Jan. 31, 1956 R. Q. BOYER 2,733,202

ELECTROLYTIC CELLS

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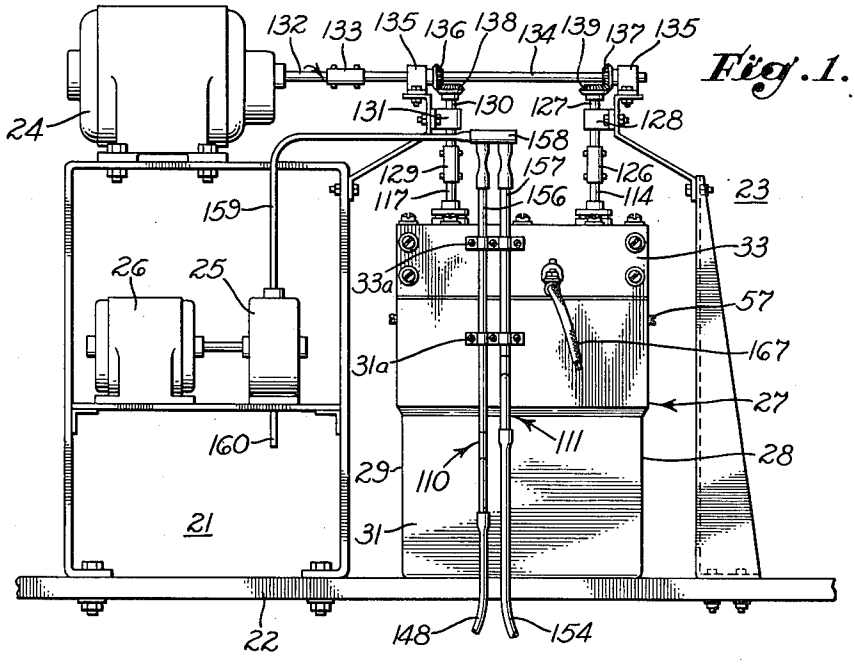
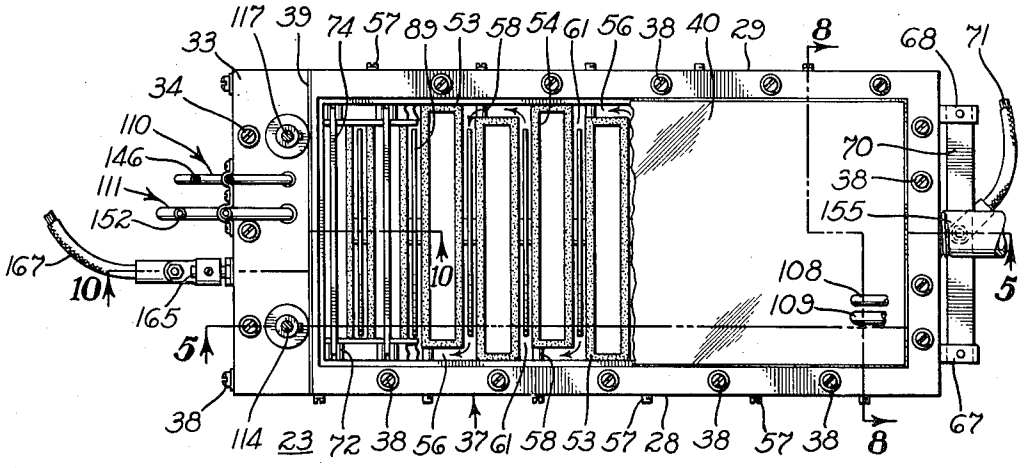


Fig. 1.

Fig. 2.



INVENTOR.
ROBERT Q. BOYER
BY Robert Q. Boyer
ATTORNEY.

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Filed Sept. 28, 1944 6 Sheets-Sheet 2

Fig. 3.

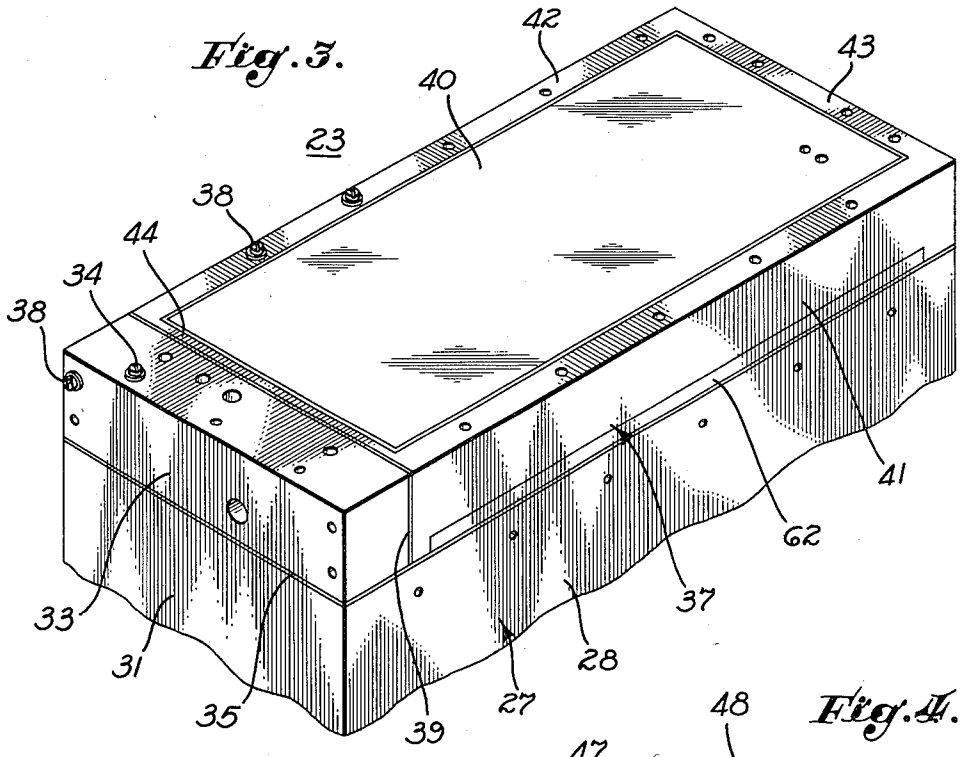
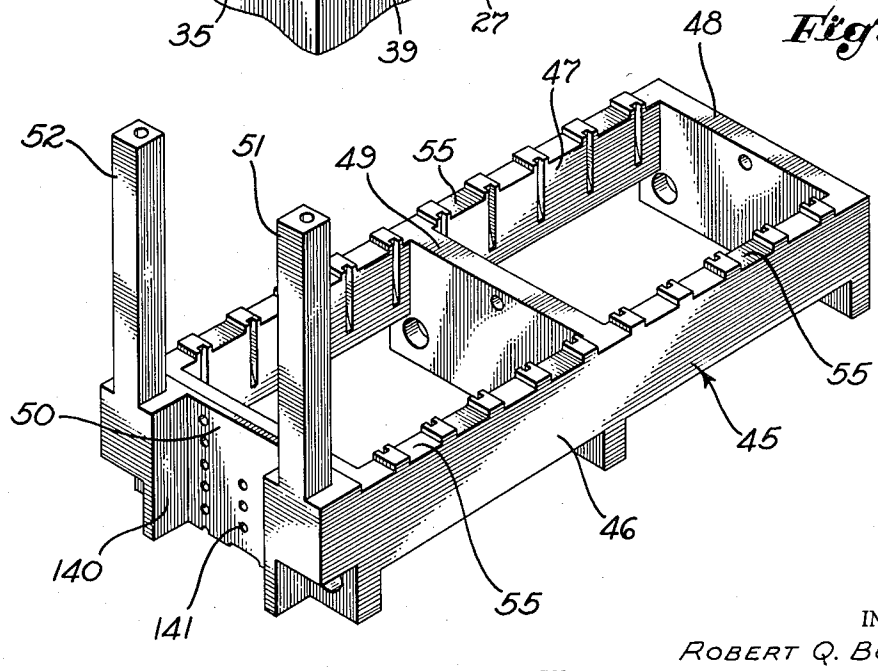


Fig. 4.



INVENTOR.
ROBERT Q. BOYER
BY Robert Q. Boyer
ATTORNEY.

