March 25, 1958 R. E. BRIGGS 2,828,257

MULTI-COMPARTMENT ELECTROLYTIC CELL

Filed Feb. 17, 1954 3 Sheets-Sheet 1

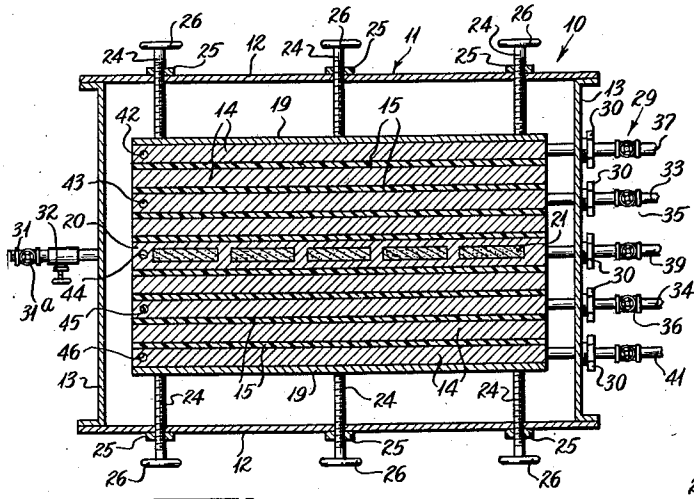


Fig. 1.

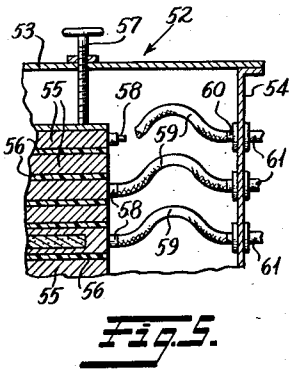


Fig. 5.

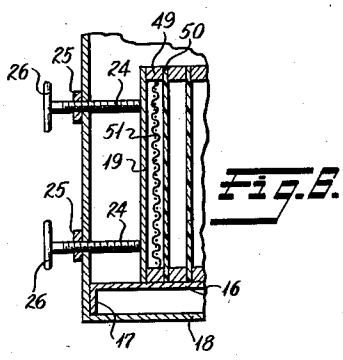


Fig. 6.

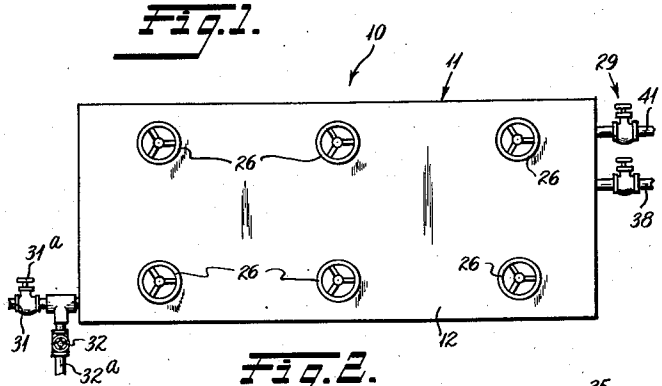


Fig. 2.

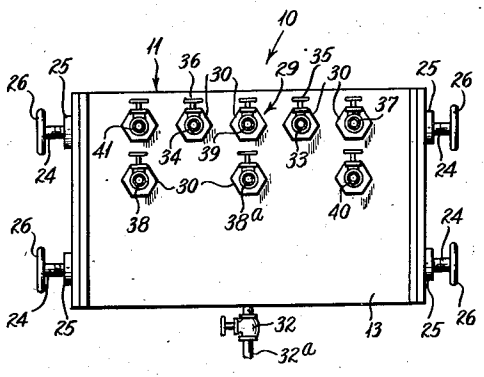


Fig. 3.

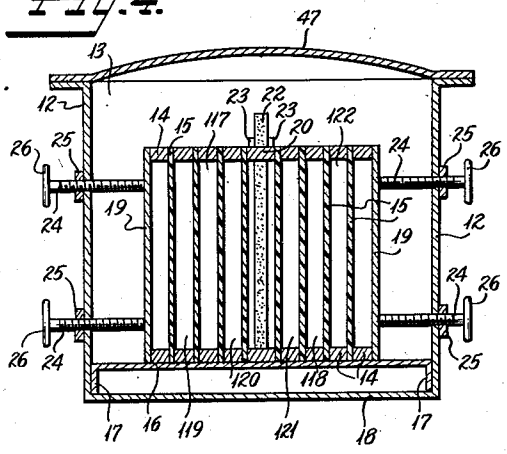


Fig. 4.

