Feb. 27, 1951

W. T. RAWLES
APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

2,543,059

Filed July 19, 1948

6 Sheets-Sheet 1

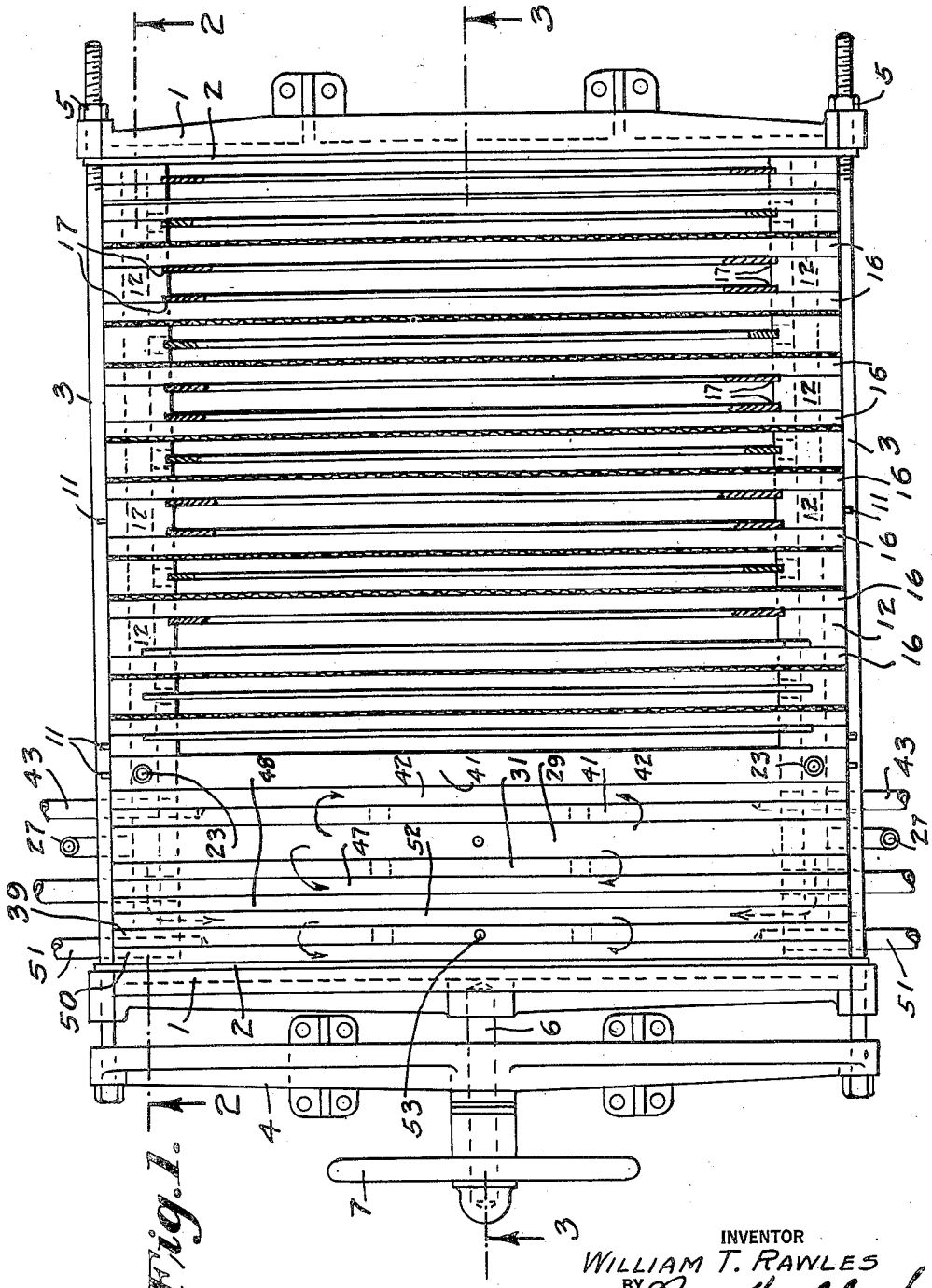


Fig. 1.

