May 9, 1933. R. M. HUNTER 1,907,818

METHOD OF ELECTROLYSIS AND MEANS THEREFOR

Filed Aug. 11, 1930 5 Sheets-Sheet 1

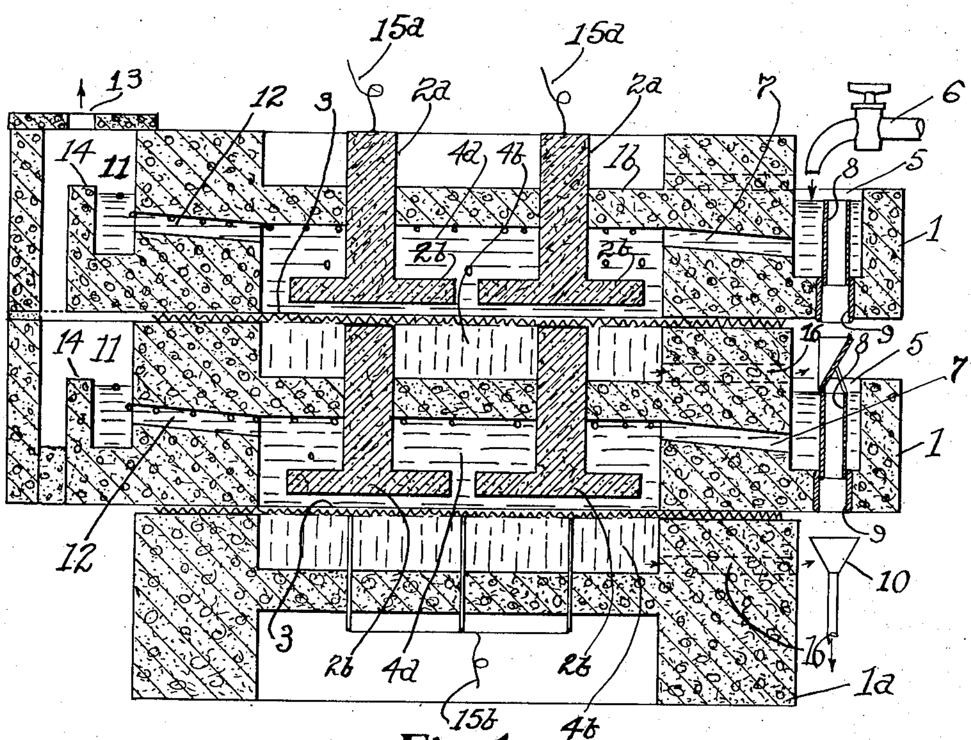

Fig. 1

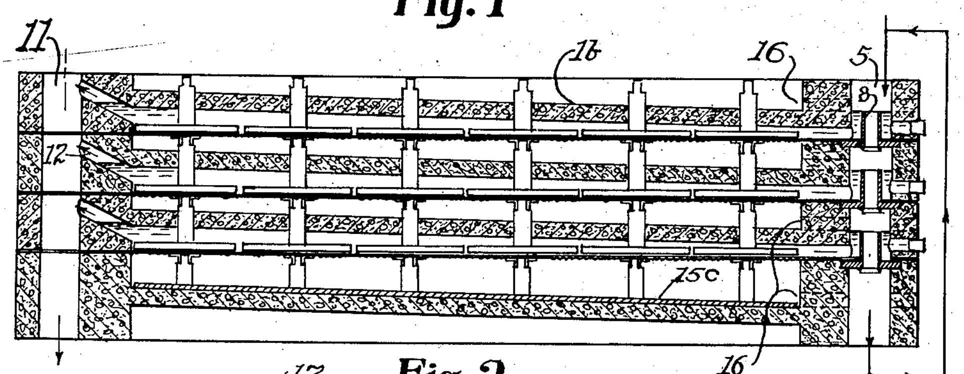

Fig. 2

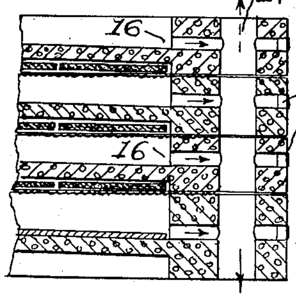

Fig. 3

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METHOD OF ELECTROLYSIS AND MEANS THEREFOR

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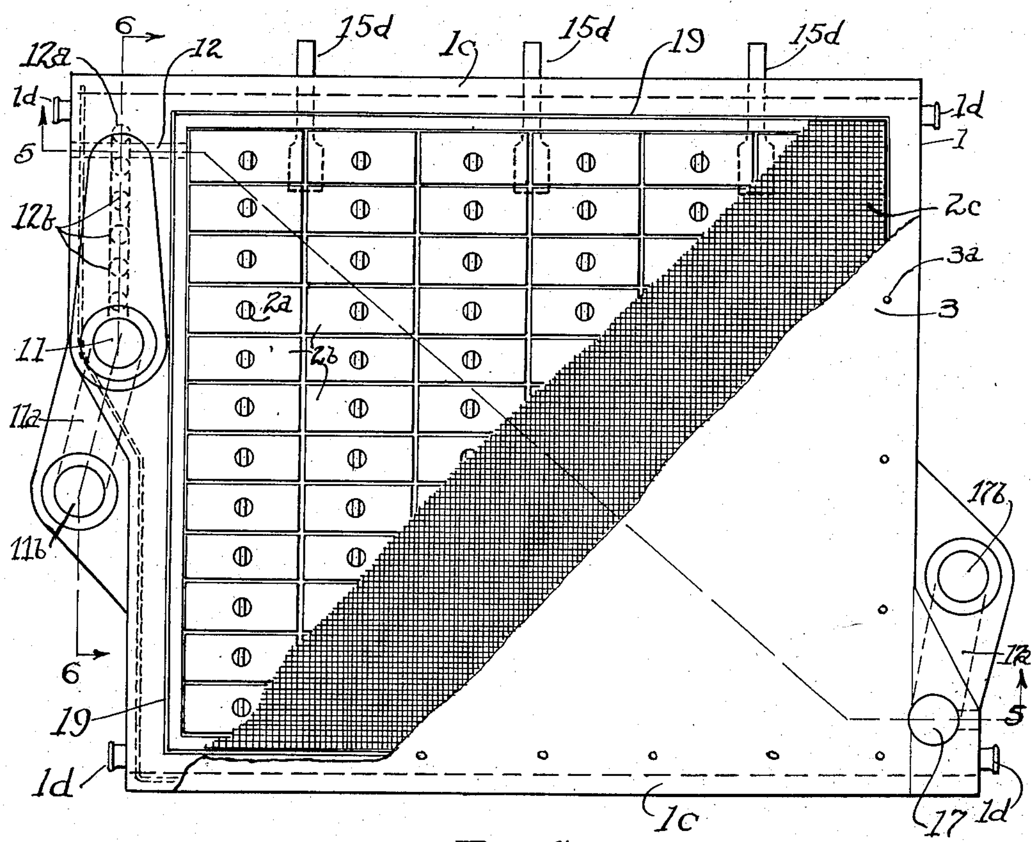

