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CONSTRUCTION OF CONTINUOUS ELECTRODE FOR A REDUCTION CELL

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Fig.1.

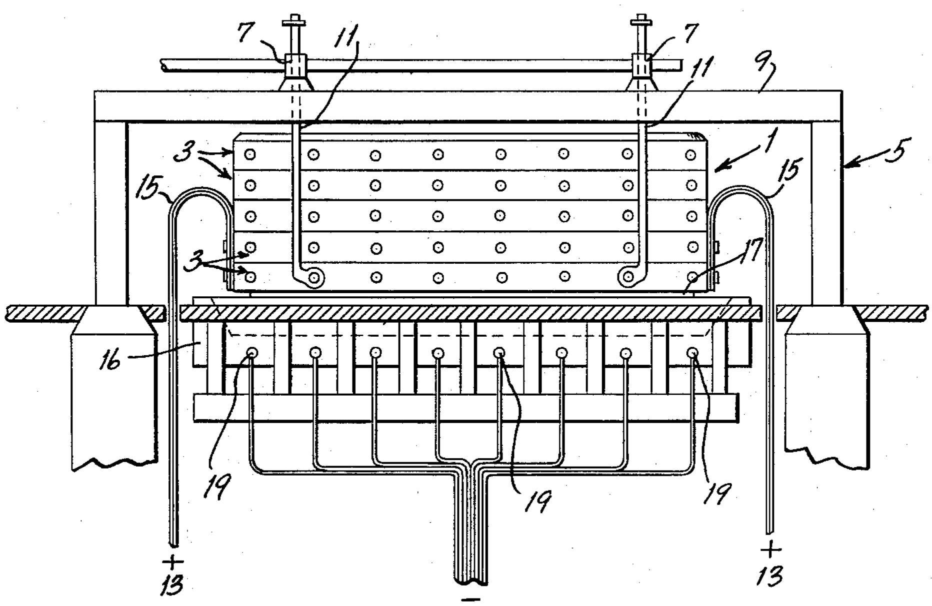
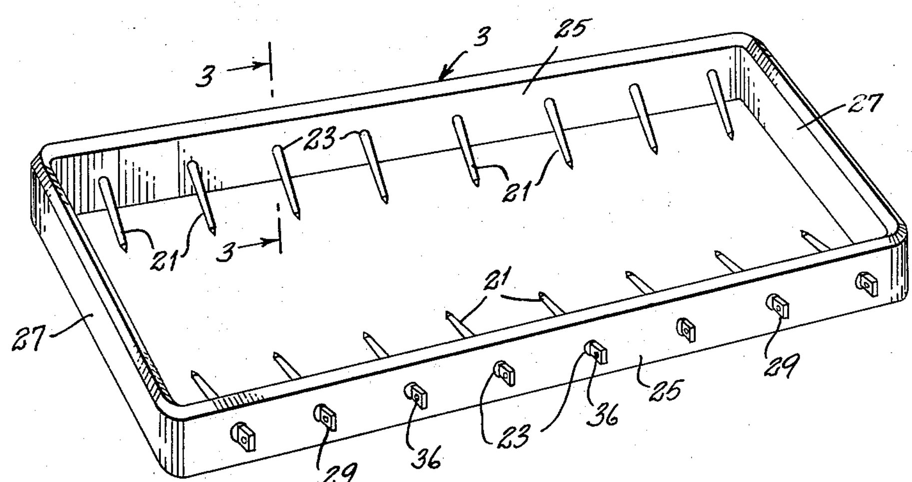


Fig.2.



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ATTORNEY

Fig. 3.

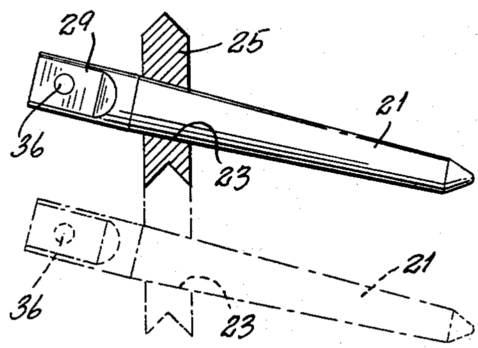

Fig. 4.

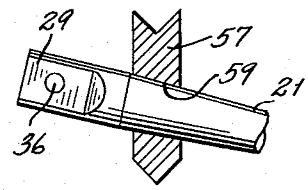

Fig. 5.

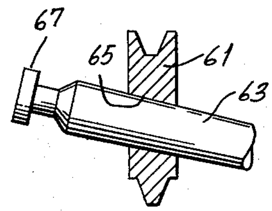

Fig. 6.

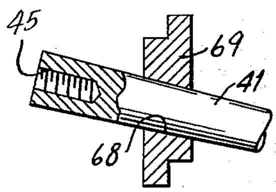

Fig. 7.

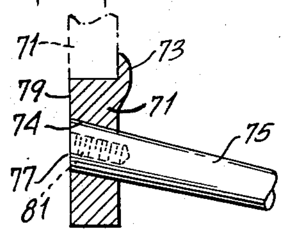

Fig. 8.

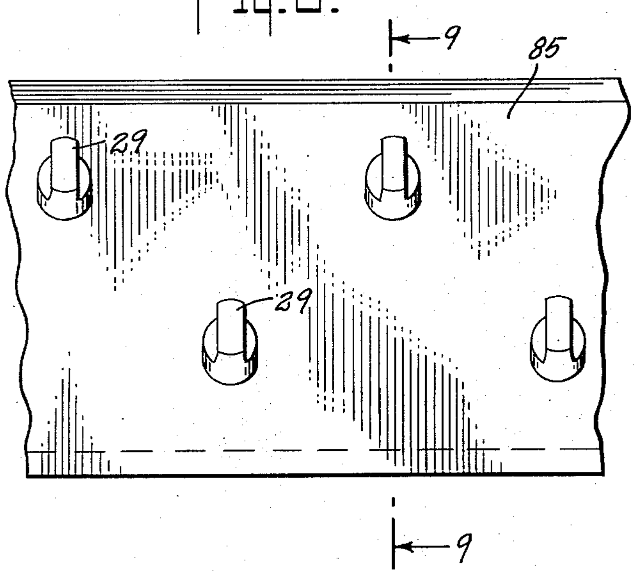

Fig. 9.

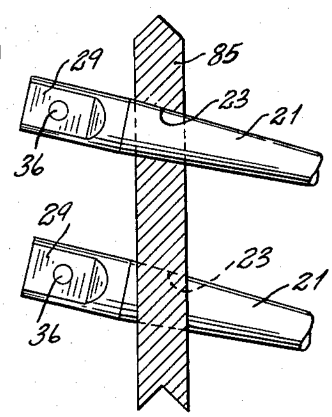

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Fig. 10.

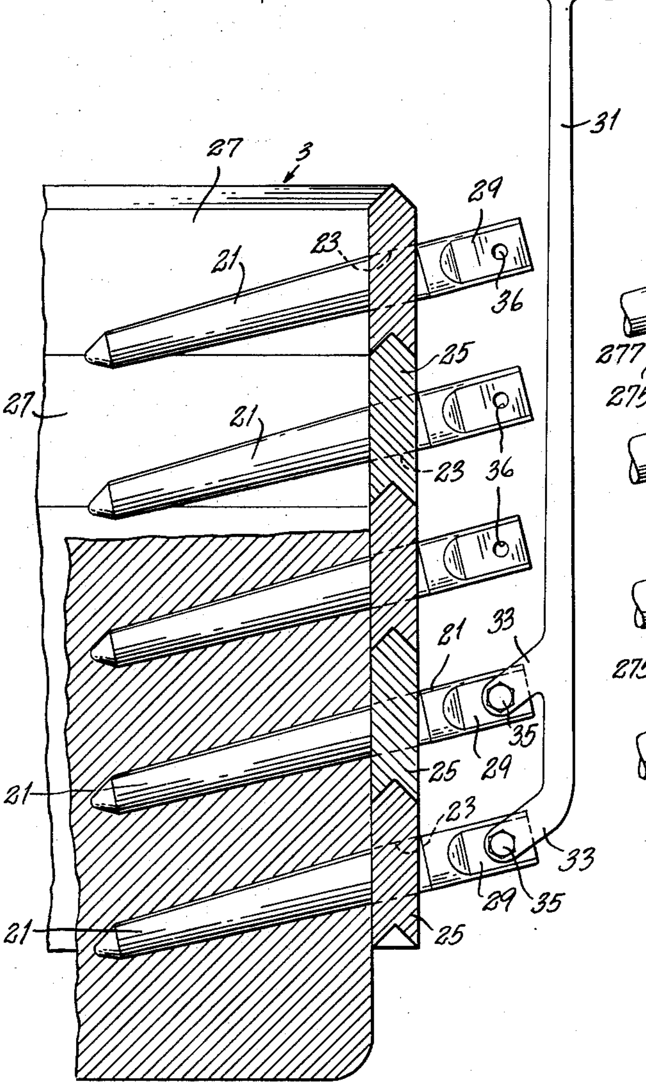
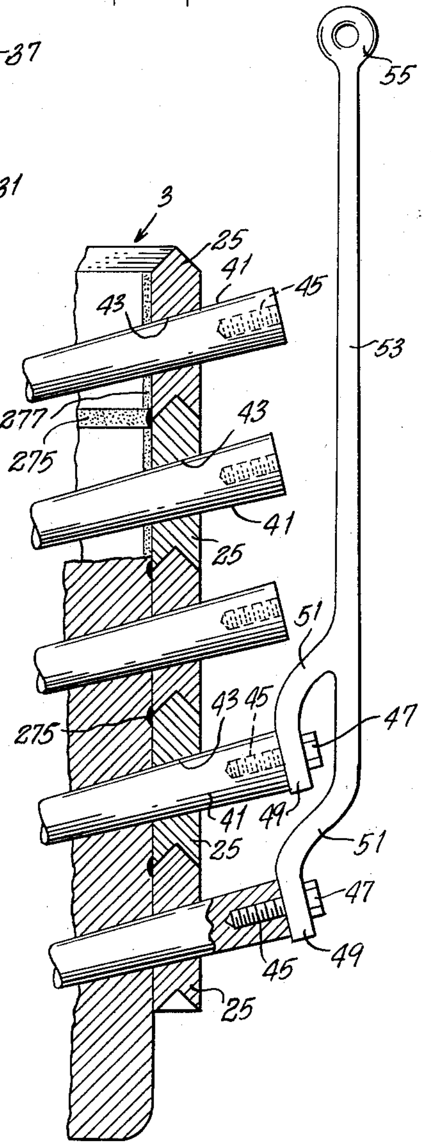


Fig. 11.