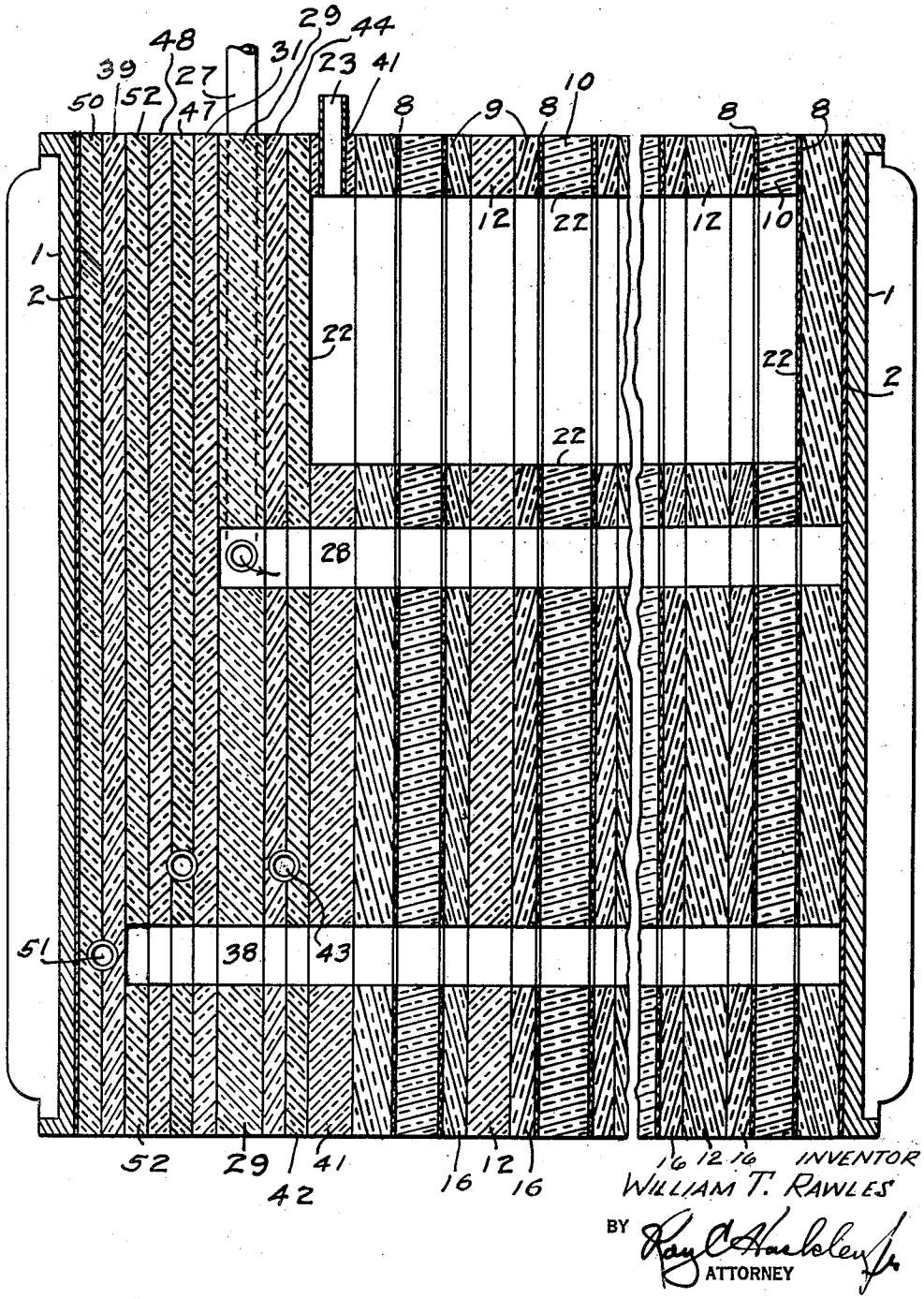
INVENTOR
WILLIAM T. RAWLES
BY Roy C. Hackley Jr.
ATTORNEY

Feb. 27, 1951 W. T. RAWLES 2,543,059

APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

Filed July 19, 1948 6 Sheets-Sheet 2

Fig. 2



INVENTOR
WILLIAM T. RAWLES

BY Ray C. Hawkins Jr.
ATTORNEY

Feb. 27, 1951

W. T. RAWLES
APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

2,543,059

Filed July 19, 1948

6 Sheets-Sheet 3

Fig. 3a.

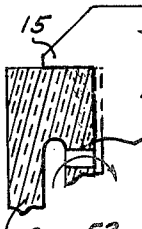


Fig. 3.

INVENTOR
WILLIAM T. RAWLES

BY Roy C. Hackley Jr.
ATTORNEY

Feb. 27, 1951 W. T. RAWLES 2,543,059

APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

Filed July 19, 1948 6 Sheets-Sheet 4

Fig. 7.

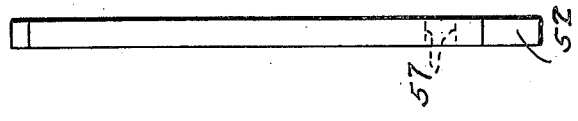


Fig. 6.

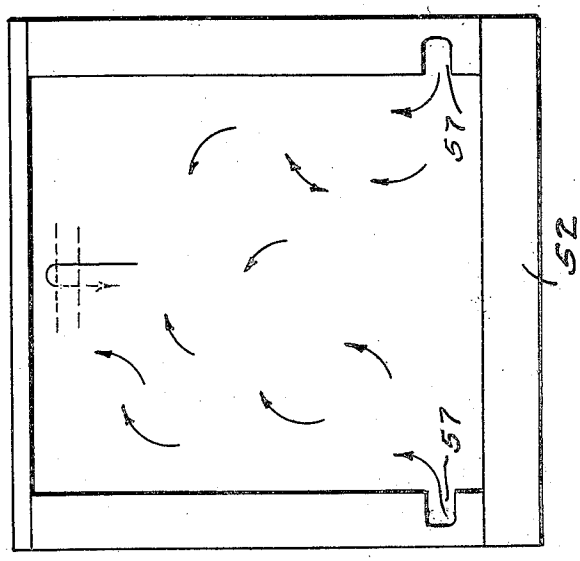


Fig. 5.

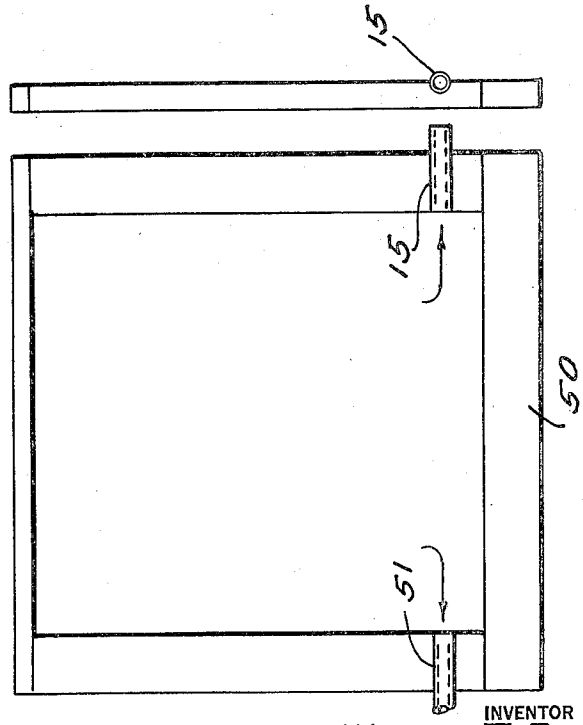


Fig. 4.