Fig.4

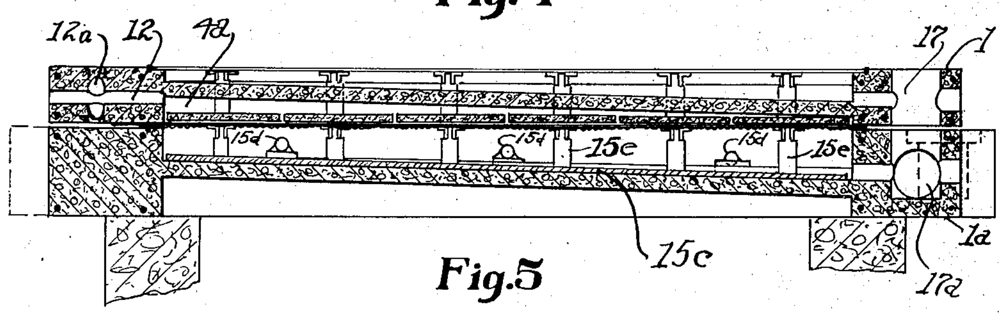

Fig.5

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METHOD OF ELECTROLYSIS AND MEANS THEREFOR

Filed Aug. 11, 1930 5 Sheets-Sheet 3

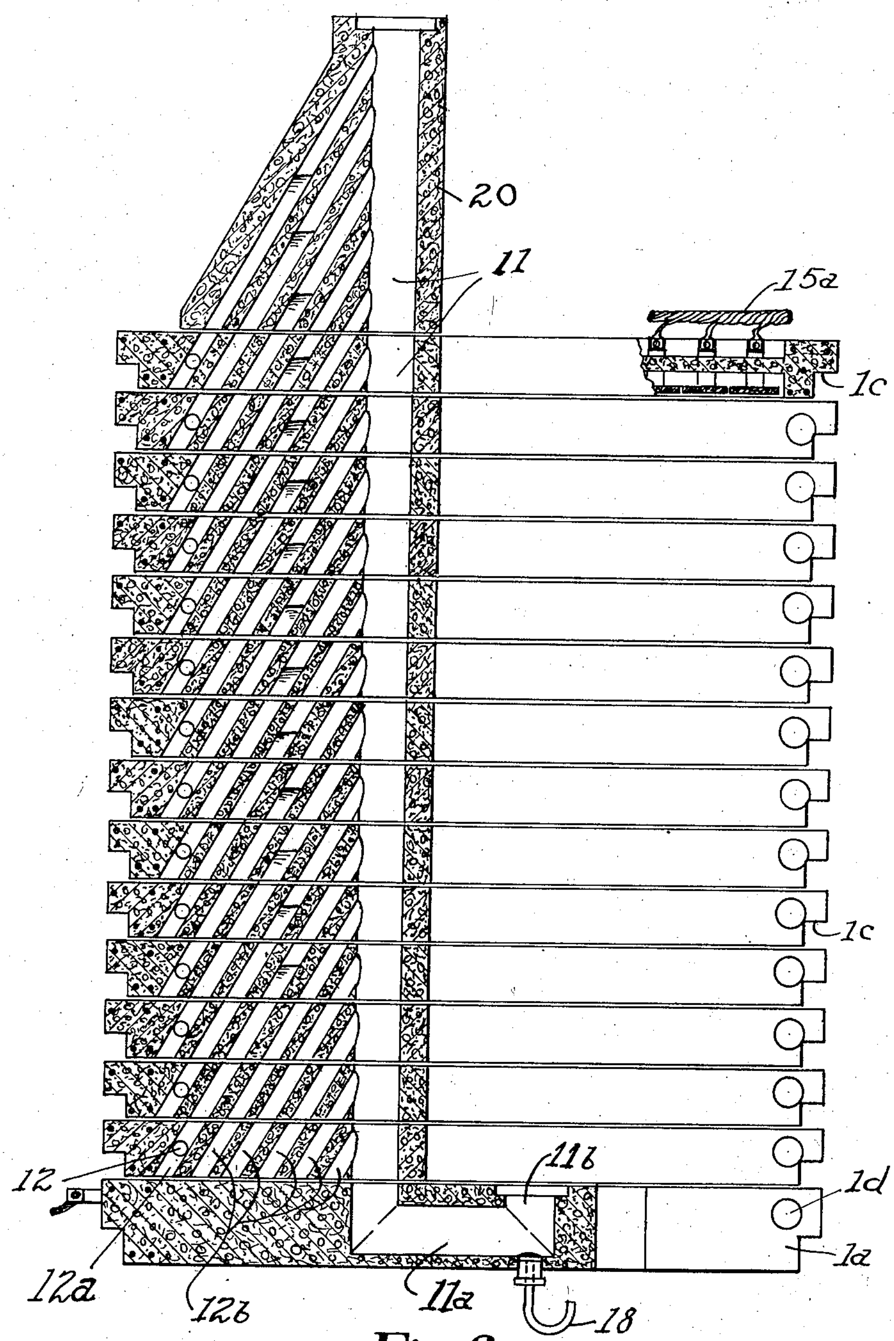

Fig.6

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METHOD OF ELECTROLYSIS AND MEANS THEREFOR

Filed Aug. 11, 1930 5 Sheets-Sheet 4

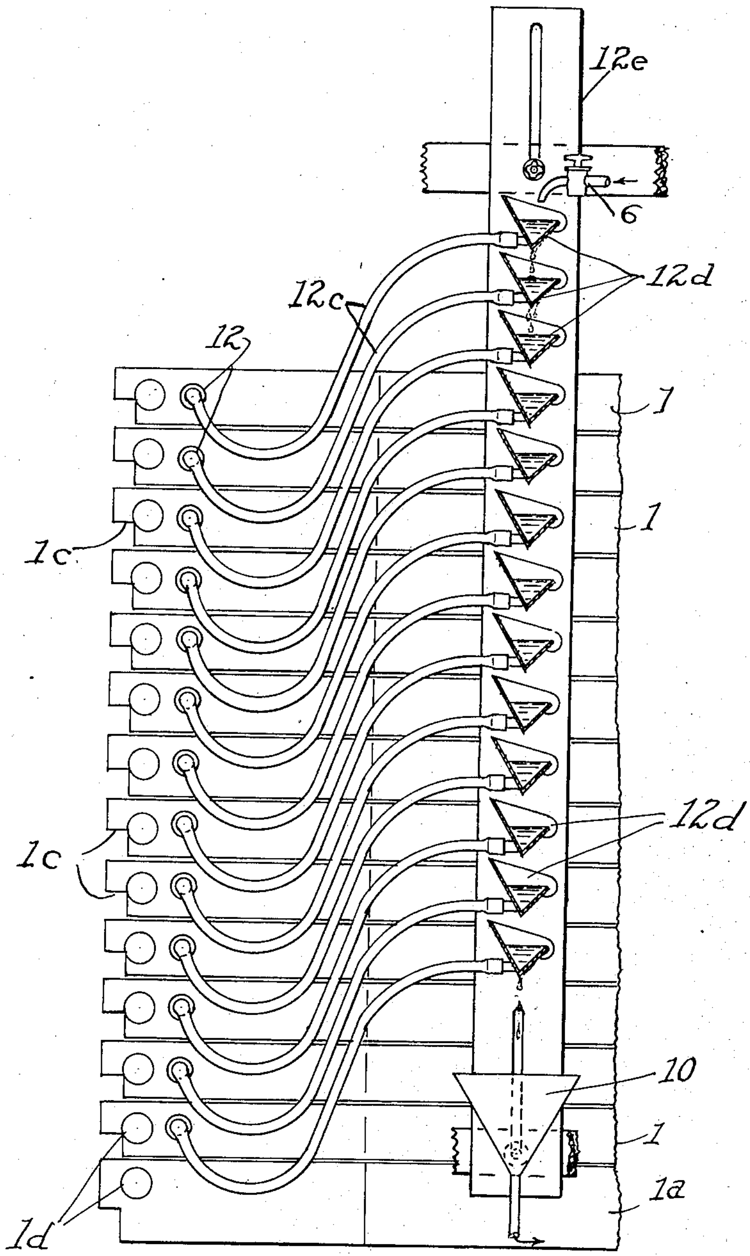

Fig. 7

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METHOD OF ELECTROLYSIS AND MEANS THEREFOR

