrication, assembly and construction readily can be understood from the description of the cell in application Serial No. 112,847.

In a typical cell, the perforations 13 extending through the steel bottom 14 of the box 11 ordinarily are about $\frac{1}{4}$ of an inch in diameter. The plastic block-like members 15 are spaced apart so as to provide channels 17 ranging from about $\frac{1}{8}$ of an inch to about $\frac{1}{4}$ inch or larger in width. Preferably the blocks 15 are about $2\frac{1}{4}$ inches wide and define channels about $\frac{1}{4}$ inch wide. The perforations 13 in a given row are spaced at a distance of about $\frac{3}{8}$ inch to about $1\frac{1}{4}$ inches apart with preferably from about $\frac{1}{4}$ inch to about $\frac{3}{4}$ inch spaces between holes in a given row. The inert coating 19 on the outer face 18 of the bottom 14 of the box 11 contains perforations 20 which at a maximum are about $\frac{1}{4}$ inch in diameter and preferably are about $\frac{1}{8}$ inch in diameter. These perforations 20 are equal in number to the perforations 13 in the bottom of the box and are aligned to be concentric with the perforations 13.

The total mercury head maintained in the distribution system is about 1 inch mercury having 4 inches of water on top. This amounts to a total mercury head of about 1.3 inches mercury. The spreader bar 29 is positioned such that the mercury falls from about $\frac{1}{4}$ inch to about 1 inch after leaving box 11 and strikes the top of the spreader bar 29. The ratio of spreader bar width, i.e. the top of the spreader bar to the diameter of the metering perforations 20 generally is not greater than about 8 times the diameter of the holes 20 in the lower surface of the mercury distributor. To obtain the desired mercury sheet on the surface of the vertical plate, the distance from the bottom of the distributor box 11 to the base, i.e. the lower edge opposite the flat face adjacent the bottom of the mercury distributing box 11 of the spreader bar 29 is maintained such that it is from about 1 to about 8 times the diameter of the holes 20 in the mercury distributor. In spacings as set forth directly hereinbefore, the pools of mercury formed by the impingement of the mercury stream on the spreader bar intercept and lap each other and completely cover the spreader bar. In the vertical cell assembly of application Serial Number 112,847 employing the improvements of the present invention, the average thickness of the falling mercury film on the cathode supports are in the range of 0.1 to 0.5 millimeter.

In the novel bi-polar electrode structure of the present invention a common backing plate is fitted into the concrete framing member at the top and bottom. The cathode member is rigidly affixed to one side of the backing plate and the anode members mounted on the opposite face of this plate. An inert resin coating is applied to the backing plate between the anodes and the cathodes extending up through the concrete top and bottom members supporting the backing plate. Conveniently the cathodes are fitted into the backing plate by providing a rectangular indentation in this plate and forcing the graphite anode having a tapered end into this rectangular indentation. The cathodes readily are affixed by forcing them into slots saw-cut in the face of the backing plate.

In a vertical mercury cathode electrolysis cell of the type set forth in Serial Number 112,847 and employing the improvements of the present invention, a steel $\frac{1}{8}$ inch

thick mercury distribution box 11 which was about $9\frac{3}{16}$ inches wide by $87\frac{3}{16}$ inches long by $5\frac{3}{16}$ inches deep had fused to the outer side of its bottom about a $\frac{1}{16}$ inch thick layer of a powdered fluorocarbon polymer. Thirty-five rows of $\frac{1}{4}$ inch holes about $\frac{5}{8}$ inch apart were drilled through the metal bottom of the box and an equal number of concentric holes $\frac{1}{8}$ inch in diameter were drilled through the fluorocarbon resin coating covering the outside bottom of the box. The distance between rows was about $2\frac{1}{2}$ inches. Blocks of polyvinyl dichloride polymer were glued across the box being positioned so as to provide $\frac{1}{4}$ inch channels along the line of centers of the holes in a given row across the bottom of the box. This mercury distribution system was mounted above a cell employing the duplex electrode assembly of the present invention and held in place by a spring clamp and block mounting means. In this assembly, a perforated cathode supporter was positioned directly below each of the rows of holes, the distance from the bottom of the perforations in the mercury distribution box to the top of the hemispherical mercury spreader bar being about $\frac{1}{2}$ inch. The width of the flat topped half-round spreader bar was $\frac{3}{4}$ inch. A cell system was fabricated having 2 complete cells, i.e. employing 3 of the duplex cathode-anode assemblies. The assembly was about 5 feet high and about $3\frac{1}{2}$ feet from outside of the first cell to the outside of the last cell and each cell was about 10 feet from end to end. Operation of the cells with a sodium chloride brine having a NaCl concentration of about 305 to 310 grams per liter resulted in production of 1370 pounds of chlorine per cell per day and 1540 pounds of sodium hydroxide output per day from the amalgam converter at a total voltage drop of 9 volts at the switch terminals and 20,000 amperes operating conditions.