INVENTOR
WILLIAM T. RAWLES
BY Roy C. Hackley Jr.
ATTORNEY

Feb. 27, 1951 W. T. RAWLES 2,543,059

APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

Filed July 19, 1948 6 Sheets-Sheet 5

Fig. 11.

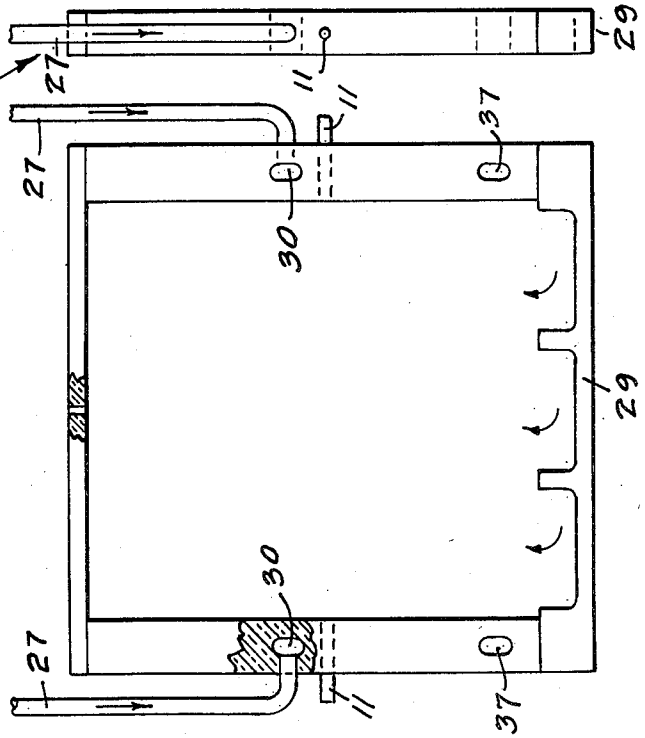


Fig. 10.

Fig. 9.

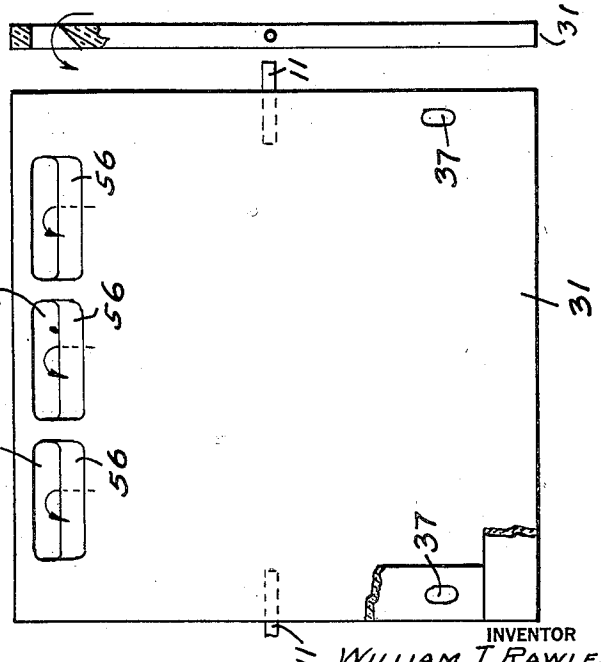


Fig. 8.