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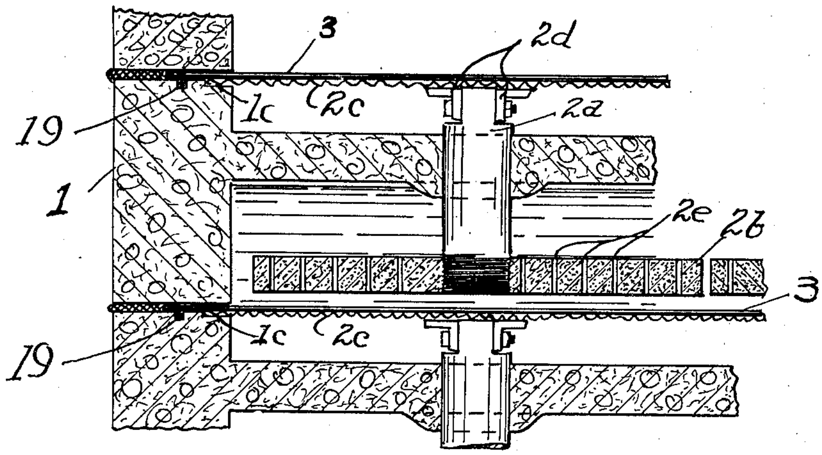

Fig.8

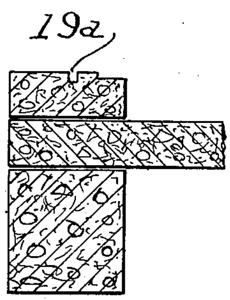

Fig.9

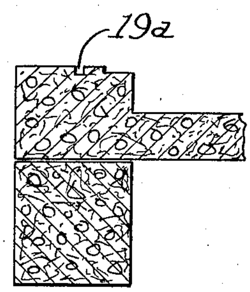

Fig. 10

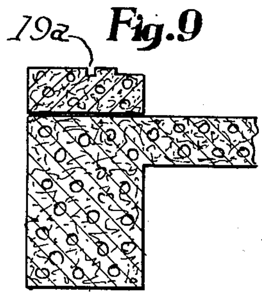

Fig.11

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Patented May 9, 1933 1,907,818

UNITED STATES PATENT OFFICE

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METHOD OF ELECTROLYSIS AND MEANS THEREFOR

Application filed August 11, 1930. Serial No. 474,392.