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CONSTRUCTION OF CONTINUOUS ELECTRODE FOR A REDUCTION CELL

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Fig. 13.

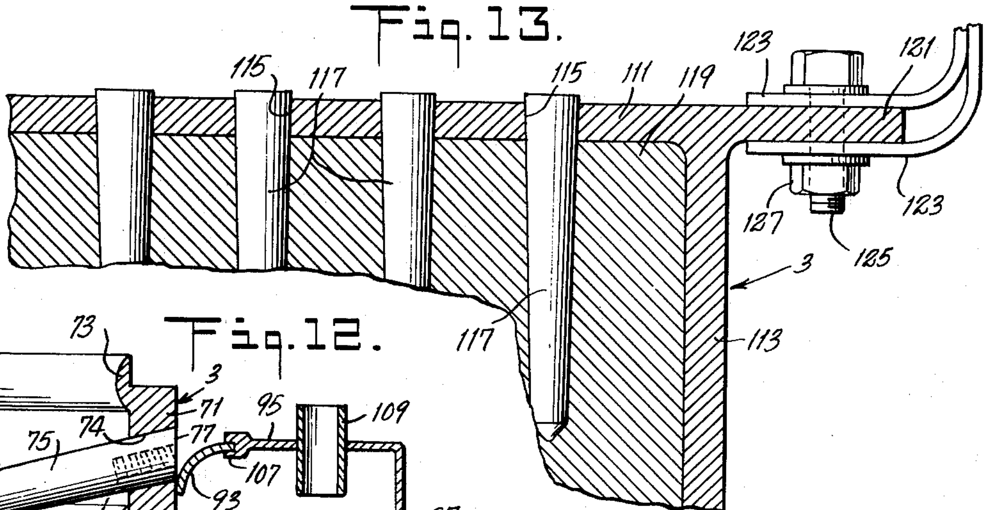


Fig. 12.

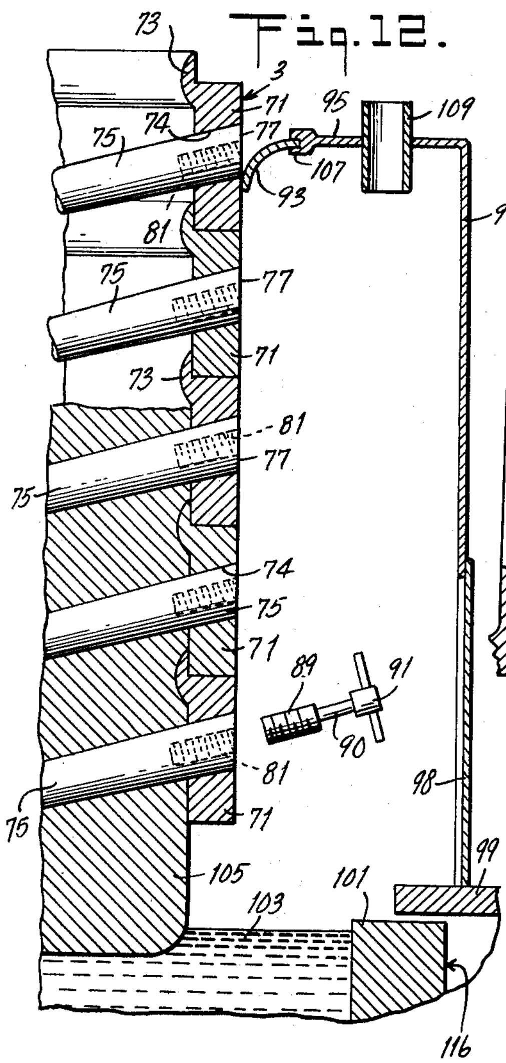


Fig. 14.

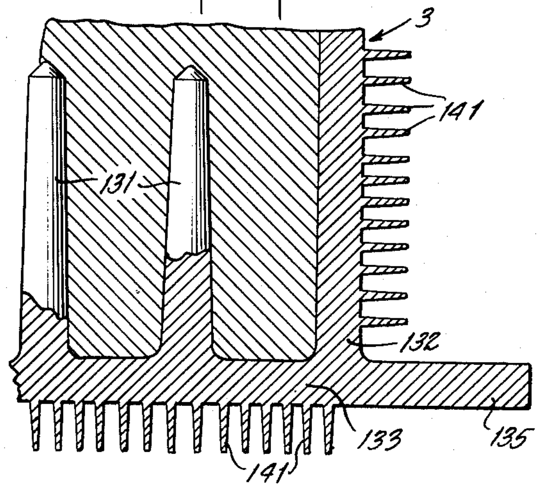
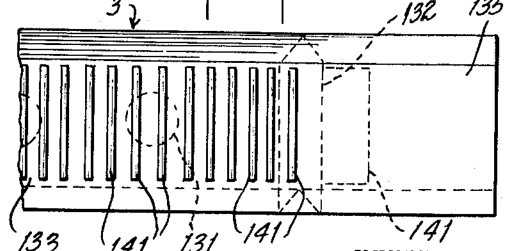


Fig. 15.



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CONSTRUCTION OF CONTINUOUS ELECTRODE FOR A REDUCTION CELL

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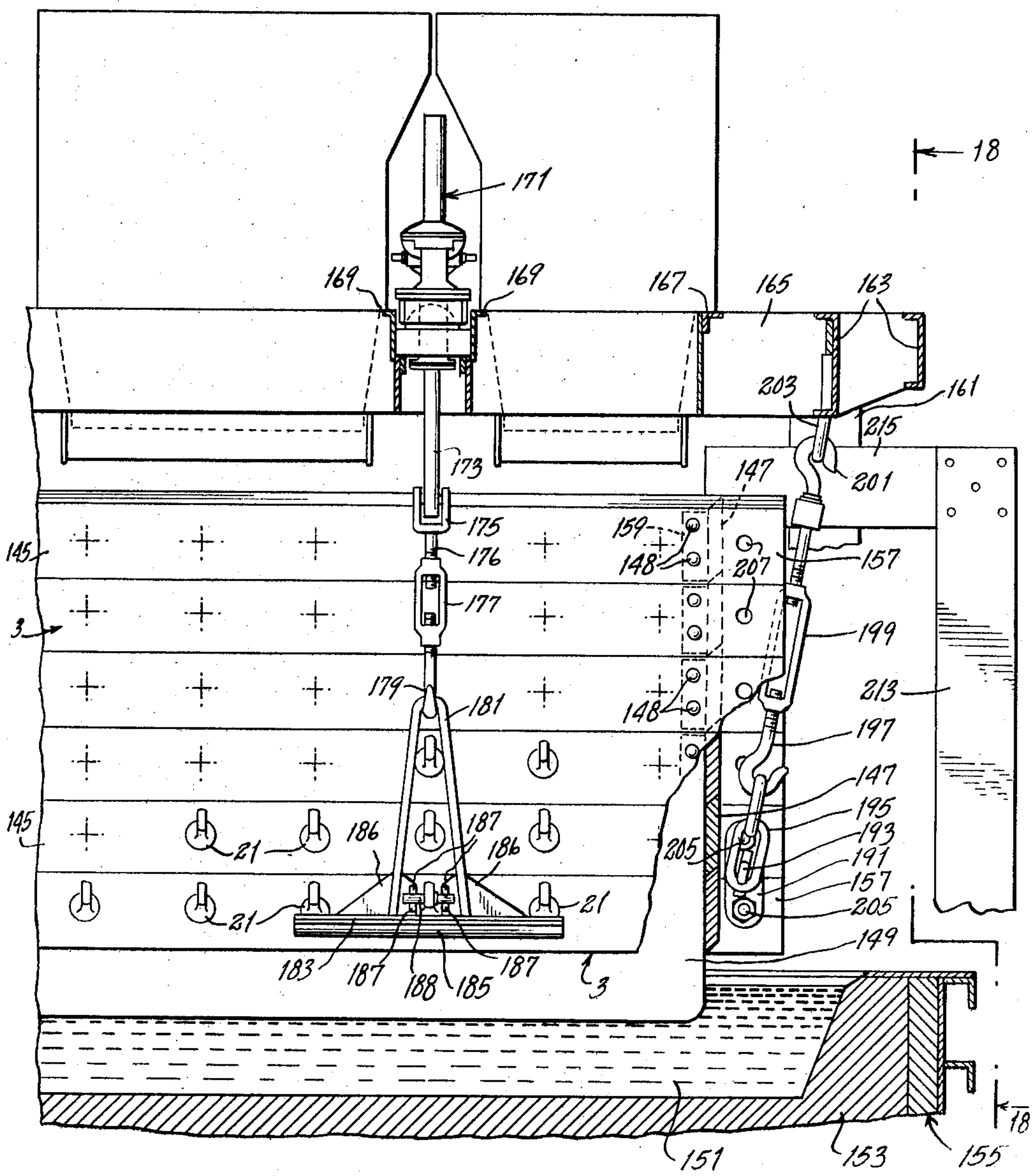
Fig. 16.