INVENTOR
WILLIAM T. RAWLES
BY Ray C. Hawkley Jr.
ATTORNEY

Feb. 27, 1951 W. T. RAWLES 2,543,059

APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

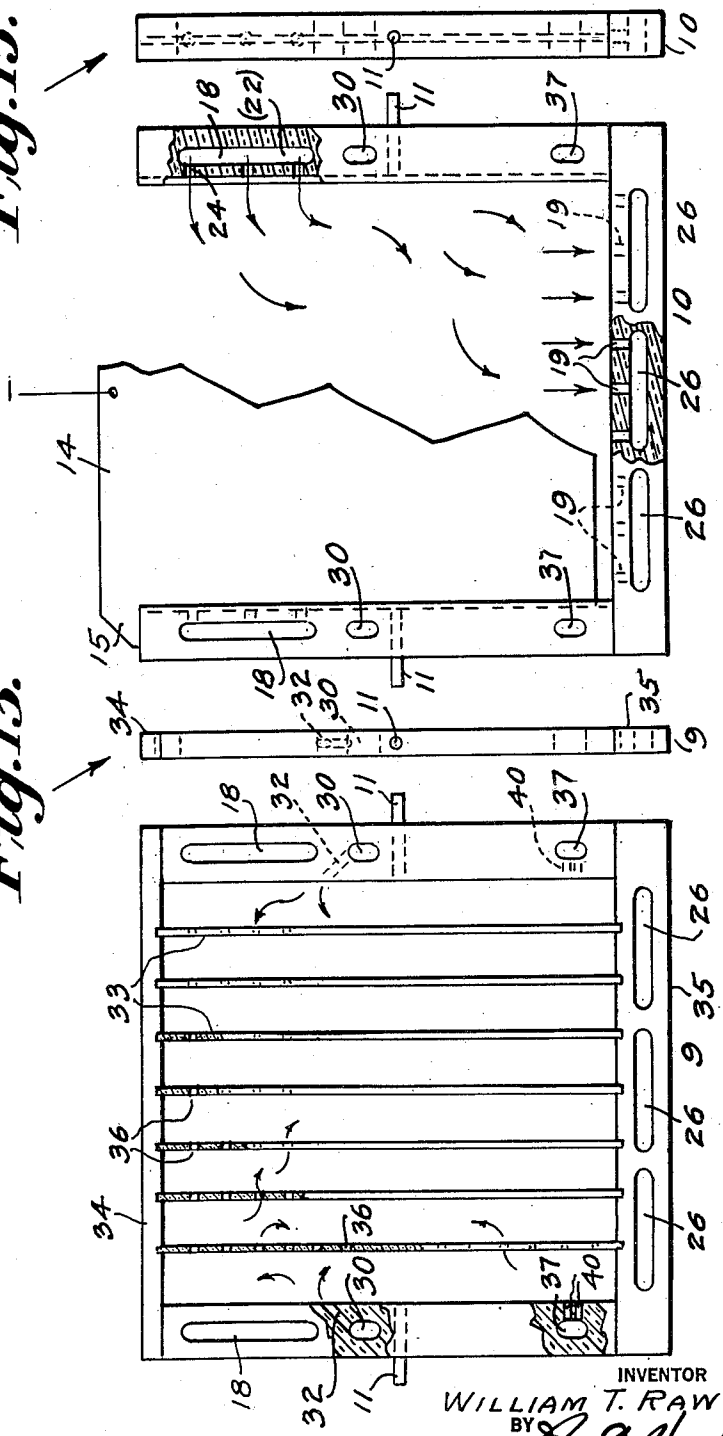
Filed July 19, 1948 6 Sheets-Sheet 6

Fig. 15.

Fig. 14.

Fig. 13.

Fig. 12.



INVENTOR
WILLIAM T. RAWLES
BY Roy A. Hackley Jr.
ATTORNEY

Patented Feb. 27, 1951 2,543,059

UNITED STATES PATENT OFFICE

2,543,059

APPARATUS FOR ELECTROWINNING OR ELECTROPLATING OF METALS

William T. Rawles, Pittsfield, Mass., assignor to the United States of America as represented by the Secretary of the Interior

Application July 19, 1948, Serial No. 39,573

1 Claim. (Cl. 204—257)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment to me of any royalty thereon in accordance with the provisions of the act of April 30, 1928 (Ch. 460, 45 Stat. L. 467).

This invention relates to electrolytic cell apparatus of the diaphragm type wherein a plurality of cells is provided with feeding and withdrawing means for the electrolytes. More particularly, this invention relates to electrolytic cell apparatus of the above type which is adapted to the independent circulation of anolyte and catholyte under controlled conditions.

Heretofore, in electrolytic cell apparatus of the liquid permeable diaphragm type wherein the anolyte and the catholyte are capable of independent circulation (sometimes known as a bifluid cell), the apparatus has been chiefly characterized by its complexity, requiring numerous pipe fittings and construction materials of great strength in order to withstand the stresses inherent in these prior arrangements. Obviously, there exists a need for bifluid electrolytic cell apparatus having a minimum of external piping and corrodable metallic construction members.

Accordingly, this invention has for an object the provision of electrolytic cell apparatus adapted to the independent circulation of anolyte and catholyte wherein substantially all of the structural members exposed to fluid contact, can be made of highly corrosion-resistant materials of a relatively low structural strength, such as the methacrylate and vinyl polymers. This invention also has for an object the provision of electrolytic cell apparatus wherein standardized anolyte and catholyte units are susceptible of repeated duplication without additional exterior piping connections to yield a cell apparatus of any desired capacity. Another object is to provide as an integral part of the electrolytic apparatus, self-contained flow-regulating means as an integral part of the electrolytic apparatus, capable of regulating the liquid level in the anolyte and catholyte compartments and thereby regulating migration of anolyte or catholyte through the permeable diaphragm, while at the same time permitting wide variations in anolyte and catholyte flow rates without substantially disturbing the controlled migration rate through the diaphragm. Still another object is to provide electrolytic cell apparatus of the bifluid type wherein the whole or any part of the apparatus can readily be disassembled for inspection and

2

cleaning. Other related objects will be apparent or will appear hereinafter as the ensuing description proceeds.

The foregoing objects are accomplished in accordance with this invention which provides an electrolytic cell apparatus of the diaphragm type adapted to the independent circulation of anolyte and catholyte and having a plurality of alternately placed anolyte and catholyte frames, permeable or pervious diaphragms interposed between adjacent anolyte and catholyte frames, supporting means for urging said frames and diaphragms into fluid sealing engagement with each other, means including a weir device for controlling the common liquid level and egress from said catholyte frames, means including a second weir device for controlling the common liquid level and egress from said anolyte frames, said frames, diaphragms and weir devices being provided with a plurality of registering apertures about the periphery thereof to define respectively, an anolyte inlet manifold, a catholyte inlet manifold, an anolyte outlet manifold, and a catholyte outlet manifold; said outlet manifolds communicating respectively with said anolyte and catholyte weir devices; inlet means for introducing said anolyte into said inlet manifold, and inlet means for introducing catholyte into said catholyte inlet manifold. This invention also provides, by the combination of anolyte and catholyte weir devices with the cell apparatus, for the automatic regulation of the liquid level in the anolyte and catholyte compartments to thereby automatically regulate migration of electrolyte through the permeable diaphragms, while at the same time providing for wide variation in anolyte and catholyte flow rates without disturbing the controlled migration rate through the diaphragm.