The present invention relating as indicated, to electrolysis in general, is more nearly concerned with electrolysis of aqueous solutions of the alkali metal halides, and is still more particularly concerned with the electrolysis of aqueous alkali metal chloride solutions such as sodium chloride for the production of chlorine, caustic soda, and hydrogen.

Among the desirable features which have been striven for by inventors in the electrolytic field with which this invention is concerned, there may be mentioned cheapness of construction, long life, high current efficiency, low operating voltage, low labor cost for operation and supervision, high output capacity per unit floor area, and minimum investment in associated equipment, such as electrical conductors, and pipe lines for gases and liquors.

Certain improvements in electrolytic cell construction are set forth in U. S. Patent 1,070,454 of August 19, 1913 to Thos. Griswold, Jr., and improvements thereon are further set forth in U. S. Patent 1,365,875 of January 18, 1921 to Louis E. Ward. One of the largest contemporary installations of cells for chlorine, caustic soda, and hydrogen in the United States has resulted from the exploitation of the above inventions. The vertical diaphragm filter press type bipolar electrode cell therein disclosed has proved to have advantages placing it in the first rank. The cheapness of construction, compactness of installation, high capacity per unit floor area, long life, low voltage, and other desirable qualities have been proved on a large scale. It has, however, the limitation of all vertical diaphragm cells that the hydrostatic head upon the diaphragm varies from a zero or low value at the upper limits of the diaphragm to a positive and considerable value at the lower limits thereof, and this is particularly true when, as has been found advisable, the caustic effluent is drained away as fast as formed leaving no balancing hydrostatic pressure upon the diaphragm as would be the case were the cathode liquor allowed to accumulate and fill the cathode compartment and merely overflow therefrom as formed. Such cells are fed with electrolyte by supplying same to the anode compartments only, under such head (which is preferably adjustable) that the rate of percolation through the diaphragm relative to the current used will reduce the strength of caustic in the effluent to the economical figure, usually in the neighborhood of 7 to 10 per cent. By such adjustment of rate of percolation to meet the exact conditions of use, either stationary or variable, the lowest cost of production may be secured.

The horizontal diaphragm, which is a characteristic of the Billiter cell (British 11,693 of 1910), is free from the limitations noted above with reference to the vertical diaphragm, and it is the object of my invention to combine with the demonstrated advantages of the filter press type of bipolar electrode cell the advantages of the horizontal diaphragm and at the same time secure other valuable advantages.

To the accomplishment of the foregoing and related ends, the invention, then, consists of the steps and means hereinafter fully described and particularly pointed out in the claims, the annexed drawings and the following description setting forth in detail certain means and modes of carrying out the invention, such disclosed means and modes illustrating, however, but several of various ways in which the principle of the invention may be used.

In said annexed drawings:—

Fig. 1 is a vertical transverse section through two superimposed horizontal diaphragm cells illustrating my invention broadly, and specifically one manner of control of the hydrostatic head. Fig. 2 is a vertical transverse section through three similar superimposed cells showing modified details of construction. Fig. 3 is a part vertical transverse section through a portion of the cells shown in Fig. 2. Figs. 4, 5, 6, and 7 show in considerable detail a form of cell and assembly of cells especially adapted to the electrolysis of an aqueous solution of sodium chloride for the production of chlorine, caustic soda, and hydrogen, suitable for use on a large scale, Fig. 4 being a plan thereof; Fig. 5 a vertical transverse section of a portion of a stack of such superimposed cells taken on the line 5—5 of Fig. 4; Fig. 6 a transverse vertical section showing further details thereof taken on the line 6—6 of Fig. 4, and Fig. 7 a part side elevation of a series of such cells illustrating a manner of feeding electrolyte thereto to maintain a desired hydrostatic head. Fig. 8 is a part transverse vertical section to a larger scale showing certain details of construction of diaphragm, electrodes, and associated parts. Figs. 9, 10, and 11 illustrate alternative details of cell frame construction. Referring now to the drawings in detail:—