INVENTOR

ROBERT E. BRIGGS

BY Bacon & Thomas

ATTORNEYS

March 25, 1958 R. E. BRIGGS 2,828,257

MULTI-COMPARTMENT ELECTROLYTIC CELL

Filed Feb. 17, 1954 3 Sheets-Sheet 2

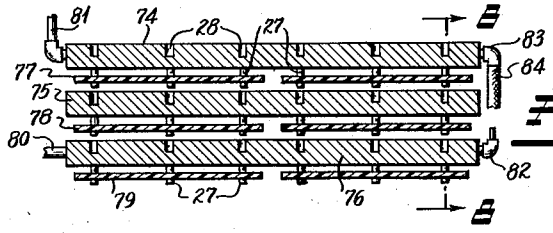


Fig. 7.

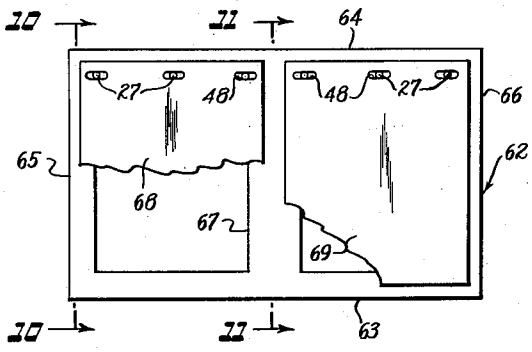


Fig. 9.

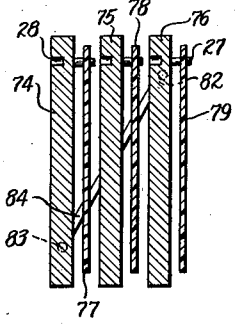


Fig. 8.

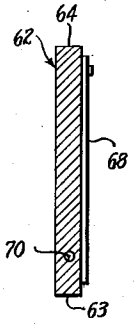


Fig. 10.

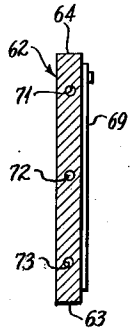


Fig. 11.

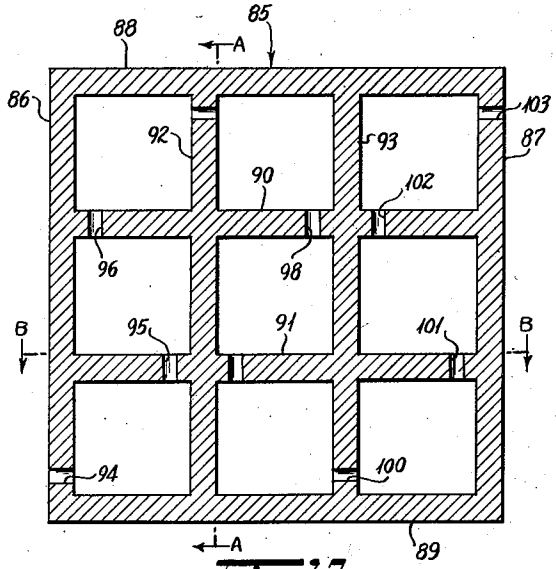


Fig. 12.