This invention therefore comprises bifluid electrolytic cell apparatus of the diaphragm type provided with integral fluid distribution and liquid-level control devices, which apparatus is susceptible of repeated unit duplication to permit wide variation in electrolytic cell capacities. This invention will be made clear by reference to the following detailed description taken in conjunction with the accompanying drawings in which:

Figure 1 is a plan view of suitable apparatus in accordance with this invention showing also a suitable supporting press;

Figure 2 is a sectional elevation, partly broken away, along the line 2—2 of Fig. 1, looking in the direction of the arrows;

Figure 3 is a sectional elevation showing the weir device and electrodes with diagrammatic electrical connections looking in the direction of the arrows shown on the line 3—3 of Fig. 1;

Figure 3a is an enlarged detail, partly broken away, showing a suitable manner in which the cathodes may be supported and also showing a duct for the distribution of catholyte from the catholyte manifold to the catholyte compartment;

Figure 4 is an elevational view of an anolyte discharge frame showing the anolyte outlet;

Figure 5 is an elevation of the anolyte discharge frame of Fig. 4 looking at right angles to the view of Fig. 4.

Figure 6 is an elevational view of an anolyte weir riser frame showing the connection with the anolyte outlet manifolds;

Figure 7 is an elevation of the anolyte weir riser frame shown in Fig. 6 and taken at right angles to the view thereof;

Figure 8 is an elevational view of a catholyte weir plate for regulating the catholyte cell level;

Figure 9 is an elevational view of the anolyte weir plate which is similar to the catholyte weir plate of Fig. 8 except that the manifold apertures are absent.

Figure 10 is an elevational view of the catholyte weir riser or spacer frame showing also the inlets for the anolyte manifold.

Figure 11 is an elevation of the catholyte weir riser or spacer frame shown in Fig. 10 but taken at right angles to the view of Fig. 10;

Figure 12 is an elevational view, partly in section, showing a typical anolyte frame and diaphragm-spacing grids;

Figure 13 is an elevational view of an anolyte spacer frame forming a part of the anolyte compartment;

Figure 14 is an elevational view, partly in section and partly broken away, of a catholyte frame showing a fragmentary cathode in position;

Figure 15 is an elevation of the catholyte frame of Fig. 14 taken at right angles thereto.

For a practical embodiment of this invention and referring now to the drawings, a suitable support is provided for the frame members of the electrolytic apparatus capable of urging the frame members into fluid sealing engagement with each other while supporting them in horizontal alignment for disassembly and inspection, cleaning or the like. As shown in Fig. 1, such a supporting device may take the form of a press mechanism similar to that in an ordinary filter press, and includes a pair of iron backing plates 1 holding a pair of corrosion-resistant backing plates 2 in the vertical position parallel to each other. A pair of threaded horizontal rods 3 pass through the backing plates 1 and a press plate 4 and in conjunction with the nuts 5 limit the opening of the press. An adjustment screw 6 is threaded through the press plate 4 and is actuated by a hand wheel 7 to urge the backing plates 1, 2 toward each other whereby the cell assembly is supported thereby and firmly held in place. Each frame is thus held in fluid sealing engagement with adjacent frames. Gaskets or sealing compound may be employed if desired to provide tight joints.

The tie rods 3 carry a plurality of vertically-positioned anolyte frames 9 alternating with vertically positioned catholyte frames 10, each frame being supported by horizontal studs 11, each stud projecting outwardly from the frame it supports to rest upon the tie rods 3. Interposed between the anolyte frames 9 and the catholyte frames 10 are vertically positioned permeable diaphragms 8. Any suitable material resistant to the corrosive influence of the electrolytic process may be employed in the construction of the diaphragms 8, such as for example, canvas, woven or felted asbestos and the like, but in the electrolytic production of chromium, for example, it has been found that pre-shrunk fabric woven of threads composed of a vinyl-acetate-vinyl chloride copolymer known as "Vinyon," is satisfactory when coated with a suitable resinous material to reduce its porosity. The alternately spaced anolyte frames 9 and catholyte frames 10 separated by the diaphragms 8 thus define alternately spaced anolyte and catholyte compartments. As shown in the drawings, each anolyte frame includes a spacer frame 12, particularly illustrated in Fig. 13, allowing for the employment of a pair of anodes 13 for each cathode 14. For convenience, the spacer frame 12 will be referred to as a part of the anolyte frame 9.

Suitable means are provided for maintaining the anodes 13 and cathodes 14 in predetermined spaced relationship to each other and to the diaphragms 8. As particularly shown in Figs. 3a, 14 and 15, each cathode 14 is provided with a pair of projecting ears 15 adapted to rest upon and be supported by the catholyte frame 10. Each side of the catholyte frame is slotted to receive the metallic cathode 14. By this means each cathode is held in spaced relation equidistant from the adjacent diaphragms 8. Similarly, each anode frame spacer member 12 is provided with a pair of recesses about its interior periphery such that when assembled together with the diaphragm retaining members 16 of the anolyte compartment frame 9, a pair of grooves 17 are provided about the interior periphery of the anolyte compartment to receive and retain a pair of anodes 13 in spaced relationship to the diaphragms 8. Vertically extending grids 33 having perforations 36 therein for circulation of electrolyte are provided in each anolyte frame 9 in order more perfectly to support the diaphragms 8 in alignment with the anodes 13 and cathodes 14. As shown in the drawings, particularly Figures 3 and 12, the perforated grids 33 are positioned on each side of the anolyte frames 9 against adjacent diaphragms, since in general the catholyte is of superior density to the anolyte and a slightly higher liquid level is maintained in the cathode compartments than in the anode compartments to inhibit diffusion of anolyte into the catholyte. This causes the diaphragms 8 to be continuously urged against the grids 33 whereby perfect alignment is secured.