Various modifications can be made in the present invention without departing from the spirit or scope thereof for it is understood that we limit ourselves only as defined in the appended claims.

We claim:

1. In a mercury vertical cathode electrolytic cell assembly comprising a fluid-tight, box-like structure, cathode supports having a mercury distribution system, graphite anodes, electrolyte inlet and discharge means, vent gas and mercury removing means, and means to impress an electrolytic current between the anodes and cathodes the improvement which comprises:

(a) at least one bi-polar electrode structure containing a multiplicity of graphite anodes and cathode supports, each of said anodes being attached to the same face of an electrically conducting backing plate and each of said cathode supports being attached to the opposite face of said backing plate, said anodes and cathode supports being in spaced apart relationship and extending outwardly from the faces of said backing plate, each anode having a tubular collector member positioned along its top edge, said collector providing communication between the interior of the cell and the electrolyte and gas venting means, each cathode support fitted with a spreader bar extending along the length of its top edge and the bottom of each of said cathode supports communicating with the bottom of the cell, a porous diaphragm covering said anodes and tubular collector members and separating said anodes and tubular collector members from said cathode supports, said bi-polar electrode structure positioned in said cell body by means of said common backing plate attached to top and bottom frame members of said cell body, and

(b) a mercury distribution system comprising an open-top box-like member inert to brine and mercury having a multiplicity of spaced perforations arranged in series of rows at spaced apart intervals along the length of the bottom of the box, each row of said spaced perforations extending substantially across the width of the bottom of the box, a conduit means for introducing mercury to said box, said conduit means

communicating with a mercury supply, said mercury distribution system positioned in said cell above said bi-polar electrode structure such that each row of perforations in the bottom of said box is above a mercury spreader bar on a cathode support.

2. In a mercury vertical cathode electrolytic cell assembly comprising a fluid-tight, non-electrically conducting cell body, a plurality of rectangular leaf-like perforated ferruginous cathode supports, a plurality of rectangular leaf-like graphite anodes, a diaphragm separating said cathode supports and said anodes, a mercury distribution system to flow mercury over the cathode supports, means to introduce electrolyte into the bottom of the cell near the bottom of the anodes, means to discharge electrolyte and vent gases from the top of the cell, mercury outlet means at the bottom of the cell, and means to impress an electrolysis current between said anodes and the mercury vertical cathodes the improvement which comprises:

(a) at least one bi-polar electrode structure containing a multiplicity of said graphite anodes and said cathode supports, each of said anodes being attached to the same face of an electrically conducting backing plate and each of said cathode supports being attached to the opposite face of said backing plate, said anodes and cathode supports being in spaced apart relationship and extending outwardly from the faces of said backing plate, each anode having a tubular collector member positioned along its top edge, said collector providing communication between the interior of the cell and the electrolyte and gas venting means at the top of the cell, each cathode support fitted with a spreader bar extending along the length of its top edge and the bottom of each of said cathode supports communicating with the bottom of the cell, a porous diaphragm covering said anodes and tubular collector members and separating said anodes and tubular collector members from said cathode supports, said bi-polar electrode structure positioned in said cell body by means of said common backing plate attached to the top and bottom frame members of said cell body, and

(b) a mercury distribution system comprising an open-top box-like member inert to brine and mercury having a multiplicity of spaced perforations arranged in series of rows at spaced apart intervals along the length of the bottom of the box, each row of said spaced perforations extending substantially across the width of the bottom of the box, inert block-like members firmly positioned at intervals across the inside of the bottom of the box so as to provide an open channel above each row of said perforations in the bottom of the box, said block-like members having a length shorter than the width of the box, a perforated conduit extending the length of the box and positioned above said blocks and communicating with a mercury supply, said mercury distribution system being positioned in said cell above said bi-polar electrode structure such that each row of perforations in the bottom of said box is above a mercury spreader bar on a cathode support.