Fig. 1 is a transverse vertical section through a stack of superimposed electrolytic cells illustrating my invention in a general way, adapted to electrolytic processes in which gases are liberated at the anode and/or cathode and in which a cathode effluent is also produced. For the sake of simplicity, elaborate details are omitted and but two superimposed horizontal diaphragm cells are shown. A series of superimposed non-conducting plate and frame members or plate-like electrode carrying members 1 are employed, which, when so superimposed one upon another with a suitable gasket or luting therebetween, form electrolyte chambers 4, here shown divided by diaphragms 3 into anolyte compartments 4*a* and catholyte compartments 4*b*. Such carrying members may take a variety of forms, certain of which are shown in the drawings and will be later described. A plate and frame member 1*a* forms a foundation for the stack. Bipolar electrodes 2 are carried in the plate portion 1*b* of the plate and frame members 1. Such plate and frame members lie in a substantially horizontal plane. The bipolar electrodes are here shown as composed of pin-like portions 2*a*, piercing the plates 1*b* of the plate and frame members and provided with or formed at their lower ends with plate-like active anode portions 2*b*. Integral with one edge of the members 1 is a series of superimposed electrolyte supply wells 5, to the uppermost of which electrolyte is supplied by the feed valve 6. Passages 7 communicate between wells 5 and the compartments 4*a*. An overflow nipple 8 in each well 5, adjustably threaded into a coupling 9, establishes the electrolyte level in the wells 5 by conducting excess feed from each well to the next well below, as will be readily understood by inspection of the drawing. By feeding electrolyte through the valve 6, in amount equal to or in excess of the cell requirements, the compartments 4*a* will be filled therewith initially in succession, and by continuing such feed will be maintained full to the levels established by the nipples 8. Excess feed may then be caught in a suitable sump, here indicated as a funnel 10, located below the coupling in the lower-most member 1. Upon the same or other edge of the members 1, a series of superimposed gas compartments 11 communicate with the compartments 4*a* via the ducts 12. Anode gas such as chlorine is conducted from compartments 4*a* into the gas chambers 11. These gas chambers communicate one with another as indicated and may be provided with a gas outlet 13 at the top of the stack, at the bottom thereof, or at any intermediate point as may be desired. A dam or retaining lip 14 in each said gas chamber 11 is provided of a height greater than the level of electrolyte in the wells 5. The gas compartments 11, superimposed and interconnecting, form a gas duct having a general vertical direction through the series of superimposed cells forming a common outlet for the gases evolved at the anodes in all of the so connected cells. For the removal of the cathode products the ducts 16, shown in dashed lines, are taken out through the frames of the plate and frame members and may deliver independently, or they may be interconnected to form a common duct for the cell effluent and gaseous cathode products. The ducts 16, in the position shown, drain the cathode compartments below the diaphragms 3, each which compartment will, therefore, contain only such amount of electrolyte as has percolated through the diaphragm above it and has not yet run out of the compartment.

Although the construction of the diaphragm is not an essential feature of my invention, I may employ one or more layers of asbestos diaphragm paper supported upon or by a horizontally disposed perforated sheet metal cathode-screen which may be of steel, or like horizontally disposed metal wire cloth cathode-screen. To avoid confusion, the detailed construction of the diaphragm and its support are indicated in Fig. 1 by the wavy line only. Such cathode-screen makes physical contact with the upper ends of electrode members 2*a*, contacting therewith electrically, whereby such perforated plate or screen becomes electrically a portion of the cathode end of the bipolar electrodes and constitutes the principal active cathode surface. The manner of providing a suitable contact between such plate or screen and the electrodes 2*a* will be described hereinafter. The electric current is supplied to the stack or series of cells by suitable current leads 15*a* connected with the upper set of electrodes, and 15*b* connected with the lower-most cathode screen.

The cell construction, as shown in Fig. 1, employs a diaphragm and a cathode-screen which are desirable or necessary features in certain electrolytic processes. It is, however, obvious that by suitable modifications, either or both diaphragm or cathode-screen may be omitted, in which case the outlet ducts 16 arranged in Fig. 1 to drain the cathode compartment would each be carried upwardly, e. g. into or through at least one superimposed member 1 to a height at least approximating the level of the brine or electrolyte in the wall 5 of such member.

It will be seen that by feeding to the cells through the valve 6 a continuous supply of electrolyte while passing a current through the series of cells, electrolysis will proceed, by the transmission of the electric current through the superimposed layers of electrolyte chiefly between the principal active anode surfaces 2*b* and the principal active cathode surfaces constituted by the electrode pins 2*a* and/or the cathode-screen, if employed, such current being led from cell to cell through the pins 2*a*. The gases evolved at the anode, e. g. chlorine, rise through the electrolyte in the anode chambers 4*a* and deliver through the ducts 12 to the common gas chamber 11. The hydrogen, or other cathode gas product evolved upon the cathode-screen and/or upon the upper ends of electrodes 2, fills the cathode chambers 4*b* and is drawn off through the ducts 16 along with the catholyte, e. g. causticized electrolyte, dripping from the diaphragm and screen onto the floor of the cathode chambers 4*b* constituted by the plate member 1*b* of the members 1. Electrolyte may be supplied in excess of the requirements of the series of the cells, the excess overflowing into funnel 10 being then returned in any desirable manner to the feed, or an automatic regulating device may be installed, e. g. at the lower cell in each series to control the cell feed. If no diaphragm be employed, cathode and anode gaseous products will mingle.

Fig. 1 illustrates broadly, as hereinbefore stated, the essential features of my invention. The plate and frame members forming the cells may be multiplied in number and stacked up or superimposed one upon another to any height practicable. For the electrolysis of a salt solution for the production of chlorine, caustic soda, and hydrogen, such cells may be made of large size, that is having a diaphragm area of 50 sq. ft. or more, each cell of suitable thickness, which may be as thin as 7 inches even in large sizes. On the basis of ½ ampere per sq. in. of diaphragm area, current capacities as high as 3,000 amperes and up are readily attainable, and a series of 16 or more cells may be superimposed in one stack employing but two electrical connections with the source of current.