Suitable internally-self-contained means are provided for separately distributing anolyte and catholyte to the anolyte frame 9 and catholyte frames 10 and for separately withdrawing anolyte and catholyte from the respective frames. Such means may take the form of a plurality of apertures about the periphery of each frame, each aperture registering with a similar aperture in an adjacent frame to define the series of manifolds or headers. As shown more particularly in Figures 12, 13, 14 and 15, near the upper portion of the vertical anolyte frames 9 and catholyte frames 10, there is formed an elongated slot 18 which in conjunction with adjacent frames in the assembled position, de-

fines a catholyte inlet header or manifold 22, as particularly shown in Figure 2. The elongated header slots 18 are formed about an axis generally parallel to the axis of the electrolytic cell assembly. An inlet is provided for catholyte, and as shown, a pipe 23 is vertically positioned in the spacer frame 24 near one end of the cell assembly. Referring to Figures 14 and 15, each catholyte frame 10 is provided with a series of ports or holes 24 generally perpendicular to the catholyte manifold aperture 22 and of smaller size to form a port 24 from the catholyte header into the interior of the catholyte frame 10. It should be noted that even though the anolyte frames 9 are provided with a catholyte manifold slot 18, there exists no passageway which would permit catholyte to enter the central portion of the anolyte frame 9.

Similarly, suitable means are provided for withdrawing catholyte from each catholyte compartment into catholyte outlet manifolds 25. The catholyte outlet manifolds 25, as shown more particularly in Figures 3, 12 and 14, comprises a series of generally horizontal apertures 26 formed in the bottom edge of each anolyte frame 9 and catholyte frame 10, about an axis generally perpendicular to the said frames and generally parallel to the cell assembly. Each catholyte frame 10 has a plurality of vertical ports 19 from the interior of the cathode frames to the catholyte outlet manifold 25 whereby catholyte may be withdrawn from the catholyte frames 10.

In the operation of the cell, for example in the electrolytic production of metallic chromium, catholyte enters the inlet pipe 23 and proceeds by way of the catholyte inlet manifold 22 axially along the cell where it is distributed to each catholyte frame 10 by way of the ports 24. It then circulates generally downwardly across the cathode and is confined by the diaphragms 8 although a small amount of controlled diffusion normally takes place into the adjacent anolyte frames 9. The spent catholyte is withdrawn through the ports 19 into the catholyte outlet manifolds 25 and the circulation cycle through each cathode frame is thus completed.

Suitable self-contained means are likewise provided for the distribution of anolyte into each anolyte frame and for individually withdrawing spent anolyte into an anolyte outlet manifold. As shown, such internal anolyte distribution means may take the form of an anolyte inlet pipe 27 communicating with a horizontal anolyte inlet manifold 28 having a terminus in the catholyte riser or spacer frame 29 particularly shown in Figure 10. The anolyte inlet manifold 28 comprises a pair of slots 30 one on each side of each anolyte frame 9 and each catholyte frame 10 about the mid-point of each vertical side member and is formed about an axis perpendicular to each frame but parallel to the axis of the entire electrolytic cell assembly. Each anolyte manifold slot 30 in each frame registers with adjacent slots 30 in adjacent frames and extends through interposed permeable diaphragms 8 to form an elongated header or manifold 28 limited at one end by a corrosion resistant backing plate 2 and terminated by a catholyte weir plate 31 at the other end.

Each anolyte frame 9 is provided with ports 32 extending from the interior of the anolyte inlet manifold 28 into the interior of the anolyte frame 9 perpendicular to the axis of the anolyte

slot 30 and communicating therewith to distribute anolyte from the manifold 28 into the anolyte frame 9. Preferably, as shown in Fig. 12, the ports 32 extend upwardly in order to insure complete circulation of incoming anolyte throughout the anolyte compartment defined by the anolyte frame 9 and adjacent diaphragms 8.

Since the anolyte is generally of a lesser density than the catholyte, and the permeable diaphragms 8 are usually flexible, suitable means are provided in the anolyte frames 9 for spacing the diaphragms 8 a controlled distance from the anodes 13. As particularly shown in Figs. 3 and 12, such diaphragm spacing means may take the form of a plurality of vertically ranging grid members 33 retained in the top member 34 and the bottom member 35 of the anolyte frame 9, and they are preferably spaced equi-distant from each other. In order to minimize the compartment size while at the same time providing for a controlled flow of anolyte across the face of the anode 13, the vertically ranging grid members 33 are of such a depth as to fill the space between the diaphragms 8 and the adjacent anodes 13. In order to provide a controlled circulation of anolyte from the inlet ports 32 across the face of each anode 13 and diaphragm 8, the grid members 33 are provided with a series of apertures 36 on horizontal axes located in a plane normal to the axis of the assembled electrolytic cell apparatus.

Suitable self-contained means are provided for individually withdrawing anolyte from each cell through a liquid level regulating device to a discharge outlet. As shown more particularly in Figures 2, 12, 13, 14 and 15, such means may take the form of a pair of elongated slots 37 formed in the upright vertical sides of each frame about an axis generally parallel to the axis of the assembled electrolytic cell apparatus, to define anolyte outlet manifolds 38 terminated at one end by the corrosion resistant backing plate 2 and at the other end by an anolyte weir plate 39. In each anolyte frame 9 a series of ports 40 extend from the anolyte outlet slot 37 about an axis normal thereto to permit withdrawal of anolyte from the interior of the anolyte frame 9 through the ports 40 into each anolyte outlet manifold 38, from which spent or impure anolyte is withdrawn through a liquid-level control device and thence discharged from the cell.

In operation, anolyte enters the anolyte inlet pipes 27 and then passes longitudinally in a generally horizontal direction through the anolyte inlet manifolds 28 to be distributed through the ports 32 into and through each anolyte compartment defined by the anolyte frame 9 and adjacent diaphragms 8. After passing over the anode 13 via the grid apertures 36 in the grid members 33, the anolyte, together with any catholyte which may have seeped or diffused through the diaphragms 8, is withdrawn through the ports 40 into the anolyte outlet manifolds 38. From there it travels through a suitable liquid level control device to be discharged.