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CONSTRUCTION OF CONTINUOUS ELECTRODE FOR A REDUCTION CELL

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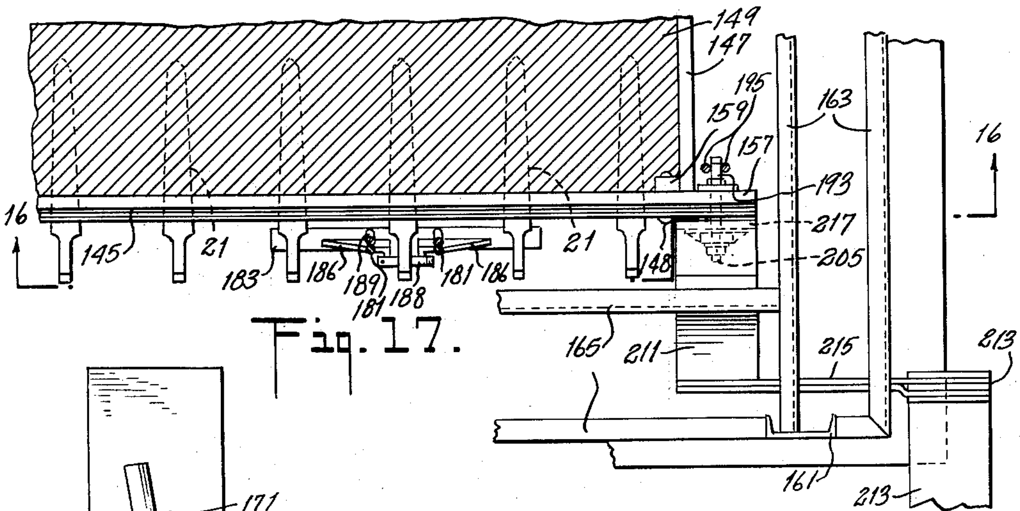

Fig. 17.

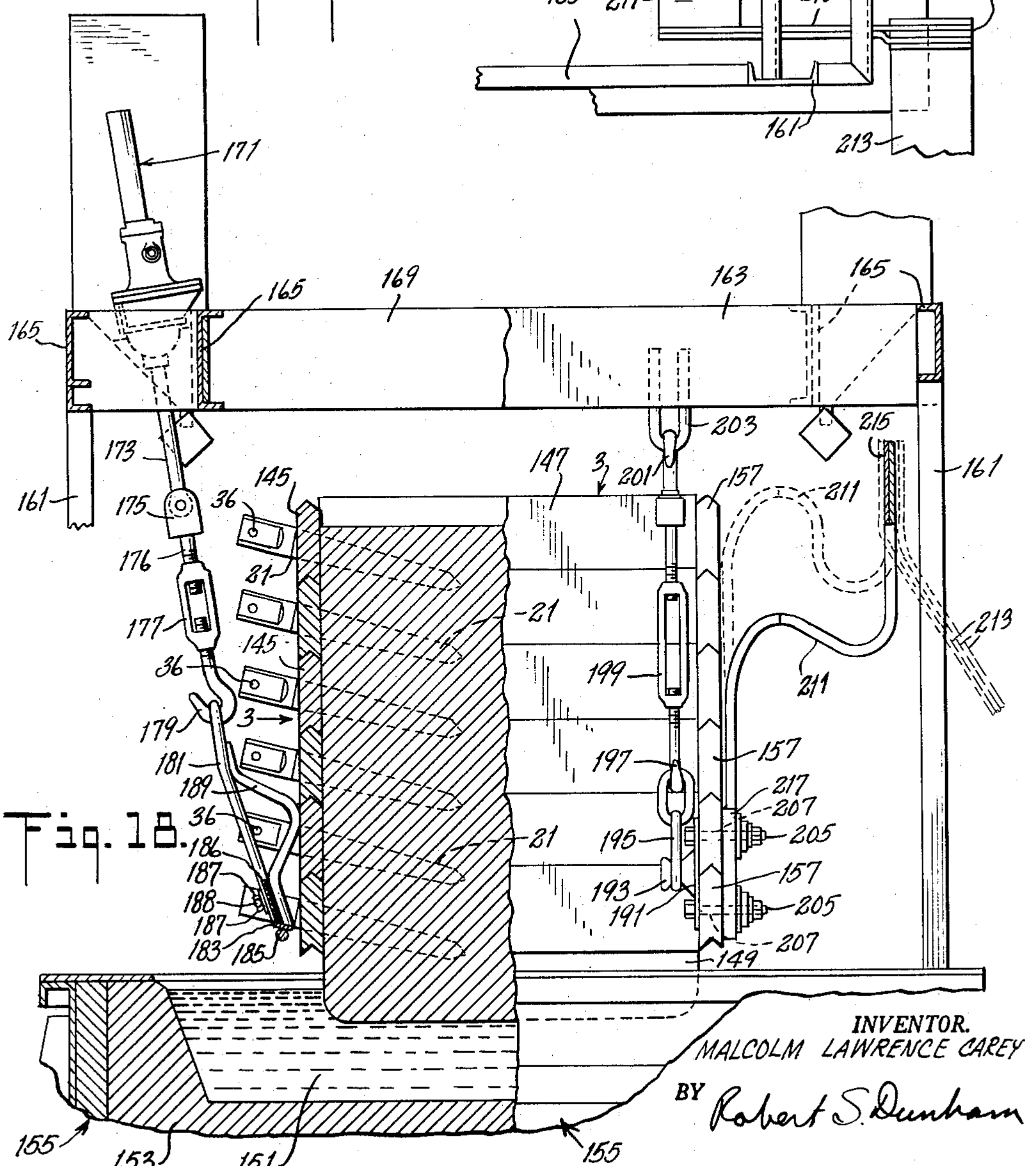

Fig. 18.

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Fig. 19.

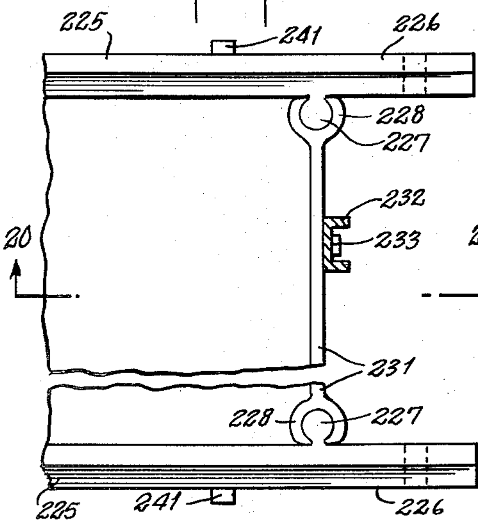


Fig. 19A.

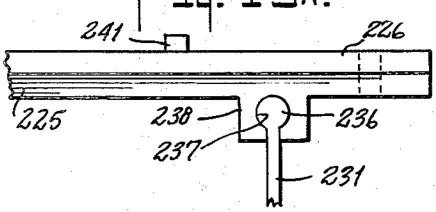


Fig. 20.

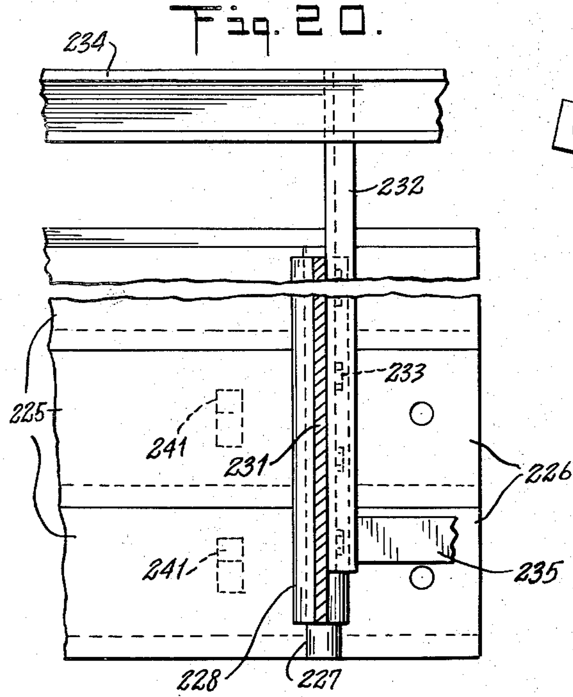


Fig. 21.

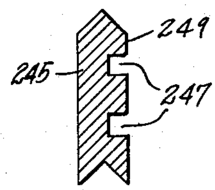


Fig. 21A.

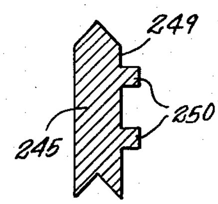


Fig. 22.

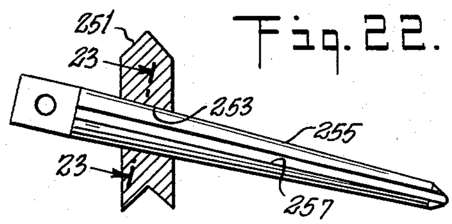


Fig. 23.

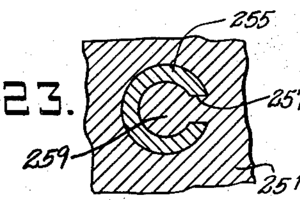


Fig. 24.

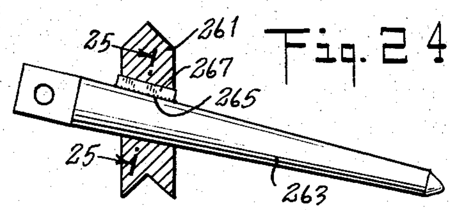
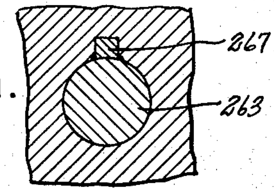


Fig. 25.