INVENTOR
ROBERT E. BRIGGS

BY Bacon & Thomas

ATTORNEYS

March 25, 1958 R. E. BRIGGS 2,828,257

MULTI-COMPARTMENT ELECTROLYTIC CELL

Filed Feb. 17, 1954 3 Sheets-Sheet 3

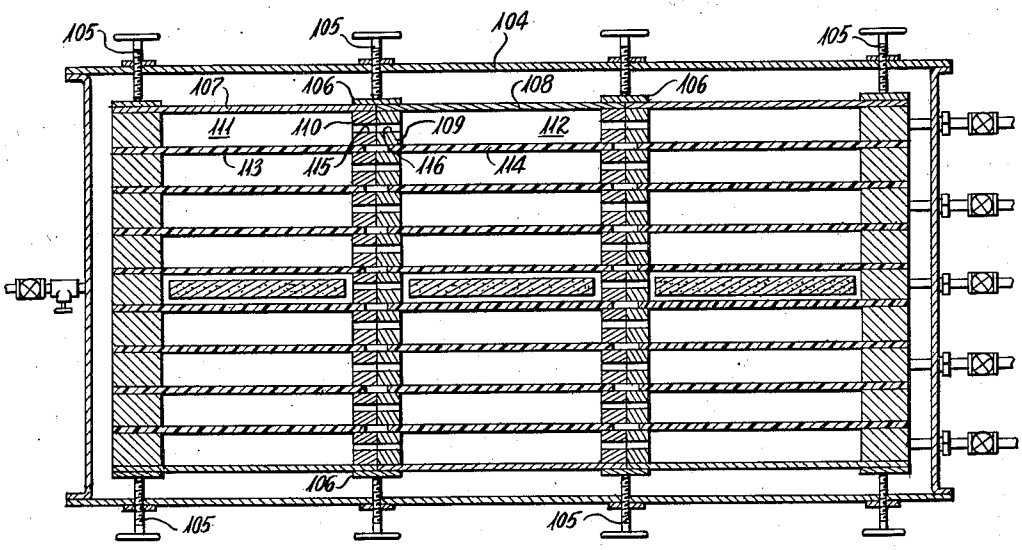


Fig. 13.

INVENTOR.
ROBERT E. BRIGGS
BY
Bacon & Thomas
ATTORNEYS

United States Patent Office 2,828,257 Patented Mar. 25, 1958

2,828,257

MULTI-COMPARTMENT ELECTROLYTIC CELL

Robert E. Briggs, Abuza, Calif.

Application February 17, 1954, Serial No. 410,985

12 Claims. (Cl. 204—263)

This invention relates to an electrolytic cell and to a method of electrolysis, and more particularly relates to multi-compartment electrolytic cells or multi-compartment cell assemblies wherein a plurality of electrolytic effects is achieved.

This application is a continuation-in-part of my application No. 285,613, filed May 2, 1952, for an Electrolytic Cell, now abandoned. That application was directed to an electrolytic cell having insoluble electrodes and having one or more buffer compartments separated by porous or permeable diaphragms between an anode compartment and a cathode compartment, or between a centrally disposed treating compartment and the anode and cathode compartments. Recent developments have made available ion exchange diaphragms which may be used to replace some or all of the diaphragms in a multi-compartment electrolytic cell of the type there described. These diaphragms, for the most part, are subject to dimensional expansion and contraction which, if not provided for in the type of mounting utilized, may readily destroy the usefulness of the diaphragm.

According to this invention there is provided a novel electrolytic cell structure which provides for the mounting of diaphragms which may or may not expand or contract under the influence of a liquid to be treated. A plurality of frames is provided for receiving the various diaphragms, and the frames are adjustably mounted so as to permit the diaphragms to be either loosely held or tightly clamped therebetween. The frames are further constructed so as to permit easy and convenient filling of the various compartments and are so arranged as to make possible any desired path of flow of the liquid to be treated, or of the anolyte or catholyte utilized in the cell.

Where three compartment electrolytic cells are utilized for such applications as water softening, a precipitation of hardness compounds occurs in the highly alkaline catholyte of the cathode compartment. This situation also obtains where ion exchange resin diaphragms are used and tends to foul the cathode compartment and necessitate frequent shut downs for cleaning operations.

According to this invention the acidic anolyte from the anode compartment, instead of being discharged to waste, is flowed through the cathode compartment where it dissolves the previously precipitated solids and neutralizes the alkali there present to prevent the precipitation of more salts. This results in a diminution in electrode compartment effluent waste and also maintains a clean cathode compartment which obviates the necessity for frequent shutdowns to eliminate precipitates and to clean the cathode.

It is therefore an object of the present invention to provide an electrolytic cell simple in design and assembly which allows expedient filling, draining and flushing.

It is a further object of the invention to provide an electrolytic cell wherein provision is made for mounting diaphragms which expand and contract under different operating conditions.

It is a still further object of the invention to provide a multi-compartment electrolytic cell wherein equal liquid pressures are maintained outside and inside of the various compartments in such a way that leaks or mixing of the segregated and concentrated or depleted electrolyte solutions in such compartments is minimized or becomes non-existent.

It is a further object of the invention to provide a process of electrolysis in a three or more compartmented electrolytic cell wherein provision is made to prevent fouling of the cathode compartment through the precipitation of salts.