In combination with the above described electrolyte internal distribution means, this invention provides suitable means separately regulating the liquid levels of the anolyte and catholyte while permitting, independently thereof, a wide variation in electrolyte flow rates. Control of the liquid levels as provided herein, controls the migration of electrolyte from the cathode compartments into the anode compartments. As shown

more particularly in Figures 3, 4, 5, 6, 7, 8, and 10, means for regulating the catholyte cell liquid level are combined with means for discharging the catholyte from the apparatus and with means for admitting anolyte into the cell structure. Referring now to Figure 3, positioned next adjacent an outer anolyte frame 9 is a blind frame 41 containing the marginal anolyte and catholyte manifolds 22, 25, 23, 38, as well as the catholyte inlet pipe 23. Next adjacent the blind frame 41 is a catholyte discharge or spacer frame 42 having a pair of horizontal pipes 43 communicating with the interior thereof to permit the withdrawal of spent catholyte therefrom. Next adjacent the catholyte discharge or spacer frame 42 is a catholyte weir plate 44, similar to Fig. 8, which has three horizontal slots 45 near the upper portion thereof for regulating catholyte liquid level. Next adjacent the catholyte weir plate 44 is a catholyte riser or spacer frame 29 shown in Figures 10 and 11. Another catholyte weir plate 31, a second catholyte discharge or spacer frame 47 and a second blind plate 48, follow in the order named. Each of these plates and frames is supported in a generally vertical position by horizontal studs 11 and is provided with anolyte outlet manifolds 38. In the operation of the catholyte liquid level control device, catholyte is withdrawn from the catholyte frames 10 via ports 19 and outlet manifolds 25 to the catholyte weir riser section shown in Figure 10. The catholyte weir riser section is provided with a vent 49 in the top horizontal member to permit escape of hydrogen or other entrained gases and to equalize the pressure between the atmosphere and the catholyte compartments. The spent catholyte proceeds upwardly through the catholyte riser or spacer frame 29 being confined therein by the two adjacent catholyte weir plates 31, 44. The regulating slots 45 are suitably placed so that all of the cathode frames will have a suitable liquid level. The spent catholyte is discharged over the weir plates 31, 44 and falls downwardly into the adjacent sandwiched pair of catholyte discharge frames 47, 42. From these plates, the spent catholyte is discharged through the outlet pipes 47 to be reclaimed or otherwise disposed of. It will be seen that within very wide variations in catholyte flow rates, the catholyte weir plates 31, 44 in combination with the catholyte outlet manifolds and catholyte compartments, regulate the liquid level of catholyte in the catholyte compartments within very close limits.

In a similar fashion to the foregoing, the liquid level of anolyte in the anolyte compartments is closely regulated within predetermined limits by a weir regulating device forming a part of the electrolytic cell apparatus. As shown in Figure 3, and in more detail in Figures 4, 5 and 9, there is provided next adjacent the corrosion resistant backing plate 2, a series of frames comprising an anolyte discharge section. In the following order proceeding from the backing plate 2, there is provided an anolyte discharge frame 53 having a pair of anolyte outlets comprising horizontal pipes 51 communicating with the interior of the anolyte discharge frame 50. Next is provided a vertical anolyte weir plate 39 shown in more detail in Figure 8, an anolyte riser frame 52 and the previously described blind plate 48, all of these frames and plates closely nest together in fluid sealing engagement as previously described in connection with the anode and cathode frames. The anolyte weir plate 39 is provided with a vertically extending vent 53 as shown in Figure 3, and a series of horizontal slots 54 provided with bevelled edges 55 on the bottom portion of the slots 54 in order that fluid level may be closely controlled. The heighth of the anolyte in the apparatus as well as in the anolyte riser frame 52 is determined by the elevation of the lower bevelled edge 55 of the weir slots 54. In general, since it is desired that migration of electrolyte proceed from cathode compartments to anode compartments rather than vice versa, the lower bevelled edges 55 of the anolyte weir slots 54 are placed at a slightly lower horizontal elevation than the corresponding catholyte slots 45 and lower catholyte weir bevelled edges 56. As shown in Figure 2, the anolyte weir plate 39 forms the closure for the anolyte outlet manifold 38. Correspondingly, the anolyte riser frame 52 shown in Figure 6 is provided with a pair of channels 57 registering with the anolyte outlet manifolds 38. In operation, anolyte is admitted to the electrolytic cell through the inlet pipes 27 shown in Figure 10, and proceeds by way of the anolyte inlet manifolds 28 and thence through the ports 32 into the anolyte frames 9. After electrolysis, impure or spent anolyte is discharged through the anolyte discharge ports 40 into the anolyte outlet manifolds 38. The spent anolyte then proceeds into the anolyte riser frame 52. Thereafter, it rises in this frame being retained therein by the blind plate 48 and the anolyte weir plate 39 to a predetermined liquid level fixed by the vertical elevation of the weir slots 54 in the weir plate 39. After passing over the weirs, the anolyte is discharged through the outlet pipes 51 of the anolyte discharge frame 50.