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United States Patent Office

3,251,763
Patented May 17, 1966

3,251,763

CONSTRUCTION OF CONTINUOUS ELECTRODE FOR A REDUCTION CELL

Malcolm Lawrence Carey, Mount Royal, Quebec, Canada, assignor to Aluminium Laboratories Limited, Montreal, Quebec, Canada, a corporation of Canada

Filed Mar. 28, 1961, Ser. No. 98,881
4 Claims. (Cl. 204—286)

This invention relates to electrolytic cells for the electrolytic production of aluminum. The invention more especially relates to an improvement in the structure provided in such cells for confining the material of a continuous electrode of the self-baking or Soderberg type. This invention particularly relates to an improvement in a sectionalized electrode material confining structure for a continuous vertical electrode adapted for movement of the sections downwardly as the electrode is consumed to positions adjacent the electrolytic bath concomitantly with addition of other sections at the upper side of an assembly of the sections.

It has been proposed heretofore to provide an electrode casing structure constructed with sectional elements, such as channel beams, disposed in an assembly one above the other at the vertical sides of a vertical electrode of the self-baking or Soderberg type, the assembly being suspended by suspension means from a supporting structure, means being provided also for removing the beams in the lowermost tier when, in the downward movement of the assembly, the lowermost tier reaches a level close to but at a certain distance above the electrolytic bath, in order that such beams which ordinarily are made of steel and suitably as channel beams may not engage the electrolyte or reach a zone of temperature in which they will be damaged by the heat thereof. In order to provide for continuously enclosing the mass of the material for the self-baking electrode of the Soderberg type, other beams are added at the top of the assembly concomitantly with removal of the lowermost beams. Thus the beams may be moved downwardly more or less continuously by means of a suitable suspension device which may include a jack or other means operable to lengthen and shorten the suspension means between the points of support and the connection of this suspension means to the assembly.

In such conventional constructions of the casing or electrode enclosing and confining structure, in order to enclose the electrode over the vertical extent thereof to a level close to the electrolyte, it has been proposed heretofore to provide a casing of sheet aluminum disposed between the beams and the electrode and movable downwardly with the beam assembly and the electrode. This sheet of aluminum extending about the electrode may remain in place as the electrode moves downwardly and may be melted into the electrolyte without detriment thereto, new sheets of aluminum being added at the top of the assembly in order to provide a continuous casing. Although the aluminum sheets af the lower end of the electrode disappear into the electrolyte, the beams must be removed upon disconnection of the suspension means and these beams may be remounted at the top of the electrode casing assembly. The aluminum sheet may extend below the lowermost beam sufficiently to encase the electrode as this lowermost beam moves to the zone of temperature sufficient to damage the material thereof where it must be removed.

The disassembling or removal of the lowermost beams from their positions adjacent the hot electrolyte for remounting at the top of the assembly is a difficult and arduous task because it must be performed under adverse conditions of heat, dust and gas. Moreover, heretofore it has been the practice to provide conductive elements in the form of studs inserted through suitable openings in

the beams and penetrating the aluminum sheet casing and entering the material of the electrode, these studs serving for mechanical support of the electrode as well as for electrical contact therewith. Conventionally the flexibles or electric conductors are connected to these studs. The studs ordinarily have been made of steel to provide a strong supporting structure for the electrode and care has been required in order to secure both a strong mechanical connection to the beam as well as sufficient electrical connection to the electrode. Usually, in order to accomplish the insertion of the studs in the electrode material, they have been driven through openings provided in the beam and so as to penetrate the aluminum casing and to pass into the material of the electrode. It has been necessary also to withdraw these studs from the beams which have moved downwardly toward the electrolyte to the level or location mentioned above the bath after reconnecting the current carrying flexibles to studs inserted through a superposed beam into the electrode. Such removal of the studs is necessary in order not to contaminate the electrolyte, that is, the molten aluminum, with scale or steel particles. The conditions of heat and of dust and gases present involve difficulties also in disconnecting, cleaning and reconnecting the electrical leads to the studs. Because it is necessary to have access to the beams and the studs supported thereby, recovery of the gases from tthe cell is difficult and at best involves considerable dilution with air.

It is an object of the invention to provide a structure for a continuous vertical self-baking or Soderberg electrode in which it is unnecessary to provide for removal of the sections or beams at the positions thereof adjacent the electrolyte of the cell.

It is another object of the invention to provide for a continuous vertical self-baking electrode for the production of aluminum a material confining structure in which sections or beams may be added to the assembly at the top thereof and may be moved downwardly with the movement of the electrode without the necessity of removing the sections or beams at the positions thereof adjacent the electrolyte.

It is a further object of the invention to provide, in such a material confining structure for a continuous vertical Soderberg electrode, for improved mechanical support of the material of the electrode as it moves downwardly and becomes baked, which support may be additional to the support provided by the conventional conductive elements or studs supported by the sections or beams.

It is a still further object of the invention to provide for controlling the movement of the sections or beams as they move into the hot zone adjacent the electrolyte after removal of the conductive elements therefrom.

It is another object of the invention, in such a structure for a Soderberg electrode, to provide for conducting through the structure which comprises the assembly of sections or beams, without utilizing connections individual to the conventional conductive penetrating elements or studs, the electric current required to be conducted to the material of the electrode.

It is still another object of the invention to provide for conduction of the electric current to the material of the electrode to the desired extent through conductive elements which do not require to be removed from the sections or beams.

It is a feature of the invention, in an electrolytic cell for the production of aluminum utilizing a continuous vertical self-baking or Soderberg electrode which is adapted to move generally vertically downwardly toward and to be consumed at its lower end adjacent the surface of the molten electrolyte in the electrolytic cell, that a frame or section is disposed with the length of the wall thereof extending generally horizontally and conforming to the horizontally extending periphery of the vertical electrode. This wall is made of aluminum and has a vertical cross section such that the wall acting as a beam is capable of supporting the load of a plurality of similar walls superposed thereon and conforming in the same manner to the electrode. This frame may be of annular form, that is to say the aluminum wall thereof may extend as an annulus about and conform to the surface of the electrode material, or the frame may be provided by aluminum walls disposed at opposite sides of the electrode and by end walls of other structure. The cross section of the aluminum wall is such that it will retain its form and cooperate with the assembly of superposed walls so as to confine the material of the electrode as it moves downwardly and is consumed at its lower end adjacent the surface of the electrolyte, the assembly of the superposed walls and of the superposed frames also moving downwardly in succession to a position adjacent the surface of the electrolyte of the cell where the aluminum walls in succession are melted into the electrolyte. Because the walls and the frames are made of aluminum this melting thereof into the electrolyte is of no detriment and the characteristics and the impurities of the aluminum product of the cell may be satisfactorily controlled.

Under usual present conditions it may be necessary or desirable to utilize studs of steel or other materials in accordance with conventional practice for penetrating and supporting the electrode material, as well as for securing an electrical conductive connection thereto. To this end the frame of aluminum broadly described above may be provided with openings extending transversely of the vertical through the wall of the frame, the studs being disposed in these openings. In cell constructions of this type it is important to limit as much as possible the losses due to resistance in the electric circuit. In order to reduce the voltage loss occurring between the wall of aluminum and the studs due to resistance across the contacting surfaces, it is essential to secure good electrical contact between the wall and the stud, as well as to provide proper mechanical engagement of the stud with the wall of the frame for rigidly holding the studs in place. For these purposes means are utilized, as will be described more fully in connection with the drawings, which take advantage of the difference of expansion in aluminum and in steel or other material of the stud. Means also may be utilized for a fused or welded connection of the stud to the frame wall.

It is a further feature of the invention that under some conditions the aluminum wall or frame may provide portions or elements of aluminum which may be molded with the wall and projecting into the material of the electrode for support thereof and for conducting the current thereto. It will be understood, when such elements of aluminum are utilized, that they also may be carried into the electrolytic bath with the frame to be melted therein without detriment, thus avoiding the necessity for removing these elements as is required, if these elements are of steel, when the frame wall approaches the hot zone adjacent the electrolyte.

It is a still further feature of the invention that heat dissipating means, such as radiating fins, may be provided on the aluminum frame wall at the exterior side thereof in order to carry the heat away from the electrode and from the wall and to transfer the heat to the surrounding atmosphere.

In another aspect of the invention, the outer face of the frame walls may be disposed in a common vertical plane to form a continuous outer surface, and sealing means carried by a cell enclosing casing may engage this outer surface as the frames move downwardly in order to confine within the casing the gases that are produced by the cell and move outwardly therefrom into the surrounding atmosphere. These gases then will be removed through a suitable conduit.

Other objects and features of the invention will be understood from the description to follow of the drawings in which:

FIG. 1 shows diagrammatically an elevation of a continuous vertical electrode cell embodying the invention;

FIG. 2 shows a perspective view of one form of the frame of the invention;

FIG. 3 shows in section on line 3—3 of FIG. 2 a wall section or member of the frame carrying a strip and, in dot-dash lines, an adjacent frame member of similar form;

FIGS. 4, 5, 6 and 7 show modifications of the frame wall section or member carrying different forms of studs;

FIG. 8 shows in elevation and FIG. 9 shows in section on line 9—9 of FIG. 8 a modification of the wall section carrying studs in staggered relation;

FIG. 10 shows in section an assembly of frames of the invention in superposed relation and carrying conductive studs with supporting and electrical connections thereto;

FIG. 11 is a vertical section similar to FIG. 10 showing a modification of the connections;

FIG. 12 shows in vertical section assembled superposed frame walls each carrying a stud, and gas confining casing means enclosing the electrode structure;

FIG. 13 shows in horizontal section a corner of an aluminum frame of the invention provided with means for connecting the conductive flexibles thereto;

FIG. 14 shows a modified form of the frame having integral studs and heat radiating fins;

FIG. 15 is a vertical elevation of the forward wall of the frame of FIG. 14;

FIG. 16 is a view, partly in elevation and partly in section, taken generally on line **16—16** of FIG. 17, showing a portion of the electrode supporting structure of an electrolytic cell, including connectible and disconnectible means for suspending the assembled frames and providing for downward movement thereof;

FIG. 17 shows a plan view taken from above in FIG. 16 with certain parts in section and certain parts omitted for clearness;

FIG. 18 is a view, partly in elevation and partly in section, taken generally on line **18—18** of FIG. 16;

FIG. 19 shows in plan a modification of the electrode confining structure utilizing permanent end walls;

FIG. 19A shows a partial plan view of a modified end wall structure;

FIG. 20 is a vertical section on line **20—20** of FIG. 19;

FIGS. 21 and 21A show in section modifications of the frame wall or member;

FIGS. 22 and 23 show a further modification of a stud secured in the aluminum frame wall or member;

FIG. 24 shows an additional modification of a stud secured in the frame wall or member;

FIG. 25 is a section on line **25—25** of FIG. 24.