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Filed Sept. 28, 1944 6 Sheets-Sheet 3

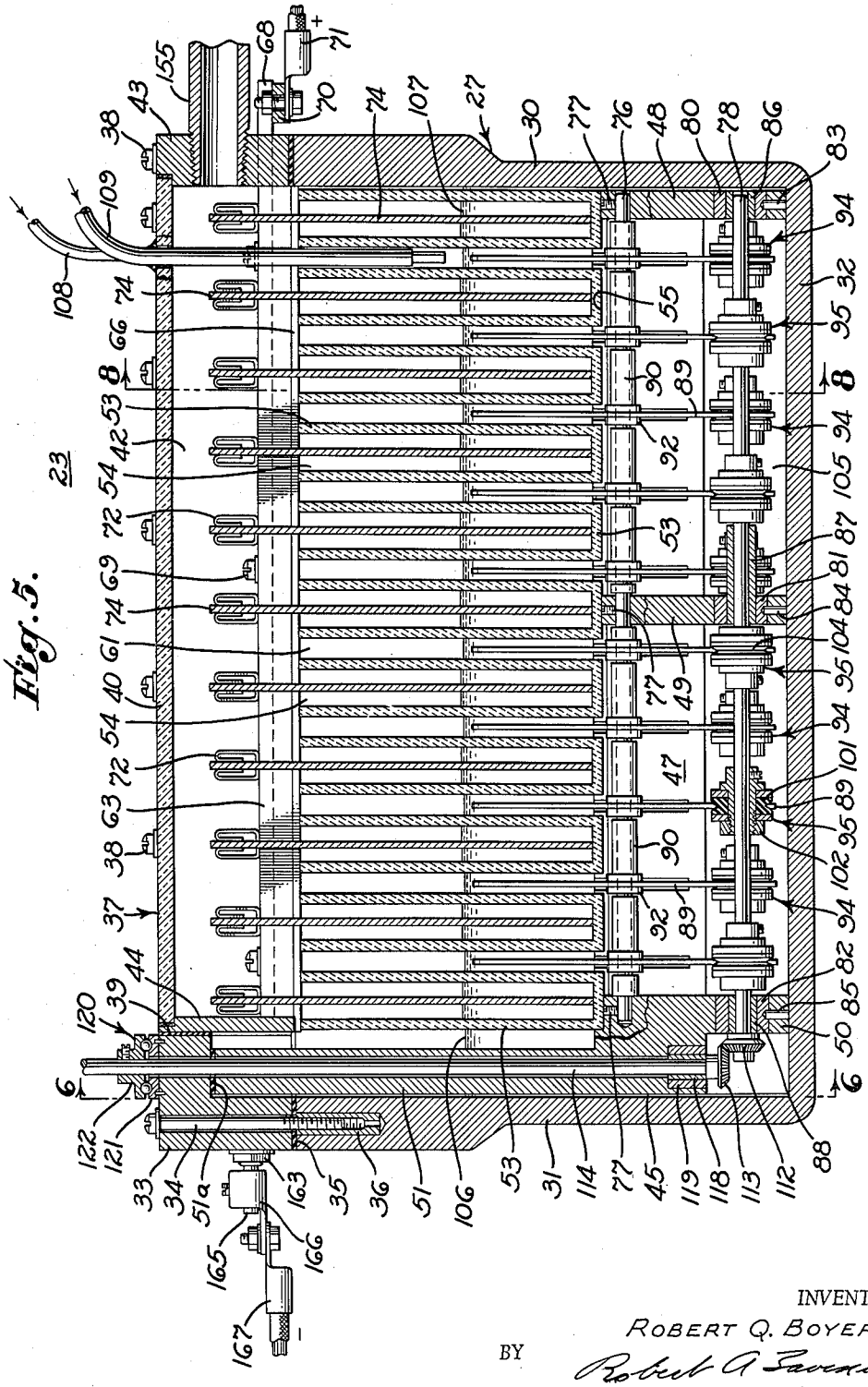


Fig. 5.

INVENTOR.
ROBERT Q. BOYER
BY Robert Q. Boyer
ATTORNEY.

Jan. 31, 1956 R. Q. BOYER 2,733,202

ELECTROLYTIC CELLS

Filed Sept. 28, 1944 6 Sheets-Sheet 4

Fig. 6.

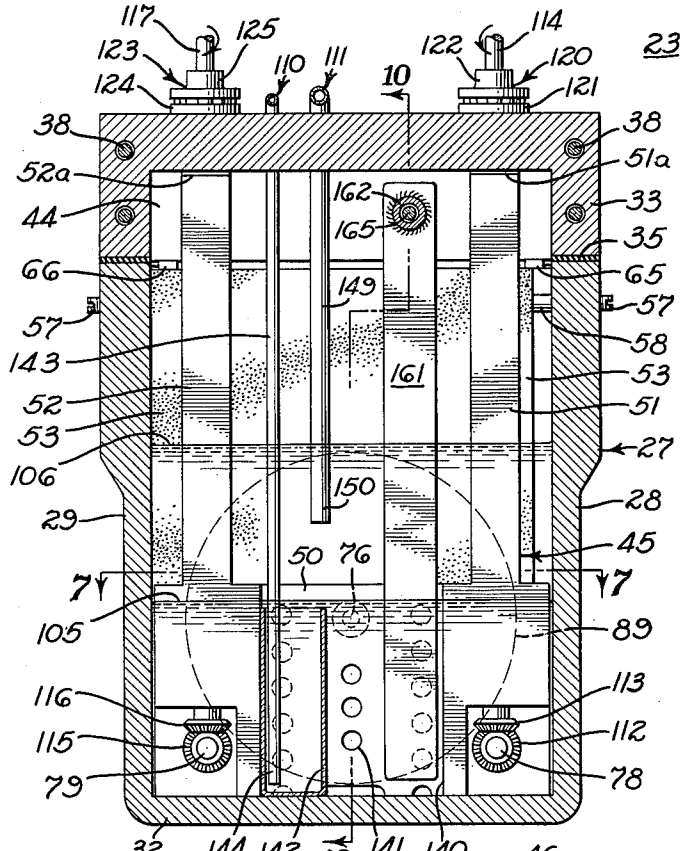
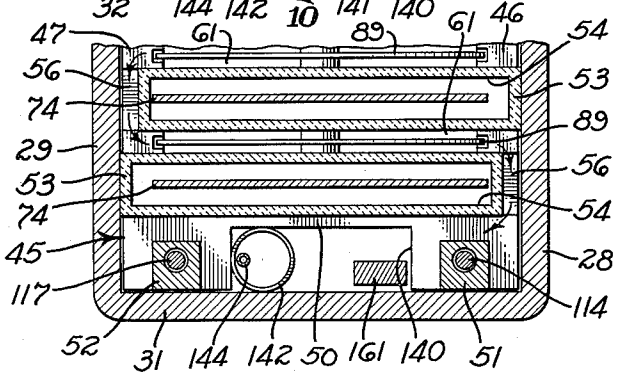


Fig. 7.



INVENTOR.
ROBERT Q. BOYER
BY
Robert Q. Boyer
ATTORNEY.

Jan. 31, 1956 R. Q. BOYER 2,733,202

ELECTROLYTIC CELLS

Filed Sept. 28, 1944 6 Sheets-Sheet 5

Fig. 8.

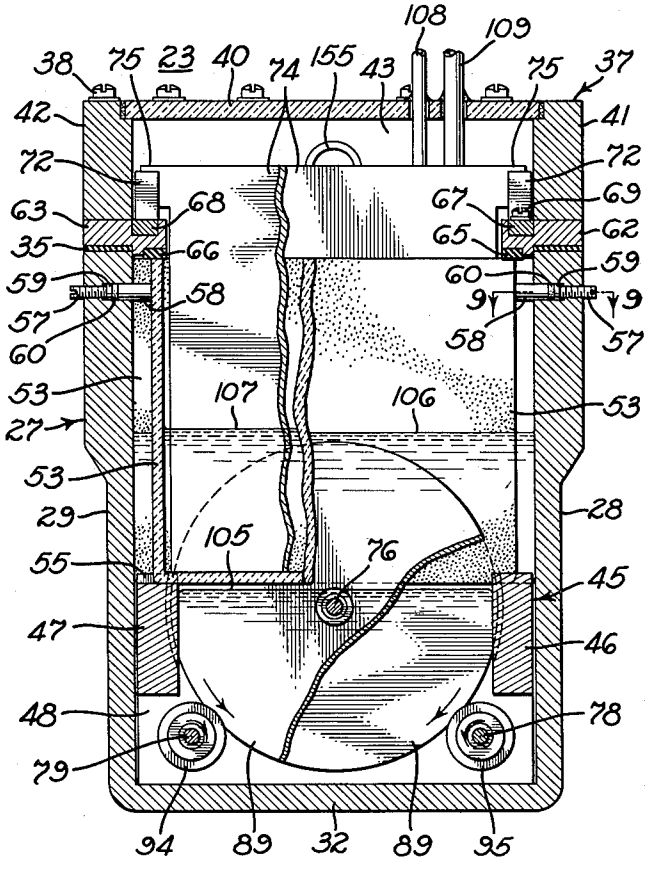
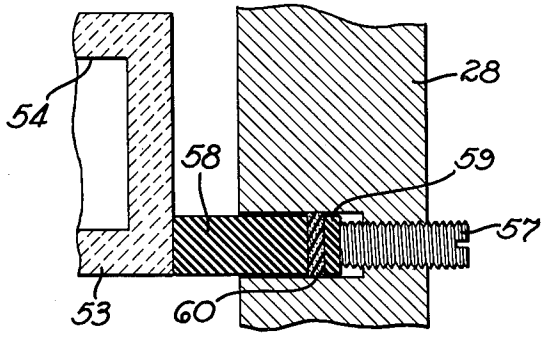


Fig. 9.



INVENTOR.
ROBERT Q. BOYER
BY Robert Q. Boyer
ATTORNEY.

Jan. 31, 1956 R. Q. BOYER 2,733,202

ELECTROLYTIC CELLS

Filed Sept. 28, 1944 6 Sheets-Sheet 6

Fig. 10.