It is a still further object of the invention to provide such a cell and process which is suitable for purification or demineralization of water or other liquids on a large scale.

It is a still further object of the invention to provide such a cell which is also useful in the concentration of various selected chemicals.

Further objects and advantages of the invention will become clear upon reference to the following drawings wherein:

Figure 1 is a horizontal sectional view of a cell constructed according to this invention;

Figure 2 is a side elevational view of the cell of Figure 1;

Figure 3 is an end elevation of the cell of Figure 1;

Figure 4 is a vertical cross-sectional view of a modified form of cell;

Figure 5 is a partial plan view of a corner of a cell which is a modification of the cell shown in Figure 1;

Figure 6 is a vertical sectional view showing a modified type of cathode assembly;

Figure 7 is a horizontal section of the frames and diaphragms in an expanded position;

Figure 8 is a vertical section of the diaphragms and frames of Figure 7 taken on line 8—8 of Figure 7;

Figure 9 is a side elevational view of a frame and diaphragms as shown in Figures 7 and 8;

Figure 10 is a vertical cross section of the frame and diaphragm shown in Figure 9 taken on the line 10—10;

Figure 11 is a vertical section of the frame and diaphragms shown in Figure 9 taken on the line 11—1-;

Figure 12 is a vertical sectional view of a frame suitable for mounting a large number of diaphragms; and

Figure 13 is a horizontal sectional view of a clamping arrangement for use with a plurality of diaphragms.

Referring more particularly to the drawings, there is shown in Figure 1 a cell indicated generally at 10 consisting of a tank 11 having side walls 12 and end walls 13. Mounted within the tank 11 is a plurality of skeletal frames 14 which have interleaved therebetween a plurality of diaphragms 15.

The frames 14 may be supported upon a support 16 having downturned flanges or feet 17 which are supported on the bottom 18 of the tank 11. At the outer faces of the outermost frames are located a pair of metal compression plates 19 which may be of iron or steel, or other suitable metal, and may serve both as outside compartment walls and as cathodes. Intermediate the innermost frames is located an anode support frame 20 which has horizontal slots 21 in the top thereof for the accommodation of a plurality of anodes 22. The anodes 22 may be formed of any suitable acid resistant material, a sheet or plate of compressed graphite or carbon being preferred. The anodes 22 may be maintained in position by means of a plurality of pegs 23 which pass therethrough and which support the anodes in the anode frame 20.

Pressure may be applied to the compression plates 19 by means of a plurality of compression screws 24 which screw threadedly engage standards 25 which may be se-

cured to the tank walls **12** by any suitable means, such as by welding. The compression screws **24** may be provided with suitable actuating handles such as the wheels **26**. By adjusting the compression screws **24**, it is possible to either rigidly clamp the diaphragms **15** in liquid tight and slip tight engagement with the compartment defining frames, or to allow such diaphragms to slip freely between the frames as they expand or contract.

Each of the frames **14** may consist of a single open rectangle as would be represented by one half of the frame shown in Figure 9. Figure 9 represents a type of frame which is suitable for supporting a pair of diaphragms which are to be used as a single wall for one compartment of a cell. The diaphragms may be adjustably supported thereon by means of a plurality of pegs **27** which matingly engage a plurality of apertures **28** in the adjacent frame, as is best seen in Figures 7 and 8 to be discussed more fully hereinafter.

Inlet and outlet connections may be as varied as the application to which the electrolytic cell is applied. In the embodiment of Figure 1, outlet connections for the various compartments are provided by means of a plurality of pipes **29** passing through packing glands **30** in the end wall **13** of the tank **11**. Such pipes are so aligned as to mate with apertures in the ends of the frames **14** when said frames are in their compressed position, the connection between the end of the pipe and the aperture being either by way of friction or by way of screw threads. Since the design of the cell is such that liquid pressure inside and outside of the various compartments is substantially equal, it is not necessary to provide fittings to resist large pressures, although this may be done if desired. An inlet connection **31** having a control valve **31*a*** is provided in the leftmost tank wall **13** and a drain line **32*a*** is connected thereto through a valve **32**. Inlets to the compartments defined by the various frames may be through orifices **42, 43, 44, 45** and **46** provided in the tops of frames **14**, and where desired capillary tubes may be placed in such orifices to provide an accurate control of electrolyte flow.