In FIG. 1 is shown an electrolytic cell providing an electrode structure **1** comprising an assembly of superposed frames **3** which are supported on a framework **5** by jacks **7** mounted on the cross beam **9** of the framework. The jacks **7** are connected by suspension rods **11** to the lowermost frame of the assembled frames **3** disposed in superposed relation to each other in FIG. 1. Electrical connections are established from the positive terminals **13** through the flexibles **15** to the lowermost frames **3** of the assembly, the flexibles in this embodiment being bolted to these two lowermost frames and providing for downward movement thereof from positions somewhat above those shown in FIG. 1 to the position shown closely adjacent the level of the electrolyte in the pot or furnace **16**. These connections may be made to one frame, e.g., the lowermost, or to several of the frames as desired. The electrode material **17** is confined within the assembly of frames and extends somewhat below the lowermost frame. The negative terminal is connected by a plurality of leads in the embodiment of FIG. 1 to a plurality of cathode bars **19**, embedded in and conductively connected to the cathode of the pot in a conventional manner.

FIG. 2 shows a single frame **3** of the assembly of frames shown in FIG. 1 and carrying a row of studs **21** which themselves may be of conventional form inserted in the openings **23** in the walls **25** of the frame **3**, or cast into it when molding the frame, and so as to extend into the material of the electrode for supporting this material and for establishing a good electrical contact therewith. In accordance with the invention, in the embodiment shown in FIG. 2 the frame **3** is of aluminum and may be cast in the form shown, the longitudinal walls **25** in this embodiment being cast integrally with the end walls **27**.

As shown in the embodiments of FIGS. 2 and 3, the vertical section of the walls **25** is of arrow shape, the two sloping sides of the point of the arrow being adapted to fit to the two sloping sides of the recess at the opposite end of the section in order that, in the assembly of the frames, the adjacent frames may fit snugly together and cooperate with each other to provide a strong vertical built up wall disposed adjacent and conforming to the material of the electrode. The thicknesses of the walls **25** and of the walls **27** are such as to resist bulging thereof outwardly under the pressure of the material confined within the assembled frames. The vertical dimension of each frame wall **25, 27** also is such as to resist, as a horizontal beam, substantial deflection or bending in the length of the wall, thereby to be capable of supporting the weight of the superposed frames as well as the load of the material of the electrode without substantial distortion when the lowermost frame or the lowermost two or three frames are suspended, by means hereinafter described, in the same general manner as the suspension is accomplished in the structure of FIG. 1.

In the embodiments of FIGS. 2 and 3 the studs **21**, which are of conventional somewhat tapered or conical form to provide for driving them into the material of the electrode and for easier extraction thereof, are disposed at the usual angle somewhat inclined to the horizontal, the openings **23** formed in the walls **25** of the frame being of corresponding conical form and disposed at the corresponding angle so that the studs **21** may be securely fitted into the openings **23** so as to be rigid and to provide good mechanical support for the electrode material and at the same time good electrical contact between the walls **25** and the several studs. The studs as shown in FIGS. 2 and 3 are provided at their outer ends, as they are conventionally, with flat parallel vertical surfaces **29** upon which may be clamped the electrical connectors for the flexibles when it is desired to establish the electrical connection in this manner. One form of making the mechanical connection to the studs having the flat vertical surfaces **29** is shown in FIG. 10 in which is provided a vertically extending suspension rod **31** having branch portions **33** extending in angular relation to the rod **31** and spaced vertically in correspondence with the vertical spacing of the studs in two adjacent frame walls **25** of the type shown in FIGS. 2 and 3. When the studs are driven to a snug fit in the openings **23** in the walls **25**, having regard also to the relatively great extent of the studs **21** into the space within the frame **3** in which the electrode material is enclosed, the attachment of the rod **31** at its branches **33** to the respective studs by bolts **35** is adequate for supporting the assembly of the frames **3** with their walls **25, 27** superposed one upon the other. If desired electrical connection also may be made to the rod **31** at its upper end for carrying the current to the two lowermost studs **21** which are disposed within the mass of the electrode material adjacent the lower end thereof. The eyelet **37** shown in FIG. 10, at the upper end of the rod **31**, however, may serve for receiving a hook or other suspension device. A plurality of the vertical rods **31** may be used along the walls **25** to function similarly to the suspension rods **11** of FIG. 1. The holes **36** in the studs **21** which receive bolts **35** also may serve for receiving a tool for withdrawing the studs from the frame.

In FIG. 11 is shown a modification of the suspension or conductive rod and its attachment to the studs. In this embodiment the studs **41** are of conical shape securely held in conical holes **43** in the walls **25** similarly to the embodiment of FIG. 10. In FIG. 11, however, each stud **41** at its outer end is provided with a tapped hole **45** extending inwardly axially of the stud from the outer end thereof, this outer end being perpendicular to the axis. Bolts **47** are threaded in the tapped holes **45** and serve to clamp to the respective studs lug portions **49** of branches **51** of the vertically extending suspension rod **53** provided with an eyelet **55** at its upper end. It will be understood in connection with both the embodiments of FIGS. 10 and 11 that, by removing the bolts **35, 47**, the suspension rods **31, 53** may be removed from engagement with the two lowermost studs disposed in the two lowermost walls **25** of the frames **3** which have reached the position close to the electrolyte. The rods **31, 53** then may be moved upwardly a distance equal to the vertical distance between adjacent studs or between alternate studs, so that the lowermost frame (or frames) then is released for further movement downwardly to and then into the electrolyte to be melted therein, having completed its service in enclosing and confining the electrode material as it moves downwardly and becomes baked. At the top of the assembly a new frame **3** may be put in position and supported by the assembly of superposed frames **3** and their walls **25, 27**, the weight of this assembly being carried by a plurality of the rods **31, 53** disposed along the frame walls **25**. It will be understood that conventional means, such as a jack or turn buckle, may be connected to the eyelets **37, 55** to provide for the requisite vertical adjustment with respect to a supporting framework, such as the framework **5** in FIG. 1.

In FIGS. 4, 5, 6 and 7 are shown walls of the frames **3** having different vertical cross sections. In FIG. 4 the section of the wall **57** is of the same shape but is inverted with respect to that of FIG. 3, the conical opening **59** in the wall being formed so as to dispose the stud **21** received therein in proper relation to the electrode.

In FIG. 5 is shown a wall **61** for the frame **3** of groove and tongue form. The conical stud **63** fits into a conical inclined hole **65** similarly to the studs **21** in FIGS. 3 and 4. In this embodiment the outer end of the stud **63** is formed with an annular groove providing the head **67** which may be engaged by a suitable withdrawing tool for withdrawal of the stud **63** from its opening **65** in the wall **61**. This type of stud may be used when the electrical connection is established to the wall of the frame **3** in a manner further to be described.

In FIG. 6 is shown a stud **41** of the same type as in FIG. 11 provided with a tapped hole **45** for receiving a bolt to secure the suspension means to the stud. This tapped hole also may receive a tool screwed therein, see also FIG. 12, for withdrawing the stud **41** from the opening **68**. In FIG. 6 the vertical section of the frame wall **69** is in the form of a shiplap with opposed shoulders for mutual engagement of the walls **69** in the assembly of superposed frames.

FIG. 7 shows a section of a frame wall **71** of generally rectangular shape but having a flange **73** at the upper corner thereof adapted to engage the lower rectangular part of a similar superposed frame wall **71** at the face thereof disposed toward the electrode, as shown in dotted outline. The frame wall **71** is provided with a conical hole **74** in which the conical stud **75** is fitted, this stud, however, having an end surface **77** disposed in angular relation to the stud axis so as to be flush with the outer vertical face **79** of the wall **71** of the frame. This end

77 of the stud 75 also is provided with a tapped hole 81 for receiving a fastener for securing the suspension means to the stud, or for receiving the threaded withdrawing tool.

In any of these modifications as in others further to be described, instead of providing holes in the frame wall to which by suitable machining operations the studs may be fitted, the studs may be cast in place when the wall or frame is cast.

In FIG. 8 is shown a frame wall 85 which is generally of the arrow shape as shown in section in FIG. 9 similar to that of of FIG. 3 but of approximately twice the vertical dimension of the wall 25 of FIG. 3 to provide for a plurality of rows of the studs 21 fitted into the conical holes 23 the same as in FIG. 3. The vertical spacing between the rows of studs 21 may be substantially the same as the vertical spacing between two vertical adjacent studs in the assembly of FIG. 10. In the horizontal direction, however, the studs are disposed in staggered relation as shown in FIG. 8. The horizontal spacing of the studs in each of the two vertically spaced rows may be substantially twice that of the spacing shown in FIG. 2, for example, or, if desired, a different spacing may be adopted to suit a particular condition. The outer ends of the studs 21 in FIGS. 8 and 9 are formed with surfaces 29 and holes 36 the same as shown in FIGS. 2 and 3 for fastening the suspension means thereto as well as the means for conducting the current to the studs.