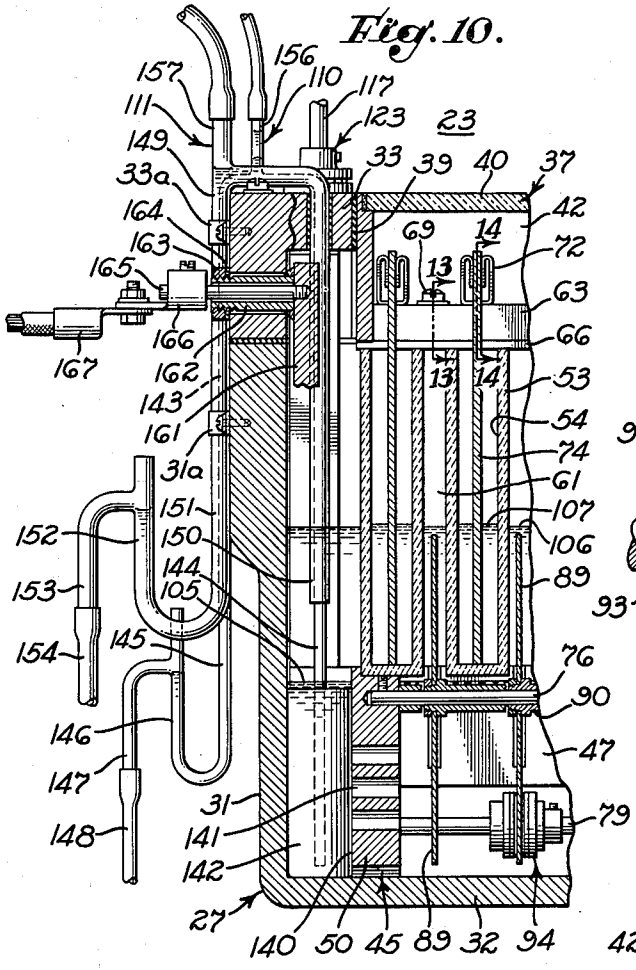


Fig. 13.

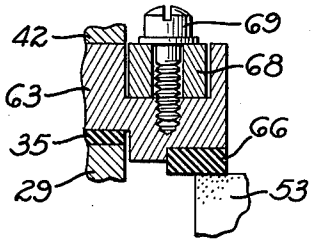


Fig. 11.

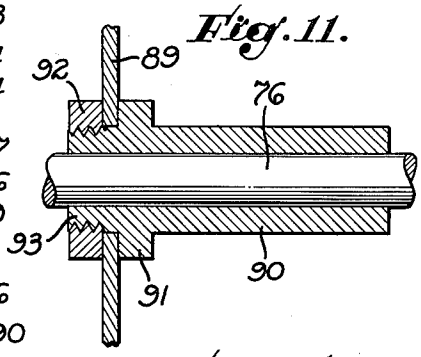


Fig. 14.

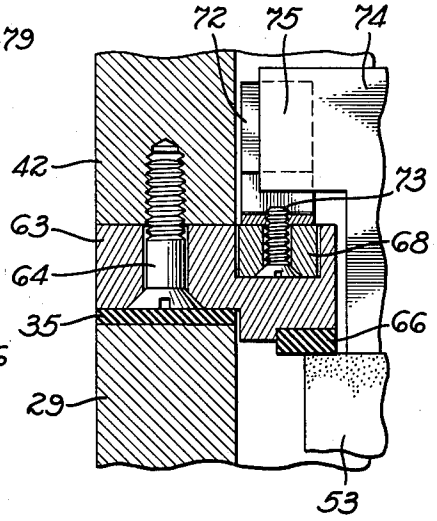
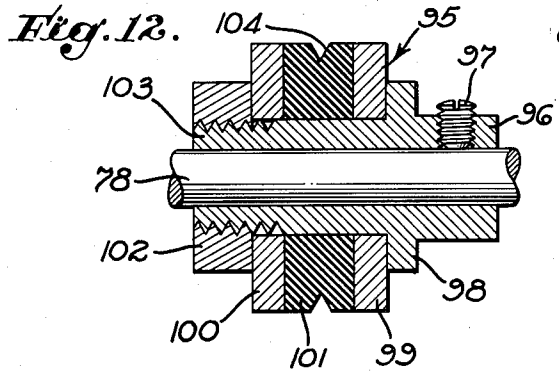


Fig. 12.



INVENTOR.
ROBERT Q. BOYER
BY Robert Q. Boyer
ATTORNEY.

United States Patent Office

2,733,202

Patented Jan. 31, 1956

2,733,202

ELECTROLYTIC CELLS

Robert Q. Boyer, Berkeley, Calif., assignor to the United States of America as represented by the United States Atomic Energy Commission

Application September 28, 1944, Serial No. 556,127

11 Claims. (Cl. 204—215)

The present invention relates to electrolytic cells and more particularly to improve electrolytic cells of the general type disclosed in the copending application of Robert Q. Boyer, Serial No. 532,162, filed April 21, 1944.

The electrolytic cell mentioned is especially useful to reduce metallic ions contained in solution, and comprises a casing that houses a liquid metal pool in the lower portion thereof and porous partition structure in the upper portion thereof defining a plurality of anode compartments and a plurality of intervening cathode compartments. Anolyte is contained in the anode compartments in contact with anode elements arranged therein, and a number of the cathode compartments are connected in series relation to form a passage through the casing through which catholyte is conducted in contact with both the liquid metal pool and cathode members arranged in the cathode compartments, the catholyte containing metallic ions that are reduced electrolytically incident to passage of the catholyte through the casing. Accordingly, fresh catholyte containing metallic ions in the higher oxidation state is continuously supplied to one end of the passage mentioned and treated catholyte containing metallic ions in the lower oxidation state is continuously removed from the other end of the passage.

While this electroytic cell is entirely satisfactory in operation, it requires the maintenance of a suitable difference in hydrostatic heads of the catholyte between the ends of the passage mentioned in order to cause the catholyte to flow therethrough at a suitable rate for electrolytic treatment, with the result that the cathode compartments adjacent the end of the passage contain less catholyte than the cathode compartments adjacent the beginning of the passage, whereby the catholyte is not subjected to as uniform electrolytic treatment in the passage from end to end as is desirable. Further, the condition mentioned tends to cause the catholyte in the cathode compartments adjacent the beginning of the passage to permeate the porous partition structure and to mix with the anolyte in the adjacent anode compartments, resulting in oxidation instead of reduction of the metallic ions contained in the catholyte.

Accordingly, it is an object of the invention to provide an improved electrolytic reduction cell comprising a casing provided with a catholyte passage of maximum length entirely within the casing, and contacting electrode structure arranged to afford a large uniform reducing action upon the metallic ions contained in the catholyte.

Another object of the invention is to provide an improved electrolytic cell comprising a casing and an improved arrangement for circulating catholyte through an elongated passage formed in the casing.

Another object of the invention is to provide an electrolytic cell comprising a casing housing rotatable cathode structure that is utilized to propel electrolyte through an elongated passage formed in the casing.

Another object of the invention is to provide an electrolytic cell comprising a casing housing a removable

frame supporting rotatable cathode structure and associated drive mechanism.

A further object of the invention is to provide an electrolytic cell comprising a casing having a cover that is adapted to be secured thereto in gastight relation in order to collect gases liberated from the contained electrolyte incident to electrolysis.

A further object of the invention is to provide an electrolytic cell comprising a casing having a gastight cover constructed in part of transparent material so that the interior of the cell may be observed from the outside.

A further object of the invention is to provide an electrolytic cell comprising a casing having a gastight cover supporting electrode structure depending therefrom into the casing and the contained electrolyte.

A further object of the invention is to provide an electrolytic cell comprising a casing housing a liquid metal pool in the lower portion thereof and electrolyte in the upper portion thereof floating on the liquid metal pool and associated siphon mechanism for removing contaminated liquid metal and treated electrolyte from the casing.

A still further object of the invention is to provide an electrolytic cell of improved construction and arrangement that is efficient in operation.

The invention both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which Figure 1 is a side elevational view of electrolytic apparatus embodying the present invention; Fig. 2 is a plan view, partly broken away, of the electrolytic cell incorporated in the apparatus shown in Fig. 1; Fig. 3 is a fragmentary perspective view of the upper portion of the electrolytic cell shown in Fig. 2; Fig. 4 is a perspective view of the supporting frame housed in the casing of the electrolytic cell; Fig. 5 is an enlarged longitudinal sectional view of the electrolytic cell taken along the line 5—5 in Fig. 2; Fig. 6 is an enlarged transverse sectional view of the electrolytic cell taken along the line 6—6 in Fig. 5; Fig. 7 is an enlarged fragmentary longitudinal sectional view of the electrolytic cell taken along the line 7—7 in Fig. 6; Fig. 8 is an enlarged transverse sectional view, partly broken away, of the electrolytic cell taken along the lines 8—8 in Figs. 2 and 5; Fig. 9 is a greatly enlarged fragmentary sectional view of a structural detail of the electrolytic cell taken along the line 9—9 in Fig. 8, illustrating the manner in which the porous cups carried by the supporting frame are blocked in place in the casing of the electrolytic cell; Fig. 10 is an enlarged fragmentary longitudinal sectional view of the electrolytic cell taken along the line 10—10 in Fig. 6, illustrating the siphon arrangements for removing catholyte from the body of catholyte and liquid metal from the pool of liquid metal contained in the casing of the electrolytic cell; Fig. 11 is a greatly enlarged longitudinal sectional view of a structural detail of the electrolytic cell, illustrating the arrangement for supporting and spacing the associated rotatable disks forming a part of the cathode structure of the electrolytic cell; Fig. 12 is a greatly enlarged longitudinal sectional view of a structural detail of the electrolytic cell, illustrating the arrangement for frictionally driving the associated rotatable disk forming a part of the cathode structure of the electrolytic cell; Fig. 13 is a greatly enlarged transverse sectional view of a structural detail of the electrolytic cell taken along the line 13—13 in Fig. 10, illustrating the arrangement for securing to the upper portion of the casing the associated busbar forming a part of the anode structure of the electrolytic cell; and Fig. 14 is a greatly enlarged transverse sectional view of a structural detail of the electrolytic cell taken along the line 14—14 in Fig. 10,

illustrating the arrangement for removably securing in place the plates forming a part of the anode structure of the electrolytic cell.