3. The cell as defined in claim 2 and including a first end unit comprising an electrically conducting plate member fitted with cathode supports, said end unit positioned such that said cathode supports interleave in spaced apart relationship with the diaphragm covered anodes of the adjacent bi-polar duplex electrode structure, a second end unit comprising an electrically conducting plate member fitted with said anodes, said anodes encased in a diaphragm, said end unit positioned such that said diaphragm encased anodes interleave in spaced apart relationship with the cathode supports of the adjacent bi-polar electrode structure, and at least one electrically conducting terminal assembly external of each of said end units.

4. The mercury vertical cathode electrolytic cell assembly as defined in claim 2 and having a multiplicity

of intermediate cells each having one of said bi-polar duplex electrode structures, said bi-polar electrodes of said intermediate cells being positioned in said assembly such that the cathode supports from a given electrode structure interleave in spaced apart relationship with the diaphragm encased anodes of a duplex assembly from the next adjacent intermediate cell.

5. In a mercury vertical cathode electrolytic cell assembly comprising a two-section, fluid-tight non-electrically conducting cell body, a plurality of rectangular leaf-like cathode supports, each of said cathode supports being a plate of ferruginous material having a thickness of between about $\frac{1}{4}$ inch and about $\frac{1}{8}$ inch and having an array of perforations which are staggered with respect to adjacent perforations but are substantially uniformly distributed over the side surfaces of the plates, said perforations having a diameter equal to from about $\frac{3}{4}$ to about $1\frac{1}{2}$ times the thickness of said plate and the area of said array being between 10 and 50 percent of the area of the side surface of the plate and each of said cathode supports having a spreader bar extending along the length of its top edge, a plurality of rectangular leaf-like graphite anodes, a diaphragm separating said cathode supports and said anodes, a mercury distribution system to flow mercury over the cathode supports, means to introduce electrolyte into the bottom of the cell between the cathodes and anodes, means to discharge electrolyte and vent gases from the top of the cell, mercury outlet means at the bottom of the cell, and means to impress an electrolysis current between said anodes and the mercury vertical cathodes the improvement which comprises:

(a) at least one bi-polar electrode structure containing a multiplicity of said graphite anodes and said cathode supports, each of said anodes being attached by one edge to the same face of an electrically conducting backing plate and each of said cathode supports being attached by one edge to the opposite face of said backing plate, said anodes on the one side of said backing plate and said cathode supports on the other side of said backing plate being in spaced apart parallel relationship and extending outwardly from the faces of said backing plate, each anode having a tubular collector member positioned along its top edge, said tubular member extending substantially the length of said anode and having a multiplicity of spaced apart slots on its lower side resting on said anode and having a slot on its top side near the end adjacent said backing plate, said tubular member providing communication between the interior of the cell and the electrolyte and gas discharge means at the top of the cell, each cathode support fitted with a spreader bar extending along the length of its top edge, said spreader bar being hemispherical in shape, the bottom of each of said cathode supports communicating with a space at the bottom of the cell, a unitary, flexible, porous diaphragm structure, said diaphragm structure fitted with pocket-like members corresponding in placement to the position of the anodes in said cell, each pocket-like member of said diaphragm structure enclosing one anode and its tubular collector member and said diaphragm structure separating said anodes and tubular collector members from said cathode supports, said bi-polar electrode structure being positioned in said cell body by means of said common backing plate attached to top and bottom frame members of said cell body,

(b) a mercury distribution system comprising an open top steel box-like member having a multiplicity of spaced perforations arranged in series of rows at spaced apart intervals along the length of the bottom of the box, each row of said spaced perforations extending substantially across the width of the bottom of said box, block-like members inert to brine and mercury firmly positioned at intervals

across the inside of the bottom of the box so as to provide an open channel above each row of said perforations in the bottom of said box, said block-like members having a length shorter than the width of the box, the width of said channels ranging from about $\frac{1}{2}$ of the diameter up to about twice the diameter of the perforations in the bottom of said box, a coating inert to brine and mercury attached to the outside face of the bottom of said box, said coating having perforations substantially equal in number to the perforations in the bottom of said box, the centers of said perforations in said coating being concentric with the centers of the perforations in the bottom of said box, said perforations in said coating, at a maximum size, being about the diameter of said perforations in the bottom of said box, a conduit having a continuous perforation along its length extending the length of the box and positioned above said blocks, said conduit communicating through the ends of said box with a mercury supply, said mercury distribution system positioned in said cell above said bi-polar electrode structure such that each row of perforations is above a mercury spreader bar on a cathode support, the ratio of the top of said spreader bar to the diameter of a perforation in said coating on the bottom of said box at a maximum being 8 and the distance from the bottom surface of said box to the base of said spreader bar ranging from about 1 to about 8 times the diameter of said perforations in the coating on the bottom of said box,

(c) a first end unit comprising an electrically conducting plate member fitted with said cathode supports, said end unit positioned in one end of said cell body such that said cathode supports interleave in spaced apart relationship with the diaphragm covered anodes of the adjacent bi-polar duplex electrode structure,

(d) a second end unit comprising an electrically conducting plate member fitted with said anodes, said anodes encased in a unitary, flexible porous diaphragm, said second end unit positioned in the other end of said cell body such that said diaphragm encased anodes interleave in spaced apart relationship with the cathode supports of the adjacent bi-polar electrode structure, and

(e) at least one electrically conducting terminal assembly on each of said cell units.