FIG. 12 shows an electrode structure for an electrolytic cell provided with a gas retaining casing or envelope. In the embodiment of FIG. 12 the frames 3 have the walls 71 thereof formed with the section providing the flange 73 as in FIG. 7. Studs 75 are disposed in conical holes 74 and have outer end faces 77 disposed in the plane of the outer vertical faces of the walls 71. As in FIG. 7 the studs 75 are provided with tapped holes 81 into which a threaded member 89 having a shank 90 and a handle 91, as shown in FIG. 12, may be screwed in order to provide for withdrawing the studs 75 from the walls 71 as the frame reaches the location adjacent the surface as the hot electrolyte as above mentioned. To prevent entry of dirt and oxidation these tapped holes may be closed by screw plugs or caps over the ends of the studs.

It will be noted, however, in FIG. 12, as the outer surface of the assembly and of the studs are in the same vertical plane, that there is no obstruction projecting outwardly from the assembly of frames 3 which are functioning to confine the electrode material and which, by virtue of the studs carried thereby, support the electrode and serve to conduct the current thereto. A smooth unobstructed vertical outer surface is thereby secured against which a gas sealing web 93 which preferably is of flexible material may bear, being curved downwardly into engagement with the outer face of the assembly from the horizontally disposed upper wall 95 of the casing or enclosure 97 which may be supported on a platform 99 disposed closely adjacent the upper surface of the wall 101 of the pot 116 in which the electrolyte 103 is disposed and into which the electrode 105 may dip or with respect to which it may be consumed adjacent the upper surface of the electrolyte. The web 93 is securely held in a groove 107 formed in an enlargement of the upper wall 95, this enlargement extending generally parallel to the face of the assembly of frames 3 and about this asesmbly in the horizontal plane, so that the web 93 may provide a relatively gas-tight closure which, however, is adapted for movement of the assembled walls 71 relative thereto downwardly to the electrolyte as above described. A sleeve 109 is secured by welding or other suitable means in an opening in the upper wall 95. Suitable conduit and suction means may be connected to the sleeve 109 for removal from the space within the casing 97 of the gases which are given off by the reaction in the electrolytic cell of the core material of the electrode with the electrolyte in the bath. As shown, a door 98 may be provided for the enclosure 97 to provide access to the electrode structure.

FIG. 13 shows in horizontal section a corner portion of a frame 3 which similarly to the frame of FIG. 2 is cast of aluminum in one piece to provide the longitudinal walls 111 and the transverse walls 113. In conical openings 115 in FIG. 13 are disposed conical studs 117 which may be similar in the conical portion thereof to the studs 21 shown in FIG. 3. Studs 117, if desired, may be made of steel as are conventional studs and may be inserted securely in the openings 115 in the walls of the frame, preferably the longitudinal walls 111. It will be understood that, as the frame 3 moves downwardly in the assembly of frames in the same manner as shown in connection with FIGS. 10 and 11, the studs 117 will support the material 119 of the electrode, these studs being disposed in inclined relation to the horizontal as in FIGS. 2 and 3, for example, or in any other suitable angular relation to the vertical wall 111 which will provide the desired support for the electrode core material 119.

Within the scope of the invention in this aspect thereof, however, the studs 117 may be made of aluminum secured to the wall 111 in a suitable manner for supporting the electrode material and to provide good electrical conduction between the stud 117 and the wall 111, so that the current requisite for the electrolytic operation of the cell may flow through the frame walls 111 and through the studs 117 into the material 119 of the core. For connecting the flexibles carrying the current in the embodiment of FIG. 13 the frame 3 is provided with a longitudinally extending end flange portion 121. Such flange portion may be provided as an extension of each of the walls 111 of the respective frames 3 that are superposed in an assembly of frames such as that shown in FIGS. 1 and 10, for example. The ends 123 of the flexibles may be bolted by bolt 125 and nut 127 to the faces of the flange 121 to carry the current through the flange into the body of the frame and the walls 111, 113 thereof to be further carried through the studs as well as through the inner faces of the walls 111, 113 into the body of the electrode material 119. It will be understood in each frame 3 of a superposed set of frames that flanges 121 may be provided on each of the four corners of the rectangular frame.

When the frame in FIG. 13 is provided with studs 117 of aluminum, it will be understood that removal of these studs as the frame reaches the lowermost position thereof adjacent the electrolyte will not be necessary and that this lowermost frame and its studs after removal of the flexibles connected thereto and reconnection of these flexibles to the next adjacent or another frame above, may be allowed to move further downwardly with the electrode material into the hot electrolyte to be melted herein. For some conditions, if desired, certain of the studs may be of steel to increase the strength of support of the electrode, other studs being of aluminum, the steel studs being withdrawn as above described.

In some cases the studs 117 of the conventional form may be omitted, the frame, however, being provided with connections for the flexibles as shown and described or with other suitable connections to conduct the electric current into the body of the frame. This arrangement may be suitable where the walls of the frames are of such form that adequate surface in contact with the electrode material is provided at the inner surface of the wall so that the requisite current may be carried into the electrode material by virtue of the engagement of the inner surfaces of the walls with the electrode material enclosed thereby. Such surfaces may be provided by walls having a recess or recesses or preferably projections, as shown in FIGS. 21 and 21A. Where this is possible the cost of preparing frames suitable for confining the electrode material before the frame becomes melted into the electrolyte will be considerably reduced.

In FIG. 14 the studs 131 of aluminum may be integrally cast with the wall **133** of the frame **3**, the longitudinal wall **133** having a flange **135** extending therefrom lengthwise thereof in the same manner as does the flange **121** in FIG. 13 for receiving the connection of the flexibles, not shown in FIG. 14. As the studs **131** can be cast when the frame **3** and its longitudinal and end walls **132** and **133** are cast, the machining or finishing operations which are necessary for fitting the studs **117** in the opening **115** in FIG. 13 are obviated. The saving thus secured is desirable in view of the melting of the frame **3** and of the studs in the electrolyte after reaching the lowermost position thereof.

In FIG. 14 also are shown fins **141** which project transversely of and outwardly of the outer faces of the walls **132**, **133**. The fins **141** are relatively closely spaced but with sufficient space therebetween to provide for movement by convection of air or gas currents which will become heated through the fins and thereby carry away a substantial amount of heat transferred to the walls from the core material and particularly the lower part thereof in the location before the frame is released for engagement with and melting in the electrolyte. The fins **141** are shown in elevation in FIG. 15 and extend vertically over the vertical outer face of the wall **133** of a frame member **3** which may have the arrow section shown in FIGS. 3 and 10. As shown in dotted line the end wall **132** may be of the same section. In this embodiment, since the studs **131** are integral with the frame wall **133** and do not project through this wall, the fins **141** may be uniformly spaced along the wall without interference by the studs.

In FIGS. 16, 17 and 18 in three views is shown an assembly of frames **3** disposed one above the other generally as described above. In this embodiment the cross section of the longitudinal walls **145** is the same as that of FIGS. 2 and 3. The cross section of the end walls **147** is in the form of a parallelogram, the abutting edge surfaces of these walls in this form also serving, similarly to the wall **145**, to maintain the assembly of the end walls in vertical alignment and against the face of the electrode **149** the lower end of which dips into the electrolyte **151** contained by the lining **153** of the pot **155**. The frames **3** are provided with flanges **157** extending beyond the end walls **147** in the respective frames and in alignment with the longitudinal walls **145** similarly to the frame described in connection with FIG. 13 for purposes further to be described. The end walls **147** may be formed with reverted flanges **159** molded or otherwise secured to and at right angles to the walls **147**, each of these reverted flanges being provided with two holes as shown in FIG. 16 through which and through corresponding holes in the walls **147** suitable fasteners **148** may extend for securing the end walls **147** to the longitudinal walls **145** rigidly to form the frames **3**. The longitudinal walls **145** may be provided with openings spaced therealong in which are disposed studs **21** which may be of the same form as shown and described in connection with FIGS. 2 and 3.

In FIGS. 16, 17 and 18 is shown more or less diagrammatically a superstructure which comprises vertical columns **161** supporting channel members **163** connected to and spinning between the columns **161**. Parallel to the longitudinal walls **145** of the assembly of frames other structural members **165** are provided together with members **167**, **169** transverse to the members **165** and forming therewith and with the channels **163** and columns **161** a framed superstructure which may be of conventional design.

A jack **171** of conventional form is supported on the superstructure adjacent the transverse members **169** and is provided with a movable element **173** movable upwardly and downwardly on the axis of the jack. The lower end of the element **173** is connected to a clevis **175** the threaded shank **176** of which is connected through a turn buckle **177** to a hook **179**. This hook engages the upper end of a loop **181** the lower ends of which are secured as by welding to a cross bar **183** which may be disposed beneath the portions of the studs **21** which extend outwardly beyond the outer faces of the walls **145**. As shown in FIGS. 16 and 18 the cross bar **183** may be reinforced by round bar **185** welded or otherwise secured thereto, the bars **183**, **185** spanning across three of the spaced sturs **21** in this embodiment. Wing plates **186** are welded to the bar **183** and carry lugs **187** engaging the ends of pin **188** removably disposed in the hole **36** of the center stud **21** so as to secure the loop **181** against movement relative to the stud, especially against movement away from the walls **145** of the assembly. The loop **181** may carry a bracing knee **189** to rigidify this part of the suspension device and, by bearing on the walls **145**, to dispose the upper end of the loop clear of the studs.