With the compression screws **24** released at the time the tank is filled, all compartments will become filled and the diaphragms, being loosely held, will be allowed to expand or contract in response to the effect of the electrolyte. Prior to operation, compression may be applied to the screws **24** bringing each frame into liquid and slip tight engagement with its associated diaphragm or compression plate so as to form flow channels in the spaces bounded on the sides by the diaphragms and on the top, bottom and ends by the frames.

The cell shown in Figures 1 through 4 may be used either for the purification of water flowing through compartments **117** and **118** or for the concentration of desired chemicals in compartments **119, 120, 121** and **122**. Demineralization will always occur in compartments **117** and **118** where non-selective barriers are used while with selective barriers the effect will be determined by the particular barrier arrangement. Where non-selective barriers or diaphragms are used and the purpose is demineralization, as in large scale water purification, the compartments **119, 120, 121** and **122** are preferably utilized as buffer compartments in the manner described in my aforementioned copending application 285,613. When thus utilized there is no waste removal from these compartments and this is the type of use depicted in Figures 1 through 4. Where ion concentration is the desired effect however, and where perm-selective barriers or diaphragms are used, these compartments may be utilized as the concentrating compartments and must be provided with outlets similar to the outlets provided in the other compartments. It will be appreciated that the number and location of outlets in cells such as are shown in Figures 1 through 4 will be dictated primarily by the particular effect to be achieved and such varying arrangements are within the purview of this invention.

Where the cell of Figures 1 through 4 is being utilized in a demineralizing capacity, as in the purification of water, compartments **119, 120, 121** and **122** may serve as buffer compartments having no inlets or outlets, and the main effluent of the demineralizing compartments may be equally divided between the discharge pipes **33** and **34**. These pipes may be provided with some suitable valving action, shown diagrammatically as valves **35** and **36**, which might be V-weirs in the atmospheric pressure embodiment of the invention shown in Figures 1, 2 and 3. Such weirs in pipes **33** and **34** would determine the liquid level in the tank. Anolyte and catholyte waste may be discharged through pipes **38, 38*a*** and **40** which are below the electrolyte level in the tank and in the respective compartments. Because of this difference in head these waste discharges may be controlled by the insertion of properly selected capillary tubes in the discharge pipes, tubes of an inside diameter of two to five millimeters usually being suitable. In addition to these capillary discharge orifices, there may also be provided, or there may be alternatively provided, waste discharge outlets **37, 39** and **41** which are at the same level as the demineralized liquid outlet **39**. Control of the waste discharged through pipes **37, 39** and **41** may be effected by control valves in the inlet orifices **42, 43, 44, 45, 46**. It is a feature of the invention that the design provides for substantially equal pressures in all compartments of the cell so that leaks or mixing of the segregated electrolyte solutions is minimized.

While the cell shown in Figures 1, 2 and 3 operates at atmospheric pressure, it is also possible to utilize cells operating at higher pressures, and the tank shown in Figure 4 is designed with this end in view. This cell is constructed in a manner similar to that shown in Figure 1 and like reference numerals are utilized for corresponding parts. The cell of Figure 4 differs from the cell of Figure 1 in that it is provided with a cover **47** which makes possible the application of pressure to the system. The inlet and outlet orifices may pass through pipes similar to those shown in Figures 1 and 3, but in this instance each outlet orifice must be supplied with some type of throttle valve. Inlet pressure may generally be of the order of 10 pounds per square inch for the particular design shown. The features of the invention may also be utilized in round tanks where high pressures are necessary or advisable.

The tank utilized in the cells made according to the invention may advantageously be made of steel but may also be made of plastic or other fabricated material which is liquid tight and capable of withstanding at least the normal hydrostatic pressure of the liquid filled tank. The frame members may be constructed of any suitable electrical insulating material, such as wood treated with a water resistant varnish or other water resisting coating or impregnating compound. Diaphragm material is unlimited and may include ion exchange or selective barriers or buffer zones. With some diaphragm materials gaskets such as gum rubber or neoprene may be required or, in the alternative, the edges of the diaphragms may be treated or coated with a non-hardening caulking compound. Diaphragms of a self supporting character such as wood veneer, porous ceramics or the like may rest upon the support member **16** and may be brought into alignment between spacer frames **14** and the compression plates **19**.