In such an assembly of cells I find that by constructing the plate and frame members of Portland cement concrete, employing graphitized carbon electrode pins 2*a* attached to graphitized carbon electrode anode plates 2*b*, as illustrated in Fig. 8 and hereinafter described, employing further a ⅜ inch mesh, ⅛ inch diameter steel wire cathode-screen, and an asbestos paper diaphragm, the life of diaphragms and cells, the strength of caustic soda effluent, the current efficiency and watt efficiency are equal in all respects to the high values heretofore obtained with the vertical diaphragm filter press cell, but that further by employing, as is possible in the horizontal type, a larger diaphragm area per cell, the output of caustic soda per sq. ft. of floor area may be raised from a value in the neighborhood of 5 to 7 pounds, to 20 or more pounds, a notable and valuable improvement. I find in addition that by employing such horizontal type cell, the hydrostatic head of the anolyte upon the diaphragm is uniform over the entire area thereof, and by employing further the adjustable overflow nipple 5 or an equivalent, a certain head may be maintained, or the head may be varied to control in like manner the amount of percolation through the diaphragm and thereby the strength of the caustic effluent and overall efficiency of the cell plant and associated equipment. I find still further that the use of my improved cell reduces the length, complexity, and cost of chlorine mains and branches, simplifies feeding of brine to the cells, and permits the easy collection of hydrogen if desired.

In the operation of such a cell I find that in addition to employing the overflow nipple 5 or its equivalent to control the hydrostatic pressure or head of the electrolyte, I may, by suitable connections to the ducts 16, throttle the venting of the hydrogen or otherwise put a back pressure upon the diaphragms, or I may put same under such degree of suction as is found advisable to increase the effective head and percolation.

The remaining figures of the drawings, 2 to 11, inclusive, show in greater detail structural features omitted from the more or less general or diagrammatic representation in Fig. 1, similar reference characters being employed in the description thereof to follow.

Fig. 2 represents a series of three superimposed horizontal diaphragm cells in accordance with my invention, in which the plate and frame members, although of the same general character as in Fig. 1, have the plate members 1*b* slightly tilted in the frame to aid in forwarding the chlorine to the ducts 12 and thence to the common chlorine chamber 11. Such inclination also assists in draining the caustic effluent to the outlet ducts 16 into a common hydrogen and caustic effluent duct 17, shown in Fig. 3, which latter figure represents a part vertical transverse section through that part of the assembly in Fig. 2 in which the ducts 16 are located, and which may be adjacent to the brine feed wells 5. These brine feed wells 5 in Fig. 2 are provided with overflow nipples 8 in somewhat the same manner as indicated in Fig. 1, such nipples being here shown flanged and socketed in a recess in the frames of the cells, the action, however, is the same in principle as shown in Fig. 1. As indicated in Fig. 2, the head is not adjustable, but may be made so by threading the nipples 8 into the flanges supporting them.

Figs. 4, 5, 6, and 7 show in plan vertical section, part vertical section, and part elevation, respectively, and in greater detail a preferred form of construction of my horizontal type cell in which a considerable number of cells are shown superimposed into a single series or assembly. Referring to the Figs. 4 to 7, inclusive, the plate and frame members 1 are superimposed upon the plate and frame base member 1*a*. Such members are provided with passages 11 of cylindrical shape, matching together in the assembly to form a vertical cylindrical anode gas assembly chamber and conduit. They are also provided with a like passage 17 forming a similar vertical caustic effluent and hydrogen collecting chamber or duct rising vertically through the assembly. The base member 1*a* is provided with matching ducts 11*a* and 17*a*, respectively, terminating in outlets 11*b* and 17*b*, such ducts in the base member 1*a* being fitted with trapped outlets 18 to drain away from the chlorine duct any brine entering same and to drain from the hydrogen duct the caustic cell effluent. Suitable conduit connections will be made with the outlets 11*b* and 17*b* to carry off the chlorine gas and hydrogen gas, respectively. Fig. 7 is a part side elevation of the left hand vertical face of the assembly in Fig. 4.

Referring to Figs. 5 and 6 it will be seen that the chlorine is delivered from each anode compartment 4*a* via the ducts 12 into a diagonal cross duct 12*a*, detailed in Fig. 6. A series of similar spaced diagonal cross ducts 12*b* are formed in each frame, the last one thereof to the right delivering into the gas conduit 11. The slope and spacing of the diagonal ducts 12*a* and 12*b* is such that when the individual cells are assembled by superimposition one upon another these ducts match to form diagonally sloping passages communicating between chlorine delivery ducts 12 and the chlorine assembly conduit 11, plainly shown in Fig. 6. No such ducts are provided in the base member 1, which seals off the unused portions thereof in the first few cell members above the base member, and in order to continue the same system of gas delivery and assembly, I superimpose upon the cell assembly a member 20 pierced by diagonal passages corresponding to those emerging from the top of the uppermost cell member 1 in which member 20 the duct 11 is continued. In this manner all of the anode compartments communicate with the duct 11 via the diagonal passages and the ducts 12 for the purpose of leading all of the chlorine gas formed into the single assembly duct 11. The outer ends of the ducts 12 may be plugged with a stopper or otherwise sealed off, it being preferable that such ducts extend to the outside of the frames as indicated for purposes of construction and access in operation.

In erecting an assembly of such cells they are readily made water and gas tight by the use of a plastic lute or equivalent, applied to the bearing surfaces, the weight of the cell members being sufficient to compress the luting and provide a seal. The construction shown enables the cleaning out from the ducts during the assembly of any luting which has been squeezed into them as the cells settle to their bearings.

In Fig. 4, which is a plan view, the diaphragm, indicated by 3, may be composed of asbestos paper and is here shown attached to the cell frame at intervals by tacks 3*a*, which tacks are driven through the paper into a wooden strip 19 embedded in the cell. Such wooden strip 19 is more clearly shown in Fig. 8 and the recess therefor at 19*a* in Figs. 9, 10, and 11. The cathode screen is shown in part plan at 2*c* in Fig. 4 and in part section at 2*c* in Fig. 8. Such screen is preferably cut to fit and fill a rebate 1*c* in the frame members whereby its upper surface is brought substantially flush with the upper surface of the frame member, permitting the flat application of the diaphragm 3, more clearly shown in Fig. 8. The electrodes and layout therefor are also shown in Fig. 4, the pins or portions piercing the plates of the frames at 2*a* and the anode faces at 2*b*.