It will be understood, upon suitable operation of the turn buckle **177** and of the jack **171** with the suspension device engaged as shown, the bars **183**, **185** being brought into engagement with the studs **21**, that the weight of the assembly of frames **3** may be carried to the superstructure through the jack **171**. Only one suspension device for engagement of the studs **21** is shown in FIG. 16 but a plurality of these devices may be disposed about the electrode structure. For example, two of such suspension devices may be disposed at each longitudinal face of the electrode in engagement with studs that are carried by the longitudinal frame walls **145**.

In FIGS. 16 and 18 also is shown a plate **191** of an auxiliary suspension device which is provided with a hook portion **193** for engaging a link **195** of a short chain another link of which is engaged by the lower hook **197** of a turn buckle **199** the upper hook **201** of which engages a loop **203** which is secured as by welding to one of the cross bars **163**. The plate **191** in this embodiment is secured to the two lowermost frames in the positions shown in these figures by bolts **205** passing through holes **207** formed in the flanges **157** which extend in alignment with the longitudinal walls **145**. In this embodiment one such auxiliary suspension device is provided at each corner of the frame assembly.

It will be understood that by operation of the turn buckle **199** the assembly of frames **3** may be held in the position, such as that shown in FIGS. 16 and 18, where the lowermost frame **3** is in the position to which it has been moved close to the surface of the electrolyte **151**. This may be accomplished by hooking links **195** in the hooks **193** and setting up the turn buckles **199** until they take the strain of the load of the assembly to hold the assembly in this position while the main suspension devices are readjusted. Thereafter slacking of the main suspension devices supported by the jacks **171** may be effected by effecting downward movement of the elements **173**. The bars **183**, **185** then may be released from engagement with the studs **21**, the pins **188** being withdrawn from the studs **21**. The loops **181** then may be moved outwardly and then upwardly by upward operation of the jack element **173** to a new position, ordinarily that in which the bars **183**, **185** engage the studs **21** of the frame next above the lowermost frame. The jack **171** then may be operated to take the strain of the load of the assembly and thereafter to effect gradual downward movement thereof by operation of the jack. When the bars **183**, **185** thus are in supporting engagement with the new line of studs **21**, the turn buckle **199** again may be operated to release the link **195** from the hook **193** which otherwise would prevent the further downward movement of the lowermost frame **3** toward and then into the electrolyte in the pot **155**. The operation of the plurality of jacks **171** which are disposed about the wall and of the plurality of turn buckles **199** and the hooks and links connected thereto may be carried out in a proper sequence so as to maintain the supension of the frames and of the electrode material confined thereby during the transfer of the main suspension devices to the new position so as to provide for the substantially continuous downward movement of the electrode and of the frames.

In FIGS. 16, 17 and 18 also are shown the conductive flexibles **211** which are electrically connected to the fixed multiple conductor buses **213** and **215**, the upper ends of the flexibles **211** being clamped or otherwise secured in a conventional manner to the horizontal bus **215**. As shown in FIG. 18 the flexible **211** may move flexibly from the upper dotted position **211** downwardly to the full position as the assembly of frames moves downwardly in the manner described by the operation of the jacks **171**. These flexibles, however, may be formed and disposed similarly to the flexibles **15** of FIG. 1.

For securing a conductive connection of the lower end of the flexible **211** to the frames, this end is welded or otherwise electrically connected to a conductive terminal **217** which is of sufficient vertical length in the embodiment of FIG. 18 to span adjacent superposed flanges **157** of the longitudinal walls **145** and of sufficient width to provide ample contact area for the current. Each terminal **217** may be secured in electrical contact with the outer faces of the two adjacent flanges **157** by the same bolts **205** which are used to secure the plate **191** carrying the hook **193** for the auxiliary suspension device. It will be understood that the bolts **205** may be loosened and removed after the main suspension device has been adjusted in a new upwardly disposed position as above described, thereby to release the plate **191** and the terminal **217** from the position shown in FIG. 18 in relation to the two lowermost flanges **157**, so that the plate **191** and the terminal **217** may be moved upwardly to a new position engaging the two flanges **157** next above the lowermost flanges **157**, the flexible **211** being bent to the dotted contour to conform to the new position of the terminal **217**. Since the auxiliary suspension device now is released from the hook **193**, the plate **191** and the terminal **217** bolted in the new position may move downwardly with the assembly of frames until the frame next above lowermost shown in FIG. 18 reaches the position of this lowermost frame and must be released as above described for further movement downwardly into the electrolyte of the cell.

It will be understood further, in order not to interrupt the current flowing from the buses through the flexibles into the frames and then into the electrode, one flexible and its terminal may be removed at a time and rebolted in the new position generally as in conventional practice except that in this embodiment of the invention the connections are made at the flanges **157** directly to the frames **3** which, being of aluminum, do not need to be removed from the assembly at the bottom for redisposition at the top of the assembly. It is only necesary to take care of releasing the lowermost frame from the main suspension device when it reaches the position adjacent the electrolyte without the need for removing the frame or its wall members and to reconnect this main suspension device to a superposed frame, the auxiliary suspension device being used for support during this operation as has been described. The reconnection of the terminal **217** and concomitantly the redisposition of the plate **191** and its hook **193** may be accomplished to accommodate to the continuous downward movement of the frames **3** with the electrode material with continuous current flow. Since the frame **3** or its members do not require removal, suitable tools may be used for reaching the suspension means for the necessary disconnection and reconnection thereof without distrubing the lowermost frame which, as it moves further downwardly, remains in place to confine the electrode material.

In FIGS. 19 and 20 is shown a modification of the electrode confining structure of the invention which utilizes horizontally extending elongated aluminum members or wall sections **225** corresponding to the horizontal elongated members **145** shown in FIGS. 16, 17 and 18. The members **225** extend in engagement with opposite side faces of the electrode and at their ends are provided with extension flanges **226** which serve for attaching the flexibles as in FIGS. 13, 16, 17 and 18. The members **225** inwardly of the ends of the flanges **226** are provided with vertical bulbous ribs **227** of arcuate surface contour in section in the horizontal plane which may be cast integrally with the members **225**. These vertical ribs are engaged by vertically extending slideway channels **228** of corresponding arcuate contour and section for engaging the outer surfaces of the ribs **227** of the members **225** for sliding movement of the ribs **227** downwardly along the channels while retaining the members **225** in place against the electrode. The slideway channels **228** are carried by and extend along the vertical edges of end wall **231** which engages the end vertical surface of the electrode. This end wall **231** is permanently supported by and secured to suitable structural members or channels **232** by suitable fasteners **233**. The structural members **232** may be secured at their upper ends to a member **234**, FIG. 20, of the superstructure and also may be supported at their lower ends by the base portion of the structure of the cell which may comprise, for example, a channel member **235** extending horizontally at such a height above the level of the electrolyte in the cell as not to be damaged by the heat of the electrolyte. The end wall **231** and the channels **228** carried thereby at their lower ends stop short of the level of the electrolyte.

In a modification, as shown in FIG. 19A, the wall **231** is provided with a vertical bulbous edge rib **236** of arcuate contour in section, this rib being received in a corresponding vertical recess **237** formed in a projecting portion **238** of each of the members **225** for retaining the members in place against the electrode while providing for sliding movement of the members **225** vertically relative to the wall **231**.

The wall **231** and its channels or ribs may be of steel or other suitable material which will provide a rigid end wall at each of the vertical ends of the electrode as a permanent structure not requiring removal as is the case with the side members **225**. The aluminum members **225** may be inserted at the top of the structure with the ribs **227**, **236** engaging respectively the slideway channel **228** and the recess **237**, and in superposed successive relation to each other may move downwardly in the manner which has been described in connection with the previous embodiments. As each of the aluminum members **225** reaches the electrolyte it may be melted into the electrolyte in the manner which has been explained above, new elongated members **225** being added at the top of the structure in the manner just described.

It will be understood that in this embodiment the members **225** may have a cross section such as those shown and described in connection with FIGS. 2 to 7, inclusive, or other suitable cross section which provides a rigid elongated member capable of supporting the members superposed thereon and of confining the electrode material between the two oppositely disposed walls constituted by the assembly of members **225**. It will be understood further that the members **225** may be provided with lugs or brackets **241** projecting from the outer faces thereof adapted to be engaged by a suitable suspension means for supporting the members **225** concomitantly with movement thereof downwardly with ribs and channels in engagement as described. Additional lugs or other means of attachment of auxiliary suspension means, not shown in FIGS. 19, 19A and 20, also may be provided so that operations such as those which have been described in connection with FIGS. 16, 17 and 18 may be carried out for supporting the assembly and for releasing the lowermost members **225** into the electrolyte.

In FIG. 21 is shown another modification of the wall section of the frame or of the elongated members for confining the electrode material at the vertical faces thereof. The member **245** of FIG. 21 is of generally arrow shaped section as, for example in FIG. 3. This member, however, is provided with longitudinal recesses **247**, two in this particular embodiment, formed at the inner face **249** of the member which will be disposed in contact with the electrode material. It will be understood, in the process of adding electrode material at the top of the electrode for movement downwardly toward the electrolyte, that this material which as yet is unbaked may be forced into the recesses **247**, so that when the electrode has moved into the baking zone this electrode will have projections engaged in the recesses **247** which will serve to support the electrode and the material disposed thereabove. The recesses may be continuous along the length of the member **245** to the desired extent. As each of the members **245** superposed one above the other may be provided with the recesses **247** a plurality of the projections of the electrode material is formed, one above the other on the face of the electrode material and particularly on the baked portion thereof to give good support for the bottom frame after the studs are removed so as to prevent this frame from dropping uncontrolled into the bath and to insure that the frame will melt gradually into the bath.

FIG. 21A shows another modification serving the same function as the wall of FIG. 21. In this embodiment the projections **250** in form may be counterparts of the recesses **247** of FIG. 21 or may be of greater lateral extent to provide greater support for the electrode material and for increased electrical contact therewith.