In order that the operation of a diaphragm type electrolytic cell apparatus in accordance with this invention be fully understood, a typical operating cycle will now be described with particular reference to the electrolytic production of metallic chromium from a chromic ammonium sodium sulfate catholyte and an anolyte of sulphuric acid containing also a small proportion of chromic acid. The catholyte is prepared from suitably purified chrome alum and comprises an aqueous solution of chrome alum mixed with Glauber's salts and ammonium sulfate and contains about 85 grams of chromium per liter, 115 grams of ammonium sulfate per liter and 60 grams of sodium sulfate per liter. The catholyte is admitted through the catholyte inlet pipes 23 and thence passes through the catholyte inlet manifolds 22 into the cathode frames 10. The catholyte then fills the catholyte outlet manifolds 25 and rises in the catholyte weir riser or spacer frame 29 to the predetermined level set by the weir slots 45 in the catholyte weir plates 31, 44. The anolyte circulating system is simultaneously filled with 25% sulphuric acid solution through the anolyte inlet pipes 27, thence by way of the anolyte inlet manifolds 28 into the anode frames 9. The anolyte then proceeds out of the anolyte frames 9 to fill the anolyte outlet manifolds 38 and rises in the anolyte riser frame 52 to the level dictated by the position of the weir regulating slots 54 in the anolyte weir plate 39. This in turn controls the liquid level of the anode compartments. It will be seen that as no make-up solutions are added, the liquid levels remain substantially constant in the cell. However, upon the addition of anolyte or catholyte, circulation in the respective anolyte or catholyte compartments takes place. Since the chromium-containing catholyte is of superior density to the

sulfuric acid-containing anolyte, and since the liquid level in the cathode frames is intentionally maintained somewhat higher than the liquid level in the anode frames, some migration of catholyte into the anolyte takes place to admit a proportion of chromium into the anolyte. The difference in liquid levels and the permeability of the diaphragms are controlled to yield a migration rate of about 1.6 gallons of catholyte per square foot of diaphragms per day.

The anodes 13, suitably positioned in the anode compartments normal to the axis of the cell, are spaced from the diaphragms 8 by the grid members 33. In the electrodeposition of metallic chromium employing the apparatus of this invention, the anodes 13 are suitably constructed of lead alloyed with a minor proportion of silver. As shown schematically in Figure 3, the anodes 13 are connected electrically in parallel. The cathodes 14 are similarly supported in the cathode frames 10 and may be constructed of stainless steel or brass for the electrodeposition of metallic chromium thereon. Continuous circulation of anolyte and catholyte suitably made up to the described feed composition, is commenced and the cathode current density maintained at about 65 amperes per square foot. With the cell voltage maintained at about 4.2 to about 4.5 volts, the metallic chromium is deposited at the rate of about 1.3 lbs. of chromium per day per square foot of cathode area.

It will be apparent from the foregoing that there has been provided a highly efficient electrolytic cell apparatus adapted to be constructed of plastic materials which are corrosion resistant but structurally weak. The apparatus of this invention provides for independent circulation of anolyte and catholyte wherein the fluid distribution is internal and requires no outside piping. Because of the unit construction of the electrolytic cell in accordance with this invention, the cell capacity can be widely varied by the addition of pairs of anode frames and cathode frames. By means of the liquid level control device of this invention, which similarly are self-contained and capable of repeated duplication in the cell, the liquid levels in the anolyte compartments and catholyte compartments can be precisely controlled even with wide variations in anolyte and catholyte flow rates through the electrolytic cell apparatus. The migration rate of one electrolyte into the other can be closely controlled by regulating the relative heights of anolyte weir orifice slots and catholyte weir orifice slots, whereby there is achieved a controlled migration rate through the diaphragms which is substantially independent of the flow rates of anolyte and catholyte.

It will further be apparent that there is provided in accordance with this invention an electrolytic cell apparatus of the bi-fluid type wherein any individual cell or fluid regulating device can readily be disassembled or entirely replaced without substantially disturbing the balance of the apparatus. All that is necessary is to open the supporting press and lift the frame unit from the assembly.

Since many apparently differing embodiments of this invention will occur to one skilled in the art, various changes can be made in the preferred embodiments herein shown and described without departing from the spirit and scope of this invention.

What is claimed is:

An electrolytic cell apparatus of the diaphragm type adapted to the separate circulation of anolyte and catholyte which comprises a supporting press provided with vertical end plates, horizontal tie rods connecting the end plates, and means for urging said end plates toward each other, a plurality of alternately-placed vertical anolyte frames and vertical catholyte frames carried by said press, a plurality of semi-pervious diaphragms supported between said anolyte frames and said catholyte frames defining therewith alternate anolyte and catholyte compartments, each of said anolyte frames, catholyte frames and diaphragms being provided with a series of apertures about its periphery registering with corresponding apertures on adjacent frames to define respectively an anolyte inlet manifold, a catholyte inlet manifold, an anolyte outlet manifold and a catholyte outlet manifold, said catholyte outlet aperture being at the bottom of said catholyte frames, each of said catholyte frames having a plurality of holes communicating with said catholyte inlet and outlet manifolds to deliver catholyte to and exhaust catholyte from said catholyte compartment, each of said anolyte frames having a plurality of holes communicating with said anolyte inlet and outlet manifolds to deliver anolyte to and exhaust anolyte from said anolyte compartments; a catholyte weir outlet section comprising a vertical weir plate carried in the supporting press in general alignment with said anolyte and catholyte frames and provided with a horizontal slot near its upper end extending through said plate normal thereto, a blind plate carried in the supporting press in general alignment with said anolyte and catholyte frames, having an imperforate central area and an aperture registering with said catholyte outlet manifold, a spacer frame carried in the supporting press in general alignment with said anolyte and catholyte frames, having an open central area and peripherally engaging the weir plate and defining therewith a catholyte riser compartment whose interior communicates with said catholyte outlet manifold, a second spacer frame carried in the supporting press in general alignment with said anolyte and catholyte frames, having an open central area and peripherally engaging the weir plate and the blind plate and provided with an outlet aperture below said weir slot to discharge spent catholyte, and an anolyte weir section communicating with said anolyte outlet manifold for regulating the anolyte liquid level and discharging spent anolyte, an inlet for the anolyte manifold and an inlet for the catholyte manifold.

WILLIAM T. RAWLES.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
583,513	Spilker	June 1, 1897
1,420,212	Paulus	June 20, 1922

FOREIGN PATENTS

Number	Country	Date
5,547	Great Britain	of 1891