Referring now more particularly to Fig. 1 of the drawings, there is illustrated electrolytic apparatus 21 embodying the features of the present invention and comprising a unitary support 22 carrying an electrolytic cell 23, associated driving mechanism including an electric drive motor 24, and associated pumping mechanism including a vacuum pump 25 driven by an electric motor 26, the driving mechanism and the pumping mechanism associated with the electrolytic cell 23 being utilized for a purpose more fully explained hereinafter.

As best shown in Figs. 2 to 10, inclusive, the electrolytic cell 23 comprises an insulating hollow casing 27, having an open top and being substantially rectangular in plan. More particularly, the casing 27 comprises two longitudinally extending and substantially parallel laterally spaced-apart side walls 28 and 29, two laterally extending and substantially parallel longitudinally spaced-apart end walls 30 and 31, and a connecting bottom wall 32. Preferably, the casing 27 is of one-piece molded construction, being formed of a conventional synthetic resin of high electrical and chemical resistance. A hollow insulating cover block 33, formed of a conventional synthetic resin of high electrical and chemical resistance, is removably secured in gastight relation to the upper edge of the end wall 31 and to the adjacent upper edges of the side walls 28 and 29 by an arrangement including three screws 34 and an associated gasket 35, formed of a suitable chloroprene type of rubber or the like. The gasket 35 overlies the upper edges of the side walls 28 and 29 and the end walls 30 and 31, and is commensurate with the open top of the casing 27, one portion of the gasket 35 being disposed between the block 33 and the end wall 31 and the adjacent portions of the side walls 28 and 29. Each of the screws 34 is threaded into a hollow bushing 36, secured within an associated hole formed in the end wall 31. Also, a cover proper 37 is removably secured in gastight relation to the upper edge of the end wall 30, to the adjacent upper edges of the side walls 28 and 29, and to the block 33 by an arrangement including a number of screws 38, the gasket 35, and a gasket 39, formed of a suitable chloroprene type of rubber or the like, the gasket 39 being arranged between the adjacent abutting portions of the block 33 and the cover 37. Each of the screws 38 is threaded into an associated hole formed in the upper edge of the adjacent end wall 30 or side wall 28 or 29.

Accordingly, the cover block 33 and the cover proper 37 are sealed in gastight relation with respect to each other and constitute cover structures sealing in a gastight manner the open top of the casing 27. The cover proper 37 comprises a top wall 40, formed of glass or other transparent material, and an insulating depending skirt, formed of a conventional synthetic resin of high electrical and chemical resistance and including two side walls 41 and 42 and two end walls 43 and 44, the lower edge of the skirt actually engaging the gasket 35, as previously explained. Preferably, the top wall 40 is substantially flush with the top of the block 33, the transparency of the top wall 40 permitting convenient visual inspection of the interior of the electrolytic cell 23 in an obvious manner.

Removably arranged within the hollow casing 27 is an insulating supporting frame 45, formed of a conventional synthetic resin of high electrical and chemical resistance. Preferably, the frame 45 is of one-piece molded construction, although it may be conveniently fabricated, and comprises two longitudinally extending side stringers 46 and 47 arranged in substantially parallel laterally spaced-apart relation, three laterally extending cross stringers 48, 49, and 50 arranged in substantially parallel longitudinally spaced-apart relation, and two upstanding posts 51 and 52 disposed adjacent the cross stringer 50 and arranged in substantially parallel laterally spaced-apart relation. When the frame 45 is arranged within the hollow casing 27 as previously noted, the side stringers 46 and 47 are disposed closely adjacent to the side walls 28 and 29, the cross stringer 48 is disposed closely adjacent to the end wall 30, the cross stringer 50 is arranged in spaced-apart relation to the end wall 31, and the upstanding posts 51 and 52 are disposed closely adjacent to the end wall 31 and extend into the hollow block 33. Accordingly, the frame 45 is arranged in the lower portion of the casing 27, the lower edges of the cross stringers 48, 49, and 50 engaging the bottom wall 32.

A plurality of hollow deep cups 53, formed of a porous semi-permeable insulating material of the ceramic type, such as Alundum or sintered glass, are arranged in the upper portion of the casing 27 and carried by the frame 45. More particularly, each of the cups 53 comprises two relatively long laterally extending side walls, two relatively short longitudinally extending end walls, and a horizontally disposed bottom wall, whereby a relatively deep anode compartment 54 is formed in each of the cups 53. The dimensions of each cup 53 are such that a relatively large number of the cups may be arranged in substantially parallel longitudinally spaced-apart relation in the upper portion of the casing 27, and that the distance between the end walls of each cup is slightly greater than the distance between the centers of the side stringers 46 and 47 of the frame 45 and somewhat less than the distance between the interior surfaces of the side walls 28 and 29 of the casing 27. More particularly, a number of pairs of laterally aligned and longitudinally spaced-apart notches 55 are formed in the upper edges of the side stringers 46 and 47 of the frame 45 in order to receive and support the bottom walls of the cups 53 and to retain them in position, whereby they extend laterally between the side walls 28 and 29 of the casing 27 and are disposed in substantially parallel longitudinally spaced-apart relation between the end walls 30 and 31 of the casing 27, as previously explained.

Further considering the arrangement of the cups 53 in the upper portion of the casing 27 and carried by the frame 45, it is noted that the cups 53 are arranged in spaced-apart series or staggered relation between the end walls 30 and 31 of the casing 27, odd ones of the cups 53 engaging the side wall 29 and even ones of the cups 53 engaging the side wall 28. More particularly, as best shown in Fig. 7, the left-hand end wall of the lowermost odd cup 53 engages the side wall 29, while the right-hand end wall of this cup is arranged in spaced-apart relation to the side wall 28; on the other hand, the right-hand end wall of the uppermost even cup 53 engages the side wall 28, while the left-hand end wall of this cup is arranged in spaced-apart relation to the side wall 29. Accordingly, the staggering of the cups 53 between the end walls 30 and 31 of the casing 27 in the manner explained above defines an elongated sinuous passage 56 through the casing 27 from end to end.

The cups 53 are retained in place upon the frame 45 in staggered relation in the manner previously explained by a blocking arrangement including two series of screws 57, respectively carried by the side walls 28 and 29. As best shown in Figs. 8 and 9, each screw 57 engages a threaded hole formed in one of the side walls 28 or 29, and the inner end thereof extends into an aligned opening formed in the wall mentioned. As illustrated, the odd cup 53 is urged into engagement with the side wall 29, by the arrangement mentioned including the screw 57. More particularly, one end of an insulating stud 58 engages the associated end wall of the cup 53, and the other end of the stud 58 is arranged in the opening mentioned formed in the side wall 28. Between the end of the screw 57 and the end of the stud 58 disposed in the opening formed in the side wall 28 are arranged an insulating follower 59 and a gasket 60, formed of a suitable chloroprene type of rubber or the like, the gasket 60 being disposed between the follower 59 and the adjacent end of the stud 58. Ac-

cordingly, when the screw 57 is tightened, engaging the follower 59, the gasket 60 is expanded between the follower 59 and the stud 58 in order to seal the opening formed in the side wall 28, thereby to preserve the gastight character of the casing 27; and the stud 58 urges the cup 53 away from the side wall 28 into engagement with the side wall 29. Accordingly, the arrangement described including the screws 57 is effective to block the cups 53 in staggered relation in the upper portion of the casing 27, and to retain the frame 45 in position in the lower portion of the casing 27, for a purpose more fully explained hereinafter.

In view of the foregoing explanation of the construction and arrangement of the cups 53, it will be understood that a plurality of anode compartments 54 are formed in the cups 53 and that a plurality of compartments 61 are defined between the spaced-apart side walls of adjacent cups, which compartments 61 are connected in series relationship by the sinuous passage 56 in the manner previously explained. The compartments 61 individually constitute cathode compartments and are utilized for a purpose more fully explained hereinafter.

Reconsidering the construction and arrangement of the cover 37 in greater detail, it is noted with particular reference to Figs. 3, 5, 8, 13, and 14 that two longitudinally extending notches are formed in the lower edges of the side walls 41 and 42 of the skirt of the cover 37 intermediate the ends thereof, and carry two longitudinally extending insulating runners 62 and 63, respectively, of substantially identical construction. The runners 62 and 63 are securely fastened to the associated side walls 41 and 42, respectively, and actually engage the gasket 35, as previously explained. As illustrated in Fig. 14, the runner 63 is secured to the associated side wall 42 by an arrangement including a number of screws 64. The outside edges of the runners 62 and 63 are substantially flush with the adjacent side walls 41 and 42, respectively, of the skirt of the cover 37 and with the adjacent side walls 28 and 29 of the casing 27; while the inside edges of the runners 62 and 63 extend inwardly into the upper portion of the casing 27 and carry gaskets 65 and 66, respectively, formed of a suitable chloroprene type of rubber or the like, that engage the upper edges of the adjacent cups 53. As best shown in Figs. 13 and 14, the inside edge of the runner 63 has a longitudinally extending notch formed therein that receives the gasket 66, which gasket 66 in turn engages the upper edges of the associated cups 53.