Diaphragms of a non-self-supporting character may be hung from the dowel pins **27** as shown in Figures 7 and 8. When utilizing such dowel pins the diaphragms may be provided with elongated holes **48** which will permit the desired expansion or contraction of the diaphragms while suspended from the dowel pins **27**. Certain diaphragms may require a combination of the two means of support.

The compression plates **19** may be of iron or steel and may serve both as the outer compartment walls and as the cathodes of the cell. An alternate method if install-

ing cathodes is shown in Figure 6 wherein there is supplied an additional frame 49 between the outermost diaphragm 50 and the compression plate 19. The frame 49 supports a foraminous cathode 51 which may be formed of any conducting material which is resistant to attack by alkalis. Iron is entirely satisfactory and a piece of iron hardware cloth has been illustrated, although perforated or continuous sheets of iron or other alkali resistant metal such as nickel or stainless steel or sheets of carbon or compressed graphite may be employed.

Whereas the cell of Figure 1 utilizes discharge connections which pass through packing glands directly into the compartment forming frames, there is shown in Figure 5 an alternative method for providing outlet connections which may be utilized where the tank is sufficiently large to provide space between the ends of the frame and diaphragm structure and the tank wall. Thus there is shown in Figure 5 a tank 52 having a side wall 53 and an end wall 54. A plurality of frames 55 supports a plurality of diaphragms 56 to form the various cell compartments. Compression screws 57 are provided as in the embodiment of Figures 1 through 4.

In this embodiment of the invention each of the compartment forming frames from which it is desired to remove an effluent is provided with a discharge pipe 58 which has attached thereto a section of flexible tubing 59. The tubes 59 may be made of any suitable material which is resistant to the particular liquid being carried, many types of plastic or rubber tubes being satisfactory. The tubes 59 are connected at their opposite ends to couplings 60 which pass through the tank wall 54 and emanate as pipes 61.

While the sectional view depicted by Figure 1 shows diaphragms which extend the full length of the frames, it will frequently be found necessary to utilize diaphragms of smaller dimensions, since many of the ion exchange diaphragms now available cannot be formed in large sizes. When the use of such small size diaphragms is necessary, a divided frame such as that shown at 62 in Figure 9 may be desirable. The frame 62 consists of a pair of horizontal frame members 63 and 64 and of a pair of vertical end frame members 65 and 66. Intermediate the vertical members 65 and 66 is a spacing member 67 which provides a bearing surface for the junction of two diaphragms 68 and 69. Flow apertures may be provided in the vertical portions of the frame member, that is to say, an inlet aperture may be provided at 70 in the vertical member 65 while connecting apertures 71, 72 and 73 may be provided in the spacing member 67, as is best seen in Figures 10 and 11.

While the cell shown in Figures 1 and 4 is shown as connected for one pass electrolyte flow, it is also possible to provide for sinuous or snake-path flow by providing the necessary connections within the tank. Thus, referring to Figures 7 and 8, there is seen a plurality of frames 74, 75 and 76 which support diaphragms 77, 78 and 79. The frames and diaphragms are shown in a separated position for the sake of clarity. The left edge of the frame 76, that is the vertical member corresponding to the member 65 in Figure 9, may be provided with an inlet pipe 80 which passes through an orifice of the type 70 shown in Figure 10. Likewise the frame 74 may be provided with a discharge pipe 81 which may pass through a similar orifice. At the outlet end of the frame 76 there may be provided a discharge fitting 82 which is inserted into an orifice in the upper portion of the vertical member 66, as is shown in Figure 8. The frame 74 may be further provided with an inlet fitting 83 in its lower edge as is shown in Figure 8. The fittings 82 and 83 may then be connected by a suitable piece of flexible tubing 84 of rubber or some suitable plastic material.

In Figure 12 there is shown a frame member which may be used where a large cell is desired but where diaphragms are not available in large dimensions. Thus, there is shown a frame member 85 which consists of vertical edge members 86 and 87 and of horizontal edge members 88 and 89. Within the edge members 86, 87, 88 and 89, there are provided horizontal spacing members 90 and 91 and vertical spacing members 92 and 93. Suitable orifices 94, 95, 96, 97, 98, 99, 100, 101, 102 and 103 may be provided in the members to obtain the desired flow. In the embodiment shown in Figure 12 a sinuous flow is obtained in the compartment formed by the frame 85. While the frame 85 has been shown as essentially square, it will be obvious that a vertically elongated frame may be obtained, as by cutting the frame 85 along the line A—A in Figure 12, or a horizontally elongated frame may be obtained by cutting the frame 85 along the line B—B of Figure 12. The vertically elongated cell structure may be utilized where it is desired to conserve floor space whereas the horizontally elongated cell results in very convenient diaphragm placement and general servicing and may be used where larger areas of floor space are available. It will be readily appreciated that with the type frame shown in Figure 12 any desired flow pattern may be secured by the proper placement of the flow orifices in the spacing members.