In Figs. 5 and 2 a terminal current carrying member 15*c*, having terminal lugs 15*d*, is shown instead of the more or less diagrammatic detail shown at 15*b* in Fig. 1. The lugs 15*d* are also indicated in Fig. 4 and serve for connection to the electric current mains. The upper terminal may be made in any manner desired, as for instance, that shown in Fig. 6 where the electric cable conductor 15*a* is connected by branches and lugs with the electrode pins. The plate member 15*c* above described may be a steel plate carrying a series of nipples or other supports 15*e* to lead the electric current from the plate to the cathode-screen and to support the latter in manner equivalent to that in each of the superimposed cells.

Fig. 8 is a partial cross section to enlarged scale in which some details of construction are more clearly shown. The bipolar electrodes are here shown comprised of the graphitized carbon pin 2*a*, the graphitized carbon plate 2*b*, and the cathode-screen 2*c*. The pin 2*a* is here shown screwed into the anode plate 2*b* and is flattened on the cathode end to permit bolting thereto two short steel angles 2*d* to which I find it advisable to spot-weld the cathode-screen 2*c*, such detail follows the disclosure in the cited Patent 1,356,875. In order to facilitate the removal of the liberated anode gas from the face of the anode, I may perforate the plate 2*b* with a plurality of holes 2*e* which may be drilled therein. The gas escapes through these holes causing a circulation of the anolyte and diminishing the polarizing effect of the gas upon the lower horizontal face of the anode.

Figs. 9, 10, and 11 show alternative methods of constructing the plate and frame members. These figures are largely self-explanatory and follow along the lines of disclosure in the above cited Patent 1,070,454. Such constructions as shown in Figs. 9, 10, and 11 may be used, although I prefer the one piece type of construction illustrated in Figs. 1 to 8, inclusive. I have in practice found arrangements for brine feed and control of hydrostatic head shown in Fig. 1 to be practicable, but in cases where a greater hydrostatic head is desirable the modifications shown in Figs. 4, 5, 6, and 7 may be employed by the use of which, as great a controllable head as may be desired is attainable.

Referring now to Fig. 7 illustrating such modified method of introducing the electrolyte, there is there shown in part side elevation an assembly of cells resting upon a base member 1*a*. Flexible hose connections 12*c* connect with the ducts 12 and with overflow cups 12*d* attached one above another upon a sliding support 12*e*, such sliding support may be raised or lowered to set, change, or control the level of the electrolyte and the head thereof upon the diaphragms. The level of the electrolyte is shown in the ducts 12*b* in Fig. 6 at substantially the same level as in the cups 12*d*. Electrolyte will be fed through the valve 6 to the uppermost cup and overflow from cup to cup to fill and supply feed to the assembly of cells, the excess overflowing the lower-most cup into the funnel 10, which excess may then be returned to the supply tank connected with valve 6.

For the purpose of handling the cell members during construction, installation, and repair, various means and arrangements may be employed. I show in Figs. 4, 6, and 7 a ledge or projection 1*c* along opposite edges of each member, under which a lifting hook of suitable type may be employed to engage the ledges for the purpose of lifting and handling the members either one at a time or a number at a time. I also show lugs 1*d* which may also be employed to engage with a suitable hoist hook for handling, but more preferably for turning the members over during preparation or repairs.

Although I have illustrated broadly in Fig. 1 and more specifically in Figs. 4 to 8, inclusive, the type of bipolar electrode construction disclosed in U. S. Patent 1,356,875, I would point out that other types and forms of construction may be used, some of which are illustrated in U. S. Patent 987,717 to Thos. Griswold, Jr., U. S. Patent 1,053,266 to E. O. Barstow, as well as U. S. Patent 1,070,454 hereinbefore cited. In other words, the bipolar electrode may comprise a conducting plate member of the cell as in 987,717, and may be provided with pins as in 1,053,266, or the plate member may be of non-conducting material and employ simple pin-like bipolar electrodes as in 1,070,454, or again such bipolar electrodes may be of composite type as illustrated herein most clearly in Fig. 8, following U. S. Patent 1,356,875.

The practice heretofore, employing horizontal diaphragm cells, has required a separate floor area for each cell. Employing, however, my improved cell, such floor area will suffice for as many cells as may be practically superimposed and operated without in any way decreasing the advantages incident to the use of the horizontal diaphragm. In the development of the vertical filter-press type of cell along the lines of the cited patents, it has been found advisable to restrict the vertical height of the diaphragm under the conditions of uneven head thereon. Such limitation no longer applies in the use of my improvement and it becomes practicable to greatly increase the diaphragm width, whereby a larger total area of diaphragm per cell may be employed thereby correspondingly increasing the current capacity per cell. By superimposing one such cell upon another, such increased cell capacity is multiplied relative to the unit floor area, still more markedly increasing the product output per unit of floor area. By so increasing the output capacity per unit floor area, the lengths and cost of chlorine, caustic, and hydrogen lines and their branches is correspondingly reduced, supervision and attendance is concentrated and cheapened. It is further obvious that the structural cost of each cell unit is not increased proportionally to the increased capacity attained by increased breadth, so that an installation may be laid down at a markedly less investment cost for the cells themselves than heretofore possible, and a lower cost of production attained.

Other modes of applying the principle of my invention may be employed instead of the one explained, change being made as regards the means and the steps herein disclosed, provided those stated by any of the following claims or their equivalent be employed.