Also, the inside edges of the runners 62 and 63 have channel-shaped grooves formed therein, into which two busbars 67 and 68 are suitably secured by a number of screws 69, as illustrated in Fig. 13. The busbars 67 and 68 extend through openings formed in the end wall 43 of the skirt of the cover 37 to the exterior, as clearly illustrated in Figs. 2 and 5. The space between the ends of the busbars 67 and 68 and the walls of the openings formed in the end wall 43, through which the busbars extend, are suitably packed in order to preserve the gastight character of the casing 27. Finally, the extremities of the busbars 67 and 68 are secured together by a laterally extending conducting strap 70 that is connected to an electrical terminal 71, for a purpose more fully explained hereinafter.

In view of the foregoing description of the construction and arrangement of the runners 62 and 63 carried by the side walls 41 and 42 of the skirt of the cover 37, it will be understood that the busbars 67 and 68, respectively carried by the runners 62 and 63, are disposed within the confines of the cover 37 and extend longitudinally over the ends of the cups 53. A plurality of laterally aligned and longitudinally spaced-apart electrically conducting resilient clips 72 are secured to the upper surfaces of the busbars 67 and 68. As clearly illustrated in Fig. 14, the clip 72 is secured to the associated busbar 68 by a screw 73.

A plurality of laterally extending plate-like elements 74, formed of graphite or the like, are carried by the aligned pairs of clips 72 in longitudinally spaced-apart relation and extending into the anode compartments 54 defined within the cups 53. More particularly, each of the anode elements 74 is provided with a pair of laterally and oppositely extending lugs 75 that are received by the associated pair of laterally aligned clips 72, whereby the anode elements 74 are carried by the busbars 67 and 68 in good electrical contact therewith. Accordingly, the cover 37 carries the anode structure in its entirety, including the electrical terminal 71, the busbars 67 and 68, the clips 72, and the anode elements 74. The anode elements 74 are so constructed and arranged that they extend into contact with the bottom walls of the cups 53 and have a length substantially commensurate with the side walls of the cups 53, whereby a maximum surface of each anode element 74 is arranged within the anode compartment 54 defined in the associated cup 53.

The frame 45 carries a longitudinally extending shaft 76 adjacent the upper edges of the cross stringers 48, 49, and 50, and substantially intermediate the side stringers 46 and 47, the shaft 76 extending through aligned openings formed in the cross stringers mentioned and being rigidly secured in place by three setscrews 77, as best shown in Figs. 5 and 6. Also, the frame 45 carries two longitudinally extending and substantially parallel laterally spaced-apart drive shafts 78 and 79; the shaft 78 extends through aligned openings formed in the cross stringers 48, 49, and 50 closely adjacent to and below the side stringer 46, while the shaft 79 extends through aligned openings formed in the cross stringers mentioned closely adjacent to and below the side stringer 47. The shafts 78 and 79 are journaled for rotation, and in the interests of brevity, only the arrangement for rotatably supporting the shaft 78 is described in detail. More particularly, three bearing bushings 80, 81, and 82 are respectively arranged in the openings mentioned formed in the cross stringers 48, 49, and 50 and are restrained against rotation by three associated keys 83, 84, and 85. Three complementary bearing bushings 86, 87, and 88 are rigidly secured to the drive shaft 78 and respectively engage the bearing bushings 80, 81, and 82. More specifically, the bushings 86 and 88 are carried by the drive shaft 78 adjacent the opposite ends thereof, while the bushing 87 is carried by the drive shaft 78 adjacent the intermediate portion thereof. Preferably, the bearing bushings 80, 81, and 82 are formed of graphite, while the complementary bearing bushings 86, 87, and 88 are formed of a conventional synthetic resin of high electrical and chemical resistance. This arrangement is very advantageous in view of the fact that the bushings 86, 87, and 88 are acid-resistant and the graphite bushings 81, 82, and 83 lubricate the respectively associated bushings in order to minimize friction. In view of the foregoing explanation, it will be understood that the frame 45 rigidly supports the shaft 76 and rotatably supports the shafts 78 and 79.

A plurality of disk-like members 89, formed of nickel or the like, are supported upon the shaft 76 for independent rotation, and constitute cathode members extending downwardly adjacent to the bottom wall 32 of the casing 27 and upwardly into the cathode compartments 61 arranged between the cups 53. The cathode members 89 are disposed in longitudinally spaced-apart relation along the shaft 76 by an arrangement comprising a plurality of associated bushings 90 that are preferably formed of a conventional synthetic resin of high electrical and chemical resistance and surround the shaft 76. As best shown in Fig. 11, each of the cathode members 89 has a centrally disposed opening formed therein engaging an annular shoulder 91 formed on the associated bushing 90, and is clamped in place between the annular shoulder 91 and an adjacent clamping ring 92, arranged in threaded engagement with a tubular portion 93 of the associated bushing 90. Accordingly, the cathode members 89 are rotatably mounted independently of each other upon the

shaft 76 and are retained in proper longitudinally spaced-apart relation by the associated bushings 90.

Reconsidering the construction and arrangement of the cups 53, the anode elements 74, and the cathode members 89 in the embodiment of the electrolytic cell 23 illustrated, eleven cups 53 are provided, defining eleven corresponding anode compartments 54 disposed between the cups 53. Accordingly, eleven anode elements 74 are respectively disposed in the eleven anode compartments 54 and ten cathode members 89 are carried by the shaft 76 and extend into the ten cathode compartments 61.

The rotatable drive shaft 79 carries five friction-drive members 94, operatively associated with the five odd ones of the cathode members 89 carried by the shaft 76; and the rotatable drive shaft 78 carries five friction-drive members 95, operatively associated with the five even ones of the cathode members 89 carried by the shaft 76. More particularly, the five friction-drive members 94 are rigidly secured to the drive shaft 79 and engage the peripheral portions of the respectively associated five odd cathode members 89, whereby the five odd cathode members 89 are driven in the same direction in response to rotation of the drive shaft 79; while the five friction-drive members 95 are rigidly secured to the drive shaft 78 and engage the peripheral portions of the respectively associated five even cathode members 89, whereby the five even cathode members 89 are driven in the same direction in response to rotation of the drive shaft 78. Thus, the five odd cathode members 89 are driven by the drive shaft 79 and the five even cathode members 89 are independently driven by the drive shaft 78.

The friction-drive members 94 and 95 are of identical construction, and in the interests of convenience the structural details of only one of the friction-drive members 95 is illustrated in Fig. 12. More specifically, the friction-drive member 95 includes a tubular element 96, surrounding the associated drive shaft 78 and rigidly secured thereto by a setscrew 97. The tubular element 96 has an annular shoulder 98 formed thereon and supports two metal disks 99 and 100 and an intervening resilient disk 101, formed of a suitable chloroprene type of rubber or the like. The resilient disk 101 is clamped between the two metal disks 99 and 100 by an arrangement including a nut 102 engaging a threaded portion 103 of the tubular element 96, the metal disk 99 engaging the annular shoulder 98 and the metal disk 100 engaging the nut 102. Preferably, the resilient disk 101 has an annular groove 104 formed in the peripheral edge thereof that engages the peripheral edge of the associated cathode member 89. The desired amount of friction between the friction-drive member 95 and the associated cathode member 89 may be readily obtained merely by adjusting the position of the nut 102 on the associated threaded portion 103 of the tubular element 96, and the consequent compression and resulting expansion of the resilient disk 101.

The lower portion of the casing 27 contains a liquid metal pool 105, preferably mercury, the upper surface of the liquid metal pool 105 being disposed just below the bottom walls of the cups 53 and immersing the drive shafts 78 and 79, and consequently the lower segments of the cathode members 89. The cathode compartments 61, connected together by the sinuous passage 56, contain a body of catholyte 106 that is to be treated electrolytically, the body of catholyte 106 floating upon the upper surface of the liquid metal pool 105 and extending slightly above the upper segments of the cathode members 89 immersed therein. The anode compartments 54 formed in the cups 53 contain a body of anolyte 107 extending slightly above the upper segments of the cathode members 89 and immersing the lower portions of the anode elements 74 arranged in the anode compartments 54.

Fresh liquid metal is supplied to the liquid metal pool 105 by an arrangement including a conduit 108 extending through an opening provided in the top wall 40 of the cover 37 into the cathode compartments 61 disposed between the two cups 53 arranged adjacent the end wall 30; and catholyte that is to be treated electrolytically is supplied to the body of catholyte 106 by an arrangement including a conduit 109 extending through an opening provided in the top wall 40 of the cover 37 into the cathode compartment 61 disposed between the two cups 53 arranged adjacent the end wall 30. Contaminated liquid metal is removed from the liquid metal pool 105 adjacent the end wall 31 by an arrangement including siphon mechanism 110; and catholyte that has been treated electrolytically is removed from the body of catholyte 106 adjacent the end wall 31 by an arrangement including siphon mechanism 111. Accordingly, catholyte that is to be treated is supplied to the electrolytic cell 23 adjacent the end wall 30 of the casing 27, and catholyte that has been treated is removed from the electrolytic cell 23 adjacent the end wall 31 of the casing 27, whereby the catholyte is conducted through the cathode compartments 61 in series relation through the sinuous passage 56 from one end to the other.