In FIGS. 22 and 23 is shown a form of a stud which is adapted to provide not only means for rigidly securing the stud to the aluminum frame wall or to a horizontally extending aluminum member but also to provide for good electrical contact between the stud and the wall or member. The member **251** may be of arrow or other suitable section. The stud **255** preferably of tapered form is of such cross section as shown in FIG. 23, annular in this embodiment, as to provide a slot **257** extending lengthwise of the stud. Although as shown in FIG. 22, this slot extends fully along the tapered length of the studs, for the purposes about to be described the length of this slot may be substantially the same as or even somewhat less than the thickness of the wall or member **251** between the vertical faces thereof.

The stud **255** is made of a material, such as steel, having a thermal coefficient of expansion less than that of aluminum. The stud of this form may be disposed in the mold in which the wall or member **251** of aluminum is cast so that the molten aluminum will run into the slot and, in the embodiment of FIGS. 22 and 23, will fill out the hollow space of the stud in engagement with the inner surface of the annular wall thereof. Although the cooling the portion of the aluminum wall projecting into the slot and into the hollow space of the stud may contract more than the material of the stud, thus possibly separating the surface of the inwardly projecting portion **259** from the inner surface of the stud, nevertheless, when the member **251** in its downward movement with the electrode and carrying the stud **255** reaches the zone of heat, especially the zone of higher heat adjacent the lower end of the electrode, the expansion of the aluminum will be greater than that of the material of the stud and the contact of the outer surface of the projection **259** with the stud will be made firm for the purpose of mechanical support as well as for electrical contact. Moreover, the aluminum in contact with the outer surface of the stud as it cools in the mold will contract more than the material of the stud and at this surface firm engagement of the stud with the wall or member **251** will be maintained until expansion again occurs as the wall or member and the stud move downwardly with the electrode material. Thus, not only strong mechanical engagement for support of the electrode material is secured but good electrical contact is obtained for carrying the current which may be conducted through the member **251** to the stud and to the electrode material.

FIGS. 24 and 25 show another modification of a wall or frame member **261** carrying a stud **263** disposed in opening **265**. In this embodiment a key element or lug of aluminum is securely attached to the stud **263** in a position projecting laterally therefrom. In the embodiment of FIGS. 24 and 25 a lug **267** of aluminum having a length along the stud about equal to the thickness of the wall **261** is welded to the stud **263** of steel. When the stud **263** is supporter in a mold in which the member **261** is molded, the aluminum of the member **261** will flow about the stud **263** and the lug **267**. Upon cooling a rigid connection may be secured between the member **261** and the lug and the stud and a good electrical connection to the stud **263**. The stud carrying the lug **267** welded thereto, however, may be driven into a preformed and suitably shaped hole in the member **261**. To this end the lug may be tapered somewhat lengthwise of the stud to facilitate extraction of the stud and lug from the member **261**. If a superior electrical connection is desired the lug may be welded to the frame at the outside surface, this welding being limited, however, so as not to interfere seriously with extraction of the stud from the member **261** as it approaches the electrolyte. In order to prevent fusion of the lug with the wall member **261**, if under some conditions this tends to occur, the tapering surfaces of the lug may be coated with graphite before driving the stud into the member **261**, thus to secure good electrical conduction and insuring recovery of the stud with its lug for reuse.

Within the scope of the invention modifications may be made of the particular form of the frames or members and of the constituent parts of the frames. The frames may be formed as integral units, as shown in FIGS. 2, 13 and 14, or may be provided by sections, members or walls mechanically connected together adjacent the corners of the electrode, as in FIGS. 16, 17 and 18, or for cooperation with permanent end walls as in FIGS. 19 and 20, or the adjacent ends of separate wall members, for example adjacent the corner of a rectangular frame, may be welded together. Other details of construction may be used which utilize the features of the invention that the frame is made of aluminum and is of such cross section as to cooperate with similar frames to support an assembly of the frames for confining the electrode material as well as for conducting the current thereto as described, each frame as it reaches the position adjacent the electrolyte being released for movement into and melting into the electrolyte. Where the structure confining the electrode material is that which utilizes two fixed end walls with longitudinal or side walls that are movable downwardly relative thereto, these longitudinal walls comprising a plurality of superposed aluminum members corresponding to the longitudinal walls of the frame decribed, suspension means similar to that which has been described may be attached directly to the members or to studs carried by these members, the transfer of the support from the lowermost member to a superposed member being accomplished in a manner similar to that described.

For securely holding the members or walls in the assembly against warping or moving out of the vertical plane, adjacent superposed members may be welded along the horizontal joint therebetween, as shown as **275** in FIG. 11, or these members may be spot welded together at spaced points therealong. The adjacent ends of the members forming each frame also may be welded as shown at **277**, FIG. 11, for securing the members together in the frame. In this way also, or by other suitable fastening means, the lowermost member or frame may be secured to the superposed supported members or frames against falling into the bath after removal and reconnection of the suspension means as described. Such welding also serves to increase the conductivity of the structure and to increase the contact surface of the members or frames with the anode material through which may flow the current delivered, as described, to one or more frames or assembly of members disposed toward the lower part of the anode. Moreover, these welded together members or frames in the structure of the invention provide a relatively gas-tight enclosure for the anode which prevents oxidation thereof due to the access of air, thereby reducing the paste consumption at the side portions of the anode.

The frames or members may be fabricated in various ways. For example, they may be cast directly around studs positioned in a suitable mold, or they may be cast with holes of such size as to permit forcing the respective studs into proper position in these holes. Further, the frames or members may be cast with oversized holes with respect to the studs to be inserted and these studs then may be disposed in proper position, molten aluminum being poured around them in the annular space between them and the frame or member to secure the requisite mechanical engagement and electrical contact between the stud and the frame or member.

Other variations and modifications may be utilized without departing from the scope of the invention as defined in the appended claims.

I claim:

1. In the structure of a continuous vertical Soderberg electrode of an electrolytic cell for production of aluminum, the combination with a continuous vertical electrode adapted to move generally vertically downwardly and to be consumed at its lower end adjacent the surface of the molten electrolyte in the electrolytic cell, of an electrode material confining structure comprising opposed assemblies of parallel superposed elongated members disposed at and conforming to opposite vertical sides of said continuous vertical electrode, each of said members being of aluminum and extending horizontally and having a vertical cross section transversely of the horizontal length of said member of greater vertical extent than the horizontal thickness thereof and providing a rigidity such that each of said members is capable of supporting the load of a plurality of similar members superposed thereon and conforming to the adjacent side of said electrode; and structures extending transversely of said opposed assemblies of elongated members and disposed generally vertically in opposed relation to each other at and conforming to the opposed vertical ends of said electrode, said end structures being fixed in relation to said cell; means providing an operative connection between said transverse structures and said elongated members of said opposed assemblies to provide for downward movement of said members in succession to positions adjacent the surface of the electrolyte where said members in the lowermost tier are melted into said electrolyte, said cross-section of said members providing a rigidity therein such that the assembly of said superposed members in cooperation with said transverse end structures is capable of confining the material of said continuous electrode as it moves downwardly and is consumed at its lower end adjacent the surface of the electrolyte, and said connection-providing means providing for said downward movement of said members relative to said fixed end structures while maintaining the cooperation of said transverse structures with said members for confining the material of said electrode; each of said elongated members carrying a plurality of rigid conductive elements rigidly connected to and supported by said member and extending therefrom in cantilever relation thereto transversely of the length thereof into said electrode for supporting said electrode, each of said elements being in electrical conductive relation to said member and to said electrode; and means carried by each of said elongated members for removably connecting electrical conductors thereto for supplying current to said electrode through said members and said elements.

2. A member of elongated form adapted to be disposed with its length extending generally horizontally and to cooperate with a similar member similarly disposed in superposed relation thereto to form a generally vertical wall for confining the electrode material of a continuous vertical Soderberg electrode of an electrolytic cell, said member being of aluminum having a cross section in the vertical plane transverse to its extent with a greater vertical dimension than the horizontal thickness thereof and providing a rigidity such that said member is capable of rigidly supporting the load of a plurality of superposed members to form said wall, said member being provided with an opening extending therethrough transversely of said extent of said member and transversely of the vertical, and a stud of a material having a thermal coefficient of expansion less than that of aluminum and disposed in said opening with its length extending transversely of said extent of said member and transversely of the vertical, said stud having a cross section transverse to its length in the form of an incomplete annular wall about a space therewithin and providing a slot in said stud wall lengthwise thereof, said member having a tongue of aluminum projecting into said opening in said member from the periphery of said opening and through said slot of said stud into said space within the annular wall of said stud and engaging said stud wall by the greater expansion of the aluminum of said tongue than of the material of said stud under the heat of said electrode to effect gripping of said tongue by said wall of said stud to provide and maintain good electrical contact between said stud and said member.

3. A member of elongated form adapted to be disposed with its length extending generally horizontally and to cooperate with similar members similarly disposed in superposed relation thereto to form a generally vertical wall for engaging and confining the electrode material of a continuous vertical Soderberg electrode, said member being of aluminum and having a cross section in the vertical plane transverse to its horizontal extent with a greater vertical dimension than the horizontal thickness thereof and providing a rigidity such that said member is capable of rigidly supporting said superposed members and of cooperating therewith to confine and support the electrode material, said member being provided with an opening extending generally horizontally therethrough transversely of said extent of said member, a stud disposed in said opening with its length extending generally horizontally transverse to said extent of said member, said stud having secured thereto in electrically conductive relation thereto an element of aluminum projecting from the stud transversely of the length of the stud and disposed within the body of said member and fused to the aluminum of said member for holding said stud rigidly with respect to said member and in electrically conductive relation thereto.

4. A member as defined in claim **3** in which said stud is of steel and said element of aluminum is in the form of a lug disposed with its length extending along the length of the stud and projecting with a substantial width and height from the peripheral surface of said stud and welded to said stud at said surface thereof.

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