I therefore particularly point out and distinctly claim as my invention:—

1. In a method of electrolyzing an alkali metal halide, the step which consists in passing the electric current in a general vertical direction through a plurality of superimposed substantially horizontally disposed layers of the electrolyte between bipolar electrodes.

2. In a method of electrolyzing an alkali metal halide for the production of halide, hy-

drogen, and caustic alkali solution, the steps which consist in feeding an aqueous solution of said alkali metal halide to a plurality of superimposed substantially horizontally disposed layers thereof serving as electrolyte and passing an electric current in a general vertical direction through said layers, between and through bipolar electrodes.

3. In a method of electrolysis of an aqueous sodium chloride solution, the steps which consist in feeding an aqueous solution of such chloride to a plurality of superimposed substantially horizontal layers thereof separated by bodies of non-conducting material and passing an electric current in series through such layers in a generally vertical direction between bipolar electrodes.

4. In a method of electrolysis of an aqueous sodium chloride solution, the steps which consist in feeding such solution, as electrolyte, to a plurality of superimposed layers thereof in chambers separated by substantially horizontally disposed diaphragms into anolyte and catholyte portions and passing an electric current in a generally vertical direction through said layers between bipolar electrodes.

5. In a method of electrolysis of an aqueous sodium chloride solution, the step which consists in passing an electric current in a generally vertical direction through a plurality of superimposed substantially horizontally disposed layers thereof between bipolar electrodes while supplying such solution to said layers and drawing off products of electrolysis therefrom.

6. In a method of electrolysis of an aqueous solution of sodium chloride, the step which consists in passing an electric current in a generally vertical direction through a plurality of superimposed substantially horizontally disposed layers of such solution between bipolar electrodes, each said layer divided into anolyte and catholyte portions by a diaphragm, while supplying fresh solution to the anolyte portions of said layers and drawing off separately products of electrolysis from said anolyte and catholyte portions.

7. An electrolytic cell comprising a chamber for electrolyte, a substantially horizontally disposed metallic screen dividing said chamber into two compartments, bipolar electrodes extending into each said compartment, one such electrode electrically connecting with said screen by physical contact therewith and a porous diaphragm supported by said screen.

8. An electrolytic cell comprising two substantially horizontally disposed plate-like electrode-carrying members, a chamber for electrolyte therebetween, at least one electrode passing through each said carrying member, a substantially horizontally disposed diaphragm dividing said chamber into two compartments, means to supply electrolyte to at least one of said compartments and means to separately withdraw anodic and cathodic products of electrolysis.

9. An electrolytic cell comprising two substantially horizontally disposed plate-like electrode-carrying members, a substantially horizontally disposed metallic screen dividing said chamber into two compartments, at least one electrode passing through each said carrying member, one of said electrodes electrically connecting with said screen by physical contact therewith, a porous diaphragm supported by said screen, means to supply electrolyte to the compartment above said diaphragm and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

10. An electrolytic cell comprising two substantially horizontally disposed plate-like electrode-carrying members, a chamber for electrolyte therebetween, a plurality of bipolar electrodes passing through each said carrying member, a substantially horizontally disposed porous diaphragm dividing said chamber into two compartments, means to supply electrolyte to the compartment above said diaphragm and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

11. An electrolytic cell comprising two substantially horizontally disposed plate-like electrode-carrying members, a chamber for electrolyte therebetween, a plurality of bipolar electrodes passing through each said carrying member, a substantially horizontally disposed metallic screen dividing said chamber into two compartments, one set of electrodes electrically connecting with said screen by physical contact therewith, a porous diaphragm supported by said screen, means to supply electrolyte to the compartment above said diaphragm and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

12. A series of electrolytic cells comprising a plurality of substantially horizontally disposed plate-like electrode-carrying members superimposed one upon another, chambers for electrolyte between said carrying members, bipolar electrodes passing through said carrying members and projecting into the adjacent chambers, substantially horizontally disposed porous diaphragms dividing each said chamber into two compartments each, means to supply electrolyte to at least one compartment of each said chamber and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

13. A series of electrolytic cells comprising a plurality of substantially horizontally disposed plate-like non-conducting electrode-carrying members, a plurality of chambers for electrolyte between said carrying mem-

bers, a substantially horizontally disposed metallic screen in each said chamber dividing each said chamber into two compartments and physically contacting electrically with at least one electrode therein, a porous diaphragm supported by each said screen, means to supply electrolyte to at least one compartment of each said chamber and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

14. An electrolytic cell assembly comprising three or more substantially horizontally disposed plate-like non-conducting electrode-carrying members superimposed one upon another, a plurality of chambers for electrolyte between said carrying members, a substantially horizontally disposed diaphragm in each said chamber dividing the chamber into two compartments, bipolar electrodes passing through said electrode-carrying members and projecting into adjacent compartments, means to supply electrolyte to the upper compartment of each said chamber and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

15. An electrolytic cell assembly comprising three or more substantially horizontally disposed plate-like non-conducting electrode-carrying members, chambers for electrolyte between said carrying members, bipolar electrodes passing through said carrying members and projecting into adjacent chambers, a substantially horizontally disposed metallic screen in each said chamber dividing the chamber into two compartments, said screen physically contacting electrically with one set of electrodes in said chamber, a porous diaphragm supported by said screen, means to supply electrolyte to the compartments above said diaphragms and means to separately withdraw anodic and cathodic products of electrolysis from said compartments.

16. In a method of electrolyzing an aqueous solution of sodium chloride, the step which consists in passing the electric current in a general vertical direction through a plurality of superimposed substantially horizontally disposed layers of the electrolyte between bipolar electrodes.

Signed by me this 7th day of August, 1930.

RALPH M. HUNTER.