In order to insure movement of the catholyte through the sinuous passage 56 from end to end thereof and in the manner explained above, odd ones of the cathode members 89 are rotated in a counterclockwise direction on the shaft 76, and even ones of the cathode members 89 are rotated in a clockwise direction on the shaft 76, as viewed in Fig. 8, whereby adjacent ones of the cathode members 89 are rotated in opposite directions. Accordingly, the body of catholyte 106 is propelled by the rotation of adjacent ones of the cathode members 89 in opposite directions from end to end in the sinuous passage 56, from the point of supply adjacent to the end wall 30 to the point of removal adjacent to the end wall 31. Rotation of odd ones of the cathode members 89 in the counterclockwise direction on the shaft 76, and rotation of even ones of the cathode members 89 in the clockwise direction on the shaft 76 is obtained by effecting rotation of the respectively associated drive shafts 79 and 78, respectively in the clockwise direction and the counterclockwise direction, as viewed in Fig. 8.

More particularly, the outer end of the drive shaft 78 disposed adjacent to the end wall 31 has a bevel gear 112 rigidly secured thereto that meshes with a bevel gear 113 rigidly secured to a shaft 114 arranged in an elongated opening formed in the post 51 of the frame 45; while the outer end of the drive shaft 79 disposed adjacent to the end wall 31 has a bevel gear 115 rigidly secured thereto that meshes with a bevel gear 116 rigidly secured to a shaft 117 arranged in an elongated opening formed in the post 52. Sealing gaskets 51*a* and 52*a*, formed of a suitable chloroprene type of rubber or the like, are respectively arranged between the upper ends of the posts 51 and 52 and the adjacent lower surface of the block 33 in surrounding relation with respect to the shafts 114 and 117 respectively, thereby to preserve the gastight character of the casing 27. The lower ends of the shafts 114 and 115 are suitably journaled in the lower ends of the openings formed in the posts 51 and 52, respectively. The arrangement for journaling the lower end of the shaft 114 in the lower end of the opening formed in the post 51 is best illustrated in Fig. 5, and comprises two complementary bearing bushings 118 and 119, the bearing bushing 118 being rigidly secured to the shaft 114 and the bearing bushing 119 being rigidly secured in a recess formed in the lower portion of the post 51. Preferably, the bearing bushing 118 carrying the shaft 114 is formed of a conventional synthetic resin of high electrical and chemical resistance, while the complementary bearing bushing 119 is formed of graphite for the purpose previously noted.

The upper end of the shaft 114 is supported by a thrust bearing 120 of the ball bearing type, including a lower ball race 121 surrounding the shaft 114 and rigidly secured to the block 33, and an upper ball race 122 surrounding the

shaft 114 and rigidly secured thereto; while the upper end of the shaft 117 is supported by a thrust bearing 123 of the ball bearing type, including a lower ball race 124 surrounding the shaft 117 and rigidly secured to the block 33, and an upper ball race 125 surrounding the shaft 117 and rigidly secured thereto.

As best shown in Fig 1, the shaft 114 is secured by a coupling member 126 to a shaft 127, rotatably journaled in a supporting bearing 128 carried by the support 22; while the shaft 117 is secured by a coupling member 129 to a shaft 130, rotatably journaled in a supporting bearing 131 carried by the support 22. Further, the electric drive motor 24 is provided with a shaft 132 that is secured by a coupling member 133 to a shaft 134, rotatably journaled in two supporting bearings 135 carried by the support 22. Two bevel gears 136 and 137 are rigidly secured to the shaft 134 and respectively mesh two bevel gears 138 and 139, respectively, rigidly secured to the shafts 130 and 127.

Accordingly, when the electric drive motor 24 is operated, the shafts 132 and 134 are rotated in the counterclockwise direction as viewed from the right hand side of Fig. 1, effecting rotation of the shafts 130 and 127 respectively in the clockwise and counterclockwise direction as viewed from the top of Fig. 1. Rotation of the shafts 130 and 127, and consequently the connected shafts 117 and 114 respectively in the clockwise and counterclockwise directions, as viewed from the top in Figs. 1 and 6, effects rotation of the drive shafts 79 and 78 respectively in the clockwise and counterclockwise directions as viewed in Fig. 6. Finally, rotation of the drive shaft 79 in the clockwise direction effects rotation of odd ones of the cathode members 89 in the counterclockwise direction as viewed in Fig. 8, while rotation of the drive shaft 78 in the counterclockwise direction effects rotation of even ones of the cathode members 89 in the clockwise direction as viewed in Fig. 8; all in the manner previously explained, in order to effect propulsion of the catholyte through the sinuous passage 56 from one end to the other for the purpose previously noted.

Considering now the construction and arrangement of the siphon mechanism 110 in greater detail with particular reference to Figs. 6, 7, and 10; as previously noted, the cross stringer 50 of the frame 45 is spaced some distance from the adjacent end wall 31 of the casing 27 in order to provide a cavity 140 therebetween disposed between the lower ends of the posts 51 and 52, which cavity 140 communicates with the liquid metal pool 105 and is consequently filled with liquid metal. More particularly, a series of holes 141 is formed in the cross stringer 50, affording communication between the cavity 140 and the remainder of the lower portion of the casing 27 containing the liquid metal pool 105 in which the lower segments of the cathode members 89 are immersed. A relatively deep cylindrical cup 142 is arranged within the cavity 140, the upper open top of the cup 142 communicating with the liquid metal in the cavity 140 adjacent the upper surface of the liquid metal pool 105, whereby liquid metal spills into the cup 142. This arrangement of the cup 142 in the cavity 140 constitutes a trap, whereby liquid metal from the liquid metal pool 105 adjacent the upper surface thereof falls into the cup 142; which arrangement is highly desirable in view of the fact that it insures removal of impurities and contaminated liquid metal in the liquid metal pool 105 that tend to accumulate on the upper surface of the liquid metal pool 105. More specifically, the siphon mechanism 110 comprises an inverted substantially U-shaped tube 143, secured to the end of the block 33 and the associated end wall 31 of the casing 27 by two clips 33*a* and 31*a*, respectively. An inner end 144 of the U-shaped tube 143 extends through an opening formed in the upper surface of the block 33 and downwardly into the cup 142; while an outer end 145 of the U-shaped tube 143 terminates in an upstanding open column 146 that communicates with a downwardly turned tube 147 connected to an outlet conduit 148, through which liquid metal is removed to the exterior. Accordingly, it will be understood that liquid metal falling into the cup 142 from the upper surface of the liquid metal pool 105 is conducted through the substantially U-shaped tube 143 to the outlet conduit 148 and to the exterior.

Considering now the construction and arrangement of the siphon mechanism 111 in greater detail with particular reference to Figs. 6, 7, and 10, it is noted that this mechanism comprises an inverted substantially U-shaped tube 149, secured to the end of the block 33 and the associated end wall 31 of the casing 27 by the two clips 33*a* and 31*a*, respectively. An inner end 150 of the U-shaped tube 149 extends through an opening formed in the upper surface of the block 33 and downwardly into the body of catholyte 106 floating on the liquid metal pool 105; while an outer end 151 of the U-shaped tube 149 terminates in an upstanding open column 152 that communicates with a downwardly turned tube 153 connected to an outlet conduit 154, through which catholyte that has been treated electrolytically is removed to the exterior. Accordingly, it will be understood that catholyte that has been treated electrolytically in the body of catholyte 106 is conducted through the substantially U-shaped tube 149 to the outlet conduit 154 and to the exterior.

During operation of the electrolytic cell 23, gases are liberated by the body of catholyte 106, as well as by the body of anolyte 107, and are accumulated in the upper portion of the casing 27 and the cover 37. These gases are removed to the exterior by an arrangement comprising a pipe 155 threaded into an opening formed in the end wall 43 of the cover 37. Also, the gases mentioned have a tendency to be trapped in the liquid metal removed by the siphon mechanism 110 and in the catholyte removed by the siphon mechanism 111 as previously explained, which gases trapped in the liquid metal removed and in the catholyte removed tend to break the siphoning action in the siphon mechanisms 110 and 111, respectively. In order to obviate this difficulty and to prevent interference with the siphoning actions of the siphon mechanisms 110 and 111, the previously-mentioned pumping mechanism, including the vacuum pump 25, is operatively connected to the siphon mechanisms 110 and 111. More specifically, the bend in the substantially U-shaped tube 143 forming a part of the siphon mechanism 110 communicates with an upstanding tube 156, while the bend in the substantially U-shaped tube 149 which forms a part of the siphon mechanism 111 communicates with an upstanding tube 157; which tubes 156 and 157 are connected by a manifold 158 to an inlet conduit 159 extending to the vacuum pump 25, the vacuum pump 25 being connected to an exhaust conduit 160. Accordingly, it will be understood that when the electric motor 26 is operated, the associaed vacuum pump 25 exhausts gas accumulating in the bends in the two substantially U-shaped tubes 143 and 149 through the connecting tubes 156 and 157, the manifold 158, and the inlet conduit 159, which gases are discharged through the exhaust conduit 160. Accordingly, the pumping mechanism described above prevents interference with the siphoning action of the siphon mechanism 110 and 111 by gases trapped in the liquid metal and in the catholyte that are respectively removed by the siphon mechanisms 110 and 111 from the casing 27.