In Figure 13 there is shown a means for joining compartment frames and diaphragms where it is desirable to use a plurality of such frames in an extended horizontal flow cell, particularly where it is desired to treat water on a large scale. There is thus shown a tank wall 104 through which passes compression screws 105 to engage with spanner blocks 106. For example, a block 106 spans the edges of compression plates 107 and 108 which in turn engage the vertical end members 109 and 110 of frames 111 and 112. Diaphragms 113 and 114 may be held in position by the frames 111 and 112. Suitable mating orifices 115 and 116 may be provided in the vertical members 109 and 110 in order to provide for flow between the adjoining compartments.

Cells constructed according to the invention make it possible to utilize substantially equal liquid pressures in the different compartments and in the space between the compartments and the tank walls, and this results in a minimizing of leakage and contamination of the various liquids. The particular structure shown makes possible the provision of simple orifice flow passages within the frame members so that tubing or pipe connections are not required as conduits from one compartment to another. Compartment frame members may therefore be of very small thicknesses and the inlet and outlet channels may be provided through the compression plates 19, which may also serve as the cathodes.

In previous electrolytic treatment cells utilizing ion exchange diaphragms or barriers, the type of flow utilized has been of a parallel nature through a plurality of parallel compartments so as to obtain a maximum current efficiency. The flow of electrolyte in the electrode compartments has been of a similar nature and has either been discharged to waste where demineralization was the object of the process, or delivered to collecting tanks where chemical concentration was the object. Under either of the two foregoing processes, the high alkalinity in the cathode compartment results in the precipitation of hardness salts where the electrolytes possess any substantial concentration of hardness compounds. The precipitation of such salts in the cathode compartment tends to foul the electrode and makes necessary the frequent shutdown of the cell for clean out of the compartment. It is a feature of the present invention that where hardness compound precipitates are not desired as an aid to removing undesired compounds from the liquid to be treated, the discharge from the anode compartment of the cell is fed to the cathode compartment to there dissolve such precipitates and to prevent the formation of further precipitates. This results in a material saving

in electric power and results in a higher output from the cell due to the elimination of shutdown periods for the purpose of cleaning the cathode compartment. Where demineralization is the object, there is also a substantial saving in the amount of liquid discharged as waste.

Whereas various structures have been shown and various methods discussed in connection with the present invention, these have been by way of illustration only, the invention being limited solely by the terms and spirit of the appended claims.

I claim:

1. In an electrolytic cell assembly; a tank, a plurality of substantially vertical aperture defining frame members arranged in said tank in substantially parallel relationship, a plurality of substantially vertical ion permeable diaphragms interleaved between said frame members so as to overlie said apertures, the top portions of said frame members having supporting elements attached thereto and extending toward an adjacent frame member and said diaphragms having openings receiving said supporting elements and of greater cross-sectional area than said supporting elements so that said diaphragms may be freely suspended between said frame members and may expand and contract therebetween, releasable clamp means attached to said tank for urging said frame members into liquid tight engagement with said diaphragms to cause said diaphragms and frame members to define liquid tight compartments within said apertures and inlet and outlet means in at least one of said frame members for flow of liquid through the aperture defined by said frame member.

2. In an electrolytic cell assembly; a tank, a plurality of substantially vertical aperture defining frame members arranged in said tank in substantially parallel relationship, a plurality of substantially vertical ion permeable diaphragms interleaved between said frame members so as to overlie said apertures, the top portions of said frame members having supporting elements attached thereto and extending toward an adjacent frame member and said diaphragms having openings receiving said supporting elements and of greater cross-sectional area than said supporting elements so that said diaphragms may be freely suspended between said frame members and may expand and contract therebetween, a pair of compression plates substantially parallel to said diaphragms and overlying the apertures in the outermost of said frame members, releasable clamp means attached to said tank for urging said compression plates towards one another so as to compress said frame members into liquid tight engagement with said diaphragms to cause said diaphragms, frame members and compression plates to define separate liquid tight compartments within said apertures, and inlet and outlet means in at least one of said frame members for flow of liquid through the aperture defined by said frame member.