6. The mercury vertical cathode electrolyte cell assembly as defined in claim 5 and having a multiplicity of intermediate cells each having one of said bi-polar duplex electrode structures, said bi-polar electrodes of said intermediate cells being positioned in said assembly such that the cathode supports from a given electrode structure interleave in spaced apart relationship with the diaphragm encased anodes of a duplex assembly from the next adjacent intermediate cell.

7. A bi-polar electrode structure for a mercury vertical cathode electrolytic cell assembly which comprises:

a plurality of rectangular leaf-like cathode supports, each of said cathode supports being a plate of ferruginous material having a thickness of between about $\frac{1}{4}$ inch and about $\frac{1}{8}$ inch and having an array of perforations which are staggered with respect to adjacent perforations but are substantially uniformly distributed over the side surfaces of the plates, said perforations having a diameter equal to from about $\frac{3}{4}$ to about $1\frac{1}{2}$ times the thickness of said plate and the area of said array being between 10 and 50 percent of the area of the side surface of the plate and a plurality of rectangular leaf-like graphite anodes, each of said cathode supports being attached by one edge to the same face of an electrically conducting backing plate and each of said anodes being attached by one edge to the

opposite face of said backing plate, said anodes on the one side of said backing plate and said cathode supports on the other side of said backing plate being in spaced apart parallel relationship and extending outwardly from the faces of said backing plate, each cathode support fitted with a spreader bar extending along the length of its top edge, said spreader bar being semicylindrical in cross-section, the curved surface thereof directed downwardly, the bottom of each of said cathode supports communicating with the bottom of a mercury vertical cathode electrolytic cell, said bi-polar electrode structure adapted to be positioned in a cell body by means of said common backing plate attached to top and bottom frame members of said cell body.

8. A mercury distributing system for a mercury vertical cathode electrolytic cell assembly which comprises: an open-top box-like member inert to brine and mercury having a multiplicity of spaced perforations arranged in series of rows at spaced apart intervals along the length of the bottom of the box, each row of said spaced perforations extending substantially across the width of the bottom of the box, inert block-like members firmly positioned at intervals across the inside of the bottom of the box so as to provide an open channel above each row of said perforations in the bottom of the box, said block-like members having a length shorter than the width of the box, a perforated conduit extending the length of the box and positioned above said blocks and communicating with a mercury supply.

9. A mercury distributing system for a mercury vertical cathode electrolytic cell assembly which comprises:

an open top steel box-like member having a multiplicity of spaced perforations arranged in series of rows at spaced apart intervals along the length of the bottom of the box, each row of said spaced perforations extending substantially across the width of the bottom of said box, block-like members inert to brine and mercury firmly positioned at intervals across the inside of the bottom of the box so as to provide an open channel above each row of said perforations in the bottom of said box, said block-like members having a length shorter than the width of the box, the width of said channels ranging from about $\frac{1}{2}$ of the diameter up to about twice the diameter of the perforations in the bottom of said box, a coating inert to brine and mercury attached to the outside face of the bottom of said box, said coating having perforations substantially equal in number to the perforations in the bottom of said box, the centers of said perforations in said coating being concentric with the centers of the perforations in the bottom of said box, said perforations in said coating, at a maximum size, being about the diameter of said perforations in the bottom of said box, a conduit having a continuous perforation along its length extending the length of the box and positioned above said blocks, said conduit communicating through the ends of said box with a mercury supply.

References Cited

UNITED STATES PATENTS

678,816	7/1901	Shinn	204—220	XR
1,815,080	7/1931	Smith	204—254	
2,952,604	9/1960	De Nora	204—220	
3,046,215	7/1962	Sullivan et al.	204—219	
3,337,443	8/1967	Raetzsch et al.	204—254	XR

FOREIGN PATENTS

575,665 5,1959 Canada.

JOHN H. MACK, *Primary Examiner*.

D. R. VALENTINE, *Assistant Examiner*.