Also, the end of the block 33 supports cathode terminal structure including a conductor 161 extending into the cavity 140 into contact with the liquid metal therein. More particularly, the upper end of the conductor 161 is secured to a hollow bushing 162 that extends through an opening formed in the end of the block 33, which bushing is retained in position by an arrangement in-

cluding a nut 163 engaging the threaded outer end of the bushing 162. Further, a gasket 164, formed of a suitable chloroprene type of rubber or the like, is arranged between the nut 163 and the adjacent end of the block 33 in surrounding relation with respect to the bushing 162, in order to preserve the gastight character of the casing 27. The hollow bushing 162 accommodates a conducting rod 165 extending therethrough, the inner end of the rod 165 being threaded into a tapped hole formed in the conductor 161. A conducting fixture 166 is rigidly secured to the outer end of the rod 165 and is in turn connected to an electrical terminal 167. Accordingly, it will be understood that the block 33 carries a portion of the cathode structure including the electrical terminal 167 and the conductor 161 extending into electrical contact with the liquid metal contained in the cavity 140, and consequently the liquid metal pool 105. Further, it will be understood that the cathode structure comprises the liquid metal pool 105 and the contacting cathode members 89.

In the construction and arrangement of the electrolytic cell 23, the component parts thereof are formed of materials that resist corrosive actions characteristic of the chemicals being treated. When the electrolytic cell 23 is utilized in the treatment of a calutron wash solution, the example disclosed below, hydrochloric acid and chlorine gas are encountered, and the component parts of the electrolytic cell are formed of materials that resist the corrosive action of these chemicals. More specifically, the casing 27, the frame 45, and similar parts are preferably formed of a conventional synthetic resin of high electrical and chemical resistance or other material of this character that resists the corrosive action of the chemicals mentioned; while the various gaskets 35 and 39 and similar parts are preferably formed of a suitable chloroprene type of rubber or other material of this character that resists the corrosive action of the chemicals mentioned.

Considering now the mode of operation of the electrolytic cell 23 in conjunction with the treatment of a calutron wash solution, which example has been selected for the purpose of demonstrating the particular utility of the electrolytic cell 23, it is noted that a solution of this character is normally about 3 N in hydrochloric acid, and usually contains the following ions: UO_2^{++}, Fe^{+++}, Cu^{++}, Ni^{++}, and Cr^{+++}. A calutron wash solution of the hydrochloric acid and ionic composition specified may be prepared in the manner disclosed in the copending application of Martin D. Kamen and Abel de Haan, Serial No. 542,378, filed June 27, 1944. Initially, liquid metal, mercury, is admitted through the conduit 108 in order to fill the lower portion of the casing 27 and to provide the liquid metal pool 105 therein in the manner previously explained, the liquid metal in the liquid metal pool 105 standing in the lower portion of the casing 27 to a height just below the bottom walls of the cups 53. Hydrochloric acid, about 3 N, is placed in the anode compartments 54 in the cups 53 in order to provide the body of anolyte 107 in the manner previously explained, the level of the body of anolyte 107 in the anode compartments 54 standing just above the upper segments of the cathode members 89, as previously noted. Hydrochloric acid, about 3 N, is admitted through the conduit 109 in order to fill the cathode compartments 61 and the sinuous passage 56, and to provide the body of catholyte 106 therein in the manner previously explained, the level of the body of catholyte 106 in the cathode compartments 61 and the sinuous passage 56 standing just above the upper segments of the cathode members 89, as previously noted. At this time, the lower segments of the cathode members 89 are immersed in the liquid metal pool 105, while the upper segments of the cathode members 89 are immersed in the body of catholyte 106; and the lower portions of the anode elements 74 are immersed in the body of anolyte 107.

At this time, the circuit including an associated source of direct current supply is completed between the electrical terminals 71 and 167, these terminals being respectively positive and negative, whereby electrolysis in the electrolytic cell 23 is initiated. Operation of the electric motor 24 is initiated, whereby odd ones of the cathode members 89 are rotated in the counterclockwise direction and even ones of the cathode members 89 are rotated in the clockwise direction, as viewed from the right in Fig. 5, whereby the catholyte in the cathode compartments 61 is propelled through the sinuous passage 56 in the casing 27 from the end wall 30 toward the end wall 31. Also, operation of the electric motor 26 is initiated, whereby the vacuum pump 25 is operated in order to cause the bends in the substantially U-shaped tubes 143 and 149, respectively, of the siphon mechanisms 110 and 111, to be evacuated, for the purpose previously explained. At this time, fresh liquid metal is continuously conducted through the conduit 108 into the liquid metal pool 105 and removed by the siphon mechanism 110 from the cup 142 and discharged through the conduit 148, in the manner previously explained; while the calutron wash solution of the character and composition previously mentioned is continuously conducted as catholyte that is to be treated through the conduit 109 into the body of catholyte 106 and removed by the siphon mechanism 111 and discharged through the conduit 154, in the manner previously explained.

During operation of the electrolytic cell 23, at least some of the ions in the catholyte 106 are reduced from the higher oxidation state to the lower oxidation state as it is conducted through the cathode compartments 61 and the sinuous passage 56. More particularly, the established rate of flow of the catholyte through the electrolytic cell 23, under standard operating conditions, is such that the uranyl ion, UO_2^{++}, and the ferric ion, Fe^{+++}, are respectively reduced by the electrolytic current to the uranous ion, U^{++++}, and the ferrous ion, Fe^{++}. Of course it will be understood that a small amount of the ions Cu^{++}, Ni^{++}, Fe^{++}, and Cr^{+++} are completely reduced to the metal states Cu^0, Ni^0, Fe^0, and Cr^0 by the electrolytic current, which metal impurities in the body of catholyte 106 are carried by the rotating cathode members 89 into the liquid metal pool 105. The metal impurities carried into the liquid metal pool 105 are either trapped therein or amalgamated therewith, whereby the body of catholyte 106 is kept free of metal impurities liberated therein incident to the electrolysis. Specifically, the copper, chromium, and nickel impurities readily amalgamate with the mercury in the liquid metal pool 105, whereas the iron impurity is trapped therein. On the other hand, none of the uranous ion, U^{++++}, is completely reduced to the metal state, U^0, due to the fact that it inherently possesses a high overvoltage.

Further, it will be understood that the rotation of the cathode members 89 is effective not only to propel the body of catholyte 106 through the sinuous passage 56 in the casing 27 from the end wall 30 toward the end wall 31, as well as to carry the metal impurities from the body of catholyte 106 into the liquid metal pool 105, in the manner previously explained, but it also agitates the body of catholyte 106 and the liquid metal pool 105 in order to facilitate the electrolysis. Finally, the constant rotation of the cathode members 89 causes a freshly amalgamated surface thereof to be presented from the liquid metal pool 105 to the body of catholyte 106, thereby maintaining substantially constant the internal resistance of the electrolytic cell 23 and consequently the electrolytic current therethrough.

Incident to operation of the electrolytic cell 23, the anion Cl^- migrates through the walls of the cups 53 to the anode elements 74 disposed in the anode compartments 54, whereby some chlorine gas is liberated and escapes from the anode compartments 54 into the upper portion of the casing 27 and the cover 37, which chlorine gas,

along with any other gases or vapor present, is exhausted through the pipe **155** to the exterior. Of course, some of this chlorine gas is trapped in the body of anolyte **107** disposed in the anode compartments **54**; however, substantially none of it migrates through the porous walls of the cups **53** into the body of catholyte **106** disposed in the cathode compartments **61**, due to the character of the porous walls of the cups **53**, the porosity of the walls of the cups **53** accommodating conduction of the electrolytic current therethrough but substantially preventing the migration of chlorine therethrough, whether in the vapor phase or in ionic form in the two bodies of electrolyte. This arrangement is very advantageous, in view of the fact that the chlorine does not contaminate the body of catholyte **106** disposed in the cathode compartments **61**, whereby the oxidizing effect of chlorine on the ions in the body of catholyte **106** is eliminated. In passing, it is noted that chlorine gas possesses a high oxidizing potential and is capable of oxidizing readily the uranous ion, U^{++++}, back to the uranyl ion, UO_2^{++}, as well as oxidizing the ferrous ion, Fe^{++}, back to the ferric ion, Fe^{+++}, thereby preventing efficient operation of the electrolytic cell **23**. However, this difficulty is overcome, due to the construction of the cups **53**, whereby the electrolytic cell **23** operates efficiently substantially entirely to reduce the uranyl and ferric ions to the uranous and ferrous ions, as previously noted.