3. A cell assembly as set forth in claim 2 wherein said plurality of diaphragms comprise an even number and wherein the centermost pair of diaphragms enclose an anode, said compression plates serving as cathodes.

4. A cell assembly as set forth in claim 3 wherein at least two of said compartments on opposite sides of said anode are completely enclosed buffer compartments.

5. A cell assembly as set forth in claim 2 wherein said releasable clamp means comprises screws extending through and threadedly engaging said tank and having ends bearing against said compression plates.

6. A cell assembly as set forth in claim 2 wherein said inlet means is an orifice establishing direct communication between said tank and the aperture defined by said frame member, said outlet means includes an orifice and a conduit establishing communication from said aperture defined by said frame member to the exterior of said tank and wherein a capillary tube is positioned in at least one of said orifices to control the flow of fluid through said aperture.

7. A cell assembly as set forth in claim 2 wherein said supporting elements comprise a plurality of pegs extending from one frame member through elongated apertures in said diaphragms and into mating openings in an adjacent frame member.

8. An electrolytic cell assembly, comprising: a tank, a first series of frame members in said tank arranged in face-to-face relation to each other, each of said frame members having top and bottom and side members defining an aperture therebetween, said frame members having their side members positioned substantially vertically in said tank, a second series of frame members in said tank arranged in the same relation to each other and to said tank as said first series of frame members and having side members adjoining side members of said first series of frame members, a plurality of ion-permeable diaphragms interleaved between the faces of corresponding frame members of each series so as to overlie the apertures defined by these frame members, a plurality of compression plates each engaging an outermost frame member of each of said series, the edges of said compression plates for adjacent frame members being in adjoining relationship, means for spanning the adjoining edges of said compression plates, adjustable clamp means attached to said tank opposite said means for spanning said compression plates and engaging said means to thereby urge said compression plates toward said frames and clamp said frames into liquid-tight engagement with said diaphragms to cause said diaphragms and frame members to define liquid-tight compartments within said apertures, the adjoining side members of said series of frame members having mating orifices for liquid flow between compartments formed by said frame members, and means for controlled flow of liquid from said tank through at least one set of compartments defined by frames having adjoining side members.

9. A cell assembly as set forth in claim 2 wherein said frame members and diaphragms define an anode compartment and a cathode compartment each having inlet and outlet means and wherein the anode compartment outlet means is connected to the cathode compartment inlet means.

10. In an electrolytic cell assembly; a tank, a plurality of frame members in said tank, each said frame member having top, bottom, side and interior-dividing members defining at least two apertures therebetween, said frame members having their side members positioned substantially vertically in said tank and having their top and bottom members arranged in substantially parallel relationship in said tank, said top members having supporting elements attached thereto and extending toward an adjacent frame member, ion permeable diaphragms disposed between said frame members, said diaphragms having openings receiving said supporting elements and of greater cross-sectional area than said supporting elements so that said diaphragms may be freely suspended between said frame members and may expand and contract therebetween, a pair of compression plates engaging the outermost frame members, adjustable clamp means attached to said tank opposite said compression plates and engaging said plates for urging said plates toward each other to clamp said top and bottom and side members into liquid tight engagement with said diaphragms, said diaphragms and top and bottom and side members defining liquid tight compartments, and inlet and outlet means in at least one of said frame members for flow of liquid through the apertures defined by said frame member.

11. A cell assembly as set forth in claim 10 wherein said inlet and outlet means comprise orifices in said frame members and wherein flow openings are provided through said interior-dividing members.

12. A cell assembly as set forth in claim 10 wherein

each pair of frame members engages and supports therebetween at least a pair of diaphragms.

References Cited in the file of this patent

UNITED STATES PATENTS

1,107,258	Burdett	Aug. 18, 1914
1,297,157	Harris	Mar. 11, 1919
2,251,083	Theorell	July 29, 1941
2,689,826	Kollsman	Sept. 21, 1954

FOREIGN PATENTS

682,703	Great Britain	Nov. 12, 1952
585,596	Germany	Oct. 10, 1933

OTHER REFERENCES

Rohm & Haas: "Amberplex Iron Permeable Membranes" (1952), pp. 19 to 23.

Langelier: "Journal of the American Water Works Association," September 1952, pages 845 to 848.