Further, it is pointed out that the metal impurities trapped, as well as the amalgam produced in the liquid metal pool **105**, are relatively light with respect to the mercury in the liquid metal pool **105**, and have a tendency to float on the upper surface of the liquid metal pool **105**; which metal impurities and amalgam fall into the cup **142**, due to the trap arrangement previously described, and are removed to the exterior in the manner previously explained. At this point, it is again noted that the pumping mechanism, including the vacuum pump **25**, prevents interference with the normal siphoning operation of the siphon mechanisms **110** and **111** respectively to remove the liquid metal from the cup **142** and to remove the catholyte that has been treated from the body of catholyte **106**. The liquid metal discharged from the casing **27** through the conduit **148** may be reprocessed for reuse in any suitable manner; while the catholyte that has been treated which is discharged from the casing **27** through the conduit **154** is subjected to further treatment in the manner disclosed in the previously-mentioned copending application of Kamen and De Haan.

In view of the foregoing, it will be apparent that there has been provided an electrolytic cell of improved construction and arrangement that is especially adapted for use in conjunction with the reduction of ions contained in wash solutions derived from calutrons employed in the calutron method of producting uranium enriched with U^{235}.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An electrolytic cell comprising a casing including a pair of substantially parallel spaced-apart walls, a removable supporting frame arranged within the lower portion of said casing between said walls, a plurality of porous cups carried by said frame and arranged in spaced-apart staggered relation against said walls within the upper portion of said casing and defining therein both a plurality of compartments and an elongated sinuous passage disposed among said cups, a liquid metal pool contained in the lower portion of said casing and submerging at least a portion of said frame, means for blocking said cups in position, whereby odd ones of said cups are urged against a first one of said walls and even ones of said cups are urged against a second one of said walls in order to prevent said frame from being floated out of position by said liquid metal pool, said compartments being adapted to receive a first body of electrolyte and said sinuous passage being adapted to receive a second body of electrolyte and to provide a conducting channel therefor through said casing, a plurality of elements respectively disposed in said compartments and constituting a first electrode, and a plurality of members disposed in spaced-apart relation in said sinuous passage and constituting a second electrode.

2. In electrolytic cell comprising a casing, partition structure arranged within said casing and defining an elongated sinuous passage therein adapted to contain an electrolyte continuously moving through said casing, said sinuous passage including loops connected by straight segments, a plurality of rotatably mounted members respectively disposed in the straight segments of said sinuous passage and constituting an electrode in contact with said electroylte ad means for rotating odd ones of said members in one direction and even ones of said members in the oppositee direction in order to propel said electroylte through said sinuous passage.

3. An electrolytic cell comprising a casing, a plurality of porous cups adapted to contain an anolyte material and arranged in spaced-apart staggered relation within said casing and defining therein both a plurality of compartments and an elongated sinuous passage disposed among said compartments, said sinuous passage including loops connected by straight segments and adapted to contain a catholyte material, a plurality of elements respectively disposed in said compartments and constituting an anode in contact with the anolyte material therein, a plurality of rotatably mounted members respectively disposed in the straight segments of said sinuous passage and constituting a cathode in contact with the catholyte material therein, and means for rotating adjacent ones of said members in opposite directions in order to propel said catholyte material through said sinuous passage.

4. An electrolytic cell comprising in combination, a casing, a plurality of separate, movable, porous cups disposed in said casing and adapted to contain a first electrolyte, a sinuous passage within said casing defined by the exterior walls of said cups and the interior walls of said casing and adapted to contain a second electrolyte, a plurality of electrodes disposed in said cups in contact with said first electrolyte, a plurality of electrodes disposed in spaced-apart relation in said passage in contact with the second electrolyte, and separately adjustable positioning means extending through the side walls of said casing and contacting said cups for positioning the same with respect to the walls of said casing, whereby odd ones of said cups may be moved adjacent a first side wall of said casing and even ones of said cups may be moved adjacent a second side wall of said casing thereby to form said sinuous passage and to insure a predetermined path of flow of said second electrolyte through said casing.

5. An electrolytic cell comprising in combination, a casing, a removable supporting frame arranged within the lower portion of said casing, a plurality of separate porous cups supported by said frame and adapted to contain a first body of electrolyte, said cups being disposed in the upper part of said casing, a sinuous passage within said casing defined by the exterior walls of said cups and the interior walls of said casing and adapted to contain a second electrolyte, a liquid metal pool contained in the lower portion of said casing and submerging at least a portion of said frame, means positively holding said frame in position, a plurality of electrodes disposed in said cups in contact with said first electrolyte, and a plurality of electrodes disposed in spaced-apart relation in said passage in contact with said second electrolyte.

6. An electrolytic cell comprising in combination, a

casing, a plurality of porous cups disposed in said casing and adapted to contain a stationary body of a first electrolyte, a sinuous passage within said casing defined by the exterior walls of said cups and the interior walls of said casing and adapted to contain a continuously moving body of a second electrolyte to be treated in said cell, means for continuously introducing said untreated second electrolyte into said passage adjacent one end of said casing, means for continuously removing said treated second electrolyte from said passage adjacent another end of said casing, a plurality of rotating electrodes disposed in said passage and serving to propel said second electrolyte therethrough and a plurality of stationary electordes disposed in said cups in contact with the stationary body of first electrolyte therein.

7. In an apparatus as defined in claim 6, means for rotating a portion of said rotating electrodes in one direction and another portion of said rotating electrodes in another direction whereby the material impelled thereby moves from one end of said casing to the other end thereof.

8. An electrolytic cell comprising in combination, a casing, a porous partition structure arranged within the upper portion of said casing and defining a plurality of separate cups with a sinuous passage along the exterior thereof, said cups being adapted to contain a stationary body of a first electrolyte and a stationary electrode in contact with said first electrolyte, a liquid metal pool disposed in the lower portion of said casing, said passage being adapted to contain a moving body of a second electrolyte floating upon said liquid metal pool, a plurality of rotatably mounted electrode members arranged within said casing in spaced-apart series relation, the lower portions of said electrode members contacting said liquid metal pool and the upper portions thereof contacting said second electrolyte, and means for rotating adjacent ones of said electrode members in opposite directions in order to propel said second electrolyte through said passage.

9. An electrolytic cell comprising in combination, a casing, a porous partition structure arranged within the upper portion of said casing and defining a plurality of separate cups with a sinuous passage along the exterior thereof, said cups being adapted to contain a stationary body of a first electrolyte and a stationary electrode in contact with said first electrolyte, a liquid metal pool disposed in the lower portion of said casing, said passage being adapted to contain a moving body of a second electrolyte floating upon said liquid metal pool, a plurality of rotatably mounted electrode members arranged within said casing in spaced-apart series relation, the lower portions of said electrode members contacting said liquid metal pool and the upper portions of said members contacting said second electrolyte, a first drive shaft operatively connected to odd ones of said electrode members, a second drive shaft operatively connected to even ones of said electrode members, and means for rotating said first and second drive shafts so that adjacent ones of said electrode members are rotated in opposite directions in order to propel said second electrolyte through said passage.

10. An electrolytic cell comprising in combination, a casing, a porous partition structure arranged within the upper portion of said casing and defining a plurality of separate cups with a sinuous passage along the exterior thereof, said cups being adapted to contain a stationary body of a first electrolyte and a stationary electrode in contact with said first electrolyte, a liquid metal pool disposed in the lower portion of said casing, said passage being adapted to contain a moving body of a second electrolyte floating upon said liquid metal pool, a plurality of rotatably mounted disks forming a second electrode and arranged within said casing in spaced-apart series relation, the lower portions of said disks contacting said liquid metal pool and the upper portions of said disks contacting said second electrolyte, a first drive shaft arranged within said casing and frictionally engaging the peripheral portions of odd ones of said disks, a second drive shaft arranged within said casing and frictionally engaging the peripheral portions of even ones of said disks, and means for rotating said first and second drive shafts in opposite directions, whereby adjacent ones of said disks are rotated in opposite directions in order to propel said second electrolyte through said passage.

11. An electrolytic cell comprising in combination, a casing, a porous partition structure arranged within the upper portion of said casing and defining a plurality of separate cups with a sinuous passage along the exterior thereof, said cups being adapted to contain a stationary body of a first electrolyte and a stationary electrode in contact with said first electrolyte, a liquid metal pool disposed in the lower portion of said casing, said passage being adapted to contain a moving body of a second electrolyte floating upon said liquid metal pool, a supporting frame arranged within the lower portion of said casing and carrying a shaft, a plurality of independently rotatable disks mounted in spaced-apart relation on said shaft and forming a second electrode, the lower portions of said disks contacting said liquid metal pool and the upper portions of said disks contacting said second electrolyte, and drive means carried by same frame for selectively rotating said disks in order to propel said second electrolyte through said passage.

References Cited in the file of this patent

UNITED STATES PATENTS

386,073	Jewell	July 10, 1888
489,216	Calhoun et al.	Jan. 3, 1893
507,130	Hoepfner	Oct. 24, 1893
699,415	Reed	May 16, 1902
892,983	Digby	July 14, 1908
870,915	Vreeland	Nov. 12, 1907
1,147,989	Towne	July 27, 1915
1,655,781	Caraccio	Jan. 10, 1928
1,712,952	Creighton	May 14, 1929
1,732,797	Eustis	Oct. 22, 1929
1,745,348	Aubel	Feb. 4, 1930
1,782,909	Pike	Nov. 25, 1930
2,109,975	Ott	Mar. 1, 1938
2,234,967	Gilbert	Mar. 18, 1941

FOREIGN PATENTS

8,837	Great Britain	of 1891
484,689	France	Aug. 7, 1917

OTHER REFERENCES

Trans. Electrochemical Soc., vol. 67 (1935